Application and study of tracer technology in M oilfield, Iraq

Ligong Cui*, Liping Jiang, Ce Duan

Chengdu North Petroleum Exploration & Development Technology Co., Ltd. Chengdu, China

*Cuiligong@zhenhuaoil.com

Abstract. Strong heterogeneity is normally appeared in the carbonate reservoirs in the Middle East. The M oilfield is the one which is more prominent located in the southern part of Iraq. There is a high permeability layer exists in the X formation of the main reservoir, which leads to large difference in permeability. Water injection connectivity and heterogeneity need to be confirmed. In order to solve the problem, the tracer technology is used to track injection water, and then the relevant numerical model is used to analyze and interpretation. The research results show that T-1 injection well group have seen tracers to varying degrees which identified X formation exists heterogeneity and the presence of a thin layer of high permeability in the X-family of the M oilfield in Iraq affects the development of water injection is also confirmed by the bimodal characteristics of the tracer output. The research results of this paper is applicable to the Middle East marine tectonic gap type carbonate reservoirs, and the analyzed data and results are especially useful for the carbonate reservoirs with strong heterogeneity with water injection development.

Keywords: Tracer; Output Curve; Simulation; Double Peak; Heterogeneity.

1 Introduction

As a carbonate reservoir with strong heterogeneity, to figure out the oil-water relationship is the key point for effective water injection and development of carbonate reservoirs. Usually, the methods to recognize the oil-water relationship include production logging, pressure testing, core analysis and so on. However, it is difficult for these methods to accurately and continuously describe the oil-water flow relationship between injection wells and production wells, especially under the special stratigraphic conditions of the south-central region of Iraq in the Middle East, these methods show more limitations [12]. The tracer inter-well monitoring technique can make up for the shortcomings of the above methods, and its interpretation results can reflect both the vertical well-to-well connectivity and the distribution of residual oil [1].

Tracers are chemical agents that can flow with the fluid and indicate the presence, direction and speed of fluid movement [2]. The tracer inter-well monitoring technology is to inject a water-soluble tracer into the injection well[3], take water samples from the surrounding monitoring wells, analyze the concentration of the tracer in the water

A. E. Abomohra et al. (eds.), *Proceedings of the 2023 9th International Conference on Advances in Energy Resources and Environment Engineering (ICAESEE 2023)*, Atlantis Highlights in Engineering 29,
https://doi.org/10.2991/978-94-6463-415-0_73

samples taken, and plot the tracer output curve, and analyze the tracer output curve by applying the tracer interpretation software, so that the flow distribution characteristics of the injected fluid in the reservoir can be determined[4]. In the case of no outflow of injected water, the more homogeneous the reservoir is, and the higher the utilization rate of injected water is, the later the tracer is seen. On the contrary, seeing the tracer in a short time indicates that the injected water flows along the high permeability layer, the reservoir is heterogeneity, and the development effect is poor.

2 Research and application status

Tracers are widely used in oil fields at home and abroad. Among foreign experts, W.H. Colter [5] invented a tracer fluid for improving oil recovery, which used easily identifiable water-soluble inorganic salts, especially nitrate and low molecular alcohol, to monitor the flow rate and formation conditions between injection Wells and producing Wells. P.e.puett et al. [6] invented a method for injecting and monitoring tracers used in drilling, and provided a set of equipment to meet the use of tracers in oil, gas and geothermal fields to continuously detect fluids in injection Wells or production Wells. R.m. oreira et al. proposed that in oilfield water injection, there are many kinds of water-based tracers to choose from, in addition to the most commonly used tritiated water, radioactive 35S can also be used to track the fluid in the water injection system.

In China, tracers can be classified into chemical tracers, radioisotope tracers and stable isotope tracers according to the concentration standard [13]. Chemical tracer is one of the important means of reservoir research, which plays an important role in the study of reservoir connectivity, reservoir physical properties, fault sealing, water injection correspondence and injection water advance speed. For example, since 1992, many field applications of chemical tracers have been carried out in Henan Oilfield. Certain results have been achieved in the judgment of reservoir connectivity and water-injection correspondence, and have played a positive role in reservoir research and dynamic adjustment [7]. In 2001, the first, second and third oil production plants in Fuyu Block of Jilin Oilfield carried out the profile control test with large dose of chemical tracers. Before and after profile control, the tracer test was used to understand the reservoir conditions, and the oil-water movement law was well evaluated [8].

3 Basic information of test block

3.1 Status of the block

The M field is located in southeastern Iraq, and its main oil reservoir, the X formation, is a carbonate reservoir with a high permeability "thief layer" distributed throughout the region, with a permeability range of 400-1000 mD. The field is developed with horizontal well and pattern injection, with some horizontal production wells trajectory diagonally across or through the high permeability layer. The trajectories of neighboring horizontal injection wells penetrate below the high permeability layer. This injection pattern and the special geological situation make the injection water to run into the production wells prematurely and the pattern of water running into the wells is difficult to be predicted. It is hoped that through the inter-well tracer technology, an injection well group T-1 can be selected to clarify the flow pattern in the plane and vertically, so as to have a better guidance and reference for the actual production.

3.2 Status of the test well group

The T-1 injection well group consists of two production wells (H-01 and H-02 wells) and one water injection well (T-1 well), all three wells were put into production in June 2011, and T-1 was transferred to injection in August 2012, with an initial injection rate of 4,000-5,000 bbl/day. The two wells saw water 4.5 months after injection and the water cut rose rapidly to about 40%.

Combined with the geological understanding, reservoir dynamic tracking analysis, reservoir numerical simulation prediction, and saturation logging interpretation results show that due to the existence of high permeability layers in the X-family system, the wells injected water breakthrough fast after the water injection development. In order to verify the influence of the presence of high permeability layer on the injection water flow direction, wave volume, propulsion direction and the heterogeneity of the high permeability layer on the water injection, it was decided to use tracer test to verify. According to the actual situation of the oilfield and relevant standards, ammonia thiocyanate was used as the tracer agent in T-1 well group through the compatibility test.

The average reservoir thickness of T-1 well group is 20m, the porosity of formation is 24.3%, the average well distance is 300m, through the reservoir analysis and research combined with the geological data, it is recognized that there is a high-permeability layer in 2-1 small layer of the X layer system, the permeability ranges from 200-500mD, and the heterogeneity nature of the layer is strong.

4 Analysis of tracer test results

4.1 Tracer Seeing Agent Analysis

The key monitoring wells in the well group are: H-01 and H-02, sampling and analyzing frequency is every day, shown in Figure 1; the general monitoring wells in the well group are: H-03, H-04, H-05, H-06, sampling and analyzing frequency is once every 2-3 days shown in Figure 2. From the monitoring results response, test wells are obviously see agent.

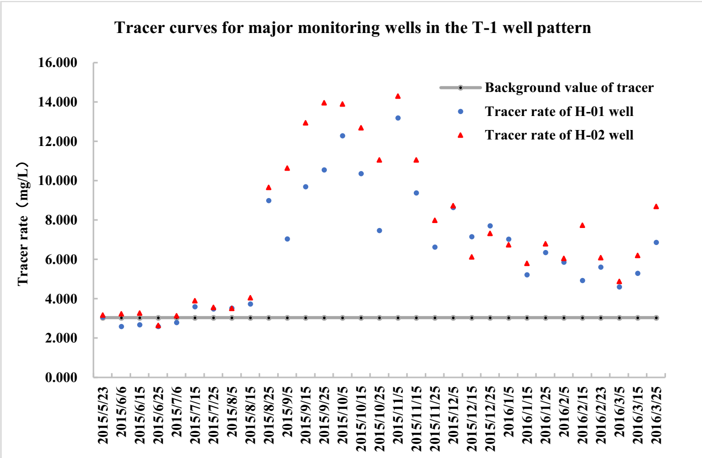


Fig. 1. Major monitoring wells tracer output curve

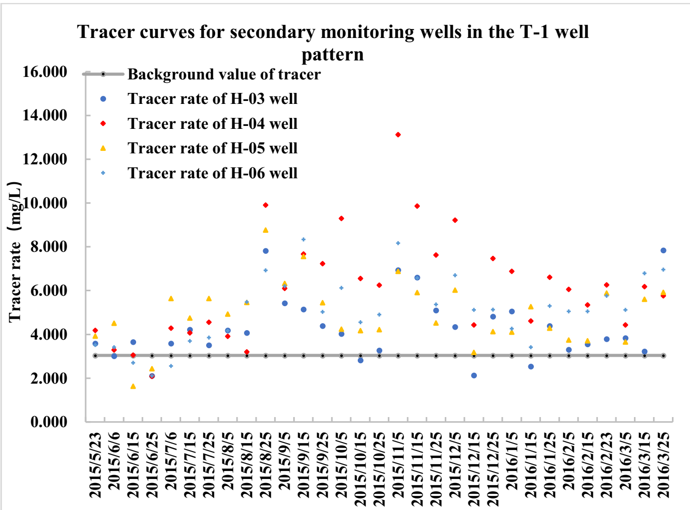


Fig. 2. Secondary monitoring wells tracer output curve

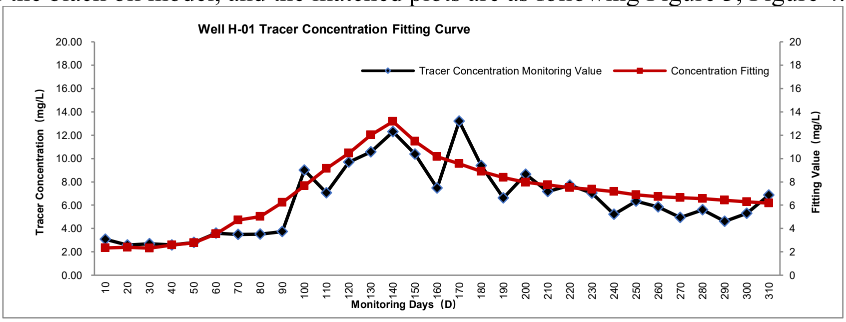
From the data in Table 1, it can be seen that the time of seeing the dose can show that the injected water of T-1 well reaches H-04 the fastest, followed by H-06; the speed of advancing can show that the injected water of T-1 well reaches H-04 and H-06 the fastest, which indicates that there is a better connecting channel between these two wells and T-1, followed by H-03 and H-05, and lastly H-01 and H-02; from the tracer after splitting, H-01 and H-02 are the two wells that produce the most dose, indicating that a large amount of injected water from T-1 well flows to these two wells. amount, H-01 and H-02 are the two wells with the highest output dose, indicating that the injected water from well T-1 flows to these two wells in large quantities.

Table 1. Tracer monitoring data of well group T-1

pound sign	Distance between wells/m	seeing-eye time	peak time	peak value	Propulsion speed 1/meter/day	Propulsion speed 2/m/day	Average post-dose concentration	See agent strength	Amount of tracer output after splitting
	on average	sky	sky	%	on average	on average	%	%	mg
H-01	300	95	171	22.79	3.2	1.8	9.91	0.21	41.5
H-02	300	95	170	22.43	3.2	1.8	12.16	0.26	62.5
H-03	646	95	170	13.63	6.8	3.8	5.08	0.11	10.9
H-04	543	95	171	23.83	5.7	3.2	8.40	0.18	29.8
H-05	626	48	171	12.46	13.0	3.7	5.68	0.12	13.6
H-06	558	79	171	14.93	7.1	3.3	6.11	0.13	**2.8**

4.2 Numerical simulation analysis of tracer test well sets

The first step is to perform a historical matching of water cut, oil production and GOR for the T-1 well group of the tracer experiment, which shows that the computed model and the historical situation match well from the well group matching. Deepen the accuracy on the well group-based matching by performing historical matching for a single well. Based on the matching based on the water cut and production of the well group, the tracer concentration of each single well was matched using the streamline model and the black oil model, and the matched plots are as following Figure 3, Figure 4.



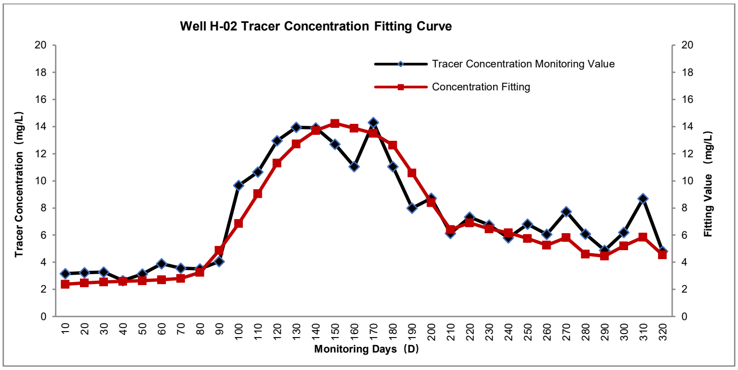
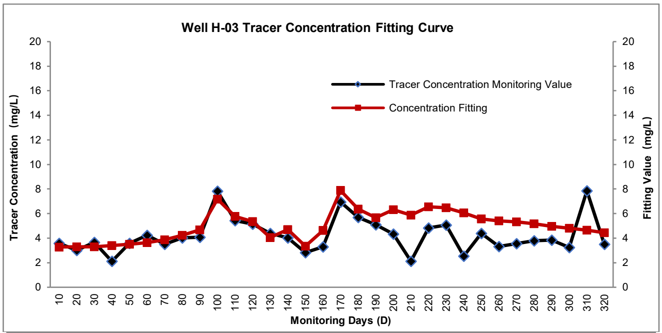
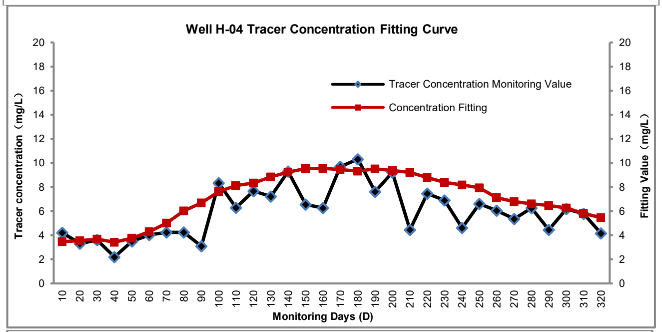
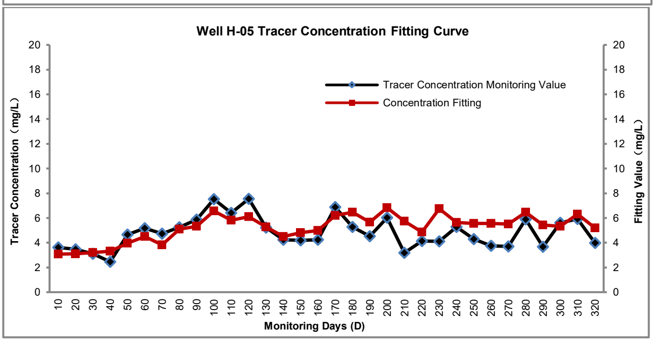


Fig. 3. Comparison between actual curve and matching curve of main tracer monitoring wells







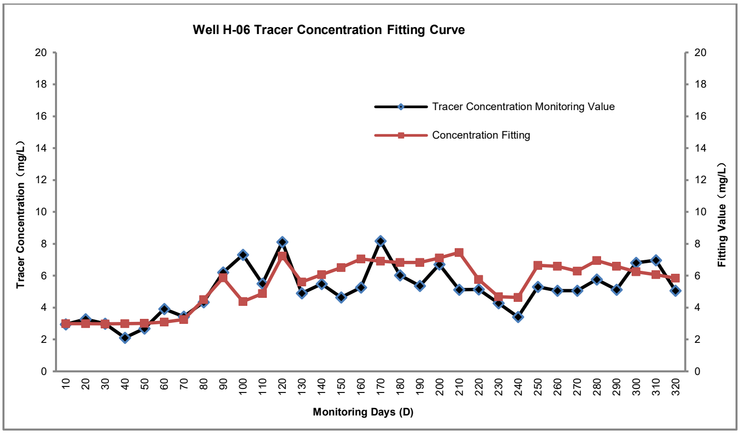


Fig. 4. Comparison between actual curve and matching curve of secondary tracer monitoring wells

As can be seen from the curve matching plots in Figure 3 and Figure 4, the tracer output curves of the wells of the T-1 well group can match curves well, indicating that the parameters provided by the interpretation software are able to reflect the actual situation of the formation, which can provide a basis for the next step of analysis.

4.3 Well group connectivity analysis

In the "environmental tracer interpretation module" of ECLIPSE, we calculated the planar wave and correlation coefficient, volumetric wave and correlation coefficient, and the equivalent permeability of the mainstream high permeability channel between wells (i.e., the average of the permeability of the high permeability channel between the wells) between the T-1 wells and the wells with the tracers, and other parameters, such as shown in Table 2, which is the result of the interpretation of the tracer wells with the tracers. Interpretation results of tracer wells.

Table 2. Interpretation Results of Inter-well volume sweep efficiency

pound sign	Inter-well volumetric wave coefficient/%						
	10 days	20 days	30 days	50 days	90 days	150 days	300 days
H-01	0.07	0.25	0.39	0.69	1.08	1.42	1.61
H-02	5.95	8.71	10.67	13.59	16.82	20.03	23.42
H-03	2.00	3.14	3.68	4.09	4.93	5.85	6.33
H-04	0.02	0.13	0.21	0.40	0.75	0.97	1.17
H-05	4.47	7.25	9.75	13.52	17.53	20.75	23.93
H-06	1.59	1.93	2.86	3.98	5.08	5.67	6.25

Table 3. Interpretation Results of Inter-well areal sweep efficiency

pound sign	Inter-well planar wave coefficient/%						
	10 days	20 days	30 days	50 days	90 days	150 days	300 days
H-01	2.02	7.50	11.73	20.71	32.63	42.80	45.90
H-02	38.30	55.31	70.42	85.42	99.21	99.96	100.00
H-03	12.86	20.32	22.59	24.92	27.12	28.21	28.23
H-04	1.05	5.96	9.66	18.28	34.57	44.63	49.10
H-05	31.17	52.21	72.64	90.15	99.26	99.96	100.00
H-06	11.74	18.04	22.37	28.38	32.48	32.49	34.78

Table 4. Interpretation results of Inter-well permeability in high permeability layer

pound sign	Average permeability (X2-1 sublayer) (10^{-3} μm)^2
H-01	248.47
H-02	261.25
H-03	269.38
H-04	265.82
H-05	270.76
H-06	320.16

As can be seen from Table 2, the software calculates that there is a high permeability layer between wells in the T-1 well group in the X2-1 sub-layer, with an average permeability of $272\times10^{-3}\mu m^2$ and a thickness of high permeability layer is 0.57m shown in Table 3 and Table 4. It can be seen from this monitoring that, after the oilfield enters into the period of water injection and development, the utilization rate of the injection water is low due to the existence of high permeability layer, and the production interfere with each other, which influences the normal exploitation of the crude oil [15], therefore how to manage the water injection under the high permeability layer is the next key work.

4.4 Characterization of bimodal features of the output curve

Due to the relatively small amount of tracer into the low-permeability layer, by the dilution of water in the layer and the subsequent water in the high permeability layer, there is often only a single-peak phenomenon [9]. When the permeability grade difference is 10.0mD and the water saturation of two layers is the same, the tracer output curve is a double peak, the first peak mainly comes from the high permeability thin layer in the layer, and the leading edge of the tracer is mixed in the injected water to be the first to arrive at the monitoring well through the high permeability layer; the second peak comes from the low permeability layer, due to the thickness of the low permeability layer, the amount of water is more than that of the high permeability layer, meanwhile, it is affected by the water of the high permeability layer, so the duration of the second peak is shorter. The second peak comes from the low-permeability layer, due to the large thickness of the low-permeability layer, the water volume is more than that of the high-permeability layer, and it is affected by the successor water of the high-permeability layer, so the duration of the second peak is shorter, and the double-peak is produced [10]. From the curve characteristics in Figure 5, it can be seen that there is a more obvious double-peak phenomenon, indicating that the heterogeneity within the layer is stronger [11].

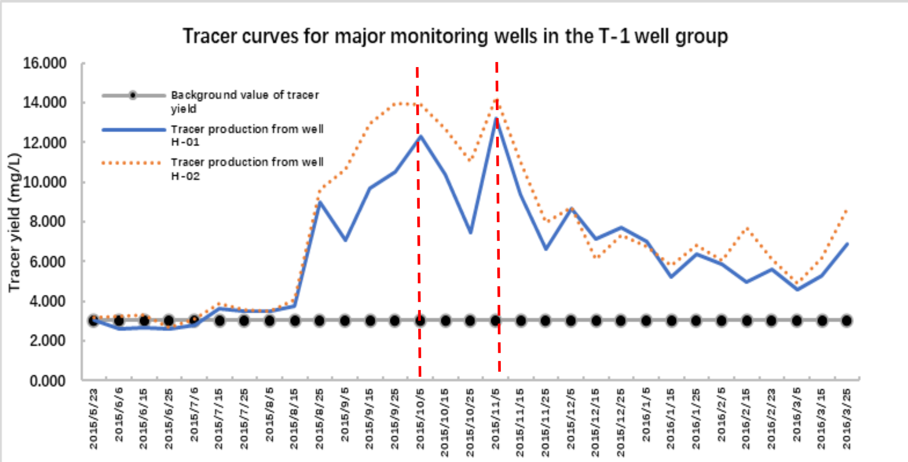


Fig. 5. Double peak features of tracer output curve in main monitoring wells

5 Conclusion

The T-1 well group was monitored for more than 12 months, and the following conclusions were reached by synthesizing the monitoring information on tracer output, the rate of injection water advancement, and the parameters of the high-permeability layer between wells during the monitoring period:

1. Through inter-well monitoring of chemical tracer in the T-1 injection and extraction well group, the connectivity between the injection and extraction wells, the propulsion direction of the injected water, and the propulsion speed were more clearly grasped, and the permeability and thickness of the high permeability layer were calculated by using software, and the test was successful.

2. Six wells in the T-1 injection well group have seen tracers to varying degrees, indicating the existence of strong heterogeneity within the T-1 injection well group. The thickness and permeability of the high permeability layer between the injection and extraction wells are not uniformly distributed, and there is heterogeneity of the high permeability layer.

3. The tracer transportation speed between wells in the T-1 injection well group is between 3.00m/d and 6.70m/d, and the tracer output is in line with the output characteristics of the high-permeability layer, indicating that there is a high-permeability layer with strong heterogeneity between the injection wells and the wells in the injection well group. It can be seen from the water-driven schematic diagram that the high permeability layer scuttling is prevalent in the range of six wells in the T-1 injection well group.

4. T-1 injection well group between the wells in the 2-1 sub-layer there is a high permeability layer, average permeability is $272 \times 10^{-3}\mu m^2$, thickness of high permeability layer is 0.57 m. The formation of the high permeability layer is the result of static factors and dynamic factors, the high permeability layer is not conducive to the development of the field water injection, the priority of the injected water into the high permeability layer to flow to the production wells, reduce the injection of the water wave area, speed up the wells water flooding rate, which inevitably leads to low injection efficiency, low crude oil recovery results. This inevitably results in low water injection efficiency and low crude oil recovery [16].

5. The fact that the presence of a thin layer of high permeability in the X-family of the M-field in Iraq affects the development of water injection is also confirmed by the bimodal characteristics of the tracer output [17].

6. The research content of this paper is applicable to the Middle East marine tectonic gap type carbonate reservoirs [18], and the analyzed data and results are especially useful for the carbonate reservoirs with strong heterogeneity and the need of water injection development [19].

References

1. CHEN Shuying. The Method of Inter-well Tracer and Heterogeneity of Reservoir [J]. Inner Mongolia Petrochemical Industry, 2005, 20(9):76-791
2. Zhao Fulin. Oil recovery agents[M]. Beijing Petroleum University Press,1997:256-259.
3. LIU Jiawen, CHEN Xueyuan, Li Wusheng. Application of Isotope Tracer Interwell Monitoring Technique in N1 of Shizigou Oilfield [M]. Application of Isotope Tracer Interwell Monitoring Technique in N1 of Shizigou Oilfield [M].
4. YU Ruixiang, ZHANG Taishan, ZHOU Weisheng. Technique in oil field tracer [J]. Industrial Water Treatment, 2007, 8(27):12-15.
5. Carter W H, Sides J L. Tracer fluids for enhanced oil recovery [P].US4299709,1981.
6. Pruett P E, Findlay M. Borehole tracer injection and detection method [P]. WO9806930, 1998.
7. YANG Lin, YUAN Guangxi, LI Xinhua. Application of chemical tracers in Henan Oilfield [J]. Application of chemical tracers in Henan Oilfield [J]. Journal of Oil and Gas Technology(JPI), 2005,27(4):470-471.
8. Liu R, Yang GJ, Zhang SC, et al. Application of inter-well tracer technology in oilfield development. Petroleum Industry Technology and Supervision. 2004,3(2):8-10.
9. LIU Rui, YANG Guangjun, ZHANG Shicheng. application of interwell tracer technology in oilfield development. technology supervision in petroleum industry. 2004,3(2):8-10. Technology Supervision in Petroleum Industry. 2004,3(2):8-10.
10. LIU Xiaolan, JIANG Ruizhong, ZHENG Yong. Research on double peak on output curve of tracer [M]. Petroleum Geology and Recovery Efficiency, 2007,1(1):76 Petroleum Geology and Recovery Efficiency, 2007,1(1:76-78).
11. LI Shuxia, CHEN Yuemin. Shape features of tracer production curve [J]. Petroleum Geology and Recovery Efficiency, 2002,9 (2):66-67,79.
12. JIANG Ruizhong, MA Ye, DAN Xinguang. Application of Tracer Analysis Technique in Reservoir Description [J]. Application of Tracer Analysis Technique in Reservoir Description [J].

13. JIANG Wenda. Application of Isotope Tracer Technique on Well Logging in Oilfield Developments of China [J]. Journal of Isotopes, 1989,2(4): 62-67.
14. Tang J S. Partitioning tracers and in-situ fluid saturation measurements [J]. SPE 22344.
15. YU Jinbiao, SONG Daowan, QIN Xuejie. Study on interpretation model of inter-well tracer [J]. Study on interpretation model of inter-well tracer [J]. Petroleum Geology and Recovery Efficiency, 2003,10(6):42-44.
16. ZHAO Guoyu. The Application of Inter-well Tracer Method in Oilfield Production [J]. Petroleum Exploration and Development, 1999,26(4):92295.
17. LIU Zhiyun, SONG Xiaofeng. Use of Inter-well Tracing in Studying the Distribution of Residual Oil in a Reservoir [J]. Journal of Jianghan Petroleum Institute, 1999,21(4):76-78.
18. Channel belt architecture formed by a meandering river[J]. Wietse I. Lageweg; Wout M. Dijk; Maarten G. Kleinhans.Sedimentology,2013.
19. A new framework for modeling the migration of meandering rivers[J]. G. Parker; Y. Shimizu; G. V. Wilkerson; E. C. Eke; J. D. Abad; J. W. Lauer; C. Paola; W. E. Dietrich; V. R. Voller. Earth Surface Processes and Landforms,2011.