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Seismic Attribute Gradient Analysis and Reservoir Configuration Study of Shallow Water Delta Reservoir in Huanghekou Sag

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Abstract

The geological conditions of shallow offshore delta oil reservoirs are complex. Under the condition of less well data and larger well spacing, the traditional reservoir configuration method is difficult to solve the detailed study of such reservoirs in offshore oil fields. Based on the comprehensive analysis of the seismic phase, data of well log. The paper identifies criteria of the quaternary configuration boundary in shallow water delta of different types with distributary sand dam is established. At the same time, this paper used sensitive factor to construct the edge detection operator based on the amplitude attribute, characterizing the boundary of sand body thickness mutation or physical property mutation quantitatively, realizing the quantitative characterization of four-stage configuration boundary in the region with no wells or few wells, guiding the efficient development of offshore shallow water delta oilfield, and realizing the increase of storage and production of Bohai oilfield.

Keywords

Shallow Water Delta, Reservoir Configuration, Attribute Gradient, Attribute Fusion

1. Introduction

Bohai Oilfield has discovered significant oil and gas resources in the shallow delta reservoirs of the shallow Neogene Minghuazhen Formation, making it one of the main oil-bearing horizons in the development of the field. However, the geological conditions of such oilfields are complex, often due to multiple migrations of watercourses, frequent diversions, and mutual cutting and overlapping

of individual genetic units, resulting in enhanced lateral heterogeneity of sand bodies and more complex oil gas water relationships [1], the research on the fine reservoir configuration of such reservoirs has always restricted the efficient development of oilfields.

Domestic and foreign scholars mainly summarize and summarize sedimentary patterns and laws through detailed dissection of field outcrops. In actual oilfield development, they use dense well pattern information to conduct detailed anatomical analysis of reservoir internal configuration [2] [3] [4], and the application effect is relatively ideal, and the technology is relatively mature. However, research based on seismic data is relatively rare, and mainly focuses on the study of deep water turbidite channel reservoirs. In addition, It is also relatively rare to characterize the internal configuration of reservoirs based on seismic data. These methods have effectively solved the reservoir refinement research under dense well patterns in onshore oilfields [5] [6], which has important geological significance for tapping the potential of remaining oil in the later stages of oilfield development [7]. However, due to the small number of wells and large well spacing in offshore oilfields, the reservoir configuration research methods for onshore oilfields have become difficult to apply [8], which seriously affects the efficient development of offshore oilfields. Aiming at the development characteristics of offshore oilfields, taking Bozhong S Oilfield as an example, based on fully utilizing single well data to identify the fourth level configuration unit interface, combined with edge detection operator technology of seismic attributes, this paper quantitatively characterizes the boundaries of abrupt changes in sand body thickness or physical properties, achieving a fine configuration study of shallow water delta reservoirs in areas without wells and few wells, providing a fine geological model for the efficient development of offshore shallow water delta oilfields.

2. Geological Setting

Bozhong S Oilfield is located in the central structural ridge of the Huanghekou Sag in the Bohai Bay, with favorable conditions for oil and gas accumulation and accumulation [9] [10]. The formation of the oil field is controlled by two sets of NE trending normal faults with opposite falls in the north and south, and the trap morphology of each layer is basically consistent. The lower member of the Neogene Minghuazhen Formation is the main oil-bearing series. The sand body in the lower section of the Minghuazhen Formation is a shallow water delta distributary channel sand body [11]. The driving force of the sediment is mainly traction and drainage. The wave action of the lake water is weak, and the provenance direction mainly comes from the northeast direction.

The research shows that the sand body in the lower section of the Minghuazhen Formation is a distributary sand bar type shallow water delta, with frequent lateral migration on the plane of the sand body. The plane distribution of the sand body is wide, but there are significant differences in lateral connectivity.

The reservoir lithology is mainly lithic arkose, fine to medium to fine grained, with low maturity of rock composition and good particle sorting. The reservoir pore type is mainly intergranular pore, with well-developed rock pores and good connectivity. The average porosity and permeability of the reservoir are 31.6% and 1787.0 × 10^{-3} μm^2.

3. Study on Sedimentary Facies of Shallow Water Delta

3.1. Study on Sedimentary Microfacies Identification

The geoelectric characteristics of different sedimentary microfacies, as well as the geoelectric geometry on the plane and profile, have certain differences. In this oilfield, using logging data and seismic data, combined with seismic plane attribute characteristics, seismic facies profile geometry, logging curve shape characteristics at well points, lateral well connection comparison, and spatial combination style, the target sand body 1 - 1167 is divided into distributary sand bar, distributary channels and distributary channel bay (**Figure 1**).

1) Distributary sand bar, diversion sand bar is the main reservoir in shallow water delta, with large sediment thickness, stable planar distribution, and good reservoir physical properties. The logging curves are generally box type and composite box type, with strong amplitude and good continuity in seismic facies.

2) Distributary channel: the overall performance of the distributary channel is as follows: the bottom of the riverbed develops detention deposits, and the upper part is filled with mud. The sediment thickness of the sand body is relatively small, generally less than 5 m, and the logging curve generally assumes a bell shaped or shoe shaped shape.

3) Distributary channel bay, the sediments in the inter distributary channel bay are mainly grayish green mudstone, with locally thin layers of silty sand deposited during the flood season. Generally, it is deposited on the front shallow water delta mudstone or shallow water delta front sand body, and the logging curve is generally finger shaped.

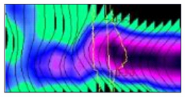
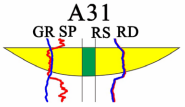
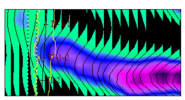
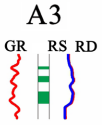
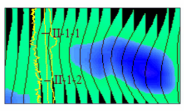
sedimentary micro	logging curve characteristics	seismic characteristics	recognition feature
distributary sand bar			logging phase,box type seismic facies, obvious waveform characteristics reservoir thickness > 5m
distributary channel			logging phase,bell-box type seismic facies, general waveform characteristics reservoir thickness < 5m
distributary interchannel			logging phase,peak shape type seismic facies, poor waveform characteristics reservoir thickness < 1m

Figure 1. Single channel boundary identification mark.

3.2. Study on Identification of Single Core Beach

The internal configuration interfaces of shallow water delta reservoirs are generally dominated by scouring surfaces and sediment deposition layers, and the configuration units mainly develop distributary sand dams, distributary channels, and inter distributary channel bays. Different types of configuration units correspond to different levels of configuration interfaces, and different levels of configuration units can also be subdivided into smaller levels of configuration units. The 1 - 1167 sand bodies that this paper focuses on are shallow water delta deposits, mainly composed of progradation, retrogradation, or lateral migration of distributary sand dams, which are stacked with each other in space and form a continuous distribution of composite channel sand bodies. Between the distributary sand dams, lake mudstones or sedimentary road passes are generally developed. A single distributary sand bar is formed by lateral superimposed deposition of multiple accretion bodies (Figure 2).

3.3. Study on Sedimentary Model of Shallow Water Delta

Based on the study of sedimentary facies, according to the special sedimentary characteristics of shallow water delta and the study of modern shallow water delta sedimentary laws, the type of sedimentary microfacies is determined by comprehensively using seismic inversion profiles and logging data, combined with the geometric morphology of logging curves, and the distribution characteristics and contact relationship of sedimentary microfacies are determined based on the relationship between the characteristics of logging facies and the geometric morphology of connected well seismic waveforms (Figure 3).

4. Methods and Results

4.1. Reservoir Architecture Anatomy Based on Attribute Gradient

The lower member of the Neogene Minghuazhen Formation in the Bohai Sea area mainly develops shallow lake basin and shallow delta deposits, which are

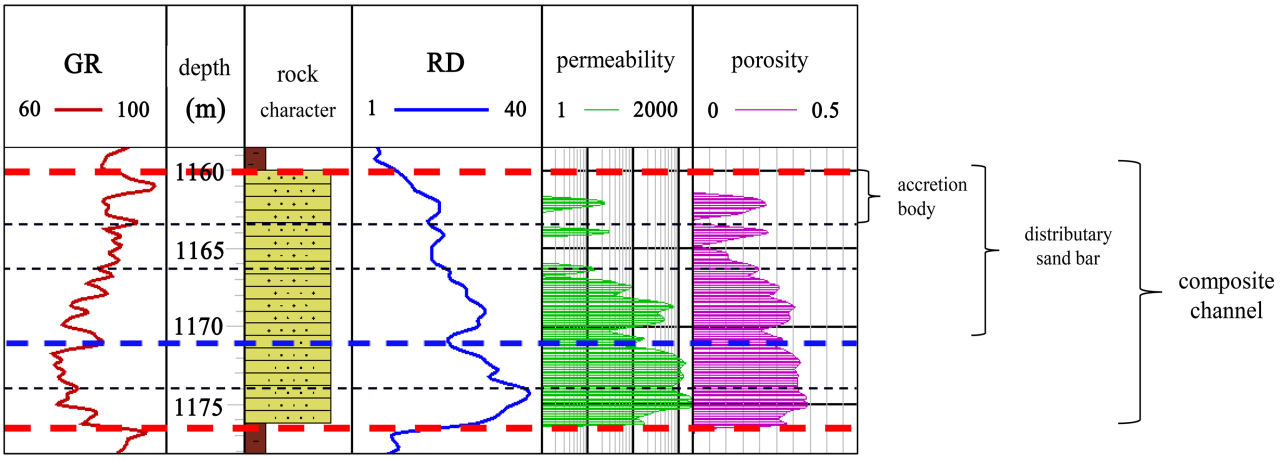


Figure 2. Division of configuration units at different levels of Bozhong S Oilfield.

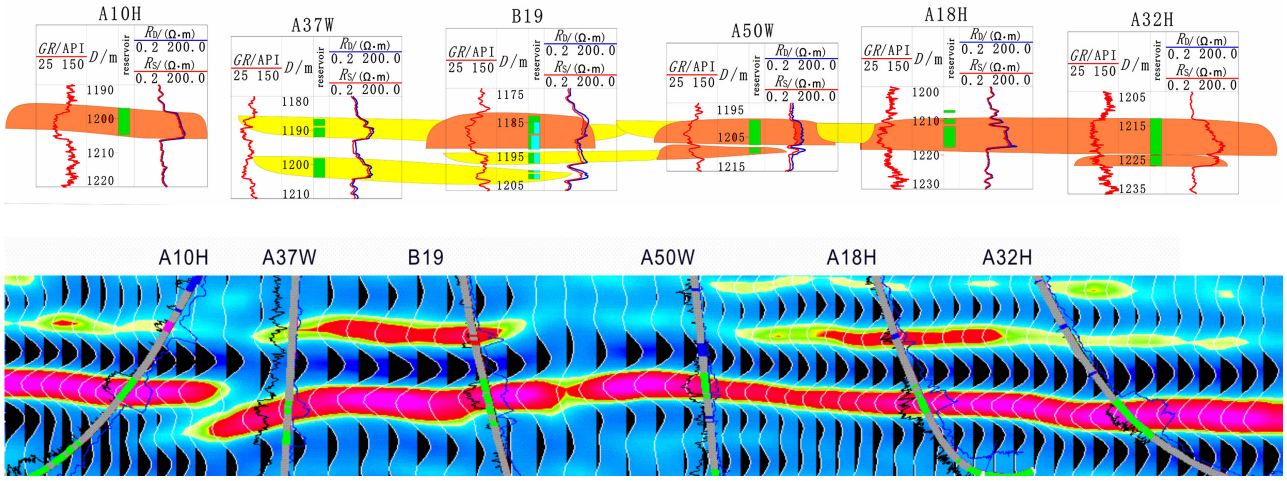


Figure 3. Section of fourth level configuration unit of 1 - 1167 sand body.

generally characterized by low sand to land ratio and good sand body identification on seismic profiles. In the target interval studied, the seismic data quality is good, the geological reflection characteristics are stable, the seismic facies continuity is good, and the faults are relatively clear. The actual drilling data of development wells indicate that the altitude depth and actual drilling error of the target layer top surface predicted by using seismic attribute data are generally less than 3 meters, and the seismic data quality is good. Therefore, it is possible to extract effective information related to the physical property change points of sand bodies from seismic attribute data, and to quantitatively characterize the distribution range of a single configuration unit. Both thickness and physical property changes have an impact on amplitude, but the rate of change of amplitude only has a significant response to sudden changes in thickness or physical property locations, and is not sensitive to slow changes in physical properties and thickness. It is believed that the interior of a single stage sedimentary sand body changes slowly, while the interiors of multiple stage sand bodies are abrupt. Therefore, the overlapping position of multiple stage sand bodies can be determined by the change rate of amplitude.

In order to fully mine relatively high-resolution seismic information, different seismic forward modeling models have been designed based on different contact relationships of single sand bodies within the study area. The results show that compared to traditional amplitude type attributes, the amplitude change rate can better track the lateral contact points of single sand bodies, indicating the lateral overlap or contact position of single sand bodies (**Figure 4**). Because amplitude seismic attributes can better characterize reservoir thickness and lateral changes in the reservoir, amplitude attributes and amplitude attribute change rates are organically integrated. The fusion attribute can more accurately represent the boundary of a single sand body (**Figure 5**), and therefore can more accurately represent the boundary of a single configuration unit, thereby realizing the transformation from seismic characteristics to geological significance.

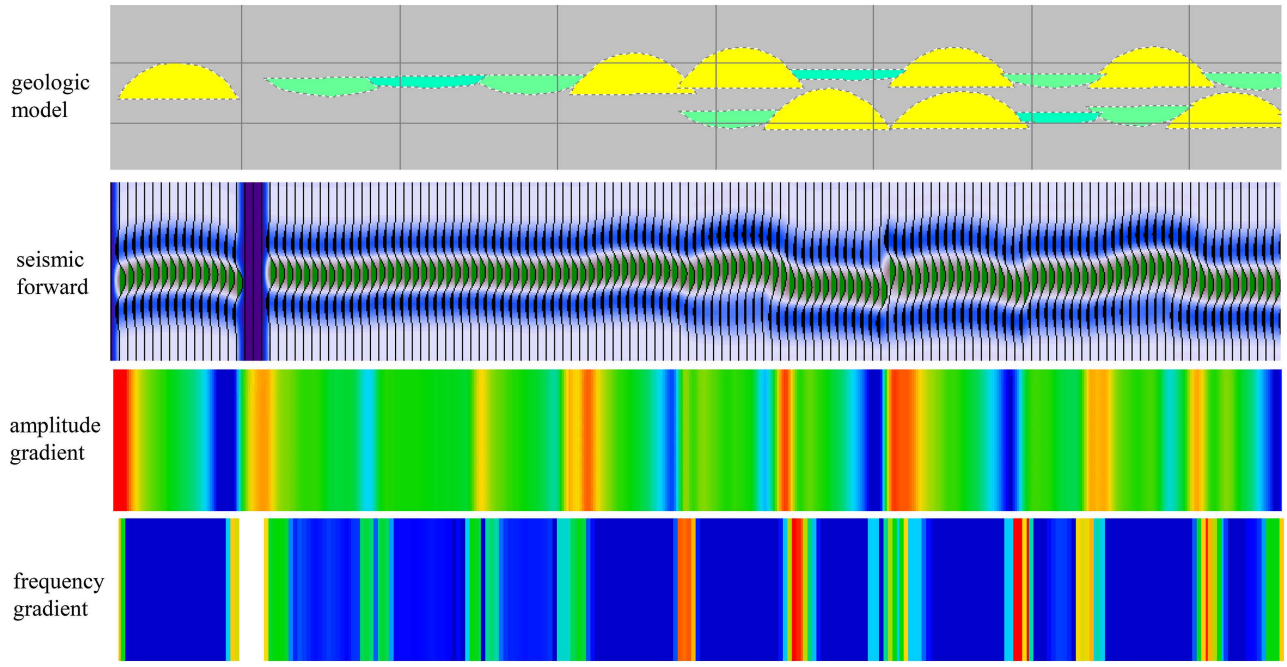


Figure 4. Seismic forward modeling of contact relationships between different single sand bodies.

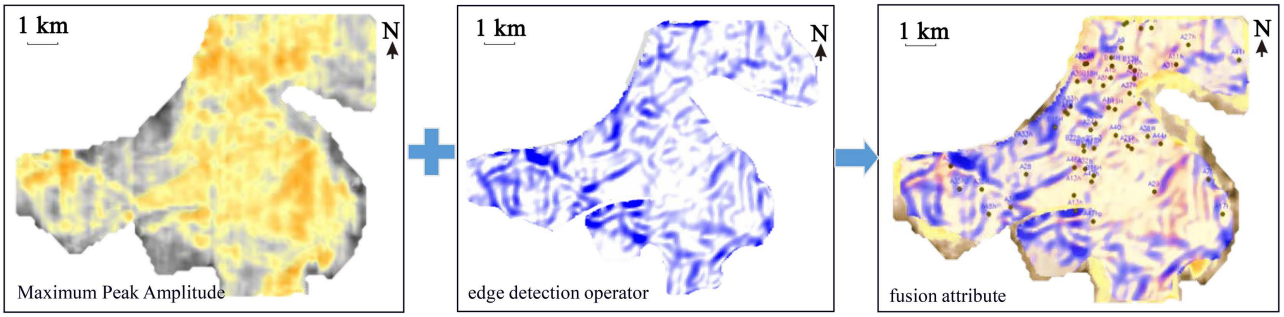


Figure 5. Qualitative identification of single configuration unit guided by attribute fusion.

4.2. Research Results

Under the guidance of the model, the vertical distribution prediction of sand bodies and the description of the planar distribution characteristics of sand bodies are carried out by combining well and seismic data and interacting with horizontal sections (**Figure 6**). The sand bodies 1 - 1167 are mainly sourced from the north, with distributary sand bars and distributary channels diverging from the north to the southwest, due south, and southeast directions, and the sand bodies spread out in a blossom-shaped manner. According to statistical analysis, the diversion sand dam of 1 - 1167 sand body has a length of 310 - 860 m, a width of 156 - 616 m, and a thickness of 2.7 - 9.8 m; the distributary channel is mainly distributed in the NE-SW direction, with a thickness of 1.5 - 4.8 m.

5. Conclusions

1) Based on the geological characteristics of the oil field, combined with the

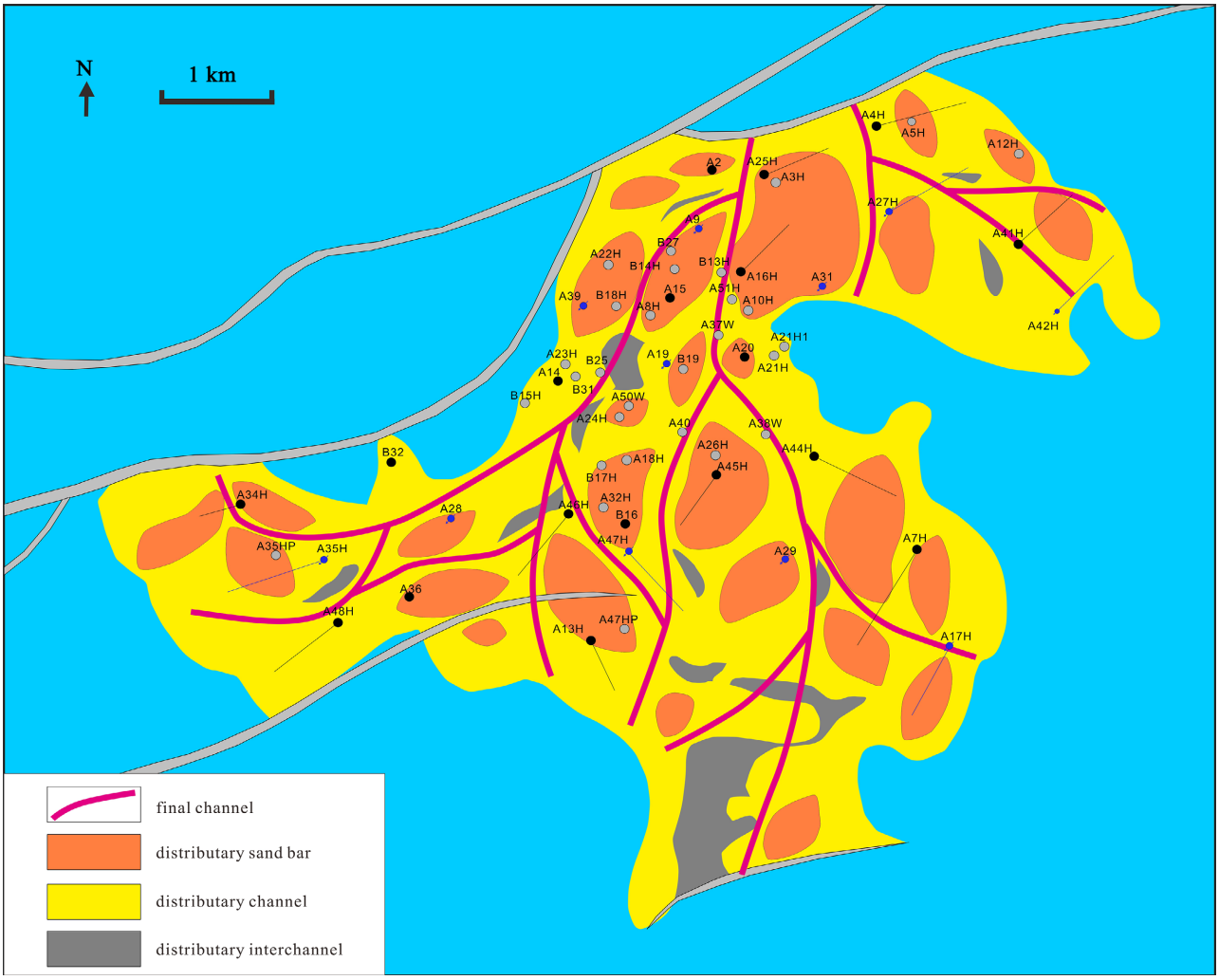


Figure 6. Anatomical plane layout of 1 - 1167 sand body configuration.

logging and seismic facies data, the sedimentary microfacies units of the distributary sandbar type shallow water delta are carefully dissected, and the boundary identification method for the sedimentary microfacies of the distributary sandbar type shallow water delta is established. The logging and seismic facies identification characteristics of the core beach, distributary channel, and inter distributary channel bay are summarized.

2) Based on seismic attribute forward modeling, the law is searched for. By calculating the gradient of a spatial surface, the speed of surface change is described, and an edge detection operator is constructed to organically fuse amplitude attributes and amplitude attribute change rates. The fusion attribute can more accurately represent the boundary of a single sand body, and can more accurately represent the boundary of a single configuration unit, realizing the transformation from seismic characteristics to geological significance.

Conflicts of Interest

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

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