Indian Journal of Geo Marine Sciences
Vol. 47 (04), April 2018, pp. 819-825

Underwater distributed channel sandstone reservoir characterization in Kumkol South Oilfield, South Turgai Basin

Liang Hongwei[1], Zhao Xiao-qing[2], Zhao Lun[1] & Fan Zifei[1]

1.Research Institute of Petroleum Exploration & Development, PetroChina, Beijing 100083, China

2. Geophysical Research Institute, Bureau of Geophysical Prospecting Incorporation, CNPC, Zhuozhou 072751, Hebei, China

[E.Mail: 574504695@qq.com]

Received 21 June 2016; revised 30 August 2016

Under the guidance of modern river distribution pattern, the architecture characteristics and sedimentation mechanism of distributed channelis studied with the core, log and seismic data. Based on the research mentioned above, with the increasing of A/S, the shape of composite distribution channel sand body is varied as sheet belt and wide belt and narrow belt and band-like belt.There are three types of single distributed channel, including the high sinuous distributed channel and the low sinuous distributed channel and the straight distributed channel. As the accommodation increasing and the sediments supply decreasing, the distributed pattern of the single distributed channel changes from the high sinuous distributed channel to the low sinuous distributed channel and the straight distributed channel. There are three types of mudstone interlayer in the single distributed channel. The continuous mudstone interlayer has high GR of SP value and is mainly developed in the straight distributed channel and its size is relatively large. The complex mudstone interlayer has medium GR of SP value and is mainly developed in the low sinuous distributed channel and its size is medium. The discontinuous mudstone interlayer has low GR of SP value and is mainly developed in the high sinuous distributed channel and its size is relatively small.

[Key words: South Turgai basin, Kumkol South Oilfield, distributed channel, architecture characterization , sandstone reservoir]

Introduction

Underwater distributed channel sandstone is one of the most important parts of delta sedimentary systems in lacustrine basin[1]. The sandstone architecture and the mud interlayer distribution of underwater distribution channel is one of the most important factors which can influence the remaining oil distribution and the water flooding exploitation in high water-cut sandstone reservoirs[2-3]. Based on the study of reservoir architecture classification[4-5], the international and domestic academics have built multiple patterns of different types of underwater distributed channel by studying outcrops and modern sedimentary[6-7]. By using seismic and well log data, the underground distributed sandstone distribution between wells is studied[8-18]. And a series of methods for underwater distributed channel sandstone reservoir characterization is widely used[19-20]. The survey found that the prior studiesaremainly focus on the reservoircharacterization of the straight underwater distributed channel sandstone. The studies about the high sinuous channel and the middle sinuous channel are rare. Therefore, this article takes the Layer Jof Kumkol South Oilfield in South Turgai Basin for example. By using the core and well logging data, the differences of distribution pattern and sedimentary mechanic of the three types of underwater distributed channel are studied. The architecture characteristics influences of the three types of the underwater distributed channelsandstone on remaining oil distribution are studied.

Materials and Methods

Kumkol South Oilfields which locates in the south of South Turgai Basin in Kazakhstan is an edge-bottom water reservoir. It is surrounded by hydrocarbon-rich Aryskum Depression with rift complicated by faults is a large drape structure over the Pre-tertiary uplifts on the pre-Jurassic basement (Fig. 1).The well space is wide (average well space is 250m) and the 3D seismic data is of high quality (the dominant frequency is nearly 50 Hz) in Kumkol South Oilfields. This oilfield has high-porosity and high-permeability reservoirs and higher heterogeneity.

The stratum of Kumkol South oilfield includes Quaternary, Tertiary, Cretaceous, Jurassic, and pre-Jurassic basement from top to bottom. There are several regional unconformities includes the regional unconformity between Aryskum Group and Akshabulak Group, the regional unconformity between Mid-Jurassic and Upper Jurassic, the regional unconformity between Lower Cretaceous and Upper Cretaceous. Akshabulak Group formed by LayerJwhich includes Layer J0, Layer JI, LayerJII, LayerJIII and LayerJIV is the main hydrocarbon bearing layer and buried at the depth between 1200-1500m. The Layer J was formed in the late stage of basin uplift and developed the delta sedimentary[2-3]. From 1990 until now, the composite water cute in this oilfield is over 80%. And the water sweeping efficiency has been affected by sandstone reservoir architecture boundaries increasingly important. Therefore, it is important that the underwater distributed channel sandstone architecture characterization is increasingly important in study area.

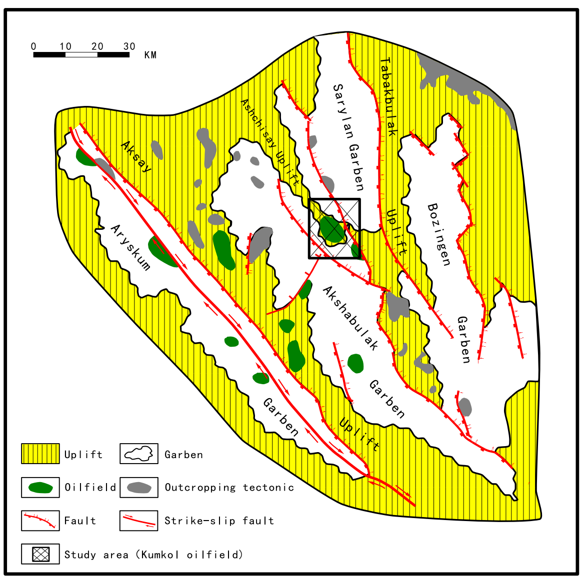


Fig. 1 — Structural map of Kumkol South Oilfields[2]

Results and Discussion

The composite distribute channels architecture characterization

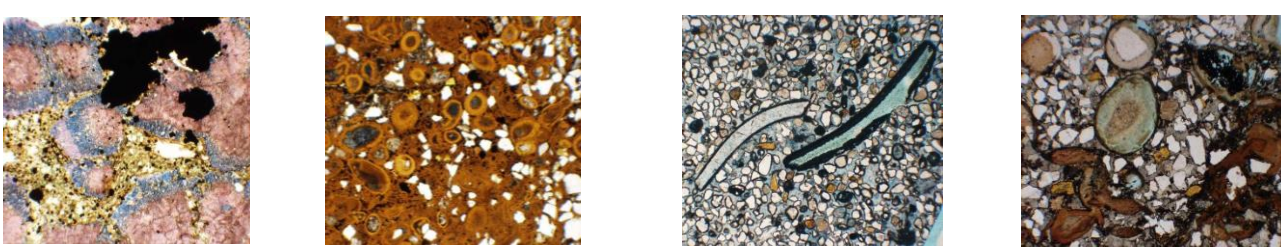
The research of composited distributed channel is equal to sedimentary microfacies. It is the first step of distributed channel sandstone architecture characterization[5].The boundaries of composite distributed channelare equivalent to the fifth level architecture boundaries[4-5]. Based on the Miall river types classification, it is found that the sedimentary environment of the Layer J mainly is the delta system with the core and logging information. And the type of the sandstone in the Layer Jmainly is the underwater distributed channel. The distribution patterns of the composited distributed channel in different layers are different and vary as the A/S changing.

Deposition environment of Layer J

In the lithology aspect, the mudstone of the Layer J mainly is dark, which indicate the underwater oxidation-reduction environment. Sandstone mainly is fine to middle with few carbonatite and phosphorite which also indicate the underwater oxidation-reduction environment. Rock slices identification shows the existing of the ostracoda, bivalve, gastropod and lots of carbonizedplant debris (Fig. 2), which means that Layer J formed in the humid Shore-lake and Shallow-lakeenvironment. Meanwhile, the primary sedimentary structure of Layer J areparallel bedding, plate cross bedding, trough cross bedding and there are erosion surfacesdeveloped at the bottom of the sandstone, which means the strong fluvial energy traction current deposits (Fig. 3). Based on the analysis mentioned above, the deposition environment of Layer J is the underwater distributed channel of the delta front.

Architecture characterization of the composited channel

In the sandstone aspect, the thick distributed channel sandstone has a band shape. Thechannel



Limestone, 1236.6, Layer JI-2, Well EK-6 | Oolite phosphorite,1223.2m, Layer JII-1,Well EK-6 | Mollusk pieces, 1258.4m, Layer J1, Well 1004 | Ostracodafossil, 1261.2m , Layer JIII, Well 1028

Fig. 2 — Microscope photos of Layer J in Kumkol Oilfield

sinuous is mainly smaller than 1.5 and some are between 1.5 and 2 in plane. The thin sheet sandstone distributes around the thick sandstone. Vertically, the thick channel sandstone are surrounded by the thin sheet sandstone. The width of the channel sandstone is between 60-200m, and its thickness is between 3-6m. The width and thickness ratio is between 20:1 and 300:1. The sheet sandstone distributes widely in plane and its thickness is between 1and 3m.

Based on the depositional mechanism, it is found that the early distributed channel sandstone changed to the sheet sandstone by the transformation of the lake in Layer J. The distributed river which is weaken by the lake is stable and the rive migration of the distributed river are rare. So the channel sandstone distributed locally and the sheet sandstone distributed widely in plane. According to the distribution pattern of channel sandstone in different layer, there are four kinds of the composited channel in Layer J, sheet-like channel, wide belt-like channel, narrow belt-like channel and band-like channel. The distribution patterns of the four kinds of composited channel are control de by the sedimentary supply rate and the accommodation increasing rate. Specifically, as the A/S increasing, the distribution pattern of the composited channel changer from sheet-like channel to wide belt-like channel, narrow belt-like channel and band-like channel (Fig. 4).

Single distributed channel architecture characterization

The research of single distributed channel is the second step of distributed river sandstone architecture characterization[4]. Boundaries of composite distributed

a. Gray mudstone,1247.8-1248m, Layer J0, Well 1004;
b. Massive bedding, inclined bedding and wave cross-bedding sandstone,1270.6-1270.8m, Layer JIII,Well 1014;
c. Massive bedding and wave cross-bedding, 1268-1268.2m, Layer JII, Well 1014;
d. Erosional basal surface, 1261.1-1261.3m, Layer JIII,Well,1028

Fig. 3 — Core photos of Layer J in Kumkol Oilfield

channelsare equivalent to the forth level architecture boundaries[4-5]. The reservoir of single distributed channelmainly is thedistributed channel sandstone. Based on the core, logging, seismic and dynamicdata, the single distributed channel sandstone are studied.

Architecture characterization of the single distributed channel

Previous study of the underwater distributed channel architecture characterization mainly used the well logging data to identify the single channel boundary. Because the average well space in Kumkol South Oilfield is 300m, which is larger than the speculated bankfull width of the single channel, the underwater distributed channel sandstone architecture characterization could not be done only by the well logging data. And the seismic information should be applied in the single channel architecture characterization.

First, the previous studies show that the underwater distributed are mainly developed in the gentle slope of the shallow water lakes. Because of the weak lake water energy and strong river energy, the fluvial disposition is more developed and sinuous near the lakeshore. And the fluvial disposition is more limited and straight beyond the lakeshore due to the strong lake water energy and weak river energy. Second, the Layer J2-22 is selected and its seismic attributes, such as the sweet attribute and the RMS attribute, are studied under the guidance of the sedimentary mechanism (Fig. 5). The study shows that the distributed channel sandstone is sinuous and superposed near the lakeshore. Its curvature is between 1.5 and 1.8. The distributed channel sandstone is straight and single. Its curvature is between 1.0 and 1.2. Third, the distributed channel

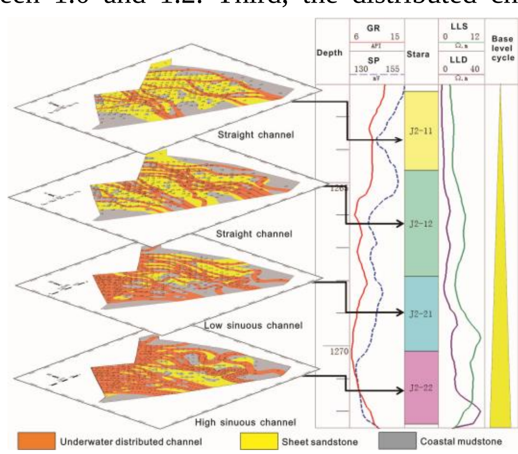


Fig. 4 — Distribution pattern of composited distributed channel of Layer J in Kumkol Oilfield

boundaries are identified with the methods mentioned by the previous studies[20]. And the identification are proved by the oil production data. For example, the water is injected by Well 2015 and produced by Well 2021 andWell 4017 and Well 2009. Because Well 2015 andWell 2021 are in the same channel sandstone reservoir, the production and the water saturation of Well 2021 are high. Because Well 2015 andWell 4017 and Well 2009 are not in the same channel sandstone reservoir, the production and the water saturation of Well 4017 and Well 2009 are low. Finally, the single distributed channel sandstone architecture characterization is done by the reasonablecombination of the well sections under the guidance of the underwater distributed channel depositional mechanism (Fig. 6).

Architecture feature of the single distributed channel

The high distributed channel are stable compared to the meandering channel and braided channel. Its width is between 80 and 300 and its thickness is between 2.5 and 8m. There are three types of distributed channel in the study area, including high sinuous distributed channel and low sinuous distributed channel and straight distributed channel. The differences of architecture features and depositional mechanism of these distributed channels are described as follow.

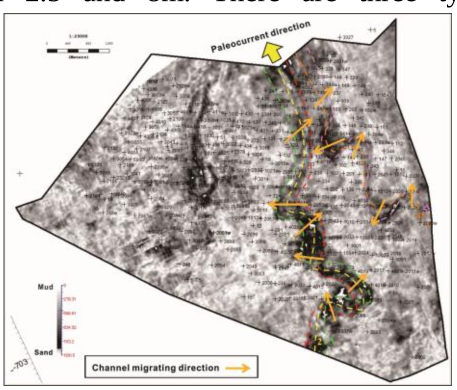


Fig. 5 — Sweet seismic attribute map of Layer J2-22 in Kumkol Oilfield

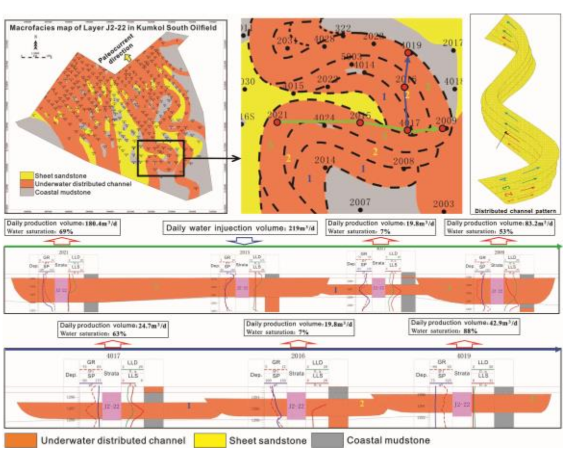


Fig. 6 — Single distributed channel architecture characterization ofLayer J2-22 in Kumkol Oilfield

The high sinuous distributed channel deposited when the sediments supply rate is much higher than the accommodation increase (Fig. 7). It is the most sinuous channel and its curvature is between 1.5 and 1.8. Its width is between 60-300m and its thickness is between 4 and 6m and its wide and thickness ratio is between 10 and 75. The depositional mechanism analysis shows that the river energy is much stronger than the lake energy, and the lateral erosion of the river to the bank are strong which lead to the asymmetry channel cross section and the largest bankfull depth and bankfull width. So the depth and width of the high sinuous distributed channel are large. The low sinuous distributed channel deposited when the sediments supply rate is higher than the accommodation increase (Fig. 8). Its curvature is between 1.2 and 1.6. Its width is between 60-270m and its thickness is between 4 and 5m and its wide and thickness ratio is between 12 and 68. The depositional mechanism analysis shows that the river energy is stronger than the lake energy, and the downward erosion of the river to the bed are strong which lead to the symmetry channel cross section and the mediumbankfull depth and bankfull width.The straight distributed channel deposited when the sediments supply rate is equal or smaller than the accommodation increase (Fig. 9). Its curvature is between 1 and 1.3. Its width is between 50-180m and its thickness is between 3 and 5m and its wide and thickness ratio is between 10 and 60. The depositional mechanism analysis shows that the river energy is equal to the lake energy, and the lateral and vertical erosion of the river are weak which lead to the smallestbankfull depth and bankfull width (Tab. 1).As

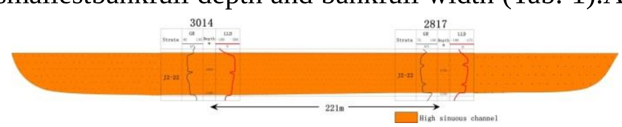


Fig. 7 — High sinuous channel profile ofLayer J2-22 in Kumkol Oilfield

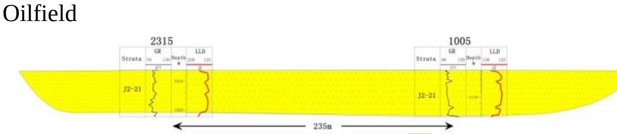


Fig. 8 — Low sinuous channel profile ofLayer J2-21 in Kumkol Oilfield

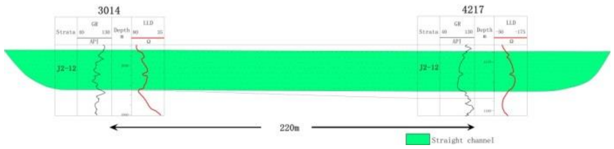


Fig. 9 — Straight channel profile ofLayer J2-12 in Kumkol Oilfield

Table 1 — Statistic of different distributed channel in KumkolSouth Oilfield

Channel type	Width/m	Thickness/m	Width/Thickness	Curve
High sinuous channel	60-300	4-6	10-75	1.5-1.8
Low sinuous channel	60-270	4-5	12-68	1.2-1.6
Straight channel	50-180	3-5	10-60	1.0-1.3

the A/S increasing, thehigh sinuous distributed channel is evolved to the lowsinuous distributed channel and the straight distributed channelvertically (Fig. 10). To be specific, the overbank sandstone stands for the natural levee and the crevasse splay and the overbank because these kinds of sandstone are not the beat reservoir.

Inner single distributed channel architecture characterization

The research of inner single distributed channel is the third step of distributed river sandstone architecture characterization[4]. Boundaries of inner single distributed channels are equivalent to the third level architecture boundaries[4-5]. The research of inner single distributed channel mainly focuses on the mudstone interlayer in the single distributed channel sandstone. Based on the core and logging data, the single distributed channel sandstone is studied.

The lithology of the interlayer is mainly mudstone and silty mudstone. Its thickness is thin which is between 0.3 and 1m.Its logging curve, such as GR and SP, has a relatively high value. And the thicker the mudstone interlayer is, the higher the logging curve value is. So the mudstone interlayer thickness can be speculated by the logging curve value.It is found that there are three type of the mudstone interlayers based on the difference of the logging curve.

a. The low logging value mudstone interlayer. This type of mudstone interlayer is cut by the late river overall or partially. Its thickness is generally smaller than 0.4m. So it has a low value of logging curve such as GR and SP (Fig.11a).
b. The medium logging value mudstone interlayer. This type of mudstone interlayer is cut by the late river partially. Its thickness is generally between 0.4 and 0.7m. So it has a medium value of logging curve such as GR and SP(Fig.11b).
c. The high logging value mudstone interlayer. This type of mudstone interlayer preserved very well and is not cut by the late river. Its thickness is generally between 0.7 and 1m. So it has a high value of logging curve such as GR and SP (Fig.11c).

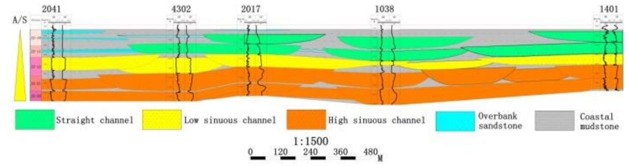


Fig. 10 — Distribution pattern of single distributed channel ofLayer J in Kumkol Oilfield

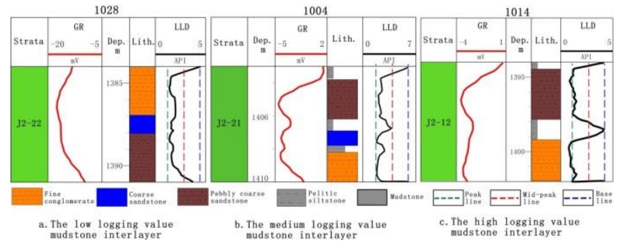


Fig.11 — Logging feature of different type of mudstone interlayers ofLayer J in Kumkol Oilfield

a. Continuous mudstone interlayer. This type of mudstone interlayer is mainly developed in the straight distributed channel.It is thick and preserved well and continuous between wells because of the weak erosion of the late distributed river. So its GR and SP value are high and is easy for inter-well-contrasting (Fig. 12).
b. Discontinuous mudstone interlayer. This type of mudstone interlayer is mainly developed in the high sinuous distributed channel. It is thin and poorly preserved and discontinuous between wells because of the strong erosion of the late distributed river. So its GR and SP value are low and is difficult for inter-well-contrasting (Fig. 13).
c. Complex mudstone interlayer. This type of mudstone interlayer is mainly developed in the low sinuous distributed channel. Because of the different erosion energy of the different distributed river, the mudstone interlayer is thin and poorly preserved and discontinuous between wells when the strong erosion of the late distributed river, and the mudstone interlayer is thick and preserved well and continuous between wells because of the weak erosion of the late distributed river. So its GR and SP value change quickly (Fig. 14).

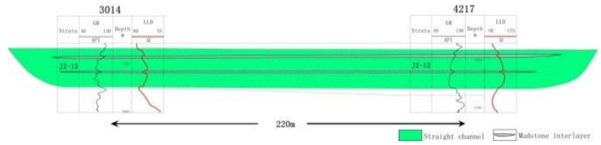


Fig. 12 — Distribution pattern of mudstone interlayers ofLayer J2-12 in Kumkol Oilfield

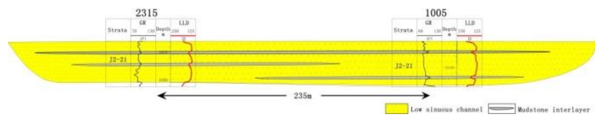


Fig. 13 — Distribution pattern of mudstone interlayers ofLayer J2-21 in Kumkol Oilfield

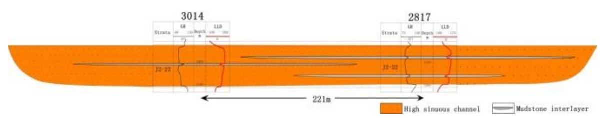


Fig. 14 — Distribution pattern of mudstone interlayers ofLayer J2-22 in Kumkol Oilfield

Table 2 — Statistic of different mudstone interlayer in KumkolSouth Oilfield

Type	Thickness /m	Density m/m	Frequency number/m	Length /m	Width /m
Discontinuous	0.2-0.5	0.05-0.15	0.1-0.5	100-300	40-180
Complex	0.2-0.7	0.05-0.2	0.15-0.7	180-400	40-220
Continuous	0.4-1	0.05-0.3	0.25-0.8	250-550	40-250

Because the river energy of the high sinuous distributed channel is very strong, the discontinuous mudstone interlayer is relatively small and poorly preserved. Its length is between 100 and 300m. Its width is between 40 and 180m. Its thickness is between 0.2 and 0.5m. Its distributed frequency is between 0.1 and 0.5 and its distributed density is between 0.05 and 0.15. Because the river energy of the low sinuous distributed channel is strong, the complex mudstone interlayer is relatively large and preserved well. Its length is between 180 and 400m. Its width is between 40 and 220m. Its thickness is between 0.2 and 0.7m. Its distributed frequency is between 0.15 and 0.7and its distributed density is between 0.05 and 0.2.Because the river energy of the straight distributed channel is weak, the discontinuous mudstone interlayer is very large and preserved very well. Its length is between 250 and 550m. Its width is between 40 and 250m. Its thickness is between 0.4 and 1m. Its distributed frequency is between 0.25 and 0.8 and its distributed density is between 0.05 and 0.3 (Tab. 2).

Conclusion

There are four types of composited distributed channel sandstone in Layer J of Kumkol South Oilfield, such as the sheet-like channel andthe wide-belt-like channel and the narrow-belt-like channel and the band-like channel. And as the accommodation increasing and the sediments supply decreasing, the distributed pattern of the composited distributed channel changes from the sheet-like channel to the wide-belt-like channel and the narrow-belt-like channel and the band-like channel.There are three types of single distributed channel sandstone in Layer J of Kumkol South Oilfield, such as the high sinuous distributed channel and the low sinuous distributed channel and the straight distributed channel. And as the accommodation increasing and the sediments supply decreasing, the distributed pattern of the single distributed channel changes from the high sinuous distributed channel to the low sinuous distributed channel and the straight distributed channel.There are three types of mudstone interlayer in Layer J of Kumkol South Oilfield. Continuous mudstone interlayer has high GR of SP valueand is mainly developed in the straight distributed channel and its size is relatively large.The complex mudstone interlayer has medium GR of SP valueand is mainly developed in the low sinuous distributed channel and its size is relatively medium.The discontinuous mudstone interlayer has low GR of SP valueand is mainly developed in the high sinuous distributed channel and its size is relatively small.

Reference

1 Xu, A.N., Mu, L.X., Qiu, Y.N., Distribution pattern of OOIP and remaining mobile oil in different types of sedimentary reservoir of China, Petroleum Exploration and Development. 25(1998):41-44.

2 Wang, J.C., Zhao, L., Zhang, X.Z,, Tian, Z.Y. and Chen, Xi, Influence of Meandering River Sandstone Architecture on Warterflooding Mechanism: A Case Study of Layer M-I in Kumkol Oilfield, Kazakhstan, Petroleum Science. 11 (2014):81-88.

3 Zhao L., Wang, J.C. and Chen, L., Infuences of sandstone superimposed structure and architecture on waterflooding mechanisms: A case study of Kumkol Oilfield in the South Turgay Basin, Kazakhstan, Petroleum Exploration and Development. 41(2014): 86-94.

4 Miall, A. D., Architectural element analysis：A new method of facies analysis applied to fluvial deposites,Earth Science Reviews. 22(1985)：261～308

5 Wu, S.H., Ji, Y.L. and Yue, D.L., Discussion on hierarchical scheme of architecture units in clastic deposits, Geological Journal of China Universities. 19 (2013): 12-22.

6 Li, Z.P., Lin, C.Y. and Dong, B., An internal structure model of subaqueous distributary channel sands of the fluvial dominated delta, Acta Petrolei Sinica. 33 (2012): 101-105.

7 Anthony, S., Andrew, H. and Mario, V., Outcrop-based reservoir characterization of a kilometer-scale sand-injectite complex, AAPG Bulletin. 97 (2013):309–343.

8 Gibling, M. R., Width and thickness of fluvial channel bodies and valley fills in the geological record：Aliterature compilation andc1assmcation, *Journal of Sediment Research*. 76(2006)：731—771.

9 Miall. A.D., Reconstructing the architecture and sequence stratigraphyof the preserved fluvial record as a tool for reservoir development：Areality check, *AAPG Bulletin*. 90(2006)：989-1002.

10 Cornel, O.，Janok, P.B., Terminal distributary channels and delta frontarchitecture of river-dominated delta systems, *Journal of Sedimentary Research*. 76(2006)： 212-233.

11 Jiao, Y.Q.，Yan, J.X. and Li, S.L., Architectural units and heterogeneity of channel reservoirs in the Karamay Formation，outcrop area of Karamay oil field，Junggar basin，northwest China, *AAPG Bulletin*. 89(4)(2005)：529-545.

12 Xiang, C.G., Method for internal reservoir modeling of underwater distributary channel：By taking a multicyclic underwater distributary channel in PB Oilfleld for example, *Journal of Oil and Gas Technology*. 32(2010)：38-42.

13 Stephen, M.H., Derald, G.S. and Haley, N., Seismic geomorphology and sedimentology of a tidally influenced river deposit, Lower Cretaceous Athabasca oil sands, Alberta, Canada, *AAPG Bulletin*. 95(2011):1123–1145.

14 Wang, H., Hu, G.Y. and Fan, H.J., Key technologies for thefluvial reservoir characterization of marginal oilfields, *Petroleum Exploration and Development*. 39 (2012) ：626—632.

15 Yu, X.H., Existing problems and sedimentogenesis-based methods of reservoir characterization daring the middle an d later periods of oilfield development, *Earth Science Frontiers*. 19(2012) ：001-014.

16 Feng, C.J., Bao, Z.D. and Chen, B.C., Application of the single factor analysis and multifactor coupling method to the remaining oil prediction in Fuyu oilfield, Acta Petrolei Sinica. 33 (2012): 465-471.

17 Feng, C.J.，Zhao, Y. and Jia, P., Reservoir architecture modelof shallow lacustrine delta, *Chinese Journal of Geology*. 48(2013)：1234—1245.

18 Feng, C.J., Bao, Z.D. and Yang, L., Reservoir architecture and remaining oil distribution of deltaicfront underwater distributary channel, *Petroleum Exploration and Development*.41(2014): 323-329.

19 Li, Y.P. and Wu S.H., Hierarchical nested simulation approach in reservoir architecture modeling, Petroleum Exploration and Development. 40(2013): 630-635.

20 Zhao, X.Q., Bao, Z.D. and Liu, Z.F., An in-depth analysis of reservoir architecture of underwater distributary channel sand bodies in a river dominated delta: A case study of T51 Block, Fuyu Oilfield, Petroleum Exploration and Development. 40(2013): 181-187.