Analysis of the genesis model of large-scale mixed tidal flats in F oilfield

YANG Lina, ZHANG Xuemin, WEI Li, SHI Changlin

Abstract— **The F oilfield has developed a set of large-scale mixed tidal flat sediments in the transitional phase between sea and land, with diverse mixed deposition forms. In order to better understand the distribution pattern of mixed reservoirs in F oilfield, improve the production of the oilfield, and enrich the relevant theories of mixed tidal flats, a large-scale study on the genesis model of mixed tidal flats has been carried out. By comprehensively utilizing core, logging, and seismic data, and based on the identification of sedimentary microfacies, the mixed deposition form and distribution characteristics of mixed tidal flats are studied; Based on the analysis of various geological elements, three connected land platform models with mixed tidal flats were established to explain the genesis of the large mixed tidal flats in the F oilfield. The research results indicate that although the three modes have different facies zones, they share common characteristics, namely, the climate in the exposed areas on land is arid, and salt marsh gypsum and evaporite dolomite are widely developed; There are terrestrial debris in the nearshore zone, and based on the abundance or scarcity of terrestrial debris material and whether the environment is clean and warm, the nearshore zone is divided into two different environments: detrital tidal flat sedimentary environment and carbonate tidal flat sedimentary environment; The high-energy shallow water barrier beach (island) on the edge or surface of the continental shelf causes the confined seawater behind it to form a lagoon, leading to large-scale mixed tidal flat sedimentation. These common features of the three modes are necessary conditions for the formation of a large mixed tidal flat in the F oilfield.**

Index Terms—**mixed tidal flat, Sedimentary characteristics, Causal mode, Asmari Group**

I.Introduction

The study of tidal flat geomorphology and sedimentology in China has made important progress in the past half century[1] –[4], From early qualitative analysis to quantitative research, from early sedimentary facies model analysis to the study of sedimentary characteristics in various microfacies zones, research on tidal flat sedimentation has become increasingly in-depth and specific. However, current research progress only involves two types of tidal flat sedimentary environments: clear water tidal flats and muddy water tidal flats, and few scholars have explored the sedimentary characteristics and genesis models of mixed tidal flats combining these two [5] –[6], The Asmari Formation in Iraq's F oilfield, as one of the main oil-bearing formations, was formed in a sedimentary environment of the continuous land platform [7], The B oil formation in the lower part of Asmari is a mixed sedimentary tidal flat composed of carbonate and clastic rocks. The lithology is complex and diverse, and the mixed sedimentary forms of the tidal flat are also relatively rich. This makes it difficult to identify the distribution pattern of the reservoir in the oilfield, which affects the single well production and reservoir recovery rate of the oilfield. In view of this, based on the study of the characteristics of mixed tidal flat sediments, this article identifies the types of mixed tidal flat forms, studies the distribution characteristics of mixed tidal flat sediments, and establishes three types of mixed tidal flat sedimentary models: "Bordered platform sedimentary model with terrestrial debris", "Bordered platform sedimentary model with barrier shoals inside the platform", and "Bordered platform sedimentary model with sandy barrier islands inside the platform", to explore and explain the genesis of the large mixed tidal flat in the F oilfield. This understanding has clarified the sedimentary genesis types of the area, analyzed the spatial distribution characteristics of reservoirs in each period, and provided strong facies control basis for predicting potential target areas. At the same time, it has played a certain role in promoting the research on the sedimentary characteristics and genesis theory of large-scale mixed tidal flats.

II.Regional Geological Background

The F oilfield is located in the southern part of the Mesopotamian Basin in the eastern Arabian Plateau, structurally situated in the low angle fold deformation zone of the Zagros foreland basin, and is part of the Alpine orogenic belt. During the long geological history of the Jurassic Early Cretaceous period, the Arabian Plateau was generally in a period of large-scale oscillatory marine transgression, and the southern region of Iraq, including the F oilfield, was located in the deep-water platform facies zone [8]. Entering the Oligocene Miocene of the Tertiary period, which is the sedimentation period of the Asmari Formation in the F oilfield, due to the subduction of the Arabian Plate towards the Eurasian Plate and the influence of the Alpine tectonic movement, the ancient Tethys Ocean was closed and shrunk, and the Arabian Plateau was extensively uplifted into land. The ancient terrain was high in the southwest and low in the northeast, with residual marine sediments in eastern Iraq. The study was located in a shallow sea environment near the coast, and the terrestrial debris came from the Arabian Plateau on the west side. Among them, during the Lower Middle Miocene to the early Middle Miocene, due to the increase in erosion products from the Arabian Plateau and the expansion of transport range, terrestrial debris was transported to the Zagros Foredeep Depression, forming sandy clastic rock sedimentary layers in Iraq, Kuwait, and southwestern Iran. At the same time, due to shallow sea carbonate rock deposition, a mixed deposition of Asmari B oil group clastic rocks and carbonate rocks was formed in the F oilfield.

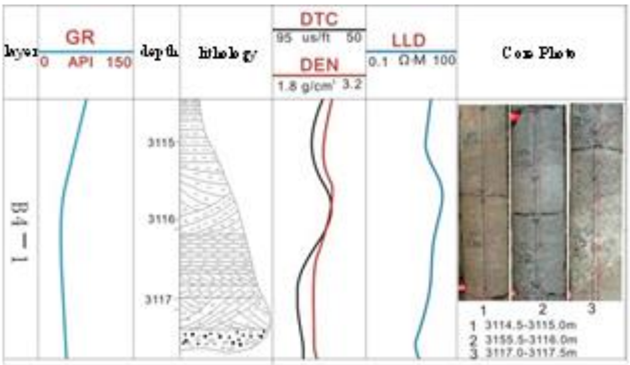
III.THE MIXED FORM OF MIXED TIDAL FLATS

The reservoir of Asmari B oil formation in F oilfield is mainly composed of a set of red green mixed to gray, dark gray carbonate rocks and clastic rocks, with rich lithological types, mainly composed of dolomite, mudstone, sandstone, dolomitic sandstone, sandy dolomite, and limestone. This reservoir is a mixed tidal flat consisting of a clear water tidal flat and a muddy water tidal flat interbedded with each other. According to different sedimentary rock types, the tidal flat can be divided into three categories: detrital rock tidal flat (muddy water tidal flat), carbonate rock tidal flat (clear water tidal flat), and lithological mixed tidal flat (Figure 1).

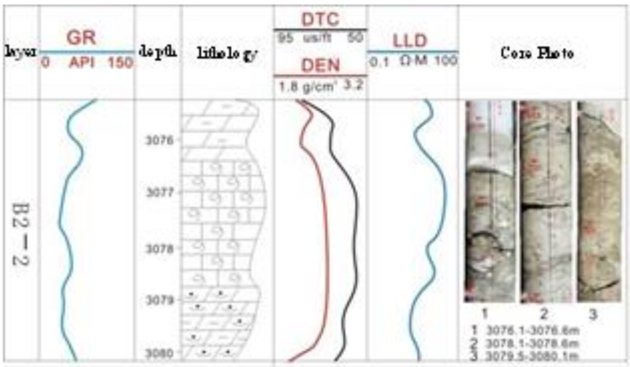
There are two forms of mixed deposits constructed in the research area. The first is the lithological mixed deposition of carbonate rocks and terrestrial debris (such as dolomitic sand flats) to form lithological mixed tidal flats. The other is the vertical multi cycle stacking of clastic rock tidal flats, carbonate rock tidal flats, and lithological mixed tidal flats to form mixed deposits. Based on core characteristics such as lithology, color, sedimentary structure, and sedimentary structure, combined with logging curve features, the study area is divided into three types of tidal flats, totaling more than ten microfacies (Table 1). The mixed tidal flats in the research area exhibit the characteristics of thin sedimentary thickness (3-6m) and rapid transformation of tidal flat types, reflecting the turbulent changes in the sedimentary environment.

Table 1. Sedimentary facies division of the study area

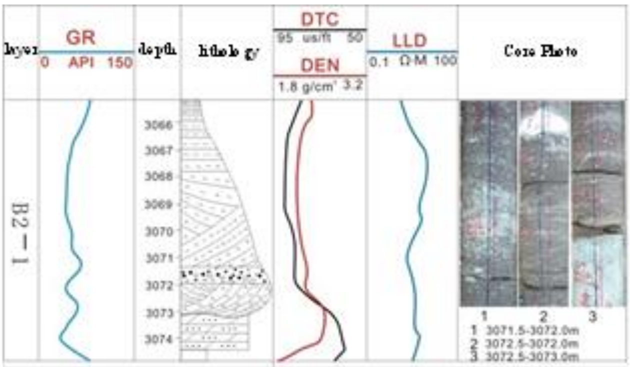
sedimentary facies		subfacies	microfacies
mixed tidal flat	detrital tidal flat	supratidal zone	mud flat, paste mud flat, sand mud flat
		intertidal zone	tidal channels, sand flat, sand mud flat
		subtidal zone	tidal channels, sand flats, underwater sandbars
	carbonate tidal flat	supratidal zone	mud flat, （mud） dolomite flat,paste dolomite flat
		intertidal zone	tidal channels, limestone flats, granular beach
		subtidal zone	tidal channels, granular beach
	Lithological mixed tidal flat	supratidal zone	dolomitic silt flat, (silty) sandy dolomite flat
		intertidal zone	tidal channels, dolomitic sand flat, sandy limestone flat
		Subtidal zone	tidal channels, sandy limestone flat



（a）Detrital rock tidal flats in the research area



（b）Carbonate tidal flats in the research area

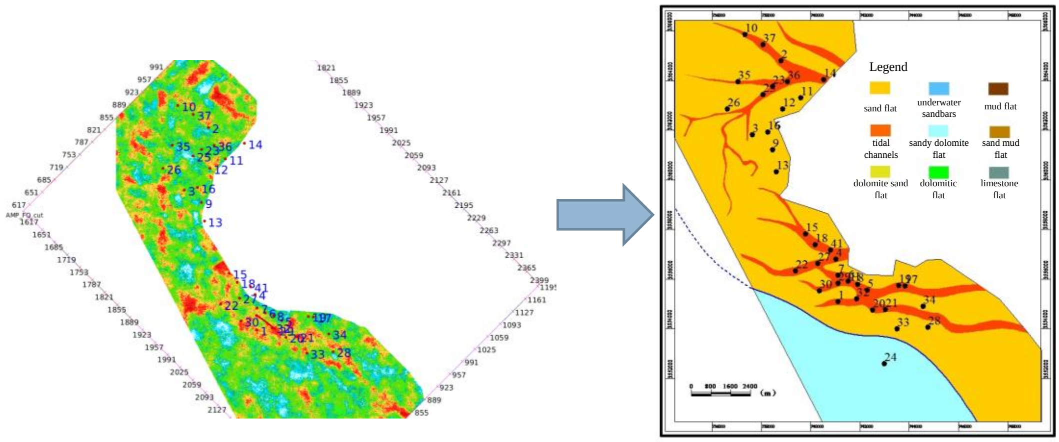


（c）Mixed tidal flats in the research area

Figure 1. Three types of tidal flats in the study area

IV.DISTRIBUTION PATTERN OF MIXED TIDAL FLATS

The lithology of the research area is complex, with most of it being thin interbedded sediments of carbonate and clastic rocks vertically. The probability volume of sandstone obtained through lithology information and geological statistical inversion on the well, combined with the judgment of tidal flow direction, obtained the distribution of sedimentary microfacies in the study area (Figure 2).



（a）Probability attribute map of root mean square sandstone （b）Sedimentary microfacies map

Figure 2. Probability attribute map and sedimentary microfacies map of B3-1 sandstone in the study area

On the plane, detrital tidal flats and carbonate tidal flats have obvious zoning characteristics and are distributed in a sheet-like manner. The two can be directly adjacent or connected by lithological mixed tidal flats. The research area mainly develops sediments in the supratidal zone and intertidal zones. Among them, the supratidal zone is mainly composed of dolomite flat and mud flat sediments, while the intertidal zone is mainly composed of sand flat and limestone flat sediments. The tidal channel winds through it and spreads in a snake like shape, becoming shallower and disappearing towards the direction of the intertidal zone. The supratidal mudflats are generally connected to the intertidal sand flats and tidal channels through sand mudflats, forming a typical detrital tidal flat facies sequence.The dolomite flat in the supratidal zone is connected to the limestone flat, granular beach, and tidal channel in the intertidal zone to form a typical carbonate tidal flat. In addition, the dolomite flat in the supratidal zone can be connected to large-scale sand flats through (powdery) sandy dolomite flat and dolomitic sand flat, forming a mixed tidal flat plane facies sequence of carbonate tidal flat - lithological mixed tidal - flat detrital tidal flat (Figure 3).

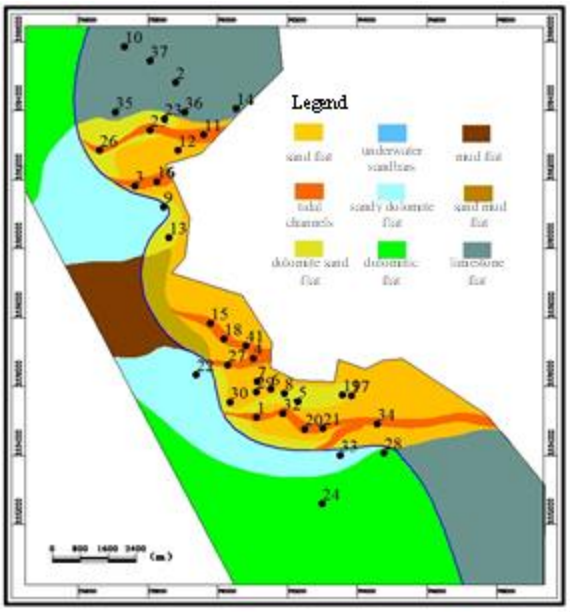


Figure 3. Planar Distribution of Microfacies of Mixed Tidal Flat Sediments in the Study Area

Vertically, during the Asmari sedimentation period, sea level fluctuations were frequent, but the overall trend was still dominated by regression, with only intermittent occurrences of marine transgression. Except for the subtidal sedimentation developed at the top of B1 in the southeastern part of the oilfield, the overall sedimentation is dominated by the supratidal zone and intertidal zone interaction of mixed tidal flats. This includes continuous sedimentation in the intertidal and supratidal zones of the same type of tidal flat, as well as interactive sedimentation in the intertidal and supratidal zones between different types of tidal flats .During the marine transgression period, due to the rise of average sea level and the deepening of seawater within the platform, the supply of terrestrial debris in the study area was relatively low, resulting in the relatively developed characteristics of carbonate tidal flats and lithological mixed tidal flats in the study area; During the regression period, due to the decrease in average sea level, the area originally located within the platform was exposed to the surface and received relatively more terrestrial debris from the western highlands, resulting in the development of detrital tidal flats in the study area (Figure 4).

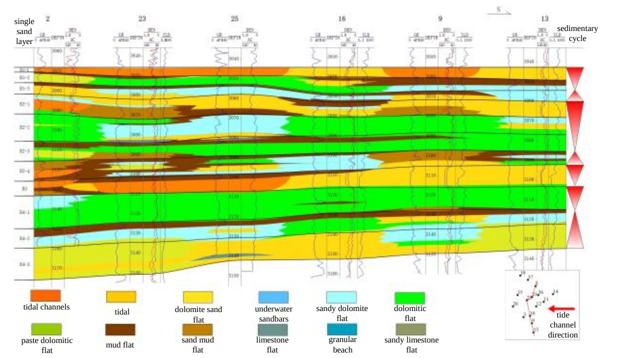


Figure 4. Distribution of sedimentary microfacies in Asmari B oil formation in the study area

V. Study on the Genesis Model of Mixed Tidal Flats

Clastic tidal flats are generally formed in nearshore coastal environments with terrestrial debris and barrier terrain [9], while carbonate tidal flats belong to the nearshore part of carbonate platform environments [10]. For the exploration of the genesis model of mixed tidal flats formed by the interaction of the two in the plane and vertical directions, relying solely on the study of the F work area is far from enough. The scope needs to be expanded to the entire shallow sea on the east side of the oilfield to study the sedimentary model of platforms with mixed tidal flats. There are currently many sedimentary models involving tidal flats, including Owen's land surface sea energy zoning model, Laporte's model, Armstrong's mixed sedimentary model, Wilson's comprehensive carbonate sedimentary model, Tucker's model, Gu Jiayu's carbonate platform model, etc. [11]. Although there are many shallow sea platform models, only Armstrong's mixed sedimentary model has been explained for the simultaneous occurrence of terrestrial debris and carbonate rocks. However, this model is different from the sedimentary situation in the study area and is not applicable to this area.

Based on the sedimentary characteristics of the study area, this article proposes three shallow sea sedimentary models for the development of mixed tidal flats, namely the "marginal platform sedimentary model with terrestrial debris", the "marginal platform sedimentary model with barrier beaches within the platform", and the "marginal platform sedimentary model with sandy barrier islands within the platform". Among the three modes, although the types of sedimentary facies zones on the plateau are different, they all have similarities, namely: the climate in the exposed areas on land is dry, salt marsh gypsum and evaporite dolomite are widely developed, there are terrestrial debris in the nearshore areas, and there are high-energy shallow water barrier beaches on the edge or surface of the shelf, causing residual seawater behind them to form lagoons and leading to large-scale tidal flat sedimentation. There are two different sedimentary environments in the nearshore areas of the three modes. One is the shallow water area with a high supply of terrestrial clastic materials. Before the deposition of tidal flats, the nearshore areas were originally terrestrial clastic beach sediments or abandoned deltas. Later, due to tidal alteration, beach sands were transformed into detrital tidal flat sediments with tidal flat characteristics; Another type is shallow water areas with limited supply of terrestrial debris materials. The environment in this area is clean and warm, and carbonate rocks are prone to sedimentation. Through the action of bidirectional tidal currents, the carbonate rock sediments generated in situ are transformed. At the same time, during a major storm surge, tidal currents and waves can break, transport, and re deposit the carbonate rocks in the semi deep water to deep water continental shelf area, forming granular limestone and plaster limestone such as internal debris, concretions, bioclasts, and spherical particles, namely carbonate tidal flat sediments. Among the three modes, the climate in the intertidal zone near the coast is hot and dry, and gypsum dolomite is widely developed. The sand flat and dolomite flat are generally connected by transitional microfacies, such as (powder) sandy dolomite flat and dolomitic sand flat, whose sediments are rock mixed tidal flat sediments formed by the mixing of carbonate rocks and terrestrial debris in lithology. The three modes are briefly described as follows.

A.Sedimentary Model of Bordered Platforms with Land Source Fragments

This model is a shallow water platform with high-energy external edges, along which high-energy barrier reefs or shoals develop, forming low-energy lagoons on its shore side. From land to sea, the facies belts are: mixed tidal flats, lagoons, platform edge reef beach complexes, and reef front slopes. In the nearshore tidal flat facies zone, sedimentary rocks mainly consist of terrigenous detrital sandstone and mudstone, as well as carbonate rocks , dolomite, marlite, granular limestone, and biogenic limestone. Due to being located in a dry climate zone, towards the land is the evaporation deposition of salt marshes, where gypsum and other evaporite rocks are formed. The clastic rock tidal flats and carbonate rock tidal flats in mixed tidal flats have obvious zoning in the plane, that is, the types of tidal flats formed in different environmental areas are different. For the lagoon, the main sediment is fine-grained material. The lagoon connected to the detrital tidal flat is divided into two sedimentary facies zones, namely nearshore sedimentary silt and mudstone, and nearshore sedimentary silt limestone or marlite; The lagoon connecting one side of the carbonate tidal flat is mainly composed of sedimentary plaster limestone. High energy shallow water sediments are developed on the edge of the plateau or shelf, while reefs and shoals are developed. Shoals are composed of biogenic limestone or oolitic limestone, which together with biogenic reefs form barrier terrain, leading to the formation of still water lagoons in the shelf behind the reefs and limiting seawater circulation. The slope in front of the reef is mainly deposited with gray sand, angular gravel, and some plaster (Figure 5).

B.Sedimentary Model of Bordered Plateau with Barrier Beach within the Platform

This model is a marginal platform sedimentary model with terrestrial debris, shallow water barrier beaches within the platform, and high-energy reef beaches developed at the platform edge. From land to sea, the facies belts are: mixed tidal flats, restricted plateaus, barrier shoals, open plateaus, reef beach complexes at the edge of plateaus, and reef front slopes. In the nearshore area, a mixed tidal flat is formed by the planar mixing of detrital tidal flats, carbonate tidal flats, and lithological mixed tidal flats. In this model, in shallow and deep water shelf areas, in addition to high-energy biogenic reefs and shallow beaches developed at the edge of the shelf, high-energy shallow water carbonate sand beaches are also developed on the shelf, which are important places for the generation of oolitic limestone or bioclastic limestone. The carbonate shoal serves as an intra platform barrier shoal, dividing the area between the nearshore tidal flat and the edge of the shelf into two parts: a confined platform behind the shoal and an open platform behind the shelf edge reef shoal. The limited seawater circulation in these two areas leads to the formation of bioclastic micritic limestone and mudstone limestone in a still water environment (Figure 6).

C.Sedimentary Model of Bordered Plateau with Sandy Barrier Islands within the Platform

A This model is similar to the "bounded platform model with barrier shoals within the platform", but the difference is that the sand barrier island separates the restricted platform from the open platform on the shelf, that is, this model runs from land to sea, and its facies are: mixed tidal flats, restricted platforms, sand barrier islands, open platforms, platform edge reef beach complexes, and reef front slopes. The barrier island may have been formed by early beach changes or abandoned delta, resulting in sandy barrier islands due to changes in sea level and wave modifications. A confined sea area is formed between mixed tidal flats and barrier islands, where relatively still water sediments such as siltstone, mudstone, silty limestone, and marl are deposited (Figure 7).

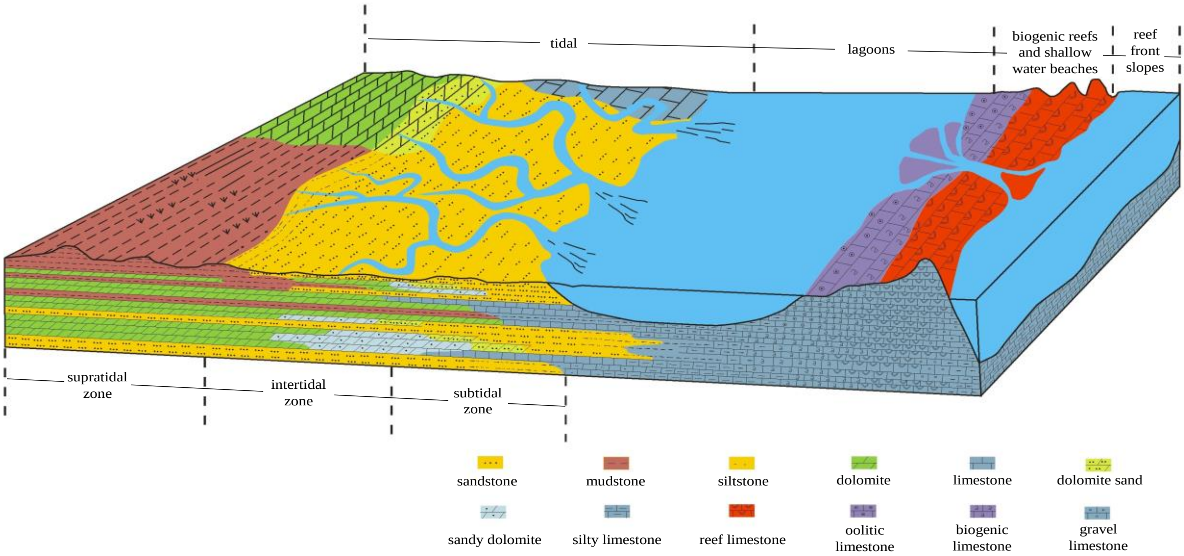


Figure 5. Sedimentary Model of Bordered Platform with Terrestrial Debris

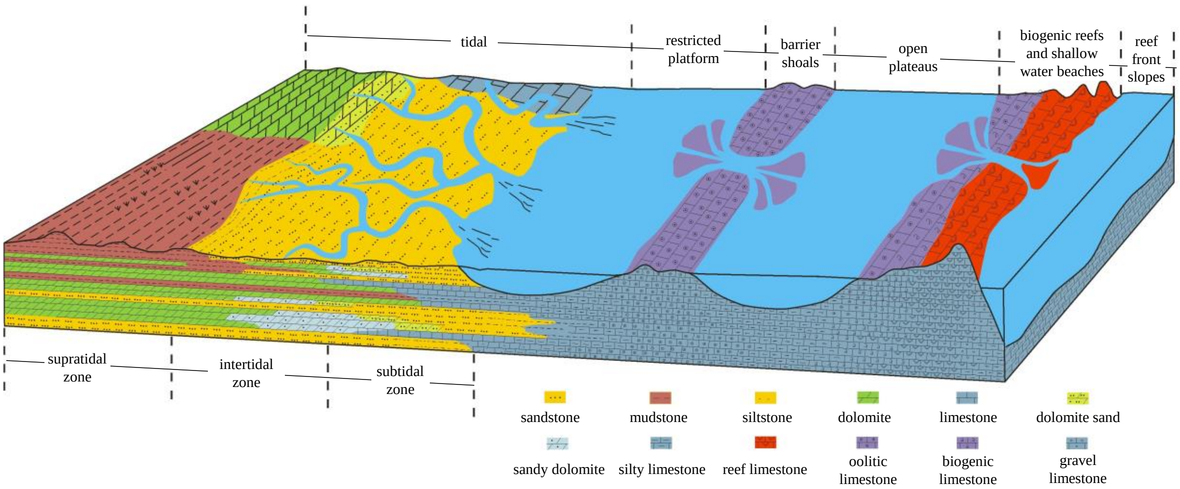


Figure 6. Sedimentary Model of Bordered Terrace with Barrier Beach within the Platform

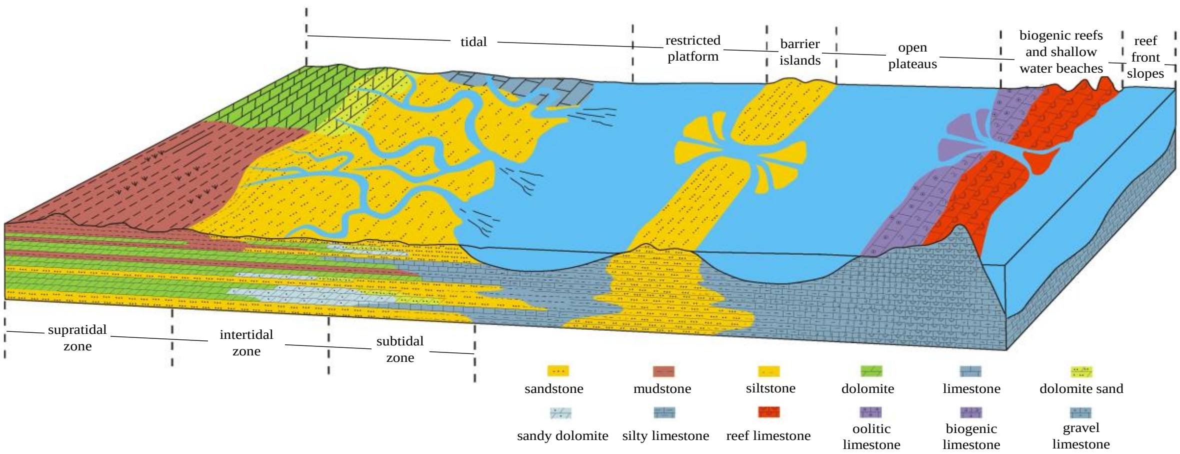


Figure 7. Sedimentary Model of Bordered Terrace with Sandy Barrier Islands within the Platform

The above three models are all causal models of mixed tidal flats. Among them, in the first mode, tidal water flows into the lagoon from the tidal inlet of the reef beach complex on the edge of the platform. Due to the absence of barrier barriers within the platform, the tidal energy is relatively strong, the impact area is wide, and it is more likely to form large-scale tidal flats in the shore area. The second type, due to the presence of barrier shoals within the platform, results in a smaller scale of the true lagoon (restricted platform) and a relatively weaker tidal energy due to obstruction. As a result, the scale of the nearshore tidal flat is not as large as the first type. The third mode is due to the presence of sandy barrier islands within the platform, which not only block tidal energy but also reduce the size of the lagoon. When the size reaches a certain level, the sand on the barrier islands may affect the sediment of the tidal flats, resulting in the exclusion and interference of carbonate deposits on the tidal flats, forming impure mud and sandy carbonate rocks. Therefore, the third mode is more likely to form interbedded debris tidal flats and lithological mixed tidal flats, while the possibility of forming interbedded debris tidal flats, carbonate tidal flats, and lithological mixed tidal flats is not as high as the first two modes.

VI.Conclusion

(1) According to the different sedimentary lithologies, the study distinguishes three types of tidal flats: detrital tidal flats (muddy water tidal flats), carbonate tidal flats (clear water tidal flats), and lithological mixed tidal flats. Two forms of mixed deposits have been constructed in the region: one is the lithological mixed deposition of carbonate rocks and terrestrial debris, and the other is the vertical multi cycle stacking of detrital tidal flats, carbonate tidal flats, and lithological mixed tidal flats. The microfacies types are diverse, mainly consisting of mudflats, sandy mudflats, tidal channels, sandy flats, dolomite flats, limestone flats, dolomitic sand flats, and sandy dolomite flats. Mixed tidal flats exhibit the characteristics of thin sedimentary thickness (3-6m) and rapid transformation of tidal flat types, reflecting the turbulent changes in sedimentary environments.

(2) On the plane, there is a clear zoning between clastic tidal flats and carbonate tidal flats. The two can be directly adjacent or connected by lithological mixed tidal flats, that is, from land to sea, they can form a typical clastic tidal flat plane phase sequence or carbonate rock plane phase sequence, or a mixed tidal flat plane phase sequence of carbonate rock tidal flats lithological mixed tidal flats clastic tidal flats; Vertically, it manifests as continuous sedimentation of the same type of tidal flat in different facies zones, as well as interactive sedimentation of different facies zones between different types of tidal flats

(3) Three models of connected land platforms with mixed tidal flats have been established. Although the three models have different zones, they share common characteristics, namely: the climate in the exposed areas on land is dry, and salt marsh gypsum and evaporite dolomite are widely developed; There are large-scale terrestrial debris in the nearshore zone, and based on the abundance or scarcity of terrestrial debris material and whether the environment is clean and warm, the nearshore zone is divided into two different environments: detrital tidal flat sedimentary environment and carbonate tidal flat sedimentary environment; The high-energy shallow water barrier beach on the edge or surface of the continental shelf causes the confined seawater behind it to form a lagoon, leading to large-scale mixed tidal flat sedimentation. These common features of the three modes are necessary conditions for the formation of a large mixed tidal flat in the F oilfield.

(4) Among the three mixed tidal flat genesis models, the "marginal platform sedimentary model with terrestrial debris" has a relatively greater possibility of forming large-scale tidal flats. In this mode, tidal water flows from the tidal inlet of the reef beach complex at the edge of the platform into the lagoon. Due to the absence of barrier walls and beach obstruction within the platform, the tidal energy is relatively strong and the impact area is wide, making it easier to form large-scale tidal flats in the coastal area.

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