Study on geological reunderstanding and adjustment potential of development zone

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Abstract: Development Zone A is a heterogeneous oil field with continental river-delta deposits. The channel sand body is small in scale and is dominated by straight distributary channel sand body. This type of sand body development scale is small, the drilling rate is low, generally only 17.71%, the plane shows a strong heterogeneity, the well pattern control degree is low, the sand body prediction accuracy under the current well pattern condition is low, generally only about 70%. Due to the small scale of sand body development and the development of faults, the contradiction of imperfect injection-production relationship of single sand body is prominent. In 2016, the expansion Wells of Development Zone A were put into operation successively. Based on the re-understanding of the geology of the new drilling area, the adjustment potential of development Zone A was studied, the injection-production relationship of single sand body was clarified, and the adjustment potential was implemented in combination with the results of multidisciplinary reservoir research, so as to achieve the purpose of improving the water drive control degree of the block and improving the injection-production relationship of sand body. After careful analysis, it was preliminatively determined that 19 Wells adjusted for injection and production system were reinjected (6 Wells were reinjected after filling holes). Internal supplementary Wells 19; One oil well was regenerated into a water well, and one water injection well was restored. A total of 41 Wells.

Key words: Heterogeneous oilfield; Fault development; The injection-production relationship.

1. A Development zone basic overview and development status

The northern development zone of T Oilfield (referred to as Development Zone A) was discovered in June 1960 by the first industrial oil flow obtained from well T2. The oil bearing area of Pu1 Formation is 110.02km^2, with geological reserves of 5289.16×10^{4}t and technical recoverable reserves of 1459.85×10^{4}t. The oil layer of Sa 2 Formation developed in the north of T14 row, with an oil bearing area of 19.3km^2 and proven oil reserves of 375.67×10^{4}t. Development Zone A was put into water injection development in 1980, and has successively carried out one infusing adjustment and local supplementary adjustment, development of block T19, expansion development, T14 row to Beisha Group 2 oil reservoir development, and achieved good development results. As of September 2019, the daily fluid volume of the area is 5854t, the daily oil production is 486t, and the comprehensive water cut is 91.69%. The average flow pressure is 3.62MPa, the cumulative oil production is 1187.68×10^{4}t, and the recovery degree is 24.06%.

1.1 The number of water injection Wells is too large, and the degree of water flooding control is low

The oil-bearing area of Development Zone A is 110.02km2. As of December 2016, there are 1,271 oil and water Wells in development Zone A, including 912 production Wells and 359 injection Wells, with a well pattern density of 11.55 / km^2 and a ratio of oil and water Wells of 2.54. A development zone is affected by faults, and the contradiction of imperfect injection and production is prominent. From the table of water drive control degree of different thickness levels (see Table 1), unidirectional and bidirectional connectivity are dominant, and the proportion of connected layers below two directions (including both directions) is 54.7%. The proportion of three-directional sandstone connectivity is only 14.4%.

1.2 The formation pressure level is low and the development effect is poor

From the current pressure level, the formation pressure in the whole area is 9.57MPa, the total pressure difference is -1.61MPa, and the pressure level is low, especially in the

well area with imperfect injection and production, the problem of low formation pressure is more prominent.
Since the development of Development Zone A, it has always put the improvement of injection-production relationship and the improvement of ultimate oil recovery in the first place. It has gradually improved the injection-production relationship of single sand body by means of primary infilling adjustment, local infilling and replenishment, and rolling edge expanding drilling, etc. In the high water cut period, multi-disciplinary joint research has quantification of remaining oil distribution. The hard and stable production in high water cut period has been achieved by adjusting the liquid production structure by means of transferring oil well, filling holes and drilling supplementary Wells. However, due to the small scale of sand body development and the development of faults, the contradiction of incomplete injection-production relationship of single sand body is still prominent. From the development effect of development zone A, compared with Xingnan Development Zone, the extraction degree of the same water cut stage is obviously lower, and the development effect is poor. At present, the comprehensive water content has reached 91.69%, and the recovery degree is only 24.06%.

Table 1 Statistical table of water flooding control degree of different thickness levels in development zone A

Effective thickness classification	One way(%)			Two way(%)			Three way(%)			Total(%)		
	Number of layers	sandstone	valid	Number of layers	sandstone	valid	Number of layers	sandstone	valid	Number of layers	sandstone	valid
≥2.0	28.5	32.7	28.3	26.4	30.7	27.1	17.7	20.3	18.6	72.6	83.7	74.0
2.0-1	24.6	29.9	24.5	25.6	32.3	25.9	15.7	21.3	16.0	65.9	83.6	66.3
0.5-1	27.1	32.9	27.2	24.0	30.8	24.2	12.9	18.2	12.8	64.0	81.9	64.1
0-0.5	33.8	42.5	34.0	20.4	25.3	20.1	6.0	6.1	6.2	60.2	74.0	60.3
Extra-surface	37.9	39.4	0.0	20.1	20.6		3.7	3.9	0.0	61.8	63.8	0.0
Total	32.5	34.8	27.1	22.2	28.0	25.5	8.7	14.4	15.5	63.4	77.2	68.1

2. Structural changes and adjustment potential before and after well earthquake combination

From 2011 to 2012, our factory established the structural model of development Zone A based on well vibration. In the following years, the model was updated in time according to the new drilling data. In recent years, new seismic interpretation data have been obtained in an area of about 55km2 in block T30. In order to improve the structural understanding accuracy of this block, the well-earthquake combined structural model was re-established in block T30 in 2016 and integrated into the structural model of large blocks.

2.1 Study of fault variation

First, new faults: 17 new faults, of which 8 are inside the work area, with small fault spacing and many suspected faults. There are 9 peripheral faults with large extension length. Most of the new faults in the working area are at the edge of development Wells. The second is the verification fault: it is mainly the fault with short extension length and small fault distance near the large fault. Verify 4 faults, and verify the existence of small faults without breakpoint control through seismic profiles. The third is the fault morphological change: the fault morphological change is 1, which is mainly a straight extension into a snake extension. The fourth is the extension length change: including the extension length of fault extension and shortening two types. It mainly refers to the fault that the main part of the fault is in good agreement, and the length of the two ends is inconsistent. There are 2 faults in total, and most of the faults are distributed on the edge of the developed well. The fifth is strike change: mainly refers to the fault that the main part of the fault is in good agreement, while the fault tail strike changes greatly. Based on the above analysis, the changes of faults in development Zone A are summarized: 8 faults are newly discovered, 4 faults are cancelled and 5 faults are changed within the comparison boundary before and after 3D seismic interpretation.

2.2 Adjustment potential of fault-changing well area

Due to the small fault spacing, most of them are suspected faults and are located at the edge of the development well, which cannot be verified with the existing data; Due to the fault verification, the originally considered disconnected Wells can form injection and production relationship. For this kind of situation, to analyze the connected relationship between oil and water Wells, and the comprehensive analysis of the oil and water well production condition, the well injection, or combined with the multidisciplinary research results, on the basis of understanding the remaining oil distribution for supplementary well potential, perfect single sand injection-mining relationship, the purpose of mining oil layer residual potential. For example, well area 45-57: the original cognitive structure is a small fault between well

45-57 and well 45-58. After knowing the new structure, the old fault does not exist. The oil Wells in 45-57 well area are relatively concentrated, and the contradiction between imperfect injection and production is prominent. Well 45-57 was designed to inject 4 wells 44-57, 45-56, 45-58 and 46-57.

3. Geological reunderstanding and adjustment potential of new drilling area

With the completion of seismic data interpretation in the edge area of the oilfield and the deployment of evaluation control Wells, it has been confirmed that there are local structural favorable areas on the edge of the developed area of the development zone A. In 2015, based on the implementation of the structure, through the analysis of oil and water distribution, it is believed that the local structure on the edge of the oilfield has the potential for external expansion. At the same time, it is proved by the real drilling data that the local well area on the edge has sporadic expansion potential. In September 2015, the Reservoir Engineering Plan of Puyi Group Outward Expanding Well in the Northern Development Zone of T Oilfield was prepared and completed. A total of 57 outward expanding Wells were designed in the 37-54 well area, 21-8 well area, 2-20 well area and local scattered well area, including 47 production Wells, 10 water injection Wells and 2 old Wells (2-20, 21-8). The next generation of the filling hole is used as a production well, and the oil well is injected 1 (22-45). Drilling began in April 2016 and 56 Wells have been drilled so far. There are 149 oil and water Wells in the old expansion zone, including 117 oil Wells and 32 water Wells. The proportion of local outspread Wells accounted for 27.32% of the total number of all outspread Wells. In order to further understand the characteristics of sand bodies, geological re-understanding of Development Zone A was carried out in 2017.

3.1 Development of newly drilled reservoir

56 local expansion Wells were drilled in Development Zone A, with an average sandstone thickness of 18.2m and effective thickness of 5.8m per well drilled. The thickness of sandstone in the pure oil section is 9.2m and the effective value is 3.8m. The thickness of sandstone in the same interval is 4.9m, and the effective value is 2.0. The thickness of sandstone in the water layer is 4.2m. (See Table 2) From the perspective of oil intervals, well area 21-8 has the largest oil layer thickness and scattered Wells have the smallest drilling thickness. In terms of the development of different thickness classes from new drilling, the off-sheet reservoir and water layer are relatively developed (see Table 3).

Table 2 Average development of newly drilled single well in Development Zone A

well group	Number of Wells	Oil layer		co-layer		water layer		Total	
		Sandstone (Meter)	Valid (Meter)	Sandstone (Meter)	Valid (Meter)	Sandstone (Meter)	Valid (Meter)	Sandstone (Meter)	Valid (Meter)
21-8 well group	12	10.3	5.4	3.5	1.6	5.5	0.0	19.3	7.0
2-20 well group	5	21.9	3.0	2.1	1.0	12.3	0.0	36.2	4.1
37-54 well group	34	7.0	3.6	5.6	2.2	2.4	0.0	15.0	5.9
Scattered well group	5	8.3	2.0	5.8	2.5	5.2	0.0	19.3	4.5
Total	56	9.2	3.8	4.9	2.0	4.2	0.0	18.2	5.8

Table 3 Development of new drilling in different thickness classes in Development Zone A

Effective thickness classification	Oil layer			co-layer			water layer			Total		
	Number of layers (Number)	Sandstone (Meter)	Valid (Meter)	Number of layers (Number)	Sandstone (Meter)	Valid (Meter)	Number of layers (Number)	Sandstone (Meter)	Valid (Meter)	Number of layers (Number)	Sandstone (Meter)	Valid (Meter)
≥2.0	23	69.9	62.6	16	50.4	45.4				39	120.3	108
2.0-1	60	112.3	83.4	25	42.4	33.4				85	154.7	116.8
0.5-1	69	84.2	48	37	46.3	25.6				106	130.5	73.6
0-0.5	70	68.6	19.8	27	23.7	8				97	92.3	27.8
Extra-surface	253	179.3	0	179	109.1	0	175	233.3	0	607	521.7	0
Total	475	514.3	213.8	284	271.9	112.4	175	233.3	0	934	1019.5	326.2

3.2 Geological reunderstanding of the new drilling area

Development Zone A is a heterogeneous oil field with continental river-delta deposits. The channel sand body is small in scale and is dominated by straight distributary channel sand body. Because of the poor continuity of the sand body, in order to better describe the change of the sand body, the method of stratification analysis of the well area is adopted according to the sedimentary facies zone map. Through the comparison of the new and old phase

zone maps, the development characteristics of sand bodies are determined, and the continuity, swing position and combination relationship of sand bodies in narrow and small channels are changed after newly drilled supplementary Wells. There are four main types:

Type 1: Newly added channels. There are mainly new narrow and small channels and wide channels. The wide channels are those with a width of more than two well distances, and the narrow and small channels are those with a width of about one well distance. For example, in the Pu-I6 unit in the well area of 20-35, the original river channel was known to flow along the direction of 21-35 and 22-F35, but after the completion of the supplementary Wells, it was found that 7 Wells such as 19-34 and 21-34 were river channels, so the branch rivers of the big river were added. In the expansion block, narrow and small river channels are mainly added.

Type 2: Continuous river becomes discontinuous. For example, in unit Pu-I21 in well area 22-F35, two Wells 22-F35 and 26-F37 in the old phase zone diagram are located in a river channel, and the two Wells are predicted to be a river channel. After the well pattern was encrypted, two new Wells were deployed between the two Wells, one well was drilled off the surface, and the other well was drilled into the pinout zone. Therefore, the predicted channel between the original two channel Wells does not exist. The continuous channel becomes discontinuous.

Type 3: River channel Changes in strike before and after expansion. For example, in the Portuguese I22 unit of well area 37-54, 37-54 in the old phase zone diagram is located in the channel, which is predicted to follow the diagonal direction (no old well). After the completion of the supplementary Wells, the new Wells 38-54, 39-52 and 40-51 were non-channel Wells, while the two Wells 35-S55 and 36-S55 were channel Wells, so the direction of the channel changed.

Type 4: Deregistration of river channels. For example, in Unit Pu-I6 in well area 41-54, 41-54 is an old channel well, and the right channel is a predicted channel. After the completion of supplementary Wells, 36-S53, 37-S53, 38-S53, and 39-54 are located in the channel, but the Wells drilled are all non-channel Wells, so the right channel is written off. And the main river widened.

3.3 New drilling area adjustment potential

After the local outward expansion of development zone A, the development status of the oil reservoir in the new drilling area is analyzed, and the location of the supplementary well is determined or the injection and production system is adjusted according to the sand body. The change types of injection-production relationship in the new drilling area are summarized, and the purpose of perfecting injection-production relationship and tapping remaining potential is realized by adopting effective adjustment measures. For the well areas where injection and production are not perfect due to the absence of injection direction or single injection direction, the well should be reinjected or supplementary Wells should be laid. The single sand body with injection and no production is caused by the perforation of water well but no perforation of oil well. In the external expansion well, the centralized well area and scattered well group are analyzed in detail, and the connectivity relationship of sand body and injection-production relationship are sorted out one by one. Combined with the numerical simulation results, 2 Wells are finally determined to supplement and 7 Wells are injected.

4. Study on adjustment potential and well layout

4.1 New drilling zone adjustment potential

After geological reunderstanding is carried out, the results are applied to multidisciplinary research work to guide the water fitting and remaining oil quantification of multidisciplinary reservoir research, so as to improve the accuracy of water fitting and remaining oil description in A development zone. According to the quantitative remaining oil analysis, the remaining oil in the narrow and straight channel sand of the front phase in the A development area accounts for 57.11% of the total remaining oil of the PuI group, and the remaining oil of the incomplete injection and production type accounts for 24.58% of the remaining oil of the inner front phase, which is the main object to improve the injection-production relationship and tap the remaining potential.

4.2 Formulate adjustment principles

(1)To improve the injection-production relationship in the well area by drilling supplementary Wells or transferring oil Wells in the non-injection direction or in the area with less injection and more production; (2) In the well area with more injection and less production and lack of production well point, the injection-production relationship in the well area should be improved by drilling supplementary oil Wells; (3) In the well area where the injection-production relationship changes greatly due to fault changes after the combination of well earthquake and re-understanding of structure, the injection-production relationship in the well area is improved by drilling and replenishing oil and water Wells or transferring oil Wells; (4) The thickness of sandstone drilled in a single supplementary well is not less than 5.0m, and the effective thickness is not less than 1.0m; (5) In order to prevent casing damage, water injection Wells are not distributed within 100 meters from the fault; (6) Transfer well, not less than 100 meters away from the fault, increase the recoverable reserves of more than 1500t.

4.3 Implementation of adjustment potential

After the preliminary implementation of the well location, the drillable thickness of a single well should be predicted based on the development status of the sand body in the supplementary well area, the utilization status of the single sand body of the well group should be analyzed based on the fine drawing results, the initial water cut and productivity should be predicted based on the results of multidisciplinary research, and the economic benefits of a single well should be evaluated. The well locations that meet the requirements of well layout are designed.

According to the above methods, a total of 19 supplementary Wells (12 production Wells, 7 injection Wells) were finally determined, 1 well was updated into a well, and 19 injection Wells were converted.

5. Conclusions

(1)Deepening geological understanding and perfecting injection-production relationship are the necessary means to improve the development effect of narrow and small channel developed oil fields; (2) Multidisciplinary reservoir study and detailed reservoir description are key techniques to deepen geological understanding and find residual potential; (3) It is an effective way to excavate residual oil in local well areas with imperfect injection-production relationship and improve the development effect of the block through replenishment and transfer.

References

1. W.H.I Mon, Translated by Wang Zhihai et al. Data Warehouse. China Machine Press.2000:1,66
2. Xu Jianjun, Huang Lida, Yan Limei, Yi Na. Insulator Self-Explosion Defect Detection Based on Hierarchical Multi-Task Deep Learning[J]. Transactions of China Electrotechnical Society, 2021,36(07):1407-1415.
3. Limei,LIU Yongqiang,XU Jianjun,et al.Broken string diagnosis of composite insulator based on Grabcut segmentation and filler area discrimination[J].Power System Protection and Control,2021,49(22):114-119
4. Yi, Q. Wang, L. Yan, et al., A multi-stage game model for the false data injection attack from attacker's perspective. Sustainable Energy Grids & Networks 28 (2021).
5. Na Yi,Jianjun Xu,Limei Yan,Lin Huang. Task Optimization and Scheduling of Distributed Cyber-physical System Based on Improved Ant Colony Algorithm. Future Generation Computer Systems, 109(Aug. 2020),134-148.
6. Yang Zhao, Jianjun Xu, Jingchun Wu. A New Method for Bad Data Identification of Oilfield Power System Based on Enhanced Gravitational Search-Fuzzy C-Means Algorithm. IEEE Transactions on Industrial Informatics. VOL. 15, NO. 11, NOVEMBER 2019 5963-5970
7. Jing Han,Xi Wang,LiMei Yan, Aida Dahlak, et al. Modelling the performance of an SOEC by optimization of neural network with MPSO algorithm. International Journal of Hydrogen Energy, Volume 44, Issue 51, 22 October 2019, Pages 27947-27957.https://doi.org/10.1016/j.ijhydene.2019.09.055