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A Brief Discussion on the Sedimentary Model of Braided River

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Abstract: *The Brained River Delta, as an important type of coarse clastic sedimentary system, the establishment and deepening of its sedimentary model have core value for guiding oil and gas exploration and development as well as geological engineering practice. Based on the classic definitions, this paper systematically reviews a variety of characteristic Brained River Delta sedimentary models proposed in recent years, including blanket type and Gilbert shallow Brained River Delta under shallow water conditions, "flood genetic type" Brained River Delta dominated by seasonal flood events, and Near source sandy and distal fine-grained Braided River Delta controlled by source distance and climate. And the arid Brained River Delta formed under the background of an arid climate. The article expounds the sedimentary background, formation mechanism and identification characteristics of various models, and points out that the research on these fine models has greatly enriched and developed the theoretical system of Brained River Delta, providing key geological basis for effectively predicting the "sweet spot" of high-quality reservoirs and reducing exploration risks.*

Keywords: *Brained River Delta, Sedimentary Mode, Shallow Delta, Reservoir Prediction*

1. Introduction

The establishment and continuous improvement of braided river delta sedimentary model has far-reaching guiding significance for the development of geological theory and resource exploration practice. This theoretical framework systematizes the complex sedimentary phenomena, reveals the internal law between the dynamic mechanism and sedimentary response under the control of provenance supply, base level change and tectonic climate coupling, and becomes a key theoretical tool for reconstructing the paleogeographic environment and restoring the evolution process of the basin. In the field of oil and gas exploration, the braided river delta sedimentary model provides a geological basis for predicting the spatial distribution of high-quality reservoirs and characterizing the heterogeneity of reservoirs, which directly affects the effectiveness of exploration deployment and oil and gas recovery. The combination characteristics of different sedimentary microfacies can effectively guide the optimization of well location and the formulation of development plan. At the same time, the model also plays an important role in the field of engineering geology. Through in-depth understanding of the structural characteristics and lithological combination of braided river delta sediments, the foundation stability, hydrogeological conditions and geological disaster risks (such as differential settlement, sand liquefaction, etc.) can be accurately evaluated, providing scientific support for major project site selection and geological safety evaluation.

To sum up, the braided river delta sedimentary model, as an important bridge connecting the sedimentary process and geological entity, has theoretical value and application significance in many fields, from basic geological research to energy exploration and development, and engineering construction safety, showing a wide range of academic value and practical guidance.

2. Main deposition patterns

As an important coarse clastic sedimentary system, braided river delta has a unique position in sedimentology. Its classic concept was first clearly put forward by McPherson in 1987[1], which was defined as the delta type formed by the braided river system progradation into the relatively static water body[1,2]. In terms of sediment composition, the grain size distribution of this type of delta is between the fan delta and the normal River Delta, which constitutes an important transition type between the two.

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Braided River Delta has obvious characteristics of tectonic controlled sedimentation in spatial distribution, which is mainly developed in the tectonic active area near the edge of active basin and syngenetic fault zone. This particular spatial distribution pattern is mainly controlled by two key factors: one is that the tectonic slope break at the edge of the basin provides an important accommodation space for sediments; the other is that the continuous activity of syngenetic faults controls the migration of sedimentary centers and the distribution of sedimentary systems. In terms of material supply system, braided river delta shows significant diversity characteristics. Its provenance system mainly includes two types: one is the sedimentary system formed by the braided river at the end of the alluvial fan after transformation, which usually has the characteristics of rapid accumulation near the source; The other is the depositional system formed by braided rivers in mountainous areas directly entering the lake basin, which often has a longer transport distance and relatively good sorting. This diversified source supply mechanism makes the braided river delta show obvious differences in lithological association and structural characteristics. In the depositional filling sequence of faulted lake basin, especially in the steep slope zone controlled by active faults, the time-space relationship between braided river delta and fan delta is particularly close. This close relationship is mainly manifested in two aspects: in the vertical sequence, the two often form a complete sedimentary cycle, showing the characteristics of regular interbedding; In the plane distribution, it shows an obvious phase band transition relationship. This transitional relationship is embodied in the gradual transition from fan delta deposits in the Piedmont to braided river delta deposits in the basin, forming a complete "source sink" depositional system. This transition in time and space not only reflects the evolution of the sedimentary environment, but also provides important geological records for the study of the tectonic sedimentary evolution of the basin.

The identification and study of this sedimentary type is of great value for restoring the paleogeographic environment and analyzing the evolution of the basin. Based on this, this paper aims to systematically sort out the main sedimentary models proposed in the research field of Braided River Delta in recent years, and provide reference for scientific research and production practice in related fields by summarizing the characteristics of different types of sediments.

2.1 Blanket type shallow Brained River Delta

Among the significant advancements in the research field of shallow braided river deltas, Zou Caineng(2008)[3] innovatively proposed the "blanket-type shallow braided river delta" as a typical variant and established a comprehensive theoretical framework for its sedimentary model. The unique sedimentary characteristics and three-dimensional spatial configuration of this delta type are illustrated in Figure 1. This type of delta predominantly forms in gentle slope environments within continental lake basins, with its distinctive morphological features primarily governed by extremely shallow water conditions and a flat paleogeomorphic setting[3].

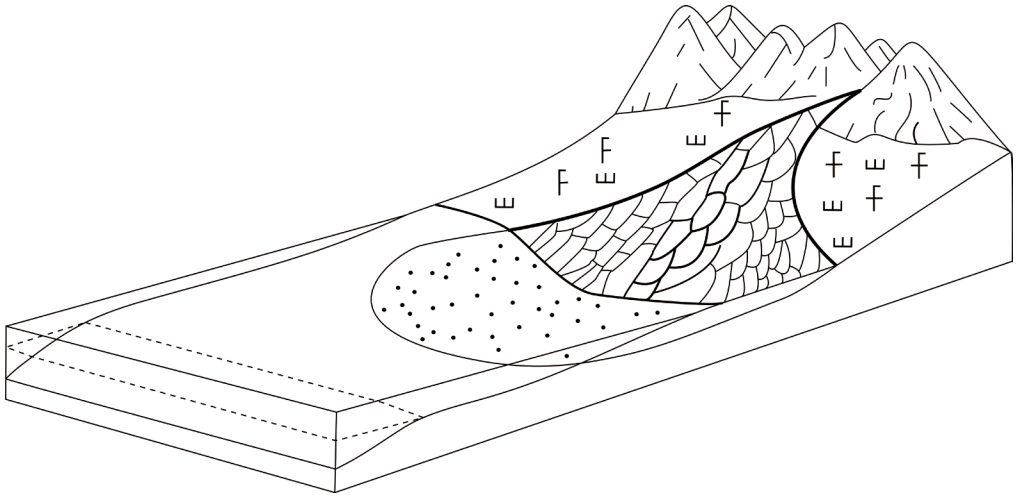

Figure 1 Sedimentary model of blanket typeshallow Brained River Delta[3]

Regarding sedimentary characteristics, this delta type exhibits notable peculiarities: firstly, its progradation is relatively weak, and the slope of the frontal top surface is exceedingly gentle, rendering it challenging to discern typical progradation reflection structures in seismic profiles and drilling data[4]; secondly, the plain subfacies and frontal subfacies display considerable spatial extents in plan

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view, with the plain subfacies predominantly composed of multi-stage superimposed sandy braided channels[4]; furthermore, the depositional system demonstrates a gradual transition with the underlying prodelta and shallow lake muddy deposits. Collectively, these features contribute to a blanket type shallow sedimentary architecture characterized by indistinct top and bottom boundaries, excellent lateral continuity, and a relatively homogeneous structure in the vertical dimension, forming a distinctive sedimentary construction pattern.

The establishment of this model not only refines the theoretical framework for shallow water deltas but also provides a crucial geological model for reservoir prediction and oil and gas exploration in analogous geological settings.

2.2 Gilbert type shallow Brained River Delta

In the classification system of shallow braided river deltas, Zou Caineng(2008)[3] identified the Gilbert type shallow braided river delta, which corresponds to the blanket type shallow braided river delta. stark contrast to the latter's gently sloping frontal terrain, the most prominent identifying feature of the Gilbert-type delta is its steep frontal slope break.

The Gilbert type shallow braided river delta exhibits typical characteristics across three main aspects: in terms of topography and geomorphology, the top surface of its front edge displays a distinct inclined morphology, creating a notable slope transition; regarding internal structure, it develops typical progradational structures, with a relatively narrow distribution range of frontal facies; and concerning sedimentary microfacies, locally developed gravity flow sedimentary bodies of slump origin coexist in a specific symbiotic association with estuary bar microfacies [3,4].

These characteristics collectively form the unique sedimentary system of the Gilbert type shallow braided river delta, with its complete sedimentary model illustrated in Figure 2. The establishment of this model offers a crucial comparative basis for identifying delta deposits in similar geological settings, providing practical application value in reservoir prediction and sedimentaryies analysis.

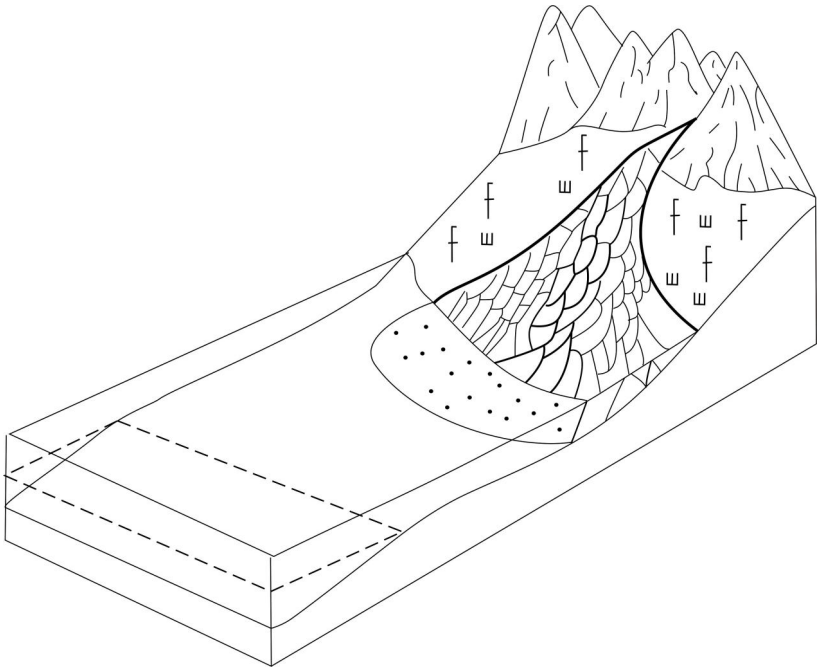

Figure 2 Gilbert type shallow Braided River Delta depositional model[4]

2.3 "Flood genetic type" Brained River Delta

Liu Ruie(2013)[5] creatively put forward the important concept of "flood genetic type" Braided River Delta when carrying out systematic sedimentology research on Permian in Ordos Basin. This study not only explains the sedimentary characteristics, lithofacies Association and formation mechanism of this kind of delta in detail, but also empirically verifies the theoretical model through precise flume simulation experiment for the first time, which establishes a scientific standard for the identification and research of this kind of special Delta.

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From the perspective of genetic mechanism, "flood genetic type" Braided River Delta refers to the coarse clastic sedimentary system mainly controlled by short-term high-intensity flood events[5]. Under the background of arid and semi-arid paleoclimate, seasonal floods have become the main driving force of sediment transport, rapidly transporting a large number of terrigenous debris to the edge of the lake basin and rapidly accumulating. This unique sedimentary process has formed a vertical sequence marked by thin sand Mud Interbeds: obvious erosion erosion erosion surfaces are generally developed at the bottom of each sand layer, the grain size gradually becomes smaller upward, and the thickness of a single rhythmic layer is usually thin. These characteristics together constitute a typical event sedimentary record.

The establishment of this sedimentary model has important theoretical value and practical significance. It not only improves the classification system of Braided River Delta, but also provides a reliable facies model index for identifying flood events in ancient sediments. Figure 3 shows the complete sedimentary model of this type, and its research results play an important role in promoting the in-depth understanding of the event sedimentation and geological record characteristics in the continental lake basin.

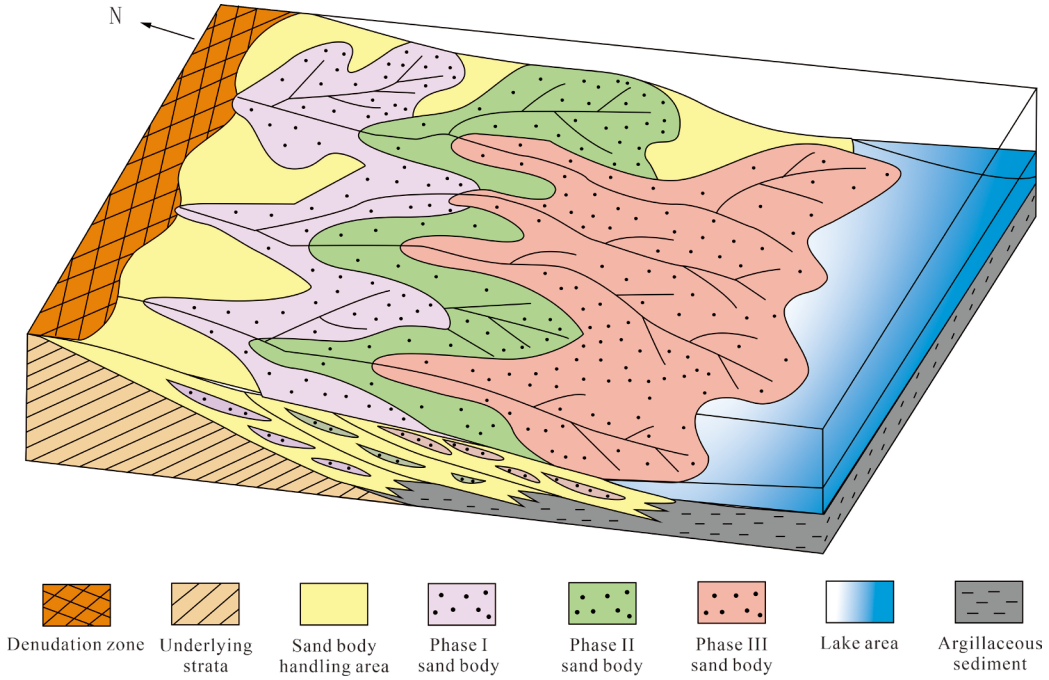

Figure 3 sedimentary model of braided river delta of "flood origin type"[5]

2.4 Distal fine-grained Braided River Delta

Qin Guosheng(2017)[6] creatively put forward the important sedimentological concept of "distal fine-grained Braided River Delta" when carrying out systematic research on L reservoir of Laojunmiao oilfield in Jiuxi basin. This concept not only enriches the classification system of Braided River Delta, but also provides a new theoretical framework for the study of fine-grained sediments in the gentle slope background.

From the perspective of sedimentary background, such deltas are mainly developed in the gentle slope zone far away from the provenance area. In this particular paleogeographic environment, the sediment has been transported for a long distance and fully sorted, resulting in its overall grain size being obviously finer, with an average grain size of about 0.08 mm, belonging to a typical fine-grained sedimentary system. This feature makes it in sharp contrast with the near source coarse-grained Delta in composition and structure.

In terms of sedimentary characteristics, the distal fine-grained Braided River Delta shows a unique identification mark. First, controlled by the low-energy sedimentary environment, the scale of sedimentary structures such as bedding is generally small, and small-scale cross bedding and wavy bedding are common. Secondly, although the single layer of channel sand body is thin, it is continuously and stably distributed in the plane, showing the characteristics of continuous and stable sediment supply[6]. In addition, this kind of delta usually develops complete ternary structure, but the

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transition between facies zones is relatively gradual, lacking obvious lithologic abrupt interface.

The establishment of this concept has important theoretical value and practical significance. Theoretically, it improves the sedimentary model pedigree of Braided River Delta and reveals the characteristics and laws of sedimentation under the background of remote gentle slope. In the exploration practice, it provides a reliable geological model for the identification and prediction of high-quality reservoirs under such background, and plays an important role in guiding the exploration of lithologic reservoirs. Figure 4 shows the complete sedimentary model of this type, which provides an important reference for related research.

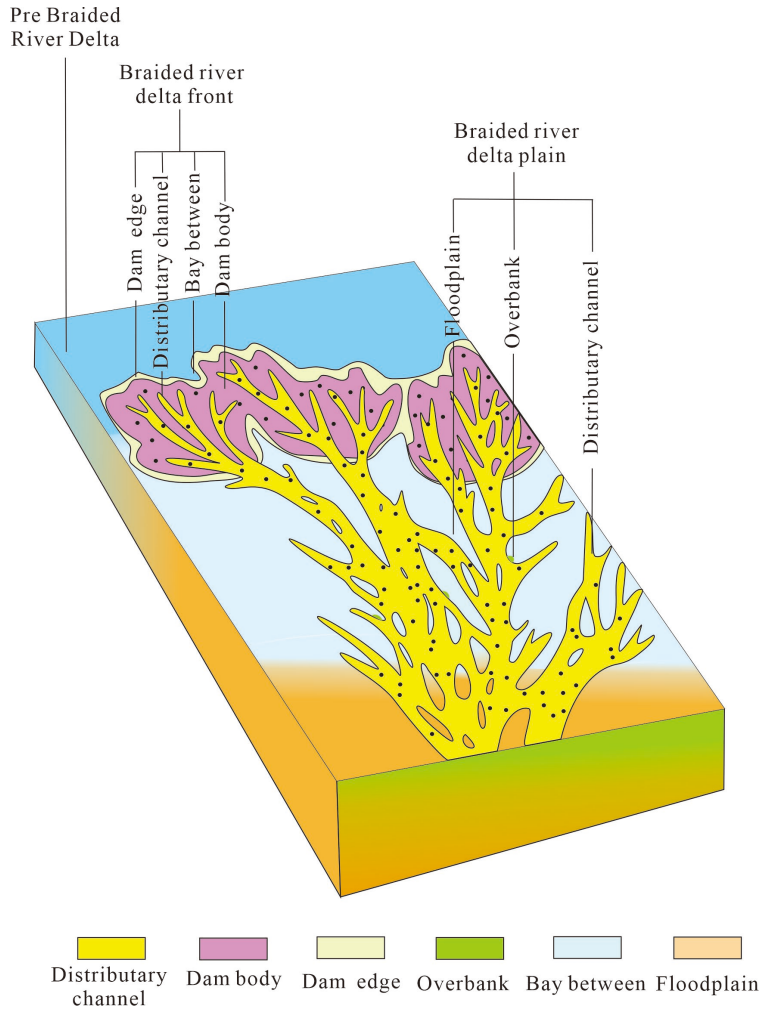

Figure 4 sedimentary model of distal fine-grained Braided River Delta[6]

2.5 Near source sandy Braided River Delta

Zhao Hanqing[7,8] and other scholars established the important sedimentological concept of "near source sandy Braided River Delta" on the basis of inheriting the previous research results and through the detailed study of the upper submember of the third member of Shahejie Formation in Laizhouwan sag, Bohai Bay basin. This type improves the classification system of Braided River Delta and provides a new theoretical framework for the study of steep slope zone sedimentation.

From the perspective of formation mechanism, such deltas are mainly developed in the steep slope structural belt at the edge of the basin, and their formation is strictly controlled by strong tectonic activity or significant paleotopographic elevation difference. Under this geological background, the coarse-grained sediments carried by mountain rivers or alluvial fan systems directly enter the lake basin without sufficient sorting and long-distance transportation, forming a unique high-energy coarse clastic delta system.

In terms of sedimentary characteristics, the near source sandy Braided River Delta shows the following typical characteristics: the sediments are mainly medium coarse sand and gravel, with coarse

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particle size and medium to poor sorting; The braided channels on the delta plain migrate actively and have high sedimentation rate, forming thick sandy conglomerate bodies with multiple vertical layers and extensive lateral connections. The direct progradation of plain subfacies has become the dominant sedimentation due to the strong energy of water body, fast sedimentation rate, steep slope of delta front, undeveloped mouth bar microfacies or vulnerable to river erosion.

This sedimentary system as a whole constitutes a sand rich sedimentary system with good continuity of framework sand bodies, significant heterogeneity and dominated by traction flow sedimentation. The establishment of this sedimentary model not only has important theoretical value, but also provides a scientific basis for the prediction and evaluation of high-quality reservoirs under similar geological background in practice. The complete depositional model is shown in Figure 5, which provides an important reference for further research in related fields.

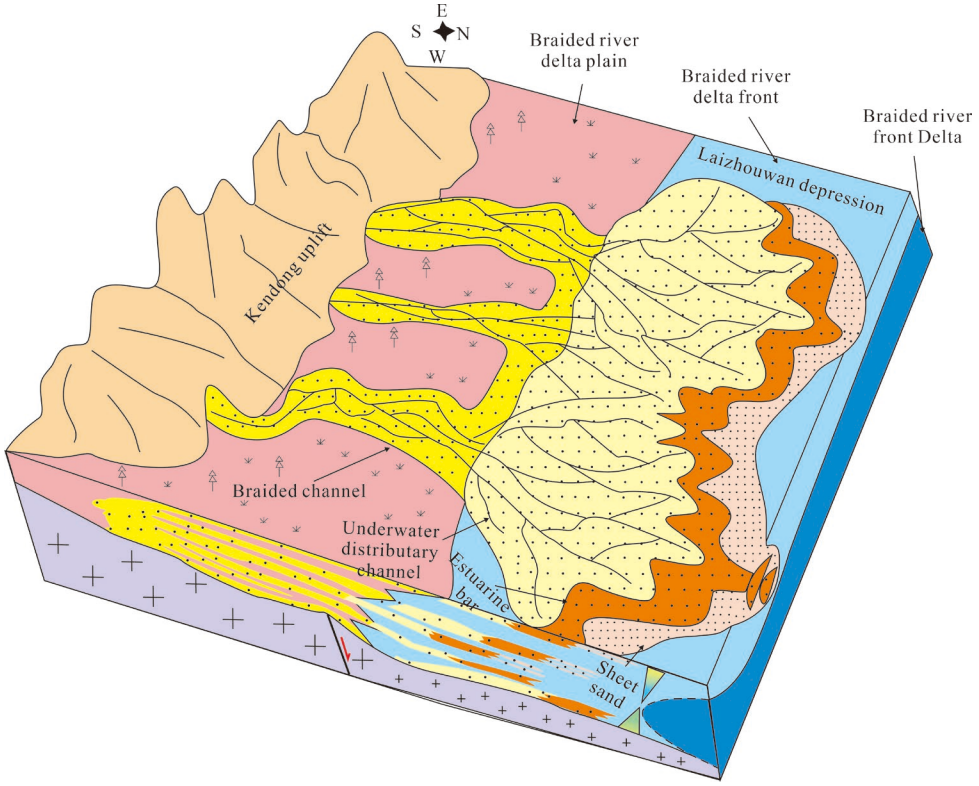

Figure 5 sedimentary model of near source sandy Braided River Delta[7]

2.6 Arid Braided River Delta

Song Fan[9] and other scholars first proposed the innovative concept of "arid Braided River Delta" in the systematic study of Yongjin area in the hinterland of Junggar Basin Based on the unique paleoclimate background and sedimentary characteristics of the area. The establishment of this type enriches the understanding of the sedimentary system under the special climate background, and provides an important theoretical support for the study of sedimentation in arid environment.

From the perspective of the formation background, this kind of delta developed in the shallow water environment controlled by arid climate, and its sedimentary system showed obvious limitations in spatial distribution. In terms of sedimentary characteristics, the most significant feature is the typical event sedimentary sequence[9,10]. In this depositional system, the conventional River delta depositional process is often interrupted by periodic drought events, forming a unique "sedimentary exposure" cycle. This feature is shown in the vertical sequence that the sandstone deposits are effectively separated by multiple stable oxidized mudstone layers, forming multiple independent sedimentary units. At the same time, affected by the discontinuity of material supply, the horizontal distribution range of single-stage sand bodies is often limited.

The establishment of this sedimentary model has important theoretical value and practical significance. Theoretically, it reveals the formation mechanism and development law of sedimentary system under arid climate conditions; In the exploration practice, it provides a new geological model

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for reservoir prediction and oil and gas exploration under similar climate background. Figure 6 shows the complete sedimentary model of this type, which provides an important reference for further research in related fields. The concept improves the type system of Braided River Delta and has positive significance for promoting the development of sedimentology theory.

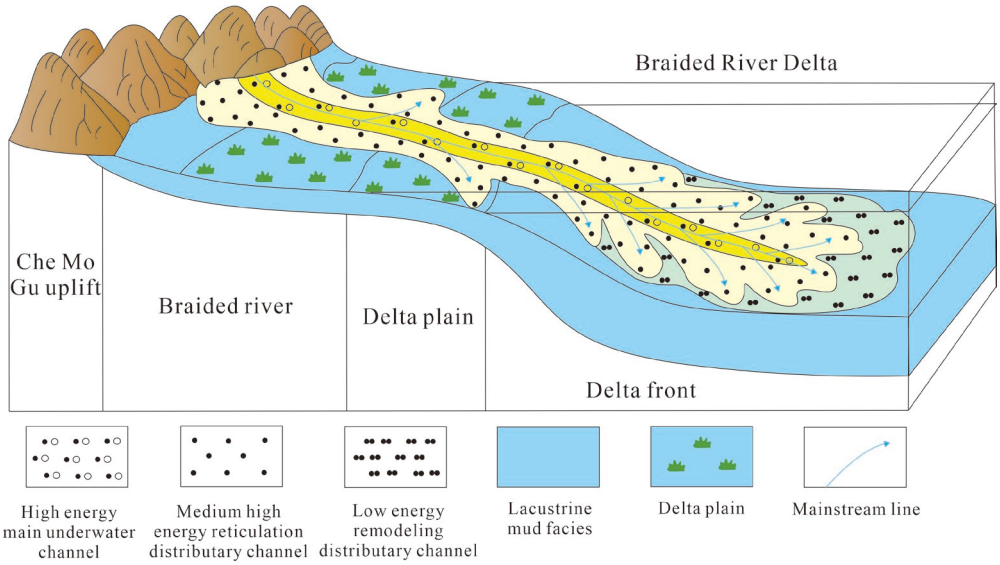

Figure 6 sedimentary model of arid Braided River Delta[9]

3. Conclusion

This paper systematically sorts out and reviews the representative sedimentary models within the braided river delta system, encompassing various types such as the blanket type shallow, Gilbert type shallow, "flood-genesis" type, near-source sandy type, far-source fine-grained type, and arid type. Through an in-depth exploration of these typical sedimentary models, it not only enriches the theoretical framework of braided river delta sedimentology but also offers crucial references for analyzing sedimentary characteristics and establishing sedimentary models in specific research areas.

In the realm of oil and gas exploration and development, the underwater distributary channels and mouth bar sandbodies at the front of the braided river delta, serving as high-quality reservoir units, have emerged as pivotal "sweet spot" targets for the exploration of tight sandstone oil and gas, shale oil and gas, and deep oil and gas resources in central and western China and its neighboring regions. Research on the sedimentary models of these reservoirs provides a solid geological foundation for predicting reservoir spatial distribution, optimizing drilling well locations, and selecting fracturing intervals, thereby significantly enhancing exploration efficiency and effectively mitigating development risks. Consequently, in-depth research on braided river delta sedimentary models holds not only substantial theoretical significance but also exhibits pronounced practical value in guiding oil and gas exploration endeavors.

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