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Study on the Depositional Characteristics of Tidal Flat and Barrier Bars in Bohai Oilfield and Reservoir Prediction

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Abstract

The Bohai A Oilfield is located in the southwest gentle slope belt of the Bohai Depression, forming an overall anticlinal structure adjacent to the southwest depression of the Bohai Depression. It possesses favorable reservoir and preservation conditions, making it highly conducive for hydrocarbon accumulation. In the study area, the deep-middle layer tidal-flat-bar reservoirs are influenced by seismic signal-to-noise ratio and resolution, making it difficult to characterize the distribution range of sand bodies using conventional methods. Based on the study of reservoir pore space characteristics, this paper clarifies the favorable development zones of tidal-flat-bar sand bodies through paleogeomorphic restoration. By waveform classification, the model waveform features of near-well paths are obtained, enabling the evaluation of the distribution characteristics of typical tidal-flat-bar reservoirs in favorable development areas. Consequently, the quantitative delineation of reservoir spatial extent and thickness is effectively achieved. The predictive results show good consistency with drilled wells and regional sedimentary understanding.

Keywords

Mid-Deep Layer, Shoal Bar, Waveform Indication, Quantitative Prediction

1. Introduction

The Bohai Oilfield is located in the Bohai Sea area and belongs to the marine part of the Bohai Bay Basin in terms of regional structure [1]. The Bohai Oilfield has obtained abundant oil reserves in the middle and deep reservoirs of the Paleogene, accounting for 40.3% of the total proven geological oil reserves of the Bohai Oilfield [2]. The efficient development of such reservoirs is of great significance for

the production and stable production of the Bohai Oilfield. Due to the complex geological reservoir conditions in Bohai Bay, as well as the complex distribution of reservoirs in mid to deep oil fields and the special nature of offshore development, there is no mature experience to draw on for efficient development technology research in complex mid to deep oil fields [3]. The research ideas and technical routes of dense well networks and small well spacing in onshore oil fields cannot be replicated in offshore oil fields [4] [5]. The research on reservoir prediction driven by geological constraints and seismic multi-attribute joint drive in mid to deep oil fields faces many challenges, such as poor seismic data quality, complex geological conditions, complex reservoir distribution, multi-stage river channel stacking, diverse geological reservoir models, high investment, and high risks [6] [7].

This article focuses on the Bohai A oilfield as the target oil field, aiming at the reservoir prediction problem of medium and deep beach and dam facies oil fields. Based on the study of reservoir space characteristics, the favorable development zones of beach and dam sand bodies are identified through paleogeomorphological restoration. By classifying waveforms, the model waveform characteristics of the wellbore were obtained, and the distribution characteristics of typical beach and dam reservoirs in favorable development areas were evaluated. This effectively identified the quantitative characterization of reservoir spatial distribution range and thickness, and explored a set of technical methods suitable for the quantitative prediction of reservoirs in offshore medium and deep oil fields.

2. Geological Setting

The Bohai A oilfield is located in the gentle slope zone of the southwest depression of the Bozhong Depression, with an overall concave-convex structure. It is adjacent to the southwest depression of the Bozhong Depression and has good reservoir and preservation conditions, with favorable conditions for reservoir formation. The drilling of the oilfield reveals that the strata from top to bottom are the Quaternary Plain Formation, the Neogene Minghuazhen Formation, Guantao Formation, and the Paleogene Dongying Formation and Shahejie Formation. The main oil-bearing strata of the oilfield are developed in the Paleogene Shahejie Formation [8] [9]. The Shahejie Formation of the Paleogene in the oilfield is a sedimentary deposit of beach and dam facies [10]. Research suggests that the gray mudstone section developed at the top of the Shahejie Formation is a comparative marker layer for dividing the Shahejie Formation. Due to the influence of ancient landforms and provenance, the western side of the oilfield is close to the provenance area, with a relatively thick formation. The Shahejie Formation is in angular unconformable contact with the underlying buried hill formation.

3. Characteristics of Reservoir Space

The Shahejie Formation of the Paleogene in the research area is a reservoir of beach and dam facies. The fluid properties are moderate, and the surface crude oil

has the characteristics of light to moderate density, moderate viscosity, high solidification point, high wax content, moderate content of asphaltene, and moderate sulfur content; Formation crude oil has the characteristics of low saturation pressure, large saturation pressure difference, moderate dissolved gas oil ratio, and low crude oil viscosity, and belongs to a normal temperature and pressure system.

Based on observations of rock cores, wall cores, and rock debris, combined with thin section identification and other research results, the lithology of the Shahejie Formation reservoir is mainly composed of medium coarse to fine-grained rock debris feldspar and feldspar rock debris sandstone. The mineral composition is mainly quartz, feldspar, and rock debris (Figure 1), with a quartz content of 15.0% to 42.0%, averaging 32.4%; The feldspar content ranges from 12.0% to 45.0%, with an average of 34.5%; The rock debris content ranges from 20.0% to 73.0%, with an average of 33.1%. The rock debris is mainly composed of magmatic and metamorphic rock blocks. Through porosity and permeability analysis of 112 core samples and wall cores, the reservoir porosity ranges from 12.0% to 23.1%, with an average of 16.0%; The permeability ranges from 1.0 mD to 451.6 mD, with an average of 22.3 mD.

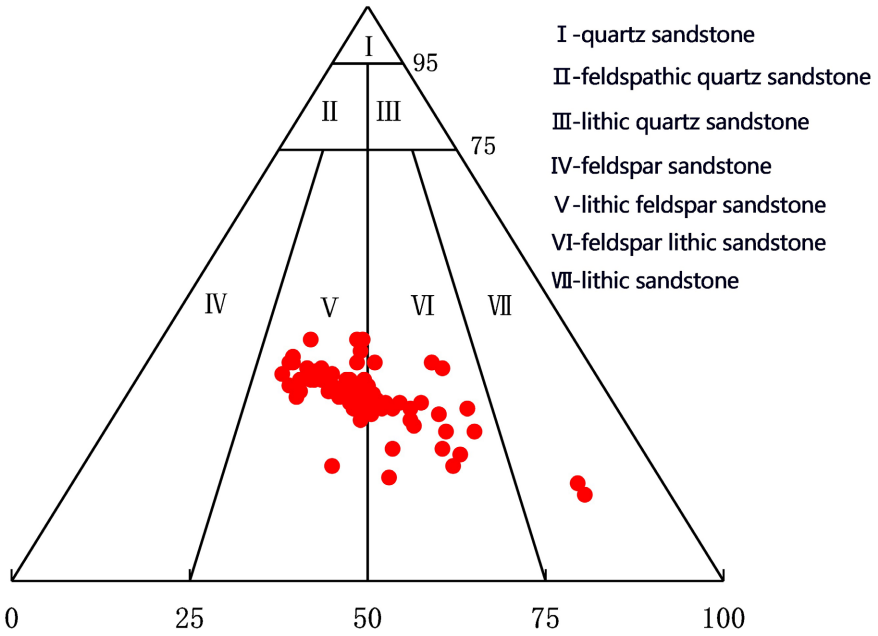

Figure 1. Triangle diagram of rock classification in Shahejie Formation.

Cast thin sections and scanning electron microscopy show that the pore types of the Shahejie Formation reservoir are mainly primary intergranular pores, with a small amount of intragranular and intergranular dissolved pores. The rock pores are generally developed and have good connectivity. The intergranular filling material is mainly composed of dolomite, calcite, and mud, with dolomite filling the intergranular space in granular form; Mud is distributed in the form of recrystal-

lized scales between grains; Calcite clumps are cemented and dispersed between particles. The particles are mainly in point line and line contact, with moderate weathering of feldspar (Figure 2).

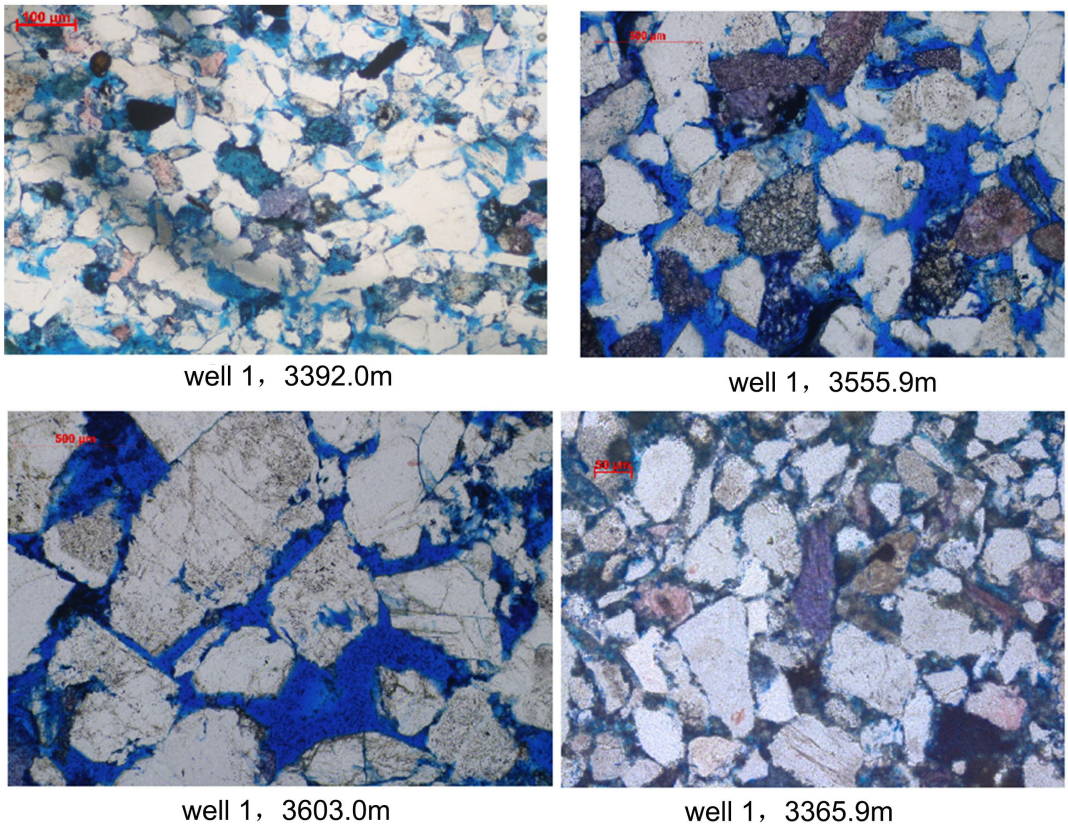

Figure 2. Rock thin section photo.

4. Fine Research on Ancient Landforms

This study is based on the integrated research of geological and geophysical exploration. Through the restoration of ancient landforms in the Shayi section, a waveform evaluation of the sandbar reservoir based on geological constraints was carried out, and the prediction of the sandbar reservoir was achieved. Paleogeomorphology is one of the main factors controlling the development and distribution of sedimentary facies, which has a significant impact on the lateral distribution of sand bodies. Paleogeomorphology and slope break zones jointly control the development range of beach bar sand bodies.

Paleogeomorphology is one of the main factors controlling the development and distribution of sedimentary facies, which has a significant impact on the lateral distribution of sand bodies. The paleogeomorphology and slope break zones in the study area jointly control the development range of beach bar sand bodies. This study restored the ancient topography of the Sha 1 section through compaction correction (Figure 3), and identified the favorable development zones for beach bar sand bodies.

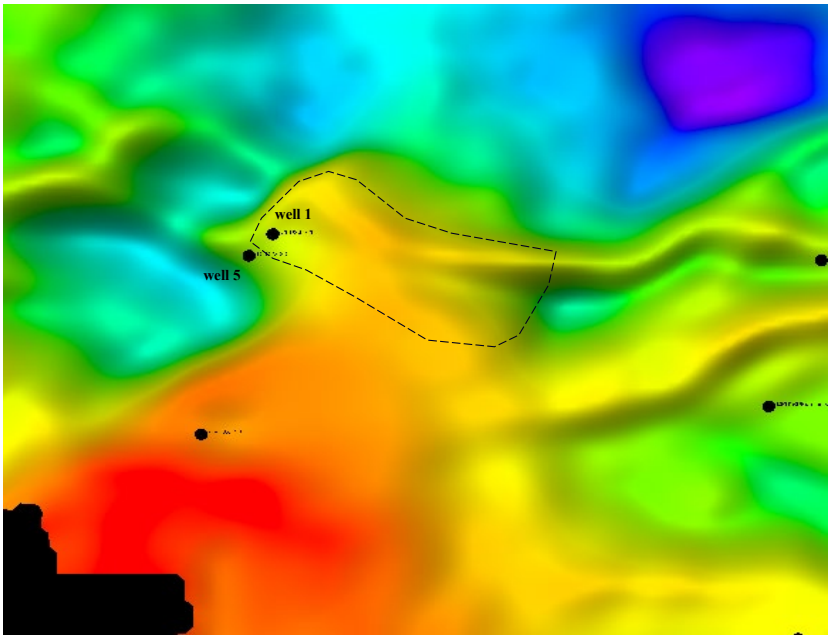

Figure 3. Paleogeomorphological map.

5. Research on Reservoir Distribution Prediction

The effective frequency bandwidth of the seismic data in the target layer of the research area is approximately 5 Hz to 35 Hz, with a main frequency of 20 Hz. The vertical resolution of the seismic data is about 40 m, and there are 2 blind wells for reservoir prediction calibration and 1 blind well. The waveform characteristics are closely related to the degree of reservoir development and stratigraphic combination. Due to the tuning effect of thin layers, the stratigraphic structure plays a dominant role in the development of thin interbedded reservoirs in the Sha-1 section. Comparative analysis was conducted on the reservoir development and corresponding seismic waveform characteristics revealed through drilling (Figure 4).

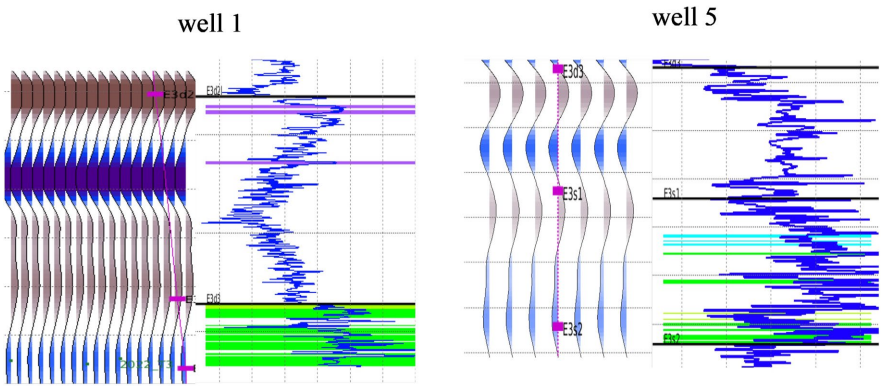

Figure 4. Analysis of wave characteristics in Shahejie Formation.

This study adopts a volume classification method to classify the number of sam-

ples from a multi-dimensional 3D data volume. The input data includes the original 3D data volume and derived attributes. The workflow includes creating the data volume, inputting attributes, optimizing attributes through principal component analysis, neural network classification verification, generating seismic facies volumes, slicing along layers, and interpreting seismic facies maps. Through comparative analysis of the reservoir development revealed by drilling and corresponding seismic waveform characteristics, this study optimized the arc length and amplitude attributes for predicting the development area of beach dams. By waveform classification, the model waveform characteristics of the wellbore can be obtained, which can then evaluate the distribution characteristics of typical beach and dam reservoirs in favorable development areas. The prediction results show that the seismic waveform information is similar to the ancient landforms of the beach and dam reservoir development zone, and is basically consistent with the development laws of actual drilling and beach and dam sandstone reservoirs (Figure 5, Figure 6).

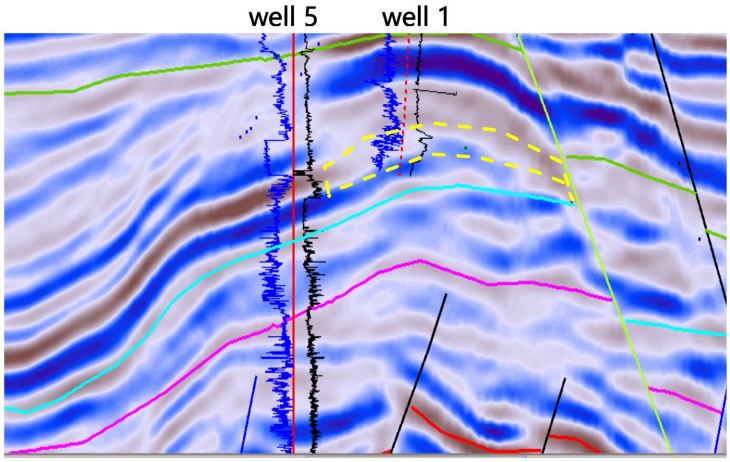

Figure 5. Characteristics of sand body profile in Shahejie Formation.

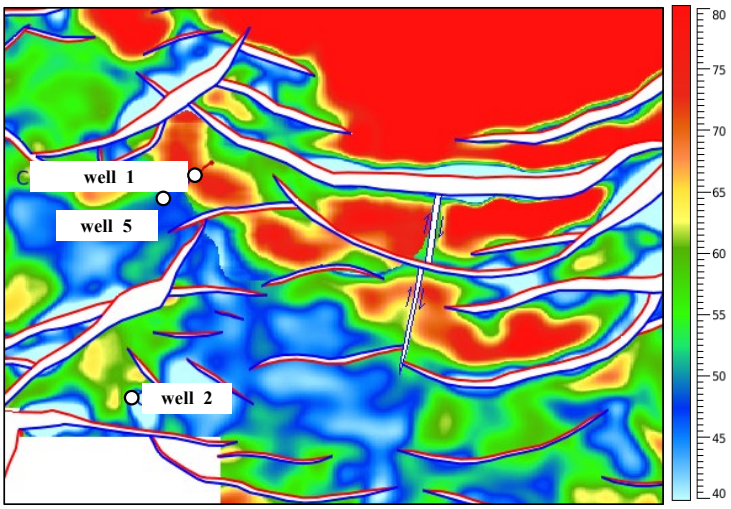

Figure 6. Sand section waveform characteristic plane attribute map.

Under the constraints of geological models and in combination with ancient landforms, the distribution pattern of reservoirs was determined through seismic forward analysis and waveform clustering analysis, and a contour map of reservoir thickness in the Shayi section was drawn (Figure 7).

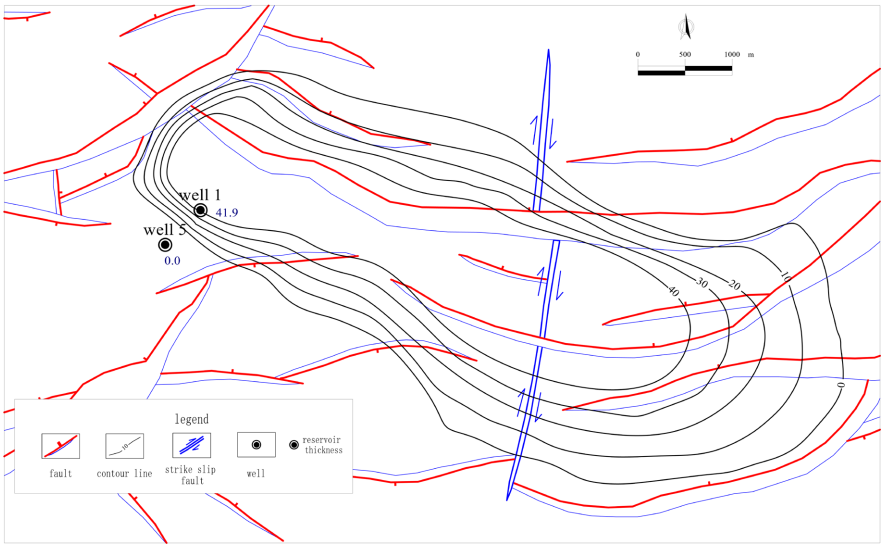

Figure 7. Contour map of reservoir thickness in Shahejie Formation.

The beach dam in the research area is developed in the platform area of the underwater ancient uplift, and the reservoir in the direction of Well 5 is not developed. The characteristic of reservoir development is that the middle is thick and the two wings gradually thin. The distribution range and thickness of the reservoir plane in the sandbar sand body mainly rely on seismic data prediction, which may have relatively low accuracy in predicting the range and thickness near the fault area due to the influence of seismic data. The above reservoir prediction work provides a relatively reliable basis for reserve estimation and lays a solid foundation for later oilfield development.

6. Conclusions

1) The first section of the Shahejie Formation in the Bohai A Oilfield is a sedimentary deposit of beach and dam facies. The reservoir lithology is mainly composed of medium coarse to fine-grained lithic feldspar and feldspar lithic sandstone. Cast thin sections and scanning electron microscopy show that the pore types of the Shahejie Formation reservoir are mainly primary intergranular pores, with a small amount of intragranular and intergranular dissolved pores. The rock pores are generally developed and have good connectivity.

2) Under the constraints of geological models and in combination with ancient landforms, the distribution pattern of reservoirs was determined through seismic forward analysis and waveform clustering analysis. The accuracy of reservoir distribution range and thickness predicted by seismic data is greater than 85%. The beach dam in the study area was developed in the platform area of the underwater

ancient uplift, while the reservoirs in the direction of Well 5 were not developed. The development characteristics of the reservoirs were thick in the middle and gradually thinning on the two wings.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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