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Study on Water Intrusion in Block S3-1

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Abstract

Since the development of block s3-1, production has been stable. However, in the previous block, the well s3-3h was shut down due to high water cut. Recently, the well s3-6h also showed abnormal changes in water cut. Up to now, there is no information about the overall understanding of bottom water in this block. In view of this, based on the production dynamics and combined with the understanding of geology in the early stage, this paper gives a general description of the current bottom water intrusion, so as to provide a reference for further study in the later stage.

Keywords

The dynamic monitoring; High moisture content; Water invasion.

1. Introduction

Block s3-1 of the condensate gas field belongs to the eastern section of the shaya uplift. The block is located in the fault step zone between the no.1 fault on the fault convex and the yanan fault, which is a mantle structure formed on the base of the pre-sinian metamorphic rock.

The bashkichik formation reservoir as a whole belongs to medium-low porosity and medium-permeability reservoirs, with uneven pore distribution and poor connectivity. According to the analysis data of 185 samples of porosity and permeability in the bashikikh formation of well s3-1, the vertical permeability difference within the reservoir is relatively obvious, with an average coefficient of variation of 0.90, which is a serious heterogeneity. At the same time, it can be seen from the drilling coring data that there is still fracture development. In addition, the analysis shows that the formation of the block is water sensitive, which is medium-strong water sensitive.

2. Development Present Situation

There are currently 6 producing Wells and 5 opening Wells in block s3-1. The daily output of oil is 96.5 tons/day, gas is 306,000 m3 / day, and the comprehensive moisture content is 2.31%.

According to the analysis of the early dynamic production and dynamic monitoring logging, it is agreed that this block can be divided into two small structures, including the eastern well area s3-1 and s3-3h, and the western well area s3-2h, s3-5h, s3-6h and s3-7h.

According to the area of the block, the reserves are divided. In the eastern block, the geological reserves of condensate are 132,100 tons, and the geological reserves of natural gas are 450 million cubic meters; in the western block, the geological reserves of condensate are 516,300 tons, and the geological reserves of natural gas are 1.758 billion cubic meters.

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Table 1. Comparison of relevant indexes between the eastern and western Wells

block	year	Geological reserves		Recovery degree%	
		Condensate (10^4t)	Natural gas (10^8m^3)	condensate	Natural gas
In the east	2007.12	13.21	4.50	9.07	8.69
	2008.12			15.69	14.78
	2009.3			16.32	15.52
In the west	2007.12	51.63	17.58	2.12	2.18
	2008.12			10.35	9.23
	2009.3			12.10	10.55

3. Study on Formation Water Intrusion in Block s3-1

3.1. Block Bottom Water Rising Profile

According to the development plan, there is a water layer of about 130m at the bottom of the gas reservoir in block s3-1, and the water body is widely distributed and the water body energy is large (the specific water body size needs to be further studied). In the development plan, it is believed that bashkikh has a uniform gas-water interface of 4107m, and it is also basically believed that the oil-water interface of the block is consistent through the drilling test in the early stage. According to the calculation of the water-avoiding height of all Wells in the production interval of each well in the statistical area, as shown in table 2, it can be seen from the table that the water-avoiding height of Wells in the block is relatively high, with a minimum of 11.15m and a maximum of 32.2m.

Table 2. Gas-water interface statistics of each well in block s3-1

Well no.	S3-1	S3-2H	S3-3H	S3-5H	S3-6H	S3-7H
Gas-water interface elevation	-4107					
Bushing elevation	954	956	964	959	956	956
Horizontal nadir	5041.75	5037.46	5039	5055.29	5042	5045
Avoid water height	19.34	25.93	32.2	11.15	20.234	17.159

In 2007, the large-scale development of block s3-1 began. According to the water breakthrough situation of each well, the water breakthrough of well s3-3h in the eastern block has been confirmed, and the water breakthrough of well s3-1 is basically not produced. The recent water from well s3-6h in the western block has the characteristics of formation water, while the water from other Wells is condensate water. Therefore, it is believed that the bottom water in the block has been rising steadily up to now, and the overall gas-water interface is basically below the production interval.

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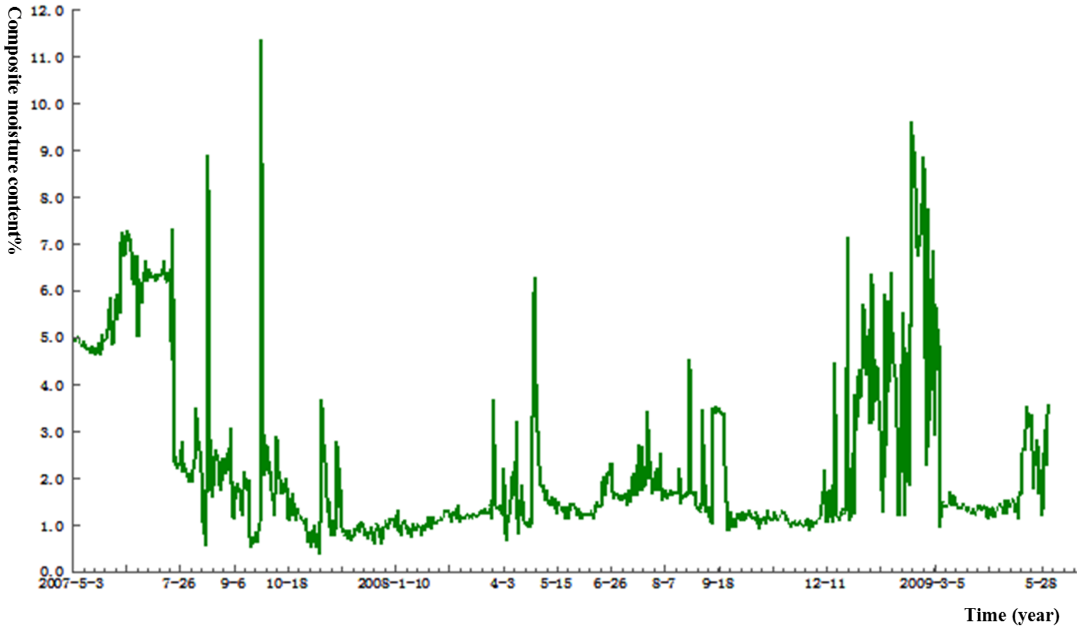

Figure 1. Comprehensive moisture content curve of block s3-1

It can be seen from the comprehensive moisture content chart that the middle water in the block is generally stable in the production process. The continuous high water cut from November 2008 to March 2009 was mainly affected by the high water cut in the s3-3h well, and the water cut rose recently due to the influence of the s3-6h well. However, the overall water content is not high, and the water output of all Wells except s3-3h well s3-6h is basically condensate water, and the formation is not fully drained.

Table 3. Table of water and chlorine in block s3-1

Well no.	date	Assay moisture content%	Chlorine root mg/L	note
S3-1	2009-5-31	1.17	/	/
S3-2H	2009-5-31	1.1	/	/
S3-3H	2009-5-31	/	78651	shut-in
S3-5H	2009-5-31	1.07	/	/
S3-6H	2009-5-31	5.7	23604	/
S3-7H	2009-5-31	1.28	/	/

Comprehensive the above analysis, the S3-1 block air water interface is unified, the early stage of the block not large-scale water breakthrough in the process of production, formation water on the whole is smoothly, S3-3 h well water breakthrough suggests that part of the formation water in early production has brought along the high permeability fast coning, have even coning in bottom hole, how to avoid the fast formation water coning is the key of the current research in formation water invasion.

3.2. Block Bottom Water Coning Study

At present, high water-cut shut-in s3-3hwas put into operation in August 2007, with a water escape height of 32.2m, which is the largest well with a water escape height. However, the same well s3-1 in the eastern region (put into operation at the beginning of 2007) has not seen water yet. It can be seen that although it is believed that the formation water in the block is advancing in a unified way, there is a coning phenomenon of bottom water in the region.

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3.3. Conditions for Bottom Water Coning in Block s3-1

3.3.1. The Stratigraphic Deviation Is Serious

According to S3-1 well bashkortostan base chick group of porosity, permeability calculation by sample analysis data of various heterogeneous parameters, reservoir internal longitudinal permeability difference obvious, the variation coefficient of 0.90 on average, the reservoirs in domestic oilfield experience coefficient of variation of more than 0.7 average, so think block vertical heterogeneity is serious, as shown in table 4.

Table 4. Statistical table of reservoir physical properties and heterogeneous parameters in block s3-1 of condensate gas field

Well no.	horizon	porosity (%)	Sample number	Permeability Md	Heterogeneous parameter		
					differential	Dash coefficient	Coefficient of variation
S3-1	gas layer	15.5	164	115	668	8.5	0.87
	Water layer	15.1	26	309	1948	4.9	0.93
	On average	14.65	95	212	1112	5.45	0.9

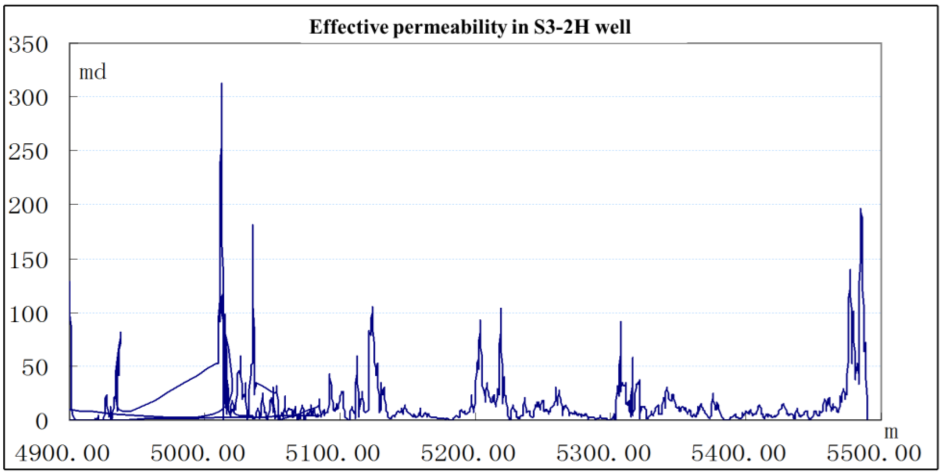

Figure 2. Block S3-1 Wells of longitudinal permeability curve

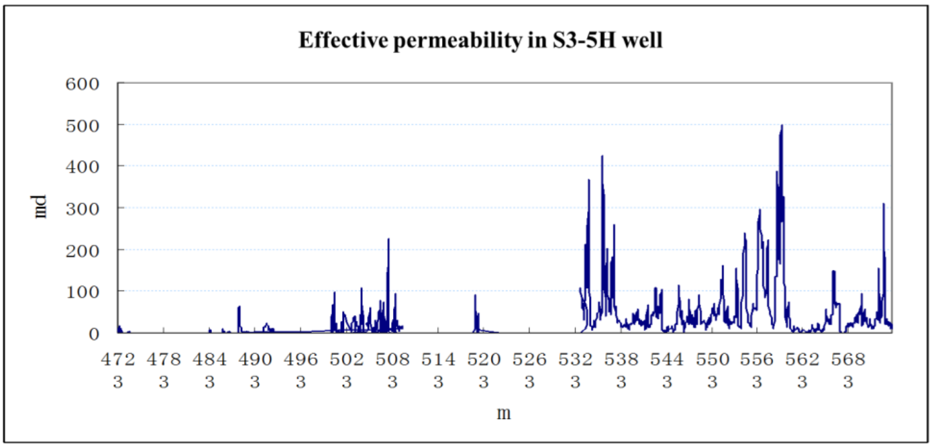

Figure 3. Block S3-1 Wells of longitudinal permeability curve

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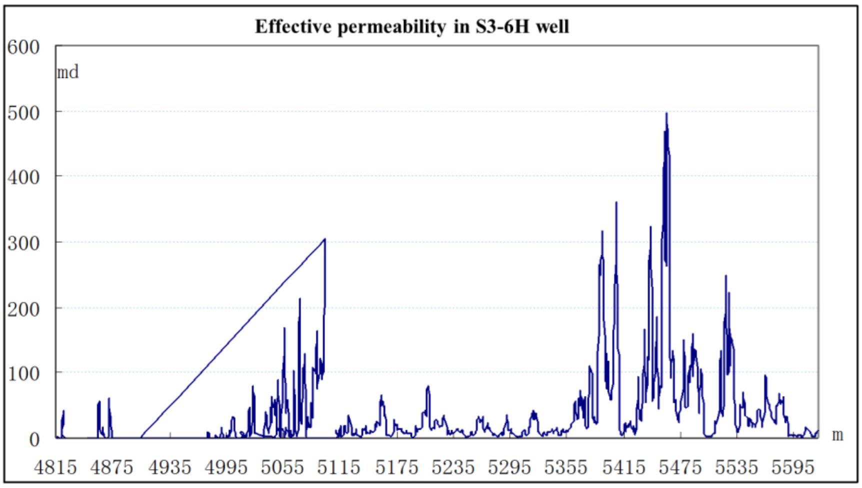

Figure 4. Block S3-1 Wells of longitudinal permeability curve

The permeability data obtained from well logging also show that the vertical non-mean value of the formation is strong. If the production interval of the producing well is located in the zone of high permeability, the formation water will be easier to coning to the bottom of the well, and the water will appear earlier.

At the same time, the study of this block suggests that the serious heterogeneity in the block may be the vertical crack.

Table 5. Statistics of gas reservoir lithology in block s3-1 of oil field

Layer no.	Well no.	Interval (m)	Core long m	Seam, hole description
1	S3-1	5031.17-5038.42	7.25	Inclined seam 3
2	S3-1	5038.42-5046.3	7.37	Flat seam 2 diagonal seam 1
3	S3-1	5046.3-5063.3	8.94	Inclined seam article 1
4	S3-5H	5066.57-5066.78	/	2 diagonal seams
5	S3-5H	5069.08-5069.24	/	1 horizontal bar
6	S3-5H	5072.81-5072.98	/	3horizontal seams
7	S3-5H	5074.55-5074.42	/	1 vertical seam

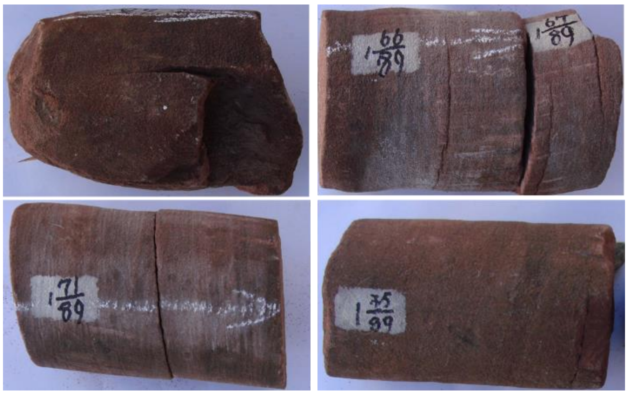

Figure 5. S3-5 h well with fracture core

It can be seen from table 5 and figure 5 that fractures develop in the block. The existence of these fractures provides favorable channels for the rapid upward movement of bottom water.

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Wells at fracture development sites see water faster than other Wells at the same mining intensity.

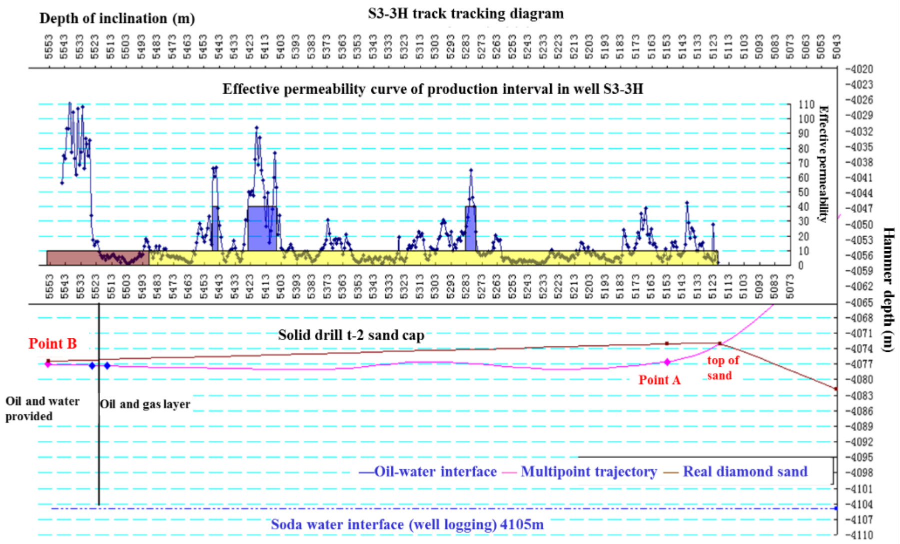

Figure 6. S3-3 h Wells wellbore trajectory and horizontal permeability distribution

It can be seen from figure 6 that the permeability distribution in the horizontal section of well s3-3h is very uneven (the permeability in the water interval is 5406-5424m and 5444-5448m, which is significantly higher than that in other sections). During production, the production pressure difference in these sections is higher than that in other sections. Under the action of high pressure difference, formation water finally enters the wellbore along the high permeability zone. At the same time, the horizontal section of well s3-3h passes through a fault (oblique depth 5520m), which continuously excites the formation and may also lead to continuous coning of formation water along the fault due to multiple switching and nozzle drainage of well s3-3h.

The s3-6h well is similar to the s3-3h well, as shown in figure 7:

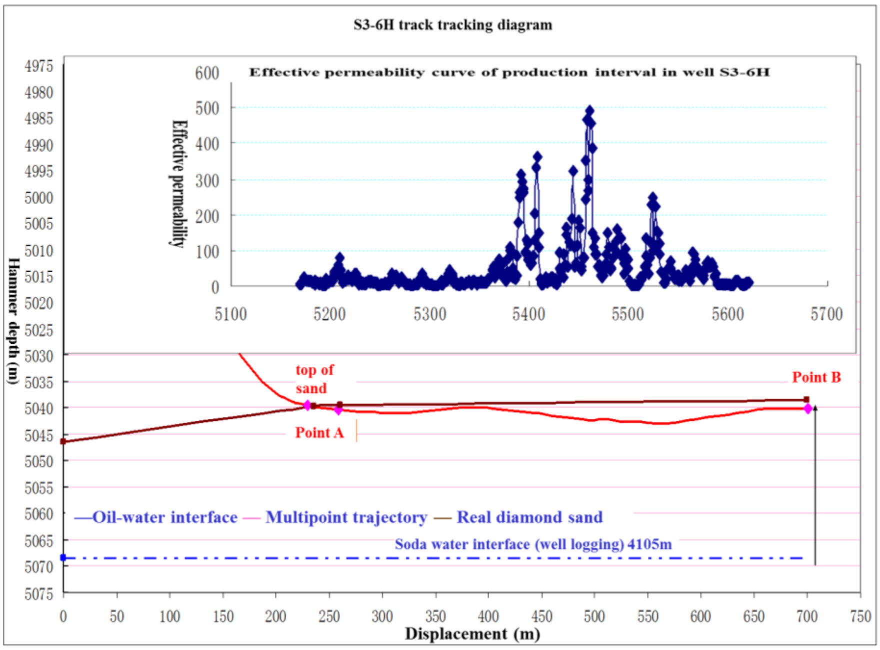

Figure 7. S3-6 h Wells wellbore trajectory and horizontal permeability distribution

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3.3.2. The Effect of Mining Speed

Condensate gas field exploitation of the S3-1 block 7 years in the second half of the year increased (5 Wells in the second half of the year and put into operation), so the block before June 07 mining speed is not high, but the second half - 07 08 mining speed is higher than the production plan (plan production speed by 6.65% and gas recovery rate 6.8%), after adjusting speed and the current geological reserves and production gas extraction speed control within the development plan, the recovery rate of recoverable reserves is still high, as shown in table 6, adopt high speed can cause falling fast formation energy, bottom water accelerate intrusion.

Table 6. Speed table of block s3-1

date	Geological reserves mining rate (%)		Recovery rate of recoverable reserves (%)	
	Condensate recovery rate (%)	Gas recovery rate (%)	Condensate recovery rate (%)	Gas recovery rate (%)
2007-1	2.13	1.79	6.07	2.89
2007-6	1.17	1.23	3.35	1.98
2008-1	8.23	8.24	23.48	13.29
2008-6	7.16	6.38	20.45	10.29
2009-1	7.32	5.88	20.90	9.48
2009-5	5.33	4.63	15.22	7.47

By comparing the mining speed of the eastern and western blocks, it was found that the mining speed in the eastern block before the water breakthrough at s3-3h was higher than that in the western block, which was higher than that determined by the scheme. The production pressure difference at high mining speed was large, which also increased the possibility of its water cone.

Table 7. Comparison of relevant indicators

block	year	Geological reserves		Recovery rate %	
		Condensate (104t)	Natural gas (108m3)	condensate	Natural gas
	2007.12			9.09	0.95
east	2008.12	13.21	4.50	6.60	6.07
	2009.3			2.82	3.30
	2007.12			4.67	4.80
west	2008.12	51.63	17.58	8.21	0.70
	2009.3			7.75	5.87

3.3.3. Study on Bottom Water Coning in Block 3-1

Up to now, water has not been observed on a large scale in block s3-1, and only Wells s3-3h have been detected. Recently, water has also been observed in Wells s3-6h, but there is no overall sign of water cut rising in the block. Therefore, the analysis shows that the formation water has invaded the bottom of the well along the high permeability belt, resulting in water observed.

4. Formation Water Condition Was Observed in Well s3-3h

S3-3 h well was put into operation in August 07, production is stable, after the production of chlorine root June 08 assay in 4263-5549 mg/L, July - chlorine root tests in November 14219-

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27356 mg/L, according to the experience of chlorine root increase formation water is likely to be invaded, December the well water began to rise rapidly, assay chlorine root 58698 mg/L, water has risen to over 90% in just three months, at present the high water cut Wells gush

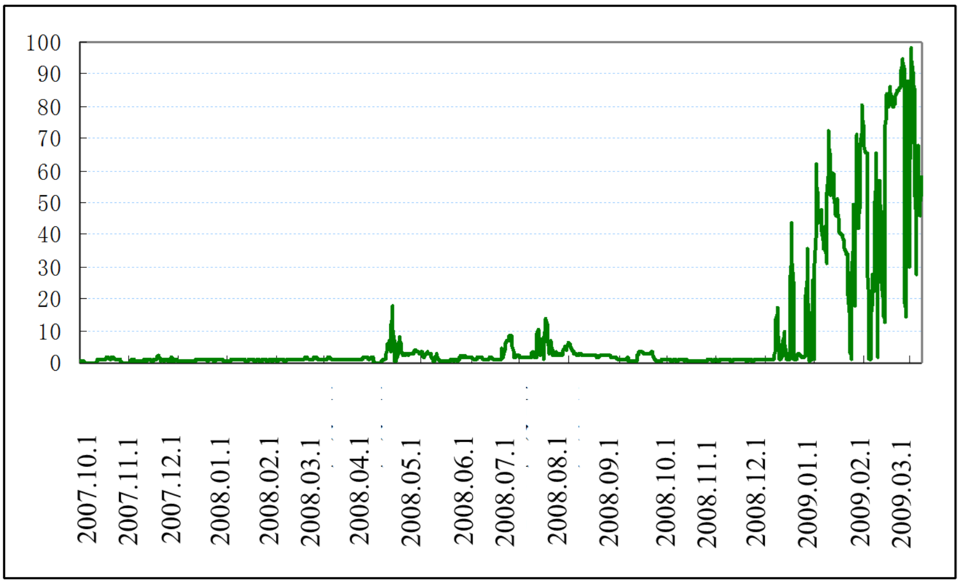

Figure 8. S3-3 h well water cut curve

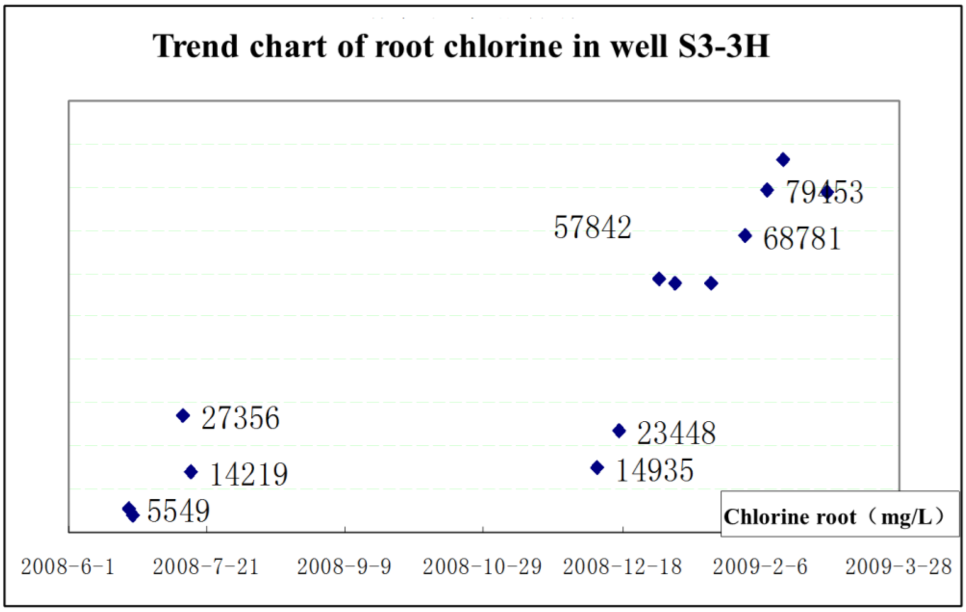

Figure 9. Chlorine root assay of well s3-3h

Visible from water cut rising curve, the S3-3 h well before water breakthrough assay water cut is not high, but water cut rising rapidly after water breakthrough, chlorine root also rise with water cut rising, that once the formation water breakthrough is difficult to control, it also gives us a warning, although the basic not well water in the block, but is likely to bottom water has been along the high permeability zone in certain position, and once the horizontal gas well see water, control will be very difficult. It can be seen from table 8 that it took five months for the chlorine content to rise from 10000mg/L to 50000mg/L, after which the chlorine content rose steadily and stabilized at 78000mg/L in March 2009, which was determined as formation water, as shown in table 8. It can be seen that the abnormal chlorine content should be paid more

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attention to immediately and production adjustments should be made in time, because abnormally high chlorine content is probably the signal of formation water intrusion.

4.1. S3-6h Well Shows Signs of Water

The s3-6h well was put into operation in November 2007, after which the production was stable. By May 9, 2009, the oil pressure was 28.2mpa, the daily oil output was 30.1t/d, and the water cut in the test was 1.26%.

Between 70,000-80000mg /L of formation water chlorgen in the block s3-1, it is believed that the water outflow from the well s3-6h has a water trend. In order to prevent formation water from rapidly invading and adjust the working system, the moisture content and chlorine content of oil nozzles both decreased after adjusting the nozzles, so it is believed that adjusting the nozzles has a certain inhibitory effect on the invasion of formation water. However, it was soon found that the water content in the test rose again, and the chlorine content also rose synchronously, as shown in figure 10.

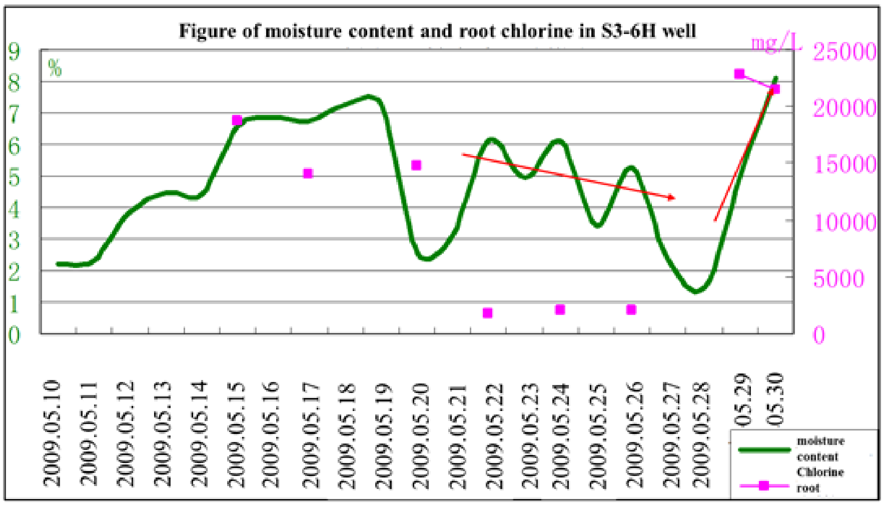

Figure 10. S3-6 h Wells moisture content before and after 21 shrink mouth curve

Chlorine root content and water content are important indicators for us to judge whether formation water is coming out. According to the recent situation of s3-6h well, chlorine root and water cut change trend are consistent, which is probably a signal that formation water has invaded the near-well zone.

In addition, it was found that the oil pressure should rise according to the working system of the 21-day reduction, but the actual production situation was that the oil pressure did not last long but fell instead. Look from the preliminary test results formation pressure is higher than the dew point pressure (PVT test measured stratigraphic dew point pressure of 44.03 Mpa), formation doesn't exist in the retrograde condensation, flow pressure test results on February 26, according to convert the bottom hole flowing pressure is 43.56 Mpa, less than the dew point pressure, think that just started to retrograde condensation near wellbore area, but the early stage of the production stability, so don't think retrograde condensation pollution is oil pressure drop the main reason. If it is bottom water intrusion, then after shrinking the nozzle, the intrusive formation water will stay more in the near-well zone and occupy the channel originally used for seepage, resulting in the phenomenon of "water locking up gas", which increases the seepage resistance and causes the bottom hole flow pressure to drop, thus showing a drop in wellhead pressure. At the same time, the previous study on the reservoir of this block indicates that the formation of this block is moderately water-sensitive, and the

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expansion of clay minerals and the blockage of pore throat after the intrusion of formation water will also cause the oil pressure to drop.

Based on the comprehensive analysis, it is believed that formation water coning into s3-6h well is more likely. If this is the case, it further indicates that bottom water coning in s3-1 block is the main form of producing water.

By comparing s3-3h and s3-6h Wells, it can be found that the tested chlorine content is closely related to water content, and the simultaneous rise of both changes is probably a signal of formation water intrusion.

4.2. Water Inflow Calculation

The current formation pressure in the western block of block s3-1 is 44.07mpa, greater than the dew point pressure (44.03mpa), that is, the reverse condensate phenomenon in the formation is ignored, and the condensate volume in the formation is SL=0. At this time, the material balance equation of the condensate gas reservoir is approximately the material balance equation of the dry gas reservoir.

$$G = \frac{Gp - (We - WpBw)\dfrac{PTsc}{PscZT}}{1 - \dfrac{P/Z}{Pi/Zi}}$$

Table 9. Basic data table of condensate gas reservoir in block s3-1

	G	Pi	Pr	Gp	Zi	Z
east	4.50	51.65	34.79	0.713	1.336	1.018
west	17.58	51.65	44.07	2.038	1.336	1.117

According to the balance equation of the dry gas reservoir, the water inflow in the western block was calculated.

Table 10. Bottom water rising height of the condensate gas reservoir in the west of well s3-1

Effective thickness	Effective porosity	Bound water saturation	Residual gas saturation	Water intrusion volume per unit height	Total water intrusion volume	Bottom water rising height
m	%	%	%	m3	m3	m
21.06	15.5	46.09	21.5	172810	862300	4.98

In terms of the area of 3.44km2 in the western block, the bottom water overall rose by about 4.99m, so the gas-water interface is about -4102m at present. According to the statistical water avoidance height, it can be seen that the overall oil-water interface is still some distance from the bottom of each well (it is the closest to the s3-5h well, about 6.16m).

4.3. Evaluation of Block Single Well Productivity By One Point Method

By using the one-point formula of professor Chen yuanchan to calculate the productivity parameters [1], and taking the current production of each single well to calculate the open flow

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rate, the condensate oil is first converted into gas according to the condensate oil conversion formula

$$\boxed{q_{GE} = 5.449 \times 10^{-2}(1.03 - \gamma_o)q_o}$$

Convert total wellhead gas production:

$$Qsc = q_{GE} + q_g$$

The open flow rate is calculated by two one-point formulas

$$\boxed{Q_{AOF} = \frac{6Qsc}{\sqrt{1 + 48P_D} - 1}}$$

$$\boxed{Q_{AOF} = \frac{Qsc}{1.0434 P_D^{0.6594}}}$$

Type:

$$\boxed{P_D = 1 - (\frac{P_{wf}}{P_R})^2}$$

Table 11. Capacity table of western block

Well no.	Pwf (Mpa)	Formation pressurePr (Mpa)	QAOF1 (ten thousand)	QAOF2 (ten thousand)
S3-2H	42.2	44.07	37.30	36.71
S3-6H	42.14	44.07	24.89	24.44
S3-7H	42.14	44.07	31.42	30.86
S3-5H	42.7914	44.07	25.47	25.84

The open-flow results of the two algorithms are basically the same, and it is theoretically believed that the production under a reasonable working system should be 1/4 -- 1/6 of the open-flow. The calculation shows that the actual production of each well in the block is basically within the required range. According to the calculation, it can be seen that under the premise of meeting the minimum liquid carrying capacity, all Wells in the western block can also adjust the working system, which can be adjusted when necessary.

5. Conclusion

According to the calculated water inflow, it is believed that the overall rise of formation water is relatively low, and the water escape height of each well in the block is relatively high. Therefore, it takes a long time for the overall bottom water to reach the bottom of the well.

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However, the longitudinal heterogeneity of block s3-1 is strong, and the distribution of the high permeability zone creates conditions for the formation water coning, which provides an opportunity for the formation water to move up rapidly under the pressure difference under the high mining rate in the early stage.

The main problem in the development is that the formation water is channeling into the bottom of the well along the high permeability belt. Therefore, it is necessary to control the mining speed in the future production, strive to control the water production in the block comprehensively, and realize the long-term and stable exploitation of the block.

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