Research on Mud Loss Prevention and Control for Deep Wells with Complex Pressure System in Mingebrak Oilfield, Uzbekistan

1st Wanjun Li
Engineering Technology R&D
Company Limited
lChina National Petroleum Corporation
Beijing, China
liwanjundri@cnpc.com.cn

2nd Qi Liu
Engineering Technology R&D
Company Limited
China National Petroleum Corporation
Beijing, China
liuqidr@cnpc.com.cn

3rd Huifeng Liu
Engineering Technology R&D
Company Limited
China National Petroleum Corporation
Beijing, China
lhfdri@cnpc.com.cn

4th Jun Yan
China National Oil and Gas
Exploration and Development
Company Ltd
China National Petroleum Corporation
Beijing, China
yanjun@cnpcint.com

5th Yong Wang
China National Oil and Gas
Exploration and Development
Company Ltd
China National Petroleum Corporation
Beijing, China
wangyong@cnpcint.com

6th Shujiu Feng
China National Oil and Gas
Exploration and Development
Company Ltd
China National Petroleum Corporation
Beijing, China
Fengshujiu@cnpcint.com

7th He Ba
Engineering Technology R&D
Company Limited
China National Petroleum Corporation
Beijing, China
bahedr@cnpc.com.cn

8th Yue Xiao
Engineering Technology R&D
Company Limited
China National Petroleum Corporation
Beijing, China
xiaoyuedr@cnpc.com.cn

Abstract

Reservoirs at Mingebrak Basin in Uzbekistan are characterized by big burial depth (5200-6500m), high temperature (150-200℃), high pressure (pressure coefficient 2.08-2.41), high salt content (220000mg/l), and high H2S content (5~6%) in the formation fluid. The Musgothic formation is especially complex because it contains different pressure systems. Leakage and blowout are easy to occur during well drilling and the average drilling period is 732 days. The data of well drilling history have been analyzed and the causes of the long drilling period have been detected. The results showed that the drilling problems in the Musgothic formation was the main cause of the non-drilling time because leakage and overflow occurred frequently and time was consumed in dealing with leakage and overflow. Three methods have been taken to conquer the drilling problems: finding out the setting positions and improving the wellbore structure; selecting the organic salt drilling fluid and optimizing the formula of it through experiments; developing different lost circulation materials to bridge different types of leakage. Leakage prevention and control technologies have been worked out through analysis and experiments. Firstly, the mudstone at the top of Musgothic and the high-pressure formation at bottom of Musgothic were taken as setting positions respectively and the wellbore structure was improved from three-hole structure to four-hole or five-hole structure. Secondly, an organic salt drilling fluid formula with temperature resistance of 180℃, salt contamination resistance of 30%NaCl and 1% gypsum, and 93.48% recycle rate was developed. Thirdly, three types of loss control materials: return loss control materials, fracture loss control materials, and permeable leakage control materials were developed to deal with different types of formation leakage. The three methods, five-hole wellbore structure, high temperature organic salt drilling fluid and 840 m3 loss control materials have been successfully used in an exploration well M15 in Mingebrak Oilfield, and the drilling period was only 390 days, only about a half of the average drilling period in this area. The study of the mud loss prevention and control technologies of this paper is significant for reducing the drilling period in Mingebrak Oilfield, Uzbekistan. Their successful application in well M15 set a good example for safe and fast drilling of deep wells in this oilfield and the technologies will be popularized for application in other wells of this area.

Keywords: HT/HP; High Salt; High H2S; Deep Well; Mud Losses

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I. INTRODUCTION

Central Asia is one of the five strategic cooperation zones of PetroChina Overseas. The oil and gas reservoirs in this area usually have deep burial, high bottom hole temperature, high pressure, high acid gas content, and high salt content, which puts forward higher requirements for drilling engineering[1-3]. Among them, the Mingebrak structure of Uzbekistan is one of the most representative blocks, and the pressure system in the regional interval is complicated. The drilling fluid exhibits a narrow density window[4-6]. When the density is high, it will cause serious lost circulation[7-8], and when the density is low, high-pressure brine gushing will occur[9-10]. In the past, 15 wells were drilled in this area with an average drilling period of 732 days. 9 wells experienced serious lost circulation during the drilling process, 3 wells experienced blowout accidents, and 7 wells were scrapped due to leakage and other reasons. Leak prevention and control during the drilling process has become the key technology to achieve the successful completion of complex deep wells and the exploration and development of such oil and gas blocks[11-13].

II. Analysis of the Causes of Frequent Drilling Loss

Mingebrak Oilfield has developed relatively complete strata, with Quaternary, Neogene, Paleogene, and Cretaceous in sequence from top to bottom. The stratigraphic sequence is shown in Table 1.

Table 1. The stratigraphic sequence division table of typical wells in Mingebrake block

Stratigraphic division				Section m	Complex display of past drilling
Pleistocene		Q		0-345	/
Pliocene	Bucktree	N_2		345-3440	M10 has serious leakage in the 940-2800m well section; M14 has leakage in 3200m
Miocene	Mascot	N_1	BPC	3440-5097	The M13 pipe string broke at 3900m, accompanied by leakage. Salt water intrusion occurred when M222 drilled to 3450m, then gas intrusion and leakage occurred
			KKC	5097-5533	M10 and M222 were accompanied by severe leakage and formation fluid intrusion during drilling in this interval. M9 has strong oil and water invasion in this interval. M5 leaks at 5237 meters at the bottom of the well
Oligocene	Sumsar	E_3		5533-5655	M9 experienced water and salt invasion at 5180-5505m
	Rishtan			5655-5717	M13 expands and shrinks in diameter of gypsum rock at 5700 and 5900m
Eocene	Turkistan	E_2		5717-5766	M6 is attacked by hydrogen sulfide at 5897-5901m
	Alai			5766-5844	M13 contains a lot of hydrogen sulfide gas when conduct open hole test at 5710-5735m
Paleocene	Buhar	E_1		5844-5918	

Based on the statistics of the historical data of drilling wells in Mingebrak Oilfield, it is found that the loss of drilling occurred concentratedly in the Bucktree and Mascot stages of the Neogene. The specific data are shown in Table 2.

The depth range from 345-3440m is Bucktree Stage, and the lithology is mainly conglomerate, sandstone, and siltstone. The thin layer of conglomerate is loosely cemented and is prone to lost circulation.

The depth range from 3440-5533m is the Mascot stage. The upper part is the Bredrosov Formation, with a depth from 3440-5097m. The lithology is mainly sandstone and siltstone, which is characterized by strong homogeneity and high permeability, and mud loss is prone to occur during drilling. The depth of 5097-5533m is the Kopicenokrasni Formation, which is dominated by multiple sets of reservoirs caprock sandstone and multiple sets of limestone reservoirs. The range of its pressure coefficient fluctuates greatly, a large section of salt-gypsum layer is developed, and it contains a high-pressure salt water layer with a pressure coefficient of up to 2.30, which is prone to complicated situations such as lost circulation and kick.

Table 2. Statistics of leakage data in Mingbulak block

Well No.	Leakage times	Typical leakage interval	Depth (m)	Leakage rate (m^3/h)	Leakage (m^3)
M3	28	Mascot	5413	38.1	342.9
M5	25	Bucktree	3255	16.8	33.4
		Mascot	5370-5372	44.5	449.34
M5	33	Bucktree	2999	9.4	70.9
M7	14	Mascot	5313	31.7	261.68
M9	24	Mascot	5251	34.3	193.7
M10	16	Mascot	5315	42.9	362.2
M12	15	Mascot	5228-5265	30	288.3
M14	19	Bucktree	3276-3651	8.9	251
		Mascot	5273-5283	18.2	177.4
M222	25	Mascot	4714	12.5	99.2
		Mascot	5355-5370	35.8	298.6

Historical data statistics show common characteristics: the Mascot stage is prone to leakage, and it shows the characteristics of large leakage and fast leakage. The data of past leakage is shown in Figure 1. The main reason is that the gypsum rock layer developed in the Mascot, the abnormally high-pressure layer and the atmospheric layer coexist, the formation pressure system is complicated, and the on-site drilling operation is difficult to control[14], resulting in multiple losses.

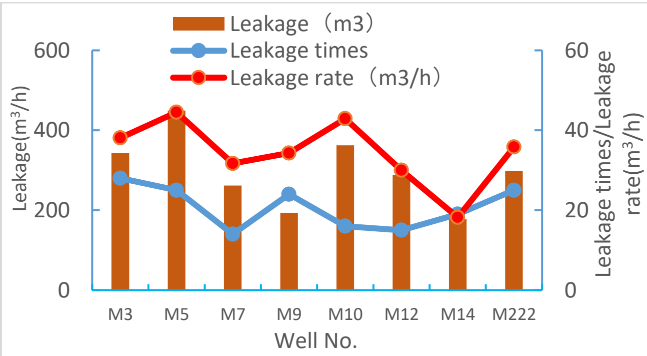

Figure 1. Statistics of Leakage Data of Mascot in Mingebrak Block.

III. Optimized design of anti-leakage well structure

Analyze the structural complexity of the Minggebulak block, draw formation pressure maps, and combine the problems encountered in the past drilling process to summarize the risks and difficulties of drilling through the four sets of strata from top to bottom.

Combining with drilling difficulties, the well structure is designed as a 4th spud structure, with 5th spud structure as an alternative. The purpose is to solidify the Quaternary shallow conglomerate layer, the middle and lower Bucktree and the high mudstone layer on the top of the Mascot, the Mascot high-pressure reservoir and the Paleogene high H_2S layer.

IV. Optimization of lost circulation drilling fluid system

Mingebrake block is characterized by deep burial, high temperature and high pressure and large fluctuation of gypsum pressure[15-16]. Under the condition of high temperature and high salinity, due to high solid content and less free water, with the accumulation of solid content or mixing with plugging materials, the viscosity of drilling fluid increases, the rheological property decreases, and the annular pressure loss increases, which is easy to induce lost circulation.

Organic salt drilling fluid technology has advantages in high temperature resistance, good fluidity, strong inhibition, good lubricity, and strong anti-pollution ability, which is suitable for drilling in formations prone to leakage, especially for keeping low viscosity and shear at high temperature.

A. Optimization of Organic Salt System

Organic salt drilling fluid system is mainly composed of fluid loss reducer, plugging and anti-sloughing agent, inhibiting lubricant, organic salt water soluble weighting agent, and the most important is compounded with strong inhibiting and high-density organic salt water solution.

The density of organic salt drilling fluid can be adjusted from 1.10 g /cm^3 to 1.52g/cm^3 through the optimization of weighting agent and ratio of drilling fluid, as shown in Table 3. In addition, by adding activated barite and iron ore powder into the drilling fluid formulation, the drilling fluid density is increased to 2.5g/cm^3, which meets the requirements of high-pressure formation drilling with pressure coefficient of 2.41 in Mingebrak oilfield.

Through optimization, the final formula was obtained as follows: clear water + 0.3% sodium carbonate + 3% polyol anti sloughing agent + 1.5% static shear strength improver # 1 + 5% fluid loss additive # 1 + 4% polyol resin + 3% fluid loss additive # 2 + 3% asphalt powder + 1% inhibition lubricant + 50% organic salt water soluble weighting agent # 1 + 30% organic salt water soluble weighting agent # 2 + activated barite + iron ore powder.

Table 3. Relationship between Weighting Agent Dosage and Drilling Fluid Density

B / A	10	20	30	40	50	60	70	80	90
10	1.10	1.14	1.18	1.21	1.23	1.26	1.29	1.32	1.34
20	1.15	1.18	1.21	1.24	1.26	1.29	1.32	1.34	1.34
30	1.19	1.22	1.25	1.27	1.30	1.32	1.34	1.36	1.36
40	1.24	1.26	1.28	1.30	1.33	1.35	1.37	1.39	1.40
50	1.27	1.29	1.32	1.35	1.37	1.38	1.40	1.40	1.40
60	1.30	1.32	1.35	1.37	1.38	1.40	1.40	/	/
70	1.32	1.35	1.37	1.39	1.41	1.42	1.42	/	/
80	1.37	1.38	1.40	1.43	1.44	1.44	1.44	/	/
90	1.39	1.42	1.43	1.44	1.45	1.45	1.46	/	/
100	1.42	1.44	1.45	1.46	1.48	1.48	/		//
110	1.44	1.46	1.46	1.49	1.49	/	/	/	/
120	1.47	1.48	1.49	1.50	/	/	/	/	/
130	1.49	1.50	1.50	1.51	/	/	/	/	/
140	1.51	1.52	1.52	/	/		/	/	/

Note: A-Weighting Agent 1(%), B-Weighting Agent 2(%).

B. Evaluation of organic salt drilling fluid system

1) *High Temperature Resistance Evaluation Test*

180 ℃ high temperature evaluation experiment was carried out for the optimized organic salt system and the results show that the formula has good high temperature stability and rheology (Table 4.)

Table 4. Experimental Data of Drilling Fluid Thermal Rolling at 180 ℃

Formula	T ℃	ρ g/cm^3	AV	PV	YP Pa	Gel Pa/Pa	FL	HTHPFL
			MPa.s				ml	
After heating	180/ 24h	2.30	81.5	76	5.5	1.0/ 1.5	2.0	8
After heating	180/ 48h	2.30	86	81	5	1.0/ 3.5	0	9.2
After heating	180/ 72h	2.30	63	61	2	1.0/ 2.5	2.4	16

2) *Evaluation of Drilling Fluid Inhibition*

Drilling fluid cuttings recovery experiment: take the formation outcrop cuttings, use clean water, Bantu mud, bentonite slurry and composite salt mud to do the recovery experiment. The recovery rates of clean water, composite salt mud and organic salt mud are 7.04%, 71.04% and 93.48% respectively.

The calcareous soil is weighed and compacted. After soaking in organic salt mud for 8 hours, the expansion is only 0.253 mm. Compared with the expansion of 4.676 mm after soaking in clean water for 8 hours, the linear expansion is reduced by 94.59%. Thus, the organic salt drilling fluid shows good inhibition.

V. Research and development of plugging agent

Based on the analysis results of formation coring data, the argillaceous sandstone and fine sandstone in the lost circulation section have loose cementation, developed fractures, mainly filled with salt paste, some fractures have a width of 1cm, and most of them extend vertically and obliquely [17-18].

According to the amount and speed of leakage, the average particle size of plugging material is usually 1 / 3-1 / 2 of the diameter of pore throat. The plugging material is assembled and filled in the fracture to block the large channel formed by the fracture, so as to reduce the drilling fluid leakage.

Through the core laboratory test and plugging agent evaluation experiment[19-20], the plugging agent formula for the large fracture and large channel leakage, the fracture leakage at the interface of mudstone and sandstone, and the permeability leakage in the formation with micro fracture and pore development are obtained. The formula and applicable conditions are shown in Table 5, which meet the requirements of Mingebrak area Block site plugging requirements.

Table 5. Formula Data of Plugging Agent

Formula	Applicable leakage type	Leakage characteristics
Formula of lost circulation plugging agent Water +3-5% Asphalt +2-4%QS-2+0.3-0.5%XC+$BaSO_4$+3-5%TP-2+2-3%ZSQD-98+3-5%ZYD+4-6% Vermiculite +4-6% Mica +2-3% Leite plugging agent +2-3%GDJ-V+1-2% Walnut shell	Loss circulation caused by large cracks and large channels	No drilling fluid returned from wellhead
Formula of plugging agent for fractured leakage Water +3-5% Asphalt +2-3%QS-2+0.3-0.5%XC+$BaSO_4$+5-8%TP-2+2-3%ZSQD-98+3-5% Vermiculite +2-3% Mica +3-5%GDJ-V+3-5% Sawdust	the interface of mud sandstone, and the filling (sodium chloride, etc.) in the fracture is dissolved, and the leakage point is formed	The initial leakage is large, then gradually constant to 15-30m^3/h
Formula of permeable plugging agent Water +4-7% Asphalt +3-5%QS-2+0.3-0.5%XC+$BaSO_4$+5-8%TP-2+2-3%ZSQD-98+3-5%DF-1+3-5% Sawdust	Microfracture and pore formation	The leakage rate is generally 2-10m^3/h

VI. Field Application and Effect Evaluation

Well M15 is a key exploration well in Mingebrak oilfield (design depth is 5918m), with The of long fractures distribution length and complex formation pressure system. In addition, leakage and overflow are easy to occur in drilling process, indicating high well control risk and operation difficulties.

In view of the above risk prediction, a series of deep well leakage prevention and control technology concepts was applied to the drilling design of well M15: the fifth-spud wellbore structure was used to seal the necessary points, the organic salt drilling fluid system was selected as the main drilling fluid of the reservoir section, and the plugging agent was chosen on site to ensure the smooth completion of the well.

According to the post drilling evaluation, the fifth spud wellbore structure of the well is well matched with the actual drilling (Figure 2), and all the necessary sealing points of the formation are sealed from top to bottom. The organic salt drilling fluid system has a wide range of density, which balances the formation pressure in the whole drilling process, ensures the wellbore safety and protects the oil and gas reservoir to the maximum extent, and plays a certain role in preventing leakage and blowout.

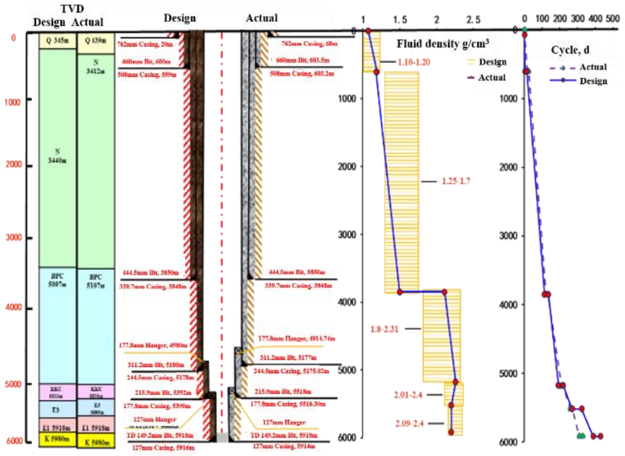

Figure 2. Comparison between actual drilling parameters and design parameters of M15 well.

Although the wellbore structure and drilling fluid have played a role in the prevention and control of the lost circulation, the lost circulation still occurred when the well was drilled in the fourth to fifth spudding section of Musgotian stage, with 34 lost circulation layers and 2800m^3 of drilling fluid.

The site accurately judges the type of leakage by the factors such as leakage rate and leakage amount, and selects the appropriate plugging agent for different types of leakage. Through plugging while drilling combined with bridge plug composite plugging technology, 53 times of plugging agent injection are implemented, and a total of 836.1m^3 of each type of plugging agent is put into the well, which improves the success rate of plugging and ensures the smooth completion of drilling construction.

The drilling cycle of M15 well is 390 days and the completion cycle is 430 days. Compared with the average completion cycle of 15 wells in the early stage of 732 days, it saves 302 days and increases the drilling speed by 41%.

VII. Conclusions

(1) The lack of understanding of formation pressure system in Mingebrake structure leads to the poor adaptability of well structure design and drilling fluid system, resulting in frequent leakage and overflow during drilling, which is one of the main reasons for the extension of drilling cycle.

(2) The optimization of wellbore structure effectively reduces the drilling difficulty of different pressure systems in the process of complex deep well drilling, and reduces the risk of vicious blowout accident in the formation with complex pressure system of Musgotian stage.

(3) Organic salt drilling fluid has the advantages of good inhibition, low solid content, strong anti-pollution ability and easy rheology

control, which has gradually become the preferred drilling fluid formula in Mingebrak oilfield.

(4) A variety of lost circulation agents are developed for different types of lost circulation mechanism, such as lost circulation, fracture and permeability, which effectively improve the adaptability of lost circulation in different formations and lithology of deep wells, and become an effective measure of lost circulation control.

(5) The successful application of leakage prevention technology in complex deep wells solves the drilling problems such as leakage and overflow caused by complex drilling fluid pressure system in Mingebrake block, reduces well control risk and ensures the success rate of drilling.

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