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RESEARCH PAPER

Techniques for high-efficient development of offshore fluvial oilfields

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Abstract: The geological reservoir conditions of fluvial oilfields offshore in Bohai are complex, with thin layer reservoirs, significant horizontal changes, poor connectivity, so these oilfields face the challenges of production well deployment, fine reservoir description, optimum resource allocation, and so on. To realize the efficient development of fluvial oilfields, this research has formed the technique of reservoir fine description and quantitative characterization in a sparse well network, the technique of regional sedimentation research and single river reservoir recognition, the well network optimization technique of single sand body, the rolling tapping potential technique in the fluvial oilfield. It is verified by 11 oilfields development of Bohai: the techniques are effective in the development of proved reserves resources, and 5 000×10^4 ton discovered reserves in the evaluation of rolling development are newly added. Thanks to the technology of reservoir fine description in forecasting reservoirs, the drilling rate is up to 98%; by the technique of fluvial single river reservoir recognition, the recovery ratio increases by 3% on average; the fluvial oilfield rolling development technique can bring a rapid transformation to the resources around the oilfield and achieve efficient development of oil and gas resources.

Key words: offshore fluvial oilfield; high-efficient development; fine reservoir description; single channel recognition; well pattern optimization

Introduction

The Bohai oilfield is located in the Bohai sea, and its areal structure belongs to the offshore part of the Bohai Bay Basin. After 40 years of exploration and development, it has got lucrative oil reserves from fluvial sandstones in the Neogene Minghuazhen Formation and Guantao Formation, which accounted for 56.3% of the total proven oil reserves in the Bohai oilfield in 2012. It is of great significance for the increasing and stabilizing yield of the Bohai oilfield to realize the efficient development of this type of hydrocarbon reservoirs.

Under the influence of new tectonic movement, the Neogene Minghuazhen Formation and Guantao Formation in the Bohai oilfield developed lots of fractures, the structure is broken, and the characteristics of the complex fault block are obvious. The Bohai sea became the catchment center of the Bohai Bay Basin after entering the Neogene, not only developed the traditional fluvial sedimentary systems, but also developed the shallow water delta systems that were mainly found around distributary channels or underwater distributary channels. The fluvial oilfield that referred in this paper not only contains meandering and braided rivers as reservoirs, but includes part of shallow water delta distributary channels or underwater distributary channels as reservoirs. Affected by the fluvial deposits, the reservoirs mostly presented curved strip shape, ribbon shape, dendritic shape and other forms on plane [1], with thin layer reservoir and large horizontal change, and the water and oil bed interaction occurrence, the characteristics of "one sand body one oil reservoir" are obvious, so the reservoir geological condition is very complex. In order to realize the efficient development of fluvial oilfields, the study is conducted using the reservoir fine description and quantitative characterization technique in the sparse well pattern, the technique of regional sedimentary evolution and single river reservoir recognition, the well network optimization technique of single sand body, and the rolling tapping potential technique in the fluvial oilfield.

1 Challenges of fluvial offshore oilfield development

The development of offshore fluvial oilfields mainly faces the following challenges.

1.1 Development well deployment

The well pattern of Chinese onshore oil field development takes a continuously improving way: first carrying out research on integrated geology and reservoir based on the implementation of the basic well pattern, then determining the

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overall development well pattern and infilled well pattern. For offshore oil fields, due to the restriction of high development cost, it would eventually result in the exploration well with low density and lack of information, also the offshore oilfields do not have conditions for repeated adjustment because of the offshore platform space, lifetime of platform, and well slot resource. To achieve efficient development of oil fields, preliminary research must be strengthened, and the deployment of development wells should be based on the fine reservoir geological description.

1.2 The reservoir

The Neogene Minghuazhen Formation and Guantao Formation in the Bohai oilfield are composed mainly of complex fault block reservoirs. Controlled by channels, the sandbody microfacies is relatively narrow, and the channel migration is frequent, with the condition of multi-level bifurcation, redirection, thin thickness (layer thickness is generally less than 10 m), multiple phase stack, poor connectivity and strong anisotropy. Moreover, with the low density of exploratory wells and large well spacing, it is difficult to realize the fine description of reservoirs by conventional techniques.

1.3 Resource allocation

There are many fluvial reservoirs with fault blocks in the Bohai oilfield, and the planar distribution of the resources is scattered [2]. The Bohai oilfield is restricted by cost and less exploratory wells, so it is difficult to evaluate each fault-block oil and gas reserves, underground resources are not clear, and an optimal allocation of underground resources and engineering facilities faces challenges. In order to achieve efficient development, we must fully recognize the oil and gas resources of mining facilities within the coverage area and employ overall planning and rolling evaluation to realize the optimal allocation of underground resources and engineering facilities.

2 High-efficient development techniques of offshore fluvial oilfields

To solve the problems existing in the development of offshore fluvial oilfields, we make full use of seismic data (including seismic data processing) to form these techniques based on the research of regional sedimentary evolution: including the reservoir fine description and quantitative characterization technique in the sparse well network, the research of regional sedimentary evolution and the recognition of a single river, the well network optimization technique of single sand body and some other applicable techniques. These techniques achieve fine geological studies on the level of single sand body, reach a rational allocation among underground oil and gas resources of fluvial oilfield and ground engineering facilities depending on the well spacing technique of single sand, and enhance the development effectiveness and economic efficiency of offshore fluvial oilfields.

2.1 The reservoir fine description and quantitative characterization technique of fluvial oilfield in the sparse well network

Facing the problems of thin reservoirs and strong heterogeneity existing in the fluvial facies oilfield, we tackle key problems and form a fine description and quantitative characterization technique under large spacing at sea. The study of this technique examines Neocene sandstones seismic identification mechanisms of the Bohai oilfield, systematically carries out core experiments, theoretical modeling and statistical analysis of log data, and so on [3–5]. Rock density is used to distinguish between the effective geophysical parameters of Neocene sandstone and mudstone. On the basis of this knowledge, combined with lower Minghuazhen Formation "mud pack sand" in geology, logging constrained is established based on the density curve sparse spike inversion techniques to carry out reservoir prediction, and it achieved good results. We can always see that seismic reflections are strong in the sands drilled region with high amplitude peaks and valleys appearing in pairs on superimposed seismic sections of connected wells from the conventional seismic data and the inversion of seismic data. At the weakening space of amplitude peaks and valleys on the conventional seismic data, the sandstone shows a performance of sandstone pinch on the inversion data. According to the inversion results, combined with the drilling data, we use SP curve, GR curve to demarcate the top and bottom of the main sand body at lower Minghuazhen Formation, meanwhile, we also make a fine tracking on the top and bottom of the sand body, which reaches the realization of the sandstone thickness and fine sand boundary characterization. During the process of offshore fluvial facies oilfield development in Bohai, by using logging constrained sparse spike inversion technique, the coincidence rate of actual drilling reservoir is more than 98%, actual drilling depth error is less than 2 m and thickness error is less than 3 m.

Based on the accurate description of the reservoir top, bottom and thickness, we further use multi-parameter synchronous prestack inversion to predict the hydrocarbon potential of reservoir [6]. This technique makes comprehensive use of restack seismic data and log data to invert P-wave impedance synchronously, Poisson's ratio, density and other elastic parameters in order to identity hydrocarbon potential of reservoir. Figure 1 shows a profile of the BZ28-2S oilfield multi-parameter synchronization prestack inversion results. It is seen that the sand with great probability of oil-bearing is proven to be real oil and gas layers after drilling, which shows the evaluation on the probability of hydrocarbon reservoirs is correct.

In addition, under certain conditions, reservoir lithology, physical properties and hydrocarbon potential changes will cause changes of seismic reflection amplitude, frequency and phase [7–8], at this time, the quantitative description technique of reservoir parameters based on seismic attributes can