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PS The Characteristics of the Sandy Debris Flow of the Triassic Yanchang Formation and Its Exploration Significance in the Ordos Basin, China*

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Abstract

The sandy debris flow is a new genetic kind of sand body, which is an improvement to the deep water sedimentology such as the Bouma Sequence and deepwater fan. Due to the significant control to the hydrocarbon accumulation in deep water, the sandy debris flow is drawn more and more attention from the geologists. Based on the large amount of the core data, field observations, and analysis as well as seismic sequence interpretation, three kinds of sediment-gravity flows (the sandy debris flow, the classic turbidite, and the slumps) were identified from the Chang 6 Formation of the Triassic Yanchang Formation in the deepwater area at the center of the ancient Ordos Basin lake. The first discovered sandy debris flow is dominant and oil prone, whereas the classic turbidite is limited in distribution, which indicate previous study about deepwater sedimentation of the Yanchang Formation may overrate the turbidite sedimentation. Further study suggests that the wide distributed, thick, deep water sediment-gravity flows sand bodies, the distribution of which is mainly controlled by the lake slope break, have favorable accumulation conditions and will be the most important exploration area in the Ordos Basin.

Introduction

The Ordos Basin, the second largest petroliferous sedimentary basin in China has developed a comprehensive series of continental river-delta-lake depositional system and the Yanchang Group of Upper Triassic is the primary oil production layer (Yang Junjie, 2002; Liu Huaqing, 2007). The middle period of the Yanchang Group (Chang 6 – Chang 7) is the prosperous development period of the basin, in which the northeast and southwest developed two massive sedimentary systems. The area (Huanxian-Huaching-Heshui-

Huangling region), spreading from northwest to southeast in the middle of two sedimentary system, is the deep water area that developed gravity flow deposits.

In recent years, aiming at the Chang 6 layer of the Yanchang Group, hundreds million tons of geological demonstrated reservoir has been obtained in the middle basin of Huachi-Heshui area. However, when it comes to the cause of thick oil containing sandstone in the middle lake basin, never could the consensus toward the controversial issue be gained. Some investigators hold that it is by virtue of a turbidity current (Xai Qingsong, 2007; Fu Qiang, 2008; Zheng Rongcai, 2006; Chen Quanhong, 2006, 2007), while few investigators have noted that the possibility of a sandy clastic current (Li Xiangbo,2009,2010;Zhou Caileng,2009).

The concept of sandy clastic current was proposed by Indian-American, G. Shanmugam, who is also the sedimentologist of Mobil Oil Company. This new idea, which represents the brand-new progress of deep water sedimentary investigation, is the result of experiment, detailed description of section, and in-depth study of the sedimentation process. Also, this new idea has changed the traditional idea involving deep water sedimentation is solely turbidity current deposits, and brings about considerable guidance to the investigation regarding the distribution of oil containing sandstone. With the application of the concept of sandy clastic current, there are three types of sediment gravity flows having been discovered in the deep water of Ordos Basin (Li Xiangbo, 2009, 2010). In attempts to provide scientific evidences for the future oil and gas exploration, this paper primarily concentrates on the analysis of sedimentary characterization and sedimentary pattern.

1. Lithological Types of Sediment Gravity Flow in the Center of Lake Basin

On the basis of observation involving the in-depth observation and analysis of drilling core (length is approximately 1100 m) of 50 wells and 10 outcrop sections, three patterns of deep water deposits of gravity flow current, namely sandy clastic current, turbidite, slump rock have been discovered in the Chang 6 layer of Yanchang Group.

1.1 Sandy Clastic Current

Primary characterizations:

1. Lithology as mid-fine arkose, lithic arkose sandstone, thick bedding/bulk bedding (Figure 1-a,b,c), there is no graded bedding and other sedimentary structures, the undersurface of sandstone is flat without erosion effect (Figure 1-a), the top surface always contacts abruptly with deep and semi-deep lacustrine mudstone or subaqueous distributary channel of delta-front, and the contact surface is fairly irregular (Figure 1-b);
2. Mudstone fragment/boulder clay distributing in the sandstone occasionally in the inner sandstone, the diameter of which ranges from 2 to 6 cm, being suspended and protracted deformation (Figure1-d);

3. The thickness of a single sandstone body is more than 0.5 m, the thickest one could reach to several meters (Figure 1-a,b), and varies rapidly in the lateral direction;
4. Interstitial material is primarily matrix (hydromica), average content is about 5% in Baibao area and 9% in Heshui area (Figure 1-e,f);
5. The analysis of grain-size data shows that not only the feature of gravity flow current exists but also characterization of traction current does. (Li Xiangbo, 2009)

1.2 Classic Turbidite

The following important features:

1. Middle-fine sandstones are extensive development, upward fining, normally graded beddings (Figure 2-a b)
2. Normally graded sandstones with the overlying parallel bedding, ripple bedding, including bedding, and level of grain layer of fine sandstone, silty sandstone, and mudstone together constitute a complete or incomplete Bouma Sequence (Figure 2 - b, c), a combination of common types of ABCDE, ABE, ACD, BCD, BC, CDE, and DE, etc. (Chen Quanhong et al., 2006).
3. Often with sand shale thin interbedded form, constitute multiple rhythmic layers (Figure 2 - c), lateral extension of stable, small thickness, single sand thickness from several dozens of cm, maximum of not more than 0.5 m.
4. Sandstone at the bottom is not flat, lithology mutation, often clearer load casts, glove cast, flute cast, and other bottom cast structures (Figure 2-d) and some sand balls, flame structure and so on;
5. From the grain curve, classic turbidites in the CM graph are showed as a straight line parallel to the CM section of the baseline, reflecting the characteristics of gravity flow (Xia Qingsong, et al., 2007).

1.3 The Slumps

The main characteristics of slump rocks in the Yanchang Formation are mud mixed with sand and strong deformation (Figure 2-e), large thickness changes, up to 2 m, common convolute structure, slump folds, distorted, and other deformation beddings. Note there are scholars that generally classified such rocks as slump turbidites (Chen Quanhong et al., 2007), the author thinks that, although such rocks in the space position are often associated with classic turbidites, from the strict sense, its origin is composed entirely of underwater gravity slide and slumping formed, not turbidity current.

2. Deepwater Gravity Flow Spatial Distribution Pattern in Yanchang Formation

The authors used seismic reflection profiles and the characteristics of sedimentary microfacies in combination and identified two types of shallow and deep water depositional slope break in the bottom of Chang 6. The former in the delta front platform or near delta plain, which mainly controlled deposits of normal traction current delta front underwater distributary sand bodies and the latter located in delta slope front deep-water area mainly control deep-water gravity flow deposits (Li Xiangbo et al., 2010).

From the map of sand bodies distribution (Figure 3), sand bodies above the deep water slope break, which were due to a distributary channel, were banded structure outlying areas in the lake basin center. Gravity flow sand under deep water slope break had a wide range of sand distribution, apart from the southeast boundary. Presently, the general distribution is east of Huanxian Mountain, south of Ma jiabian-Qiaozhen, and vast area north of Qingyang-Ningxian.

The research also indicated that distribution patterns of gravity flow sand in the north and south sides of the lake basin were significantly different. In the southwest of the lake basin-Heshui area, owing to steep slope break (Steep slope type) (Li Xiangbo, et al., 2010), loose sediments from the delta front, which were in the unstable state of fast deposition or triggered by a chance mechanism (wave, volcanoes, earthquakes, storms, etc.), randomly happened landsliding to form gravity flow events. Supply matter origins of these gravity flow sediments are generally line source (Chen Quanhong, et al., 2010), no fixed supply channel, often with the delta to move and advance. Every time gravity flow events formed individual sand bodies smaller in size, profile for the lens, plane for flaky, lobate, and so on. Owing to frequent occurrence of slump and gravity flow, there was eventually multiple lenticular sands stacked in vertical distribution under the deep water slope break and contiguous in the horizontal trend, roughly parallel to the slope break (lake shoreline) distribution (Figure 4).

In the Baibao region, northeast of the lake basin, as deep water slope break was relatively gentle (gentle type) (Li Xiangbo, et al., 2010), the normal traction current delta front sandstone directly bridged over deep water slope break deposition distances (Figures 3 and 4), to be a gravity flow sand of deeper water area of fixed sand supply source. Thus, the above deep water steep slope with different type sands under deep water slope break of gentle type had causes of both gravity flow and traction current, but mainly the gravity flow sands and these gravity flow sands had a fixed transport path. Transport distance was relatively far.

From the spatial distribution, subjected to the impact of a fixed supply channel, sands (including the causes of gravity and traction current flow) in the vertical mostly moved forward superimposed along the matter source direction, in the plane, generally displayed banded distribution, perpendicular to the slope break (lake shoreline).

3. Meaning for Oil and Gas Exploration

In the central area of the lake basin of Ordos Basin, by virtue of the massive thickness, wide distribution of deep water gravity flow current sandstone body, and being accompanied with mud shale of deep lake, the lithological trap of upward wedge out type can always be formed, of which sandy clastic current is the predominant pattern. Also, the top and bottom of the sandstone body develops huge-thickness hydrocarbon, which could make reservoir combination of bottom-generation and upper-storage or upper-generation and bottom-storage come into being. As a consequence, the investigation can bring about far-reaching practical value for oil and gas exploration in the central area of the continental lake basin of the Ordos Basin. Moreover, it is highly possible that the sandy clastic current is universally in continental lake basin. As a result, such investigation can provide valuable reference for other basins (including fault basin and depressed basin) in the exploration and development of lithological reservoir.

Selected References

Chen, Q., L. Wenhou, G. Yongxiang, G. Yanqin, F. Juanping, Z. Daofeng, C. Hongxia, and L. Jiwei, 2007, The deep-lake deposit in the upper Triassic Yanchang formation in Ordos Basin, China and its significance for oil-gas accumulation: Science in China Series D Earth Science, v. 50, Suppl. 2, p. 47-58.

Chen, Q, L. Wenhour, G. Yanqin, L. Jiwei, C. Junping, and Z. Daofeng, 2006, Turbidite systems and the significance of petroleum exploration in the Yanchang Formation in the southern Ordos Basin, China: Acta Geologica Sinica, v. 80/5, p. 656-663.

Fu, Q, L. Miaomiao, and L. Yongdou, 2008, Developmental characteristics of turbidite and its implication on petroleum geology in Late-Triassic Ordos Basin: Acta Sedimentologica Sinica, v. 26/2, p. 186-192.

Li, X., 2010, Characteristics of Slope Break Belt in Large Depression Lacustrine Basin and Its Controlling Effect on Sandbody and Petroleum: Taking the Triassic Yanchang Formation in the Ordos Basin as an example: Research Institute of Petroleum Exploration & Development, v. 28/4, p. 717-729.

Liu, Hua-qing, J. Yuan, X. Li, Y. Wan, and J. Liao, 2007, Lake basin evolution of Ordos Basin during Middle-Late Triassic and its origin analysis: Lithologic Reservoirs, v. 1, p. 52-56.

Yang, J., 2002, Tectonic Evolution and Oil-gas Reservoirs Distribution in Ordos Basin, Beijing: Petroleum Industry Press, (in Chinese).

Xia, Q. and T. Jingchun, 2007, Characteristics and geological significance of seismites of the Yanchang Formation, Upper Triassic, Ordos Basin: Acta Sedimentologica Sinica, v. 25/2, p. 246-252.

Xia, Q. and T. Jingchun, 2007, Sedimentary characteristics of sublacustrine fan of Upper Triassic Yanchang Formation in southwestern Ordos Basin: Journal of Palaeogeography, v. 9/1, p. 33-43.

Xia, Q., T. Jingchun, and H. Changwu, 2007, Study on the recognition marks of seismites in Upper Triassic Yanchange Formation, Ordos Basin, China: Journal of Chengdu University of Technology, v. 34/3, p. 312-317.

Zheng, R., W. Huaguo, H. Yonlin, W. Haihong, Z. Chao, and C. Jialan, 2006, Discovery and significance of lacustrine slump turbidite fans in Chang 6 oil-bearing formation of Baibao region in Ordos Basin, China: Journal of hendu University of Technology, v. 33/6, p. 566-575.

Figure 1. Sedimentary structures of sandy clastic current, Yanchang Formation, Ordos Basin.**a**- bulk-like mid-fine sandstone (sandy clastic current), section in the quarry, under the highway of Huluhe bridge, Chang 62-3, undersurface of sandstone is flat without erosion effect, the width of the outcrop is 2 km, the thickness is 20 m; **b**- bulk-like mid-fine sandstone (sandy clastic current), location is the same as Figure a, Chang 62-3, the top surface contacts abruptly with the subaqueous distributary channel of the delta-front; **c**- oil containing bulk-like fine sandstone (sandy clastic current), Yuan 414 well, Chang 63, 1995.3 m; **d**- boulder clay containing bulk-like fine sandstone (sandy clastic current), location is the same as Figure a, mudstone fragment/boulder clay distributing in the sandstone occasionally in the inner sandstone, the diameter ranges from 2 to 6 cm, being suspended and protracted deformation. **e**- matrix supporting, Huachi, well Bai 280, 2197.8 m, Chang63, ×100; **f**- matrix supporting, Heshui, well Zhuang 43, 1795.51 m, Chang 63, ×100 .

Figure 2. Sedimentary structures of classic turbidites and slumps, Yanchang Formation, Ordos Basin. **a**- Bouma Sequence A, graded bedding (arrow indicates that grain turns fine upwardly), well Ning 36, well Chang 63, 1597 m; **b**- combination of Bouma Sequence ABC, well Bai 281, well Chang 63, 1969.9 m; **c**- combination of Bouma Sequence AE, well Ning 36, well Chang 63, 1583.9 m; **d**- flute cast structures in the bottom of sandstone, top and bottom is oil shale, Upper Triassic Nanzhao profile; **e**- slump distort, well Wu 25, well Chang 62, 1903.4 m.

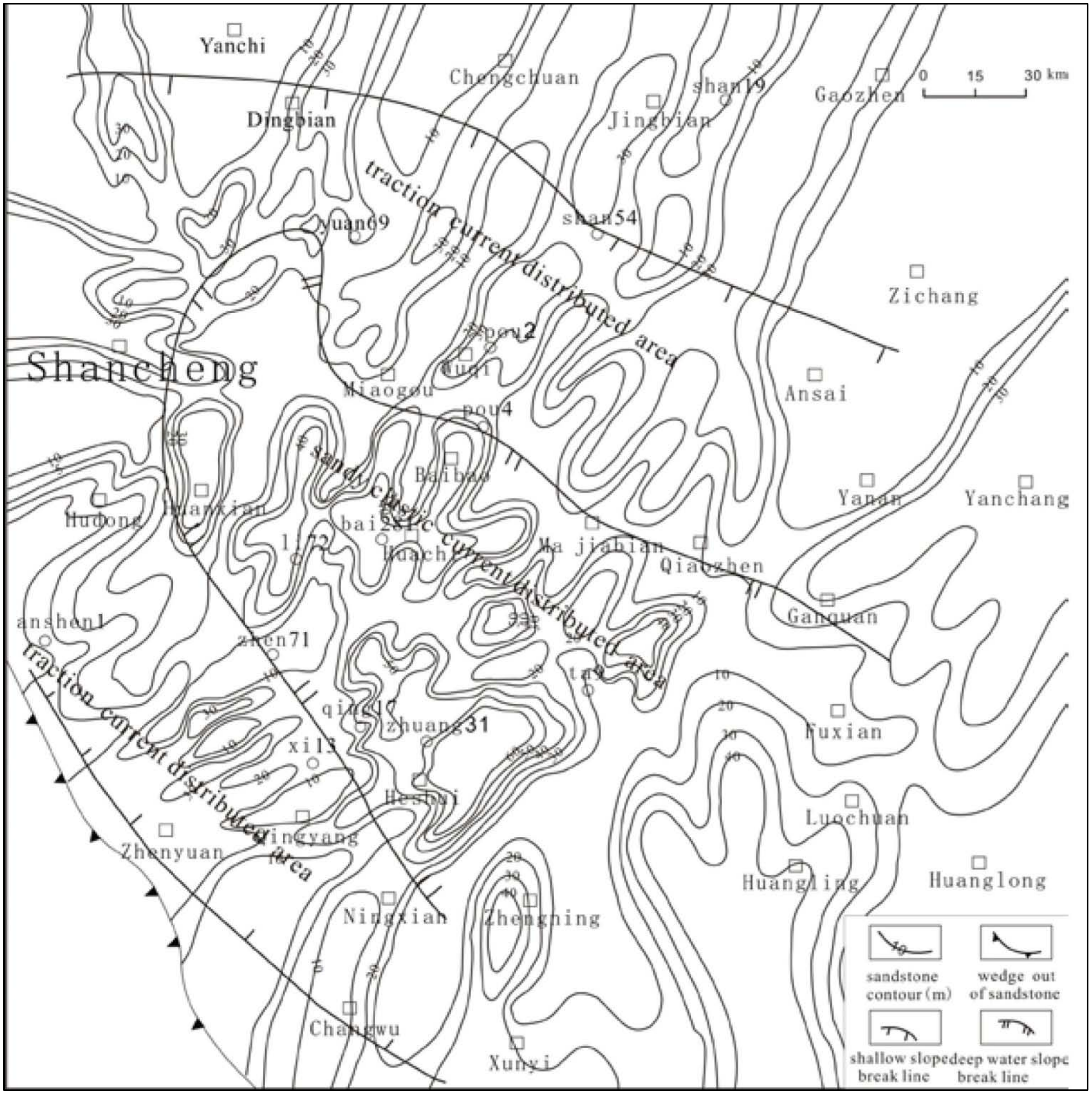

Figure 3. The map shows distributions of sandy debris flow in Chang 6 of Yanchang Formation

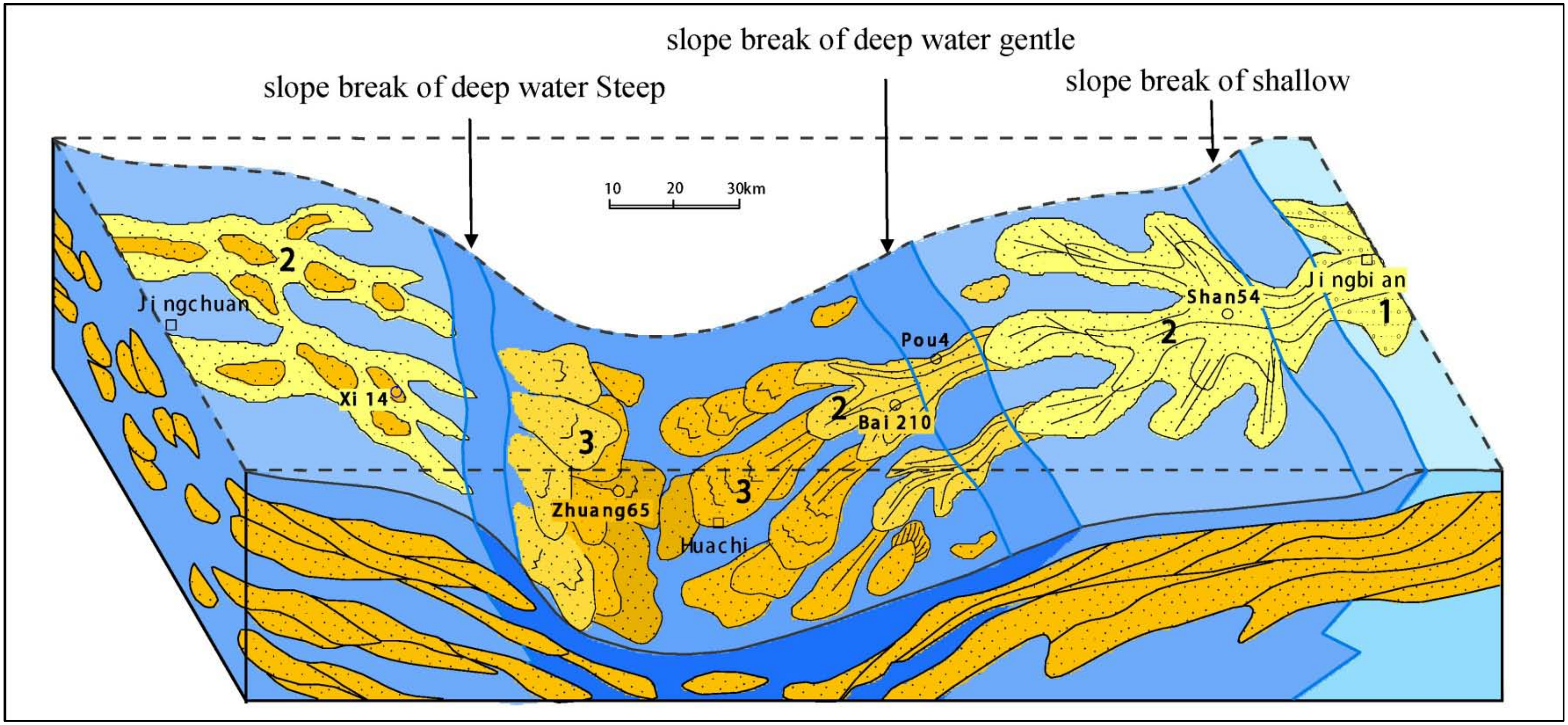

Figure 4. Sand model in the Chang 6 of Yanchang Formation.**1**- distributary channel sands in delta plain; **2**- underwater distributary channel sands in delta front; **3**- gravity flow sands in deepwater sediments.