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Gravity Flow Sedimentary Characteristics of Chang 6 in Panke Area, Ordos Basin

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Abstract

The Panke area is located in the southern Ordos Basin with an area of 4910km^2. And the sedimentary characteristics are not clear. The sedimentary characteristics of Chang 6 reservoir in the Panke area are studied through the detailed observation of the core and adequate analysis of logging data. It is considered that there are 6 types of lithofacies in Chang 6 reservoir of the study area, they are flat-shaped mudstone facies, high amplitude box-shaped massive sandstone facies, medium-amphibious box-shaped sandstone facies, bell-shaped sandstone facies, funnel-shaped sandstone facies and finger-like sandstone facies. The high-amplitude box-shaped massive sandstone facies and funnel-shaped sandstone facies are formed by sandy debris flow, while the slump sandstone is the genesis of medium-amplitude box-shaped massive sandstone facies. The bell-shaped sandstone facies and the finger-like sandstone facies are formed in turbid currents. According to the vertical combination, the phase sequence types in the study area are divided into 4 species. They are the combination of multi-layered sandy debris flow, the combination of sandy debris flow and turbidity flow, the combination of sandy debris flow and sandy slump and multi- layer turbidity flow combination. And the first two types of phase sequence are the most important type of phase sequence combination in the study area. Based on this study, a gravity flow deposition model was established in Panke area. From the point of view of sedimentary model, due to the differences in the fluid conversion process and the final conversion results during the deposition process, the most prospective sand debris flow thick block sand bodies in the study area are distributed along the gullies in the direction of the delta front water channel. This study can provide new ideas for the next step in reservoir prediction in the southern Ordos Basin.

Keywords: massive sandstone, sandy debris flow, turbidity flow, gravity flow, Chang 6

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INTRODUCTION

Deep-water gravity flow sedimentation is a hot spot in current global oil and gas exploration and research (Bourget et al. 2010, Dalla and Gamberi 2010, Li et al. 2010, Luo et al. 2017, Zhang et al. 2016). Since the formation and establishment of turbidity flow theory in 1950 (Kuenen and Migliorini 1950) to date, great progress has been made in the study of the phase pattern of deepwater deposition. Initially, during the extensive use of the Bouma sequence (Bouma 1962), the classic Bouma turbidite facies model was established (Shanmugam 2014). Later, based on the Bouma sequence, scholars established a number of classical fan models for deep-water deposition. Among them, the Walker integrated fan model (Walker 1978), which has certain predictability for reservoirs, has an important influence on the exploration and development of oil and gas. Since the late 1990s, a group of scholars such as Shanmugam et al. established the slope deposition model based on the sand debris flow concept based on the extensive questioning of the Bouma sequence and fan model. Shanmugam divided the slope pattern of sandy debris flow into two types, the non-water system under the supply conditions of rich sand shelf and the watercourse system under the supply conditions of rich mud shelf sources (Shanmugam 2014). The introduction of this new model has caused the traditional turbidite deposition model to be challenged to some extent represents a new development in the field of gravity flow research.

Since the 1970s, there have been more reports on gravity flow deposits in the Ordos Basin (Chen et al. 2006, Fu et al. 2008, Liu et al. 2007, Pang et al. 2009, Wang and Wang 2017, Zheng et al. 2006). In recent

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a. Well Z46, 695.08m, shale swarf, "mud-coated" structure; b. Z46 well, 751.4m, "mud-coated " structure; c. Well N24, 1500.61m, wrap bundling; d. Well Z55, 1229.30m, sand pillow structure; e. Well Z55, 1238.00m, Bouma sequence DE; f. Well N38, 1733.81m, slot mode; G. Well N20, 1654.84m, heavy mode

Fig. 1. Sedimentary characteristics of sandy debris flow and turbidity flow of the Chang 6 member in Panke area in Ordos Basin

Large sets of massive sandstones, which are in sudden contact with the top and bottom mudstones, reflect the "global freezing" handling mechanism of the sand debris flow. Because of the small amount of clay-water matrix in the interior, the clay-water matrix is in the form of a thin film between particles, resulting in a large adhesion force, making the sediment formed by sandy debris flow dominated by thick layered fine sandstone. This type of sandstone is relatively pure and has almost no grain sequence changes. As the plasticity of the sand during the handling process, the shale with weak shear resistance is torn and drawn into it to form elongated argillaceous swarf. Floating ball and quartz gravel are strong evidence of water flow intensity (Shanmugam et al. 2013).

years, with the further development of gravity flow theory, the sand debris flow slope pattern has been gradually introduced into the Triassic Yanchang Formation gravity flow study (Li et al. 2009, Fu et al. 2012, Sun et al. 2017, Zou et al. 2009). Previously, gravity flow sediments were mainly divided into sandy debris flow, turbidite and slumped deposits (Li et al. 2009, Fu et al. 2012, Sun et al. 2017, Zou et al. 2009), but the study of the characteristics, origins, and depositional patterns of the gravity flow sand bodies in the Ordos basin is not perfect. In view of this, the author combines gravity, flow logging and logging data to study the gravity flow sedimentation characteristics of the Chang 6 oil-bearing formation in the Panke area of southern Ordos Basin. The types of lithofacies in the study area and their characteristics, genesis, types of combination of phase sequence, and deposition patterns are highlighted. In order to provide a reliable example for the exploration and development of the southern Ordos Basin and for further study on the gravity flow deposition in the continental depression basin in China.

LITHOFACIES TYPES AND THEIR GENESIS

By observing and describing the cores of 26 core wells and 432.16m in the Panke area, 89 borehole and mud logging data were analyzed, and the lithology, sedimentary structure, and logging contour isomorphic signs of the Chang 6 oil reservoir group were studied. Six types of lithofacies were identified, including flat-shaped mudstone facies, high box-shaped massive sandstone facies, medium-sized box-shaped massive sandstone facies, bell-shaped sandstone facies, funnel-shaped sandstone facies, and finger sandstone facies.

Flat Mudstone

The flat-shaped shale facies are the most widely distributed lithofacies in the study area. It is dominated by black and black-gray mudstone and mud shale, see the gray silty mudstone and muddy siltstone thin interbed. Occasionally coal lines, development level bedding. The top interface is a mutation contact. Thickness. The natural gamma curve has a very low amplitude and is a micro-toothed flat (**Fig. 2-1a**).

The thick black mudstone and mud shale reflect very weak hydrodynamic conditions and represent a deep-water deposition environment.

High Box-shaped Massive Sandstone Phase

The high box-shaped sandstone facies is the most common sandstone facies in the study area. Its lithology is gray, brown-gray fine sandstone, and powder-fine sandstone. There was no change in grain-sequencing, showing a massive sedimentary structure with long strips of argillaceous tears (**Fig. 1a**), mudballs (**Figs. 1a**, **1b**), and quartz gravel (**Fig. 1a**). Most of the bottom of the mutation contact, see the flushing surface. The top has both sudden and gradual contact. Its thickness is greater than 0.5m and its maximum thickness is 9m or more. The amplitude of the natural gamma curve is higher, and there are more boxes and micro-toothed boxes. Part of the curve is more obvious at the top, and the amplitude gradually becomes lower (**Fig. 2-1b**).

Medium-sized Box-shaped Massive Sandstone Phase

The lithology of the mid-range box-shaped massive sandstone facies is dominated by grey blocky siltstones and fine sandstones. The overall structure of the sandstone facies shows a massive structure. However, unlike the high-sandstone sandstones, the facies of the sandstone facies contains sand. The body is often curled and deformed, and in the siltstone and silty mudstone, the formation of entrapment bedding (**Fig. 1c**), sand ball structure, sand pillow structure (**Fig. 1d**) and flaming structure, etc. Liquefied sandstone veins. The top and bottom interfaces have large differences in lithology, both of which are mutations. Sandstone thickness changes greatly. The natural gamma curve presents a mid-range box and a toothed box (**Fig. 2-1c**).

In the deep water environment, the delta front sand body liquefies, sliding, slumping often forms a mid-range massive sandstone facies. During slumping, the sand body often curls, forming a lapped bedding, sand ball and sand pillow structure. The uneven pressure of the overlying sand layer causes the underlying mudstone to flow, forming a flame structure. The genesis of intestinal liquefied sandstone veins is complex and is considered to be caused by strong triggering mechanisms such as paleoearthquakes.

Bell-shaped Sandstone Phase

The lithology of the bell-shaped sandstone facies is mainly gray, brownish-gray siltstone, silty mudstone, and argillaceous siltstone, and the grain size is coarse and fine, showing no obvious positive grain sequence (**Fig. 1e**). Occasionally, small-scale parallel bedding and cross-stratification. At the bottom, the flushing surface and trench molds (**Fig. 1f**), slot molds, heavy charge molds (**Fig. 1g**) and other bottom mold structures are commonly seen, and the top is a gradual interface. The thickness of sandstone is small, generally less than 2m. The natural gamma curve is a mid-toothed bell shape (**Fig. 2-1d**).

The turbulent flow characteristics of the turbidity flow cause the sediments to decrease in proportion to the specific gravity, forming a Bowman sequence with positively tapered bedding. Therefore, the Bowman sequence is a typical signature of turbidity currents. The positive grain order in the bell-shaped sandstone phase is the presentation of an incomplete Bowman sequence. Parallel bedding and staggered bedding reflect the turbulent flow traction process. Therefore, the bell-shaped sandstone phase is the cause of turbidity flow. In addition, turbulent flow is erosive and often forms flushing surfaces and bottom mold structures at the bottom of turbidites.

Funnel Sandstone Phase

The funnel-shaped sandstone phase is gray and the dark gray siltstone gradually transitions up to fine sandstone. The whole is a reverse grain sequence and the upper part is a massive structure. Occasionally parallel grain layers. The bottom is a sudden contact and the top is a gradual contact. The thickness is more than 0.5m. The natural gamma curve is a micro-toothed funnel (**Fig. 2-1e**).

The sand particles of the sandy debris flow collide with each other due to the dispersion pressure during the movement, so that the large particles are pushed up to the free top surface of the water flow. The formation of an anti-gradation layer in the lower siltstone and the upper fine sandstone.

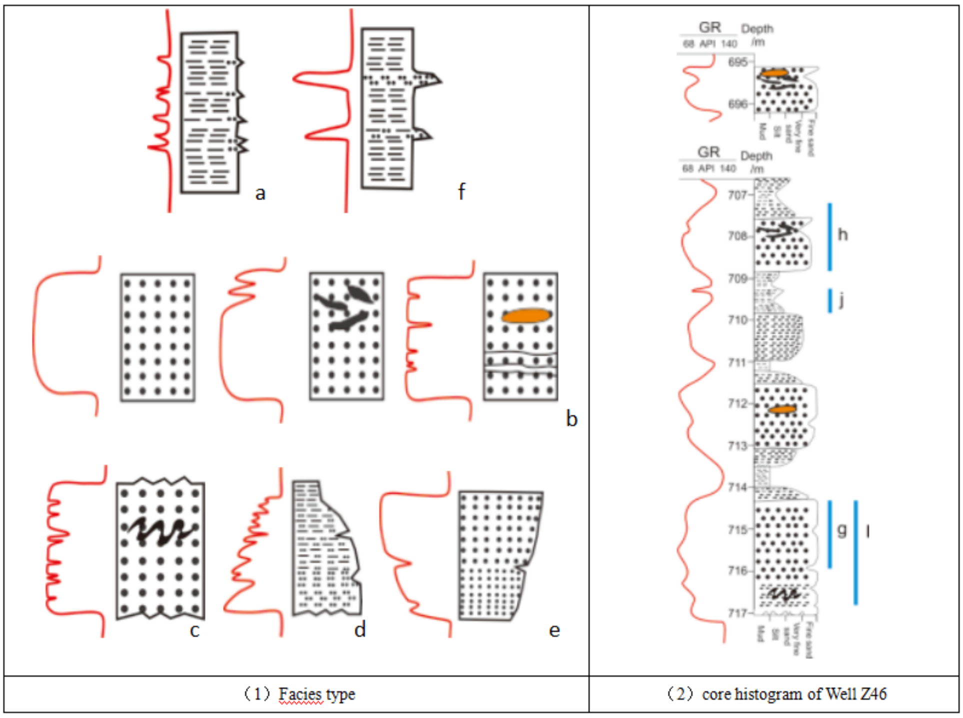

Fig. 2. Lithofacies section profile of of the Chang 6 member in Panke area in Ordos Basin and core histogram of Well Z46

Finger Sandstone Phase

Finger sandstones are gray, grayish brown siltstone, argillaceous siltstone and black-gray mudstone. The interfacial top and bottom interfaces are mostly abrupt contacts, and the thickness is small, generally less than 0.5m. The natural gamma curve is finger-like without obvious rhythm (**Fig. 2-1f**).

Thin siltstones and argillaceous siltstones are the products of single-phase turbidity deposits, and the unequal interbedded layers of mudstones reflect the multiple stages of turbidity deposits.

TYPICAL PHASE SEQUENCE COMBINATION

In the deep-seated sedimentary core data of the 26 wells in the comprehensive study area, the typical phase sequence combinations developed in this area are grouped into four types according to their vertical type. Each type of phase sequence combination represents a transition between different fluids on a deposition or a superposition relationship between fluids of different phases.

(1) Multi-phase sand debris flow combined phase sequence (**Fig. 2-2g**). This combination is most common in the study area, mainly due to the deposition of products from different stages of sand debris flow at the same location. Small periods of relatively short, large-scale multi-phase sand debris flows directly. Sandy debris flows with long intervals and smaller are separated by black mudstone.

(2) The combination of sand debris flow and turbidity flow (**Fig. 2-2h**). This combination is common in the study area and may be the conversion of sandy debris flow to turbidity current in the same period. It may also be caused by the direct contact of sand debris flow and turbidity flow at the same site in different periods.

(3) The combined sequence of sand debris flow and sand slide (**Fig. 2-2i**). This type of combination is more common near slopes near the source area, which is represented by thick layered sandstone deposits formed by the development of sandy debris flow above massive sandstones formed by sand-slumping. It can be directly contacted or separated by mudstone. It is speculated that after the formation of sediments at the front of the slope caused by the sand slump, the instability of the slope resulted in the accumulation of gravity flow sediments.

(4) Multi-layer turbidity flow combined phase sequence (**Fig. 2-2j**). This combination is

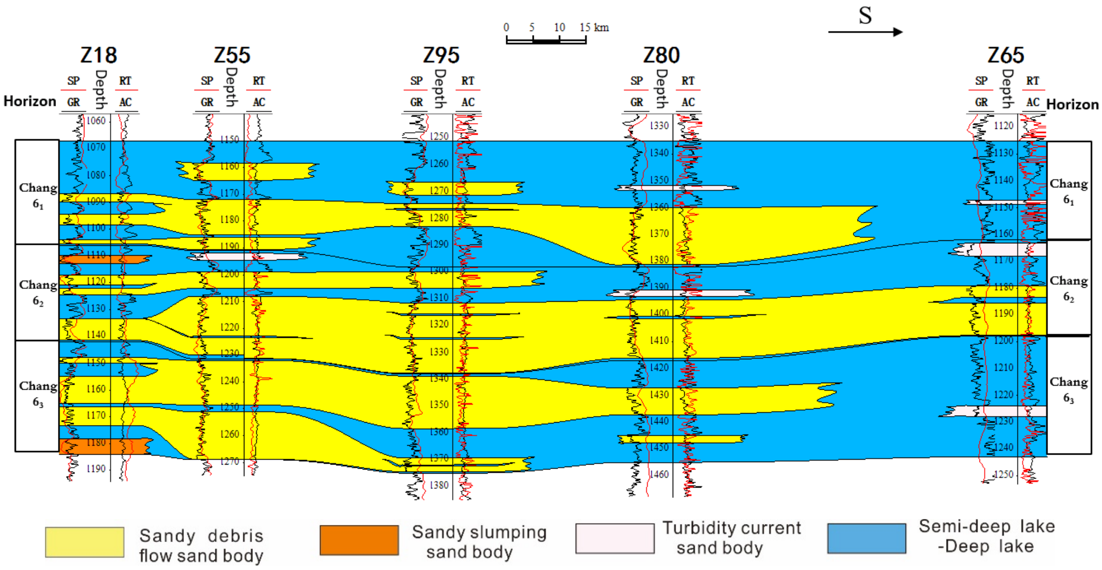

Fig. 3. Cross section of the Chang 6 member in Panke area in Ordos Basin (direction of source direction)

common at the end of the slope. It is the deposition of turbidity products from different stages in the same place. Due to the small size of sediments, they are often separated by dark mudstone.

HORIZONTAL DISTRIBUTION OF LITHOFACIES AND THEIR COMBINATIONS

Through the study of the type of individual rock facies and the combination of the phase sequence, the overlying relationship of the lithofacies of the Chang 6-dark facies in Panke area was clarified. On this basis, the sand body connectivity profile from the semi-deep lake to the deep lake plain in the study area was selected (**Fig. 3**). It can be seen from the figure that the sand debris flow sand body is mainly developed in the study area, showing multiple stages of thick The stacking shape has the widest horizontal extension range; the turbidite sand body has the second largest thickness, and the horizontal distribution is divided into smaller ones and is mainly developed in the deep-lake plains; the sand-slumping sand body is the least developed in the study area. Seen in the semi-deep lake near the slope break.

DEPOSITION MODE

Based on the above study of lithofacies, phase sequence combinations and their lateral distribution patterns in the Panke area, considering the sedimentary characteristics, origins, and triggering mechanisms of gravity flow deposition, the gravity flow deposition pattern in the study area was summarized. 4). The sand body on the delta front is triggered by volcanic activity, earthquakes, floods, and other factors, resulting in instability and gravity flow deposition. Affected by the slope of the terrain, the sedimentary subfacies and microfacies in the gravity flow in different regions are also different. The study area is located in the steep slope belt in the southern Ordos Basin. Deep-seated sedimentary sand bodies are mainly caused by three kinds of causes: sandy debris flow, turbidity flow, and sand slide.

In the Chang 6 gravity flow deposition model in Panke, the distribution and scale of sediments of different origins are different. These differences are the result of common control of multiple factors, but are essentially the result of differences in fluid conversion processes and final conversion results during deposition. The triggering of external forces leads to debris from the delta front into the lake, forming a sandy slump sand body. Due to the relatively steep slope of the lake basin and the inertial effects of the water flow, the water flow has a strong hydrodynamic force and can scour and erode along the front of the delta to form a gully similar to the water channel. The sand slough sand body is carried by the water and falls into the gulch that is closer to the slope break belt, forming a single-stage small-scale distribution or sediment that overlaps with the sand debris flow sand body. After entering the semi-deep lake-deep lake environment, the fluid continues to move under gravity. The flow pattern of water flow gradually changes to laminar flow, forming sediments dominated by sandy debris flow. Sandy debris flow sediments are mainly located in the middle-lower part of the concave-slip surface of the semi-deep lake-deep lake, and the scale is relatively

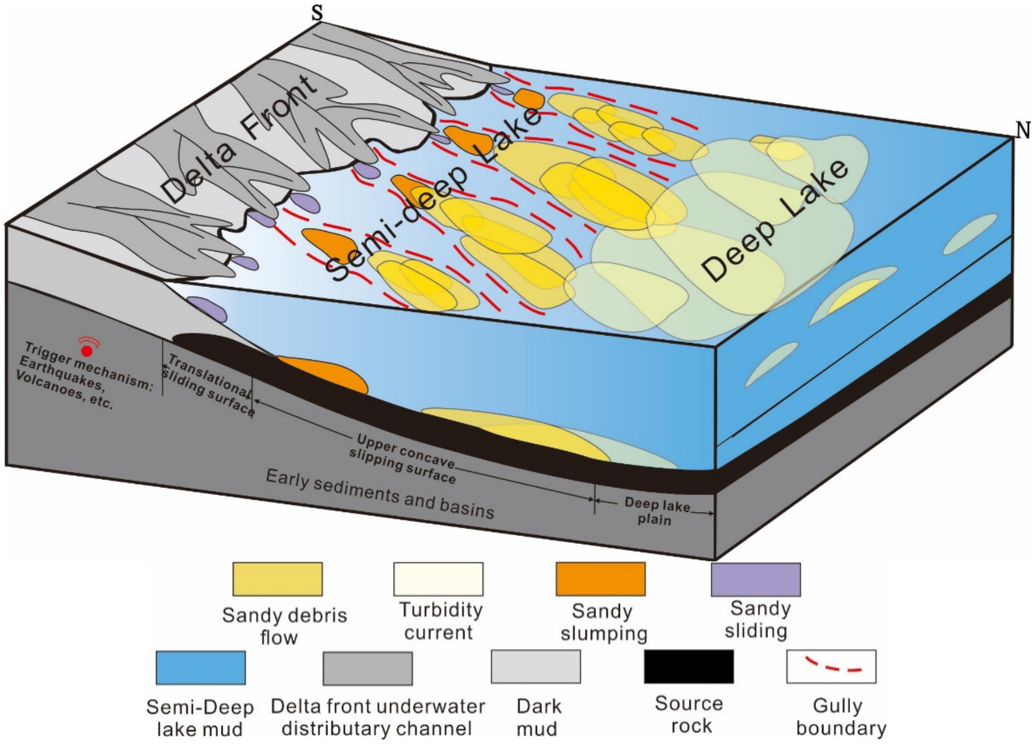

Fig. 4. Sedimentary pattern of gravity flow of the Chang 6 in Panke area in Ordos Basin

large. It is often distributed along the track of the gully to the direction of the deep lake, showing multiple stages of superposition or superposition with turbidite sediments, forming the most important thick layered sandstone in the study area. After entering the deep lake environment, as the volume content of water continues to increase, the viscosity of the sandy debris flow gradually decreases, eventually transforming into a turbidity flow. Due to the space available for accommodation, the transformed turbidity stream occupies the deep lake plain, so from a flat point of view, these little turbidity currents are distributed in front of or at the top of the debris flow. However, because of its fine grain size, the thickness formed in a single phase is relatively thin, and the deposition products in different phases are often separated by (semi-) deep lake mud, making it difficult to form an effective sand body.

A comprehensive study of the types of lithofacies, sequence combinations, and sedimentation patterns in the study area found that the most important sand debris flow-thick layer massive sand bodies in the study area are distributed along the gullies in the direction of the delta front water channel. The sand body has the characteristics that the longitudinal extension is not far, and the transverse overlaps the connecting pieces. The surface of the tongue appears to be an irregular stack of tongues. Therefore, large-scale sand bodies with superposed sand debris flow should be found in the gullies in the direction of the waterway leading edge of the delta slip front.

CONCLUSIONS

The following conclusions have been drawn from the study of the gravity flow deposition characteristics of the Chang 6 reservoir group in the Panke area of the Ordos Basin:

(1) The types of lithofacies of the study area Chang 6 include flat mudstone facies, high box-shaped massive sandstone facies, medium-sized box-shaped massive sandstone facies, bell-shaped sandstone facies, funnel-shaped sandstone facies, and finger sandstone facies. . Among them, the high box-shaped massive sandstone facies and the funnel-shaped sandstone facies resulted from the sandy debris flow, and the mid-range box-shaped massive sandstone facies formed as slump sandstones, bell-shaped sandstone facies, and finger sandstone facies. Turbidity flow.

(2) There are four typical phase sequence combinations in the study area. They are: multi-layer sandy debris flow combined phase sequence, sandy debris flow combined with turbidity flow phase sequence, sandy debris flow combined with sandy sliding phase sequence and multi-layer turbidity flow combined phase

sequence. The first two are the main types of phase sequence combinations in the study area.

(3) The distribution characteristics of the gravity flow deposition system are mainly affected by the differences in the fluid conversion process and the final conversion results during the deposition process. The most important sand debris flow thick block sand bodies in the study area are distributed along the gullies in the direction of the delta front water channel. The next exploration should look for large-scale sand bodies where sand debris flows are stacked in the gully direction of the delta front water channel on the concave sliding surface.

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