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RESEARCH PAPER

Research on oil displacement mechanism in conglomerate using CT scanning method

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Abstract: Taking the conglomerate from Xinjiang Oilfield as study object, the porosity distribution characteristics of the conglomerate were analyzed with CT scanning; through the online monitoring of the water and polymer flooding process in a conglomerate core using an CT scanning system, the saturation profile along the core and the CT reconstructed images of core section during the displacing process were obtained; oil displacement mechanism was analyzed according to a new characterization parameter, "oil saturation frequency distribution". The results show that the conglomerate has strong heterogeneity, resulting in "dominant channels", and in turn ineffective water circulation and low water flooding oil recovery, moreover, the oil in high oil saturation area is produced first. In polymer flooding, the oil in high and medium oil saturation areas can be produced but the oil in low oil saturation areas still cannot be produced. Oil produced in the subsequent water flooding is still mainly from the high oil saturation areas. For conglomerate reservoirs, previous water flooding should reach as high water cut as possible so as to strengthen the slug effect of the polymer. Meanwhile the injection volume of polymer should be reduced, and a subsequent water flooding should be used to push the polymer slug to produce oil.

Key words: conglomerate; CT scanning; water flooding; polymer flooding; oil saturation; profile along the core; frequency distribution

Introduction

The conventional water flooding for conglomerate reservoirs which are characterized by intense heterogeneity and complex pore structure usually ends up with high remaining oil saturation, high water cut and low production, polymer flooding can effectively improve the recovery [1–2]. However, the mechanism of low waterflooding recovery rate and polymer flooding for conglomerate remains unclear. In the past research, core displacement experiments were mainly used to collect data at both ends of cores from which macro parameters were calculated to describe the oil displacement process, which could not reveal the displacement mechanism completely.

CT scanning technology can make up the shortcomings of the traditional method. It can make quantitative and image analysis of petrophysics, and visual characterization of pore structures; meanwhile, the saturation distribution inside the core can also be obtained from CT scanning to visualize the displacement process, and get better insight into the oil displacement mechanism [3–5]. Nowadays CT scanning, already a routine test technique in international oil industry [6–8], has been adopted in some research in China [9–11].

Taking the conglomerates from Xinjiang Oilfield as objects, CT scanning was adopted to analyze the dual-porosity structure characteristics and oil displacement mechanism of the conglomerates in the study; furthermore, a new characterization parameter was put forward based on CT scanning to compare the displacement characteristics of water flooding and polymer flooding, and a reasonable injection method for conglomerate reservoirs was put forward accordingly at last.

1 Core experiments based on CT scanning system

1.1 Experimental apparatus

CT scanning core displacement system developed by Enhanced Oil Recovery Department, Research Institute of Petroleum Exploration& Development, PetroChina was employed in this experiment. A LightSpeed 8 CT scanner from GE with a resolution scale of 0.18 mm was used as the scan-

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ning system. The cores were scanned under 120kV and 130 mA with a 1.25 mm scanning pitch. Two groups of QUIZIX 5200 pump were used as the injection system and one group of ISCO pump as the overburden pressure controlling system. A special core-holder was used, so X-ray could penetrate through and the beam hardening effect could be eliminated. This displacement system allow the scanning of the displacement process of cores with CT scanner online, and collect the flow rate and pressure at the inlet and outlet of the coreholder. Finally, Core CT Analysis Software (CCTAS1.0) was used to process the experimental data.

1.2 Core samples and fluids

LY-1 and LY-2 samples taken from Xinjiang Oilfield were used in the experiment, their petrophysical parameters are listed in Table 1. With intense heterogeneity, both samples are typical dual porosity media.

1.3 Experiment procedure

The experiments were conducted at an ambient temperature of 22 °C, an overburden pressure of 5MPa and no back pressure. The specific process was as follows: the core was placed in the core holder after drying and then scanned by CT; next, the core was vacuumized, fully saturated with simulation formation water and then scanned by CT, to get the core porosity [12] and its 2-D/ 3-D porosity distribution. Irreducible water state was established for the core with simulated oil, and then the simulated oil inside the core was replaced with degassed oil added with 5% iodohexane (reinforcing agent for CT value). Brine was injected into the LY-1, LY-2 cores at an injection rate of 0.05 mL/min (1st water flooding). The 1st water flooding of LY-1 and LY-2 ended at a water cut of 98% and 90% respectively. The core was scanned at a regular time interval during the water flooding process (a single scan took 17s), to get the saturation distribution in the course of displacement [13–14]. At last polymer solution of 0.7PV was injected, then both LY-1 and LY-2 were displaced with brine again until the water cut surpassed 98% (2nd water flooding), the saturation distribution of the core during the polymer and 2nd water flooding process was also obtained through CT scanning, and the effect of different water and polymer injection modes on recovery percent was compared.

2 Pore structure analysis of dual porosity media

The CT value of every slice of LY-1 and LY-2 exhibits a bimodal feature (Fig.1, 2 slices of LY-1). The corresponding reconstructed images of CT value distribution also show intense heterogeneity (Fig. 2).

Table 1 Petrophysical parameters of core samples

Sample No	Length/ cm	Diameter/ cm	Pore Volume/mL	Porosity/ %	K_{air}/ 10^{-3} μm^2
LY-1	5.12	3.78	16.0	27.8	1 419
LY-2	7.78	3.74	17.1	20.1	379

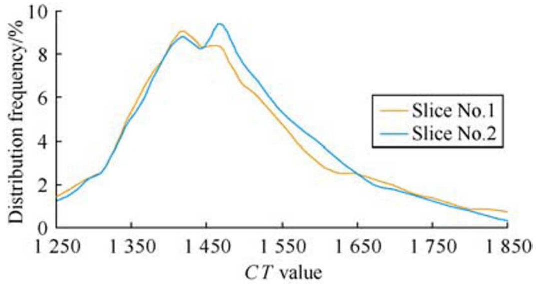

Fig. 1 CT value distribution of two slices from LY-1

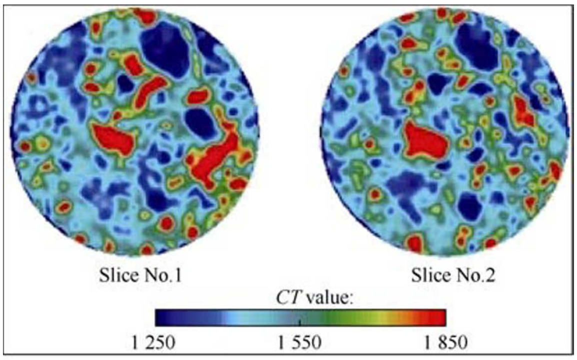

Fig. 2 CT value reconstructed images of two slices from LY-1

The porosity frequency distribution of LY-1 and LY-2 was calculated and shown in Fig. 3. It can be seen that the porosity frequency distribution of both cores exhibit a bimodal feature. 3-D reconstructed graphs of porosity distribution of both cores were derived by CCTAS and shown in Fig. 4 which reveal intense heterogeneity of the cores.

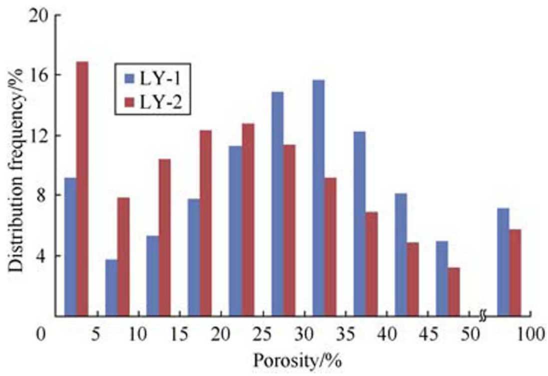

Fig. 3 Porosity distribution of LY-1 and LY-2

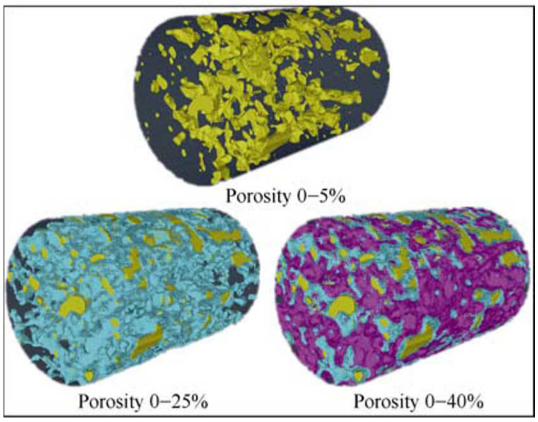

Fig. 4 3-D reconstructed images of porosity distribution for LY-1