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NUMERICAL SIMULATION STUDY ON HYDROCARBON MIGRATION OF PALEO-RESERVOIRS IN TAZHONG OIL FIELD, TARIM BASIN, NORTHWESTERN CHINA

WENFENG TANG, GUOZHONG ZHAO, LUOBIN XU, BAOCHEN ZHANG AND WEI ZHAO

Abstract. Tazhong Oil Field located in the center of Tarim Basin is one of the greatest discoveries during the petroleum exploration in Tarim Basin. The course of many years for hydrocarbon exploration and development has proved that there existed a much larger ancient reservoir than present-day reservoir and residual oil section below present WOC is of obvious characteristics of water displacement. Study shows that after it early formed, the paleo-reservoirs had been reformed to a great extent by hydrodynamic pressure caused by compacted water flow, which had played a dominant role in the redistribution of oil and gas in the evolution process of paleo-reservoir to present one. The previous method to study secondary migration caused by hydrodynamic pressure is as follows: to draw oil and water potential energy diagrams by utilizing pressure data of exploratory wells; to judge hydrocarbon migration direction and possible accumulation position by combining them with geological conditions; thereafter, to forecast potential oil reservoirs from the macroscopic view. Application of reservoir numerical simulation technology to hydrocarbon migration by hydrodynamic pressure has its advantage whether in its mechanism or in the accurate description of oil and water distribution. This paper has first presented the existence of the paleo-reservoir, and then constructs its geological model on the basis of recognizing its configuration at different geological stages.

Key Words. hydrocarbon migration, numerical simulation, exploration orientation.

1. Introduction

Tazhong4 area in Tazhong Oil Field is a typical structural trap (Figure 1) with CIII oil-bearing section, its main oil-bearing bed is characterized by that present-day WOC is at -2510m below sea level and the bottom of transitional zone from oil to water is at -2610m below sea level. Residual oil saturation is obviously dominated by physical properties, i.e., the residual oil saturation in the formation where physical properties are good is lower than that where physical properties are relatively poor; and there is remaining oil-bearing interbed. This phenomenon indicates that there existed a destroyed paleo-reservoir with unitive ancient WOC (now at -2610m below sea level) in the geologic history.

The existence of ancient WOC can shed more light on studying the evolution of Tazhong Oil Field as well as its exploration orientation. (1) In the long evolution process of Tazhong Oil Field, there ever existed a paleo-reservoir which is larger than that at present. How many was the reserve? (2) The existence of residual oil indicates that the reservoir had ever undergone adjustment and reconstruction.

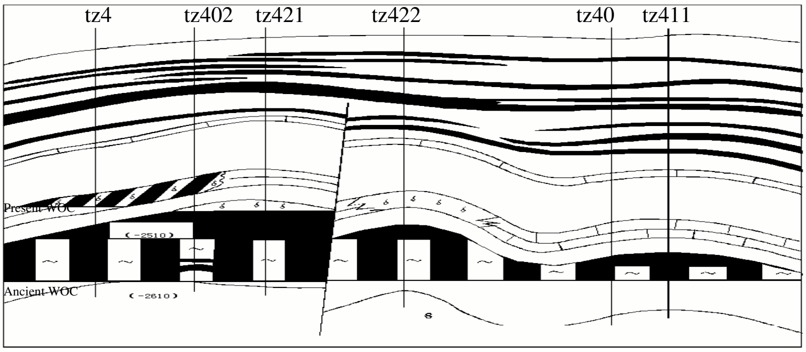

FIGURE 1. Tazhong4 area structural trap.

How about is hydrocarbon loss? Where does hydrocarbon migrate and accumulate towards then? (3) How to find secondary reservoirs scientifically? Many tough problems listed above are really urgent to tackle during exploration. This paper applies reservoir simulation technology to study hydrocarbon migration process of paleo-reservoirs, and partially answers the redistribution of oil and gas after it destroyed.

2. Hydrocarbon Migration Model

Black oil model is designed for developing the oil field. It is fully a new trial to utilize it to simulate large-scale hydrocarbon migration. Its simulating space and time is as much hundreds and even millions times as the general development block. Moreover, in each simulating unit fluid flow is very slow and the solved variables may have approached to tolerant errors, so the simulation requires software fast and more accuracy. Therefore, parallel VIP simulator is employed to perform calculations on ORIGIN2K parallel computer.

The modeling consists of two parts. First, a section model is designed to study the mechanism of migration as well as to analyze the relation between hydrodynamic gradient and the amount of migration followed by determining a reasonable distribution of hydrodynamic field in this district. Then it is to set up a 3D numerical modeling of the whole area and to predict spatial distribution of secondary reservoirs on the basis of matching the proven reservoirs.

2.1. The Section Model. The section model of Tazhong Oil Field is set up which is 41km long, vertically including CII and CIII oil-bearing sections and can be used to study both plane and vertical migration. The model has 8 modeling layers with each layer of 25m in effective thickness. WOC is at -2610m (the ancient WOC). There is a water injection well on one side to simulate hydrodynamic pressure and on the other side it is open boundary. The fluid inflow and outflow varies with pressure.

2.2. 3D Simulation Model. In order to find locations where there may exist potential secondary reservoirs and hydrocarbon may accumulate again, we design a large work area model which contains 32 exploratory wells in Tazhong zone. Simulating area is 106km(EW)$\times$ 74km(NS)=7844km^2 . According to the integrated

TABLE 1. Thickness variation of oil beds under the different pressure gradients.

Pressure gradient (KPa/KM)	Thickness of reservoir(m)	Thickness of reservoir(m)	Thickness of reservoir(m)
	So>55%	20%<So<55%	So<20%
40	75	25	40
50	50	20	70
60	10	15	115

geologic research, four layers are set vertically, with the total grids $80 \times 50 \times 4 = 16000$.

Due to multiple period of reservoir formed, we set up three different paleo-reservoir models of CIII oil-bearing in the Tazhong zone, including Cretaceous model, Tertiary model and Quaternary models, which simulate migrating features in the evolution process respectively. The grids are the same in three models.

3. Simulation of the Section Model

3.1. The Section Model Results. Simulation study on the mechanism of migration shows the variation of migrating velocity is actually dependent on the pressure gradient in the pathway. Thus study on the relation between pressure gradient and residual oil also reflects how migrating velocity affected residual oil.

By building up different pressure gradients to yield the proportion of different oil saturation in the reservoir after the migration (see TABLE 1). Comparing distribution maps of oil saturation under different pressure gradient and at different migrating stages, it comes to the following conclusions:

Hydrodynamic strength is the decisive factor on the amount of migration and there exists a minimum pressure gradient [1]. When pressure gradient is less than it, migration would not take place. With the pressure gradient increasing, both pure oil belt and transitional belt correspondingly become smaller until all oil is expelled from the structure.

With source pressure maintenance, force on oil acted by buoyancy and hydrodynamic pressure will change as the oil volume varies. Since oil formation becomes thinner, the pressure gradient in the pathway becomes smaller and smaller. So the amount of migrated oil is also less and less. When both close to a balance point, migration stops and hydrodynamic trap is formed. Therefore, although migration is slow, the migrating scale is large in the beginning, then gradually less till stopping (FIGURE 2).

3.2. 3D Simulation Model Results. At the beginning of migration (0-5000 years), since northwestern structure was relatively smooth, oil was basically migrated as a whole in the large scale for all of three models. However, some regions had great difference. In the Tertiary and Quaternary models, a large amount oil went south as it migrated along the structure; whereas in the Cretaceous model oil mainly migrated along the center uplift (FIGURE 3).

In the middle phase of migration (5000-500000 years), oil mainly migrated along the center uplift. As structure gradually became large, it moved more collectively, particularly in Cretaceous reservoirs where oil hardly went south. After TZ4 reservoir had formed, oil continued migrating to reach buried hill structure (FIGURE 4).

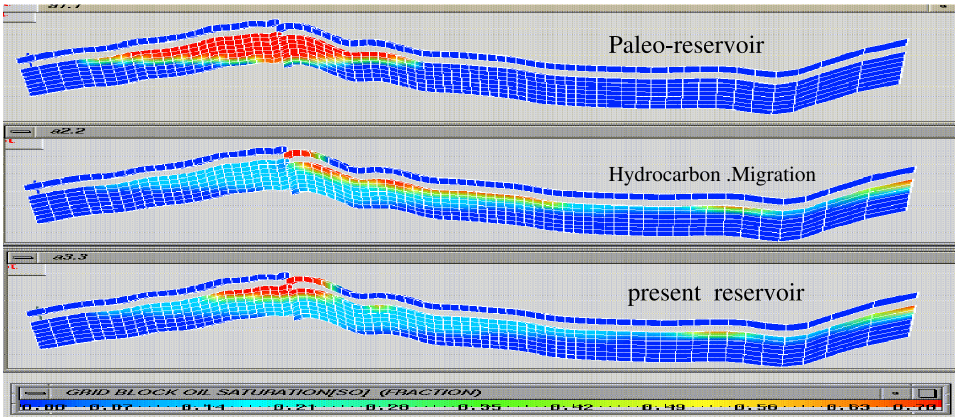

FIGURE 2. Hydrocarbon migration mechanism simulation (cross model).

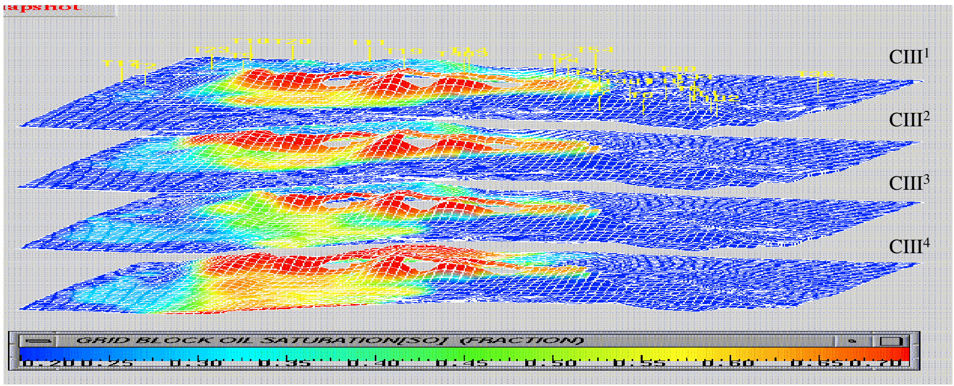

FIGURE 3. The beginning phase of migration (Cretaceous model).

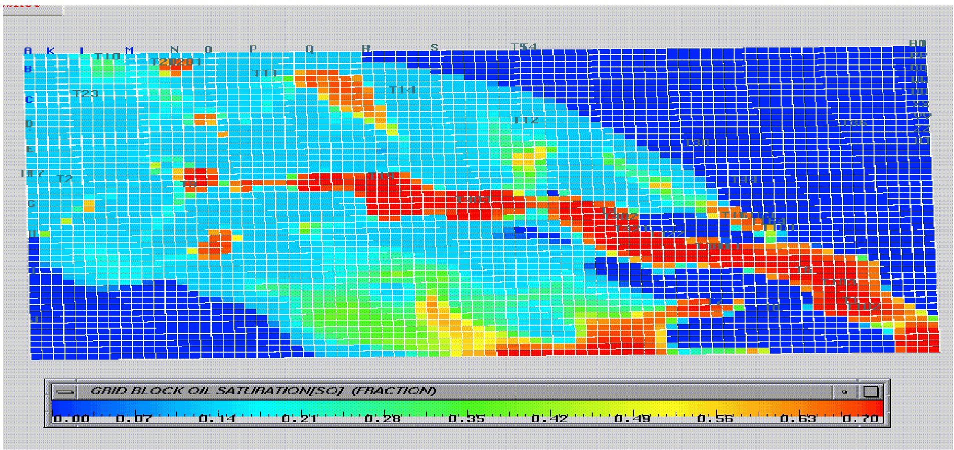

FIGURE 4. The middle of migration (5000-50000years, Tertiary model, CIII[1] layer).

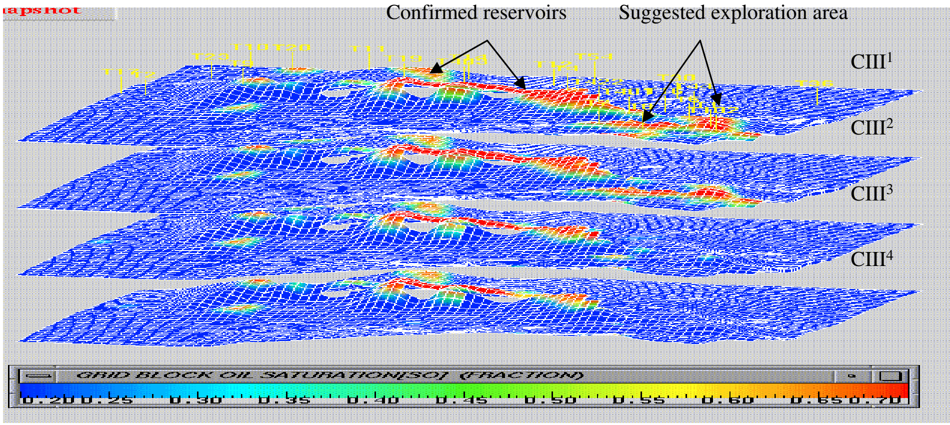

FIGURE 5. After simulating, hydrocarbon distribution in the area (Quaternary model).

During the late period of migration (500000 years -1Ma), major reservoirs had formed. As time went on, the thickness of oil layers gradually became thinner; hydrodynamic pressure and buoyancy came to the balance; and the amount of oil migration gradually decreased till nearly stopping after 1Ma (FIGURE 5).

Simulating results are basically consistent with discovered reservoirs, which means they are reasonable. Based on this, we have analyzed oil migration paths and locations of some secondary reservoirs.

4. Conclusions

After it is modified and adjusted, the black-oil model can be employed to simulate wide extent and large-scale hydrocarbon migration. By integrating hydrodynamic pressure, buoyancy as well as capillary pressure the model can correctly reflect the hydrocarbon distribution both on the plane and in the vertical direction. By application of 3D display and random statistical technology, it can simulate the formation and destruction of reservoirs visually and quantitatively. This technology provides a new effective method for finding oil in the future exploration.

After the paleo-reservoir in the Tazhong zone were destroyed, a large amount of oil below present WOC and in the pathway had been lost during its evolution to present-day reservoirs, and the rest oil of $1.5\times\ 10^8$t continued migrating, and finally form several larger-scale secondary reservoirs were formed.

According to simulation results, the next exploration area is suggested.

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Exploration & Development Research Institute of Daqing Oilfield Co. Ltd., Heilongjiang, China