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Study on the architecture of tidal controlled estuarine complex sand bodies in M oilfield, Oriente Basin, Ecuador: A case study of LU Formation

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Abstract: The M oilfield in Oriente Basin, Ecuador has the characteristics of large well spacing and few Wells, and it is difficult to determine the lateral distribution range of sand bodies between Wells. Based on the well logging and seismic data, this paper discusses the sand body configuration characteristics of the Upper Cretaceous tidal controlled estuary reservoir in Oriente Basin in detail. The vertical and lateral contact relationships of reservoir are studied by single well identification, well point phasing, well profile analysis, and fine boundary characterization of seismic simulation, etc. Combined with microfacies types, the vertical overlapping relationships of 3 kinds of 7 types of sand bodies and lateral distribution relationships of 3 kinds of 5 types of sand bodies are summarized. It provides ideas for the study of this kind of sedimentary environment configuration and lays a foundation for the next study of remaining oil distribution law.

Keywords: Tide-controlled estuary; Complex sand body configuration; Oriente Basin.

1. Introduction

As a transitional sedimentary system, estuaries have gradually become one of the key sedimentary environments in recent years. Especially in recent years, a large amount of oil and gas has been found in the sedimentary environment of tide-controlled estuaries. Such sedimentary environments as Athabasca area of Alberta Basin [1-2], Carboniferous system of Tahe oilfield [3], Miocene system of Yangjiang Sag of Pearl River Mouth Basin [4], Hangzhou Bay of Qiantang River Mouth [5] and Cretaceous system of Oriente Basin of Ecuador have attracted the general attention of experts and scholars. Li Yang et al. [6] studied the sedimentary model of LU member of Napo Formation in the northern part of Oriente Basin, and confirmed that the Lu member developed tide-controlled estuaries and shelf, and was located in the position of Chinese and foreign estuaries. Huang Jixin [7] et al. studied the lithofacies characteristics of tidal sand bar of McMurray Formation in the Maikai River block based on core analysis of core Wells. Li Shunli [8] et al. determined the evolution law of the southern transgression-controlled estuarine in Xihu Depression during the Oligocene by using basin simulation techniques, multiple cluster analysis, attribute optimization fitting and vertical superposition mapping methods. Yang Jinxiu [9] et al. took D-F oilfield of Oriente Basin as the research object, and focused on analyzing the occurrence of differential compaction and its influence on reservoir heterogeneity due to the high mud content of mudstone wall, which further affected the distribution of reservoir. Hu Guangyi [10] et al. proposed a configuration characterization method applicable to the development scale of offshore oil fields based on the study of fluve facies in Bohai Bay oilfield, and summarized the concept of complex sand body configuration, which enriched the configuration theory.

Based on previous research results, it is found that there are few researches on the architecture of tide-controlled estuaries. Under the control of both tidal and river energy, the complex sand body has strong complexity and uniqueness. In order to determine the characteristics of the composite sand body configuration in this sedimentary environment, this paper mainly uses logging data and seismic data to carry out detailed research on the composite sand body configuration of the tidal controlled estuary in the study area, and provides some ideas for the research on the configuration characteristics of this kind of environment.

2. Regional geological overview

As shown in Fig 1, the M oilfield is located in the northeast of Oriente Basin, a backarc foreland basin developed on the eastern side of the Ecuadorean Andes. The basin is bounded by the overthrust fault front of the Cordyera Mountains in the west, the Amazon Craton in the east [11], the Vaupes-Macarena uplift in the north, and the Shionayacu shear zone in the south. The Cretaceous strata in the study area developed successively from old to new: Hollin Formation, Napo Formation and Tena formation. The study horizon is the Napo Formation of the upper Cretaceous, and the whole process from the Hollin Formation of the lower Cretaceous to the study horizon is pre-transgression and then regressive, and then the Tena Formation is deposited, which is a second-order sequence.

3. Study on configuration of composite sand body

Complex sand body configuration is the main geological factor restricting underground liquid flow and remaining oil enrichment. The vertical superposition relationship and lateral distribution relationship of reservoir sand body determine the flow path of fluid. In this study, four types of configuration units are identified: tidal channel, tidal sand bar, tidal sand flat and muddy mixed flat.

According to Hu Guangyi's classification scheme of complex sand body architecture based on fluvial facies a classification scheme of complex sand body architecture applicable to the sedimentary environment of tidal controlled estuaries at home and abroad was proposed in this study. This study focuses on the configuration interface between class 6 single tidal channel zone and class 5 composite tidal channel zone.

3.1. Study on vertical overlay relationship of sand body configuration

The vertical overlapping relationship between microfacies sandbodies has an important influence on the distribution of remaining oil, and is one of the focuses of current research on the configuration of composite sandbodies. Sand bodies in the depositional environment of tide-controlled estuaries are affected by both fluvial energy and tidal energy, and a complex superimposed relationship of sand bodies is formed. In this study, the superposition relationships of sand bodies in vertical composite sand bodies and the different types of interfaces that cause the different formation of superposition relationships are determined based on the sedimentary background of tide-controlled estuaries.

3.1.1. Causes of vertical superposition of composite sand bodies

When the tidal energy is greater than the river energy, it is conducive to the formation of favorable storage groups such as tidal sand bar. When the river energy is higher than the tidal energy, it will promote the formation of the inner beach bar and point bar, but it will obviously destroy the sand dam reservoir formed by the tidal action [12].

The sedimentary patterns and distribution characteristics of tidal sand bars in estuaries are different from those in inner and outer estuaries. The sand bars in inner estuaries are dense, mostly composed of composite deposits, but with small scale, high lateral migration rate and relatively developed interbeds. The distribution of sand bars in the outer estuary is scattered, mostly in banded or goose pattern, with a wide distribution range and good continuity. However, the sand bars are relatively spaced and the interlayer development is relatively simple, so they belong to favorable storage collective [13].

In this time, the key horizon LU was located in the position of Chinese and foreign estuaries, and the sand bodies were well developed in the position of middle estuaries, while the outer estuaries were mostly composed of matted mud mixed flat [19]. In the study area, the sand bar sand bodies are distributed in strips in the sand flat body, and the sand bar sand bodies are scattered in a large range, and the sand bodies extend along the channel direction.

3.1.2. Interface division of composite sand body configuration

Through the identification and extraction of argillaceous interlayer, the configuration interface of composite sand body is divided.

The LU sand body of M oilfield has a large thickness, and the features of the oil reservoir are developed in contiguous regions. In order to further clarify the geological understanding and improve the research accuracy of the internal configuration characteristics of the sand body, it is necessary to divide the configuration interface of the LU sand body.

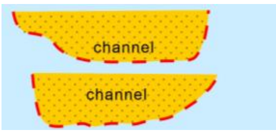
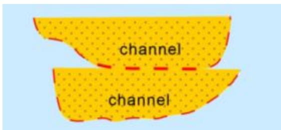
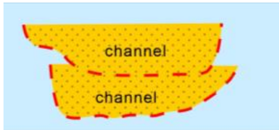
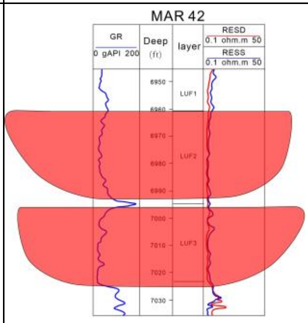
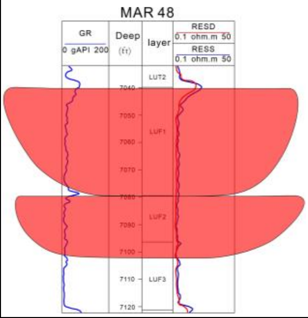
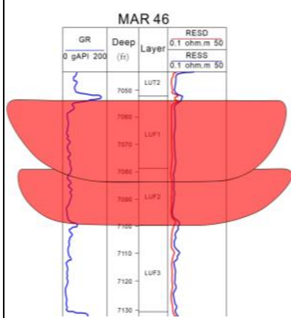
	Separated type	Superimposed type	Cut and fold type
Sand body development model			
Single well log response			
Interface identification mark	The gamma-ray logging curves are bell - shaped and box - shaped with stable mudstone interlayers and obvious curve return	The upper and lower gamma-ray logs are box shaped, with fine deposits in the middle and very thin thickness	The gamma-ray logging curve is box-shaped, and the fine sediment layer at the top of the early channel sediment sand body is seriously eroded by the later channel

Fig. 1 Development styles of complex sand bodies in the study area

As shown in Fig 1, through single well formation correlation, logging facies analysis and sedimentary cycle study, it is concluded that the LU sand body presents three vertical overlapping modes. The upper gamma-ray curve of well MAR42 is bell shaped, while the lower part is box shaped. The stably developed mudstone interval in the middle separates the upper and lower two sets of sand bodies. The mudstone thickness is about 1.5m. The upper and lower gamma-ray logging curves of well MAR48 are box-shaped, with the upper channel sand body superimposed on the lower channel sand body, and the middle is fine-grained deposit with very thin thickness and argillous siltstone lithology. The gamma-ray logging curve of well MAR46 is box-shaped. The fine sediment layer on the top of the sedimentary sand body of the early channel and its own sand body are seriously eroded by the later channel, which makes the two stages of the channel become one. Therefore, according to the cut degree of the channel and the superposition mode of complex sand bodies, the LU layer of M oilfield can be divided into LU Tidal and LU Fluvial, and further divided into five sets of sand bodies, LUT1, LUT2, LUF1, LUF2 and LUF3.

3.1.3. Vertical overlay style of composite sand body

By using GR wave seismic simulation technology to identify the spatial distribution range of single sand bodies, combined with logging phase analysis and without distinguishing microfacies types, the spatial superposition relationship of tidal sand bodies can be divided into three types: vertical separation type of microfacies sand bodies, vertical intersection superposition type of microfacies sand bodies and upper microfacies sand bodies cutting superposition type of lower microfacies sand bodies cutting superposition type. As shown in Fig 2, according to the vertical superposition relationship of different microfacies types, superposition types can be divided into 7 categories. The microfacies logging characteristics of sand bar are funnel shape inverse rhythm with coarser grain size and large thickness. Channel microfacies logging features are box shape positive rhythm with coarse grain size and large thickness. The characteristics of sand flat microfacies logging are finger shape with fine grain size and small thickness.

(1) Overlapping mode of separated sand body

The separated sand body is a single sand body deposit formed in the transgressive stage under the condition of rising sea level, insufficient provenance supply, less sedimentary material and large accommodating space. According to the microfacies type, this type of superimposed sand body can be divided into four categories: sand-channel, sand-flat - sand-bar, watercourse - watercourse and sand-bar.

(2) superimposed sand body superimposed mode

In the stage from transgression to regression, the source supply is gradually sufficient, sedimentary materials increase, and the space that can accommodate gradually decreases. Lateral migration occurs in tidal channels, and lateral deposits with cross-bedding are mostly formed, with thin argillaceous lateral deposits inside. The argillaceous lateral deposits are called compartments and have weak barrier ability, and the thickness of single-layer sand bodies is thin and the distribution range of sand bodies is small. This type of superimposed sand body only overlaps tidal bar microfacies over tidal channel microfacies.

(3) The superimposed mode of cut superimposed sand body

In the regressive stage, the source supply is sufficient, the sedimentary material content is rich, and the accommodative space is very limited. The channel is constantly diverted, and the phenomenon of side cutting and downcutting is frequent. The late tidal channel deposits and erods the top fine grain of the channel developed in the early stage, resulting in the superposition and cutting of the tidal channel sand bodies with good extensibility [12]. According to the microfacies type, this superimposed pattern can be divided into two types: channel-sand bar and channel-channel.

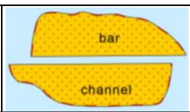
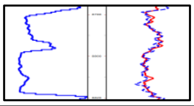
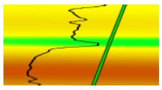
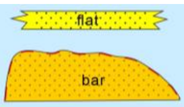
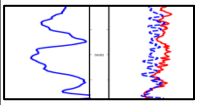
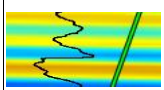
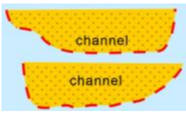
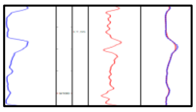
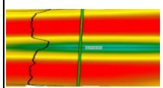
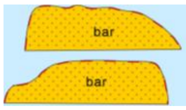
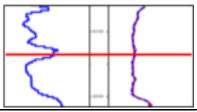
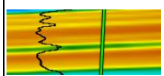
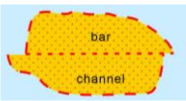
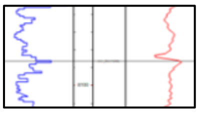
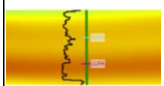
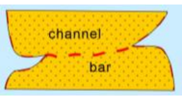
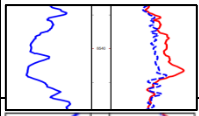
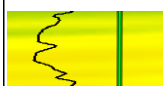
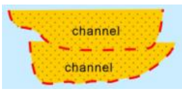
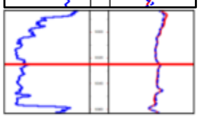
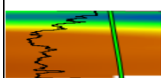
	Superimposed feature		Logging characteristics	Inversion feature	Interlayer lithology	water blocking capacity
1	Sand bar - Channel				mudstone	completely blocking
2	Sand flat - sand bar				mudstone	completely blocking
3	Channel-Channel				mudstone	completely blocking
4	sand bar -sand bar				mudstone	completely blocking
5	Sand bar-Channel				Mudstone - siltstone	partially blocked
6	Channel-sand bar				siltstone	Weak septal ability
7	Channel-Channel				siltstone	weak septal ability

Fig. 2 Tidal Sand body overlay style

3.2. Research on lateral distribution relationship of sand body configuration

3.2.1. Characterization method of lateral distribution relationship of composite sand bodies

The study of planar sand body configuration is mainly to determine the planar distribution relationship of sand body and the interface characteristics formed by it. The main method is to accurately determine the sand body boundary by using seismic waveform indication simulation technology and connecting well profile (internal configuration characterization method). Take the contact relationship of LUT1 sand body of key player in the study area as an example, the specific steps are as follows:

(1) Determine microfacies type by logging curve morphology, and roughly delineate sedimentary microfacies boundary.

The microfacies type of the well location was determined by the logging curve morphology of each well, and the distribution range of microfacies sand body was roughly described by the planar microfacies characterization method.

(2) As shown in Fig 3, Sand body configuration boundary was fine-determined through seismic attribute simulation and lateral distribution range of sand body was accurately determined according to sand body distribution distance shown in seismic simulation.

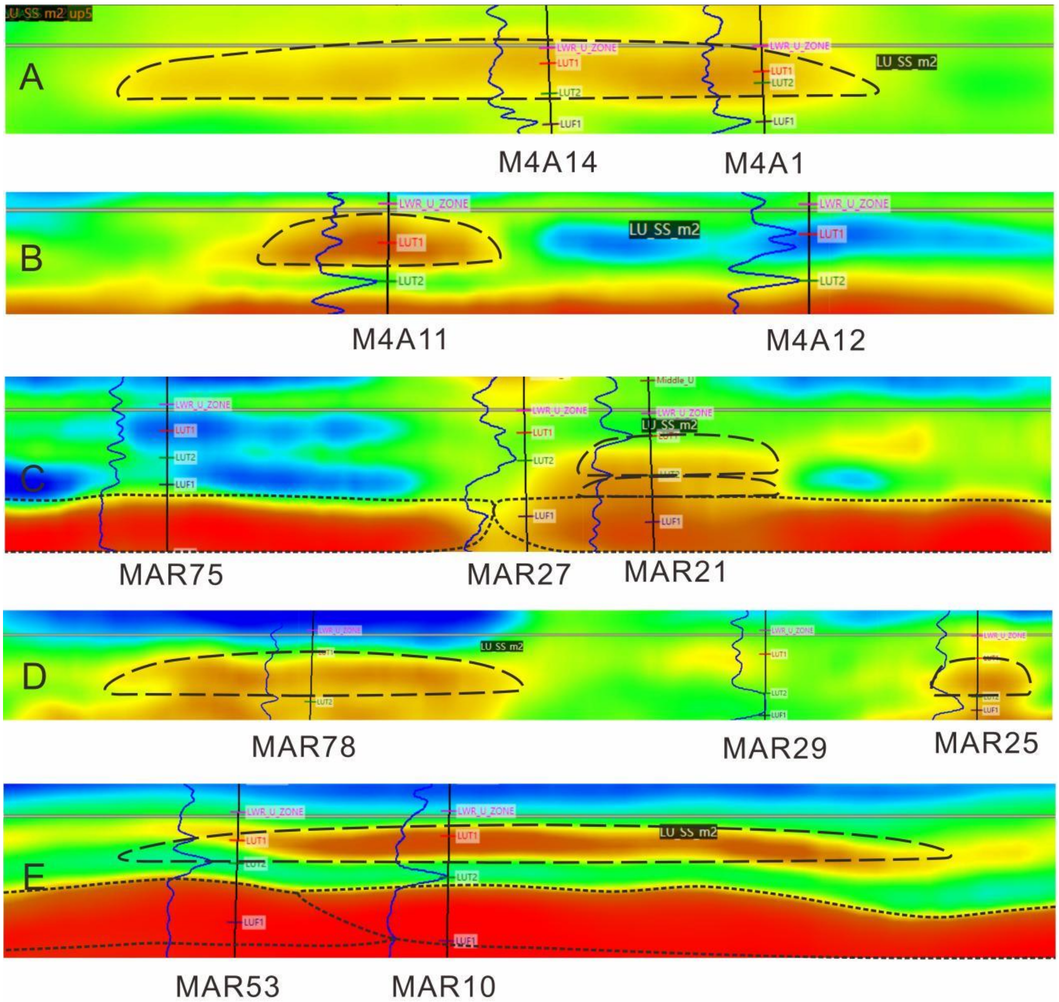


Fig. 3 Simulation section

The result map of sedimentary microfacies is more accurate after microfacies boundary is fine-determined by GR waveform simulation, which can accurately display the lateral distribution range of sand body and characterize the lateral distribution relationship of sand body.

3.2.2. Lateral distribution pattern of composite sand body

According to the above research on lateral distribution relationship of sand body, three lateral distribution patterns of sand body are identified: lateral separation type, lateral tangent type and lateral contact type. As shown in Fig 3A, Fig 3B and Fig 3D , the tidal bar sand body at well M4A11 exists in isolation and is mainly surrounded by argillous deposits. The distribution pattern is lateral separation. As shown in the simulation results in Fig 3C, a tidal channel sand body is developed in well MAR75, and another tidal channel sand body is developed in well MAR21. Well MAR27 between the two Wells is the tidal channel edge on the right side. As shown in the figure, two tidal channels contact with each other between well MAR27 and well MAR75, but have not yet entered the stage of mutual erosion.As shown in Fig 3E, the tidal channel sand body in the early stage of LUF1 formation in well MAR53 was laterally eroded by the tidal channel developed in late stage of well MAR10. This configuration pattern is laterally tangential.

4. Conclusion

In this study, four types of sedimentary microfacies in tidal controlled estuaries were identified, three types of superimposed vertical composite sand bodies were identified, and three types of lateral composite sand body distribution patterns were identified. The vertical superposition patterns of favorable sand bodies in the study area are divided into separation type, superposition type and shear superposition type. The upper part of LU layer has a large proportion of separation type, and the lower part of LU layer has a wide range of superposition type and shear superposition type. Lateral distribution patterns include separation, contact and tangential. The vertical separation type and lateral separation type are mainly developed in Tidal formation in the upper part of LU layer, and the vertical superposition type, tangential overlap type, lateral contact type and tangential type are mainly developed in Fluvial formation in the lower part of LU layer.

References

[1] Liu Yanxin, Yin Yanshu, Zhou Han. Reservoir architecture of large estuarine oil sands: A case study of Athabasca area, Alberta Basin, Canada [C]//. Abstract Collection of the 15th National Academic Conference on Palaeogeography and Sedimentology.,2018: 437.

[2] Zheng Minqian. 3D geological modeling of tidal controlled Estuarine reservoir [D]. Yangtze University,2018.

[3] Liu Guizhen, Bao Zhidong, Du Weiwei, Zhu Junrui. Sedimentary environment and lithofacies analysis of tidal estuary: A case study of Carboniferous deposits in Tahe Oilfield [C]//. Abstracts of the 12th National Conference on Palaeogeography and Sedimentology.,2012:14.

[4] Liu Guizhen, Bao Zhidong, Du Weiwei, Zhu Junrui. Sedimentary environment and lithofacies analysis of tidal estuary: A case study of Carboniferous deposits in Tahe Oilfield [C]//. Abstracts of the 12th National Conference on Palaeogeography and Sedimentology.,2012:14.

[5] Zhou Han, Huang Jixin, Feng Wenjie, Liu Shangqi, Yin Yanshu. Analysis on development characteristics and Formation factors of sand bars in tidal controlled estuaries: A case study of Qiantang River [J]. Geological Review, 2020, 66(01): 101-112. DOI:10.16509/ j.ore -The 2020. 01. 007.

[6] Li Yang, Jin Zhenkui, Zhu Xiaoer, Shi Shuting, Yuan Kun, Li Rui, Wang Jinyi. Lithofacies types and sedimentary models of tidal controlled estuarine: A case study of LU Member of Upper Cretaceous Napo Formation in northern block of Oriente Basin, Ecuador [J]. Journal of sedimentary, 2020, 38 (4): 826-837. DOI: 10.14027 / j.i SSN. 1000-0550. 2019.068.

[7] Huang Jixin, Liu Shangqi. Lithofacies and configuration analysis of tidal controlled Estuaries [C]//. Abstracts of Sedimentology and Unconventional resources Papers of the 2015 National Sedimentology Congress.,2015:131.

[8] Li Shunli, Yu Xinghe, Zhu Xiaomin. Sedimentary dynamic characteristics and evolution law of the coastal zone of the Oligocene Huagang Formation in Xihu Sag [C]//. Proceedings of the 2015 National Sedimentology Conference on Sedimentology and Unconventional Resources. 2015 :359.

[9] Yang Jinxiu, Zhang Kexin, Chen Heping, Lu Shuangfang, Wan Xuepeng, Tang Mingming, Xiao Dianshi, Zhang Xianxian. Origin of mudstone wall and its influence on reservoir distribution in D-F oilfield of Oriente Basin [J]. Oil & Gas Geology, 2017,38(06):1156-1164.

[10] Hu Guangyi, Fan Tingen, Chen Fei, Jing Yongquan, Song Laiming, Liang Xu, Xiao Dakun. Configuration theory of composite sand body and its application [J]. Oil & Gas Geology,2018,39(01):1-10.

[11] Zhang Meng, Wu Shaobo, sequence stratigraphic framework and development model of Cretaceous Napo Formation in Mariann Oilfield, Oriente Basin, Ecuador [J] Energy and Environmental Protection. 202. 44(04) 109113+ 120. DO1 019389 .nk. 103-0506 202.04.018.

[12] Xue Song. Study on mud coating and multi-point statistical modeling of sedimentological system in tidal controlled estuary [D]. China University of Petroleum (East China),2016.

[13] Tang Tao. Numerical simulation of sediment in tidal controlled Estuary [D]. Yangtze University, 2018.