Precise Drilling Strategies to Improve Quality and Efficiency in Oilfield A

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Abstract. An oilfield is a key overseas oil and gas production project of PetroChina, located in a rainforest environment. The oilfield is developed using cluster wells, and the problem of wellbore anti-collision is prominent. During the drilling process, the mud shale section is long and the clay mineral content is high. Some sections of the well have large coal seams, and the stability of the wellbore is poor. It is prone to mud wrapped drill bits and diameter shrinkage, resulting in complex accidents such as resistance and jamming during tripping, which affects the drilling efficiency. This article focuses on the drilling difficulties in A oilfield, optimizing the drilling fluid system, wellbore structure, drill bit, and drilling parameters to form a drilling quality and efficiency improvement plan for A oilfield with drilling fluid+wellbore structure+drill bit+drilling parameters as the core. Optimize the formation of a solid free polymer drilling fluid+plugging type low solid polymer system coal seam drilling fluid scheme to address difficulties such as poor stability of coal seam wellbore walls; Optimize and upgrade the wellbore structure plan based on the difficulty level of the wellbore trajectory; By evaluating and optimizing the performance of drill bits used in multiple wells in the early stage, a series of PDC drill bit models suitable for the formation in this block have been formed; Optimize drilling parameters based on the characteristics of different drilling operations and develop a drilling acceleration plan. The on-site application results show that a drilling quality and efficiency improvement plan has been developed for A oilfield, ensuring safe drilling of mudstone and coal seam sections, significantly accelerating drilling speed, and ensuring the smooth implementation of drilling operations and production capacity construction tasks in A oilfield[1,2].

Keywords: drilling; improving quality and efficiency; increase speed; optimize parameters; drilling fluid.

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1 Introduction

The A oilfield is located in a block with diverse biodiversity, dense vegetation, and extremely high environmental sensitivity. The main oilfield block has a development history of 40 years and is in the middle and late stages of development. Exploration and development have entered the "double high" stage of high water content and high recovery rate. The number of wells on a single drilling platform continues to increase, and the difficulty of well layout is becoming greater. The environmental protection laws of resource rich countries are strict, and the unstable social environment, soaring prices of commodities and raw materials, and prolonged supply cycles also bring many adverse challenges. Therefore, it is urgent to take measures from the aspects of drilling fluid system, geological engineering integration, wellbore structure optimization, preferred drill bit models, and optimized drilling parameters to provide technical support for A oilfield to reduce drilling costs, improve quality and efficiency, and ensure the smooth implementation of drilling quality and production capacity construction tasks[3,4].

2 Speed Up Measures for Drilling in a Oilfield

2.1 Optimize the Mud System to Ensure Downhole Stability

The main formations encountered during the drilling process in Oilfield A are: Group A, B, C, D, E, etc.

The lithology of Group A is mainly composed of blue gray mudstone with high montmorillonite content, which is easily highly hydrated and dispersed. A small amount of greenstone sandstone is interspersed, and there are coal seams of varying thickness in some areas. When drilling in this type of formation, not only should the drill bit be prevented from mud entrapment and diameter reduction, but also attention should be paid to preventing coal seam collapse.

The lithology of Group B is mainly mudstone, with slightly lower montmorillonite content compared to Group A. Some layers are interbedded with sandstone and mudstone, and some sandstone formations have high porosity and good permeability. In addition, the lower strata of this group contain hard abrasive gravel layers. When drilling in this type of formation, it is necessary to prevent the hydration and expansion of the rock formation, the peeling and falling of shale layers, leakage, shrinkage, and collapse. Reasonable drilling parameters should also be selected to achieve safe and rapid drilling.

The C group is composed of variegated (mainly red) terrestrial and coastal mudstone, calcareous mudstone, a small amount of thin limestone layers, and siltstone. The montmorillonite content in this formation is lower, while the kaolinite content has increased, and the characteristics of the illite montmorillonite mixed layer are obvious. When drilling in this type of formation, the key is to prevent wellbore collapse and block falling, as well as the loss of sandstone layers and the complex underground conditions such as shrinkage and sticking caused by thick mud cakes.

The lithology of Group D is mainly composed of mudstone and brittle shale with high kaolinite content, interbedded with thin layers of high permeability sandstone or tight layers. When drilling in this type of formation, the main goal is to slow down the instability of the wellbore caused by weak hydration and sealing ability, as well as the shrinkage and sticking caused by thick mud cakes in high permeability layers.

The lithology of Group E is mainly composed of thick layers of quartz sandstone interbedded with thin layers of mudstone or calcareous mudstone, with pure sandstone quality. When drilling in this formation, it is important to prevent pressure differential from sticking the drill[5,6].

Years of drilling practice in A oilfield have shown that the main challenges faced during the drilling process are wellbore stability and its derivative issues. The statistical results of the main complex underground problems are shown in Table 1, and the falling blocks during the drilling process are shown in Figure 1.

Table 1. List of Main Problems during Drilling Process.

Item	Surface well section	middle well section	oil reservoir well section
Main issues	Mudstone hydration dispersion Coal seam rockfall Shrinking diameter Drill bit mud bag Calcium invasion	Mudstone swelling Unstable wellbore Shrinking diameter Drill bit mud bag MBT control	Unstable wellbore Shrinking diameter Drill bit mud bag MBT control

Fig. 1. Block falling during drilling process.

The phenomenon of drilling tool mud bags is also common in the actual construction process, as shown in Figure 2.

Fig. 2. Mud package of drilling tools at the drilling site of Oilfield A.

The above problems have long constrained the safe and rapid drilling construction of A oilfield. To solve the above problems, the following drilling fluid system was adopted for drilling, and the on-site test results were good.

The use of solid free polymer drilling fluid containing calcium nitrate in the coal seam section alleviates the problem of slurry formation in long sections by maintaining a certain calcium ion content (1600-2000ppm) and using solid control equipment to control the solid content. The occurrence of diameter shrinkage and mud wrapped drill bit phenomenon is slowed down by large displacement (greater than 1000GPM) and irregular short trip drilling. Regular injection of cleaning slurry ensures that the rock debris concentration in the wellbore is within a controllable range. Before entering the coal seam, the drilling fluid was converted and a low solid polymer system with certain sealing and inhibition capabilities was used to successfully address the highly hydrated dispersion and shrinkage issues in the A mudstone formation. Before entering the coal seam, the drilling fluid is converted into a plugging type low solid polymer system to maintain wellbore stability and ensure the smooth entry of casing into the well.

Use G. without clay phase or low clay phase in the second well section A. The P system uses a combination of two clay inhibitors, polyammonium and polyol, to maintain a high inhibitory ability and prevent the hydration expansion of mudstone and the formation of mud on drill bits. Use a moderate displacement (800-900gpm) to reduce the scouring force on the gravel layer, thereby achieving the goal of stabilizing the wellbore. Reasonably use filtrate reducers to maintain no clay phase or low clay phase in the system, prevent the formation of thick mud cake, and avoid the occurrence of shrinkage phenomenon. Strengthen the compound use of sealing agents, improve the sealing ability of drilling fluid on the basis of strong inhibition performance, and thus prevent shale from peeling off and falling off.

When drilling in the oil reservoir section, a solid free oil soluble temporary plugging drilling fluid system is used to solve the problem of wellbore instability caused by the collapse of shale C and D, while maximizing the protection of the reservoir. After drilling the oil reservoir section of the horizontal well, N-Flow chemical treatment agent can be replaced in the production section before inserting the screen pipe, which can quickly and effectively remove the mud cake in the wellbore and facilitate subsequent production. Different from the upper well section, it is necessary to strictly control the content of useless solid phase and maintain the drilling fluid density as low as possible (8.8-10ppg). On the basis of maintaining strong inhibition of the system, improve the temporary blocking ability of the production layer and the control of filtration loss, so that the filtration loss is less than 5ml[7,8].

2.2 Close Cooperation in Geological Engineering to Reduce the Cost of Horizontal Wells

Due to the thin and single oil reservoir, large burial depth, and strong edge and bottom water in Oilfield A, higher requirements are placed on horizontal well drilling. The landing point of a horizontal well not only requires accurate positioning, but also the range of inclination angle variation between 85 ° and 87 °. The wellbore trajectory must be within a range of 5ft above the oil reservoir, and the inclination angle error of the landing point must be less than 0.5 °.

In order to ensure that the horizontal section accurately passes through the optimal oil reservoir position, the method of drilling guide holes was often used in the past. Through close cooperation between geology and engineering, advanced geological fine description theory is adopted, and advanced technologies such as geological guidance and rotary guidance are used in underground combination. The ability to control wellbore trajectory is greatly improved, which not only expands the field of exploration and development, but also provides guarantees for optimizing wellbore structure. Previously, only by drilling a guide hole could the horizontal well of the oil reservoir be accurately located. Now, the horizontal section can be drilled directly.

By adopting high-tech, the removal of guide holes in horizontal well construction has been successfully achieved. The application of this technology alone has directly saved drilling costs of approximately 800000 US dollars in each horizontal well construction. As shown in Table 2:

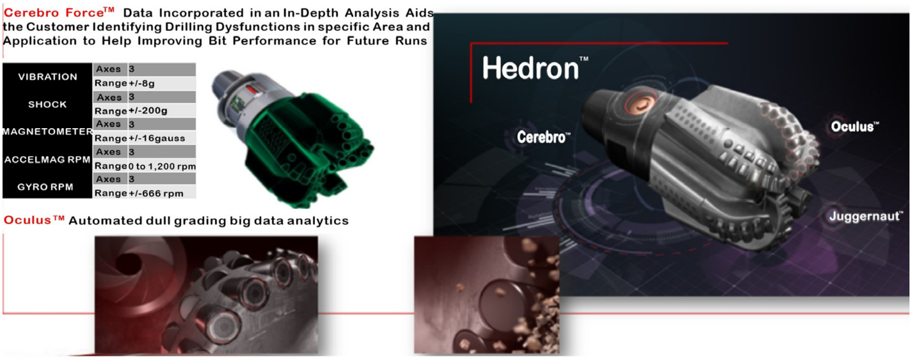
Table 2. The impact of pilot eyes on drilling costs.

Increased cost of Pilot Eyes	Pilot Eyes	MD m	Drilling period d	Average drilling cost $
Esperanza 3H	Yes	3214	30.31	4624284
Average value of four horizontal wells	No	3286	24.41	3860498
Reduction		32	10.24	763786
Reduce ratio			41.95%	15.50%

When drilling in the horizontal section, a combination of LWD measurement while drilling, including PWD+DGR+EWR+CTN+ALD+MWD, is used to evaluate the formation using tools such as resistivity (EWR), compensated thermal neutron (CTN), and azimuthal rock density (ALD). Real time measurement of formation data and wellbore data, and the ability to detect the lithology of the formation 10.5 meters ahead of the drill bit, and adjust the wellbore trajectory in a timely manner.

2.3 Optimizing Drill Bits and Drilling Parameters to Improve Drilling Speed

Using advanced drill bit selection software, based on the formation and drilling technology, different rock properties such as strength, hardness, and abrasiveness of adjacent wells or specific blocks are obtained based on previous actual use, and corresponding drill bit IADC codes are provided. Combined with the wellbore structure, the required drilling depth for different diameter drill bits, and the drilling speed and footage of different IADC coded drill bits in the area, different types (PDC or roller drill bits) and models of drill bits are screened to select the most suitable drill bit. Figure 3 shows the technical analysis of drill bit selection[9].

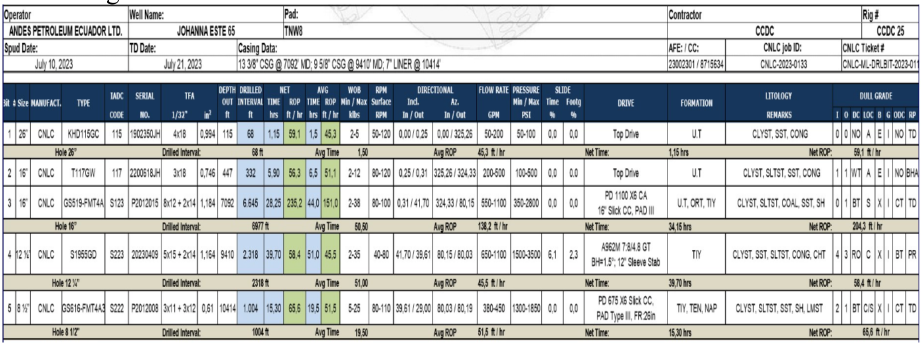


VIBRATION	Axes	3
	Range	+/-8g
SHOCK	Axes	3
	Range	+/-200g
MAGNETOMETER	Axes	3
	Range	+/-16gauss
ACCELMAG RPM	Axes	3
	Range	0 to 1,200 rpm
GYRO RPM	Axes	3
	Range	+/-666 rpm

Fig. 3. Analysis of drill bit selection technology.

Evaluate and optimize the performance of PDC drill bits from different drill bit manufacturers such as Baker Hughes, Hycalog, Security, Geodimand CNLC in the early stage of multiple wells, optimize the structure of the drill bits, and form a series of PDC drill bit models suitable for the formation in this block, improve the cutting ability of the drill bits to the formation, and increase the mechanical drilling speed; Secondly, the tooth arrangement of the drill bit is optimized, especially the optimization of the retaining teeth, to improve the strength of the drill bit, avoid damage to the drill bit inside the casing or wear in high grinding formations, and improve the construction efficiency of the drill bit; The water hole of the drill bit has also been optimized. On the one hand, it improves the cleaning ability of the drill bit to avoid mud bags, and on the other hand, it enhances the hydraulic jet rock breaking ability of the drill bit water hole, greatly improving the mechanical drilling speed[10].

The improvement of the drill bit has achieved good results. From the perspective of the use of new drill bits, the improved drill bit has minimal damage after construction, which not only improves the efficiency of drill bit use, but also avoids the situation of mechanical drilling speed reduction caused by drill bit damage. Figure 4 shows the actual usage record of drill bit 65.



Operator	Well Name:	Pad:	Contractor		Rig #
ANDES PETROLEUM ECUADOR LTD.	JOHANNA ESTE 65	TNW8	CCDC		CCDC 25
Spud Date:	TD Date:	Casing Data:	AFE: / CC:	CNLC job ID:	CNLC Ticket #
July 10, 2023	July 21, 2023	13 3/8" CSG @ 7092' MD; 9 5/8" CSG @ 9410' MD; 7" LINER @ 10414'	23002301 / 8715634	CNLC-2023-0133	CNLC-ML-DRLBIT-2023-01

Bit #	Size	MANUFACT.	TYPE	IADC CODE	SERIAL NO.	TFA 1/32"	TFA in²	DEPTH OUT ft	DRILLED INTERVAL ft	NET TIME hrs	NET ROP ft / hr	AVG TIME hrs	AVG ROP ft / hr	WOB Min / Max klbs	RPM Surface RPM	DIRECTIONAL Incl. In / Out	DIRECTIONAL Az. In / Out	FLOW RATE GPM	PRESSURE Min / Max PSI	SLIDE Time %	SLIDE Footg %	DRIVE	FORMATION	LITOLOGY REMARKS	DULL GRADE I	O	DC	LOC	B	G	ODC	RP
1	26"	CNLC	KHD115GC	115	1902350JH	4x18	0,994	115	68	1,15	59,1	1,5	45,3	2-5	50-120	0,00 / 0,25	0,00 / 325,26	50-200	50-100	0,0	0,0	Top Drive	U.T	CLYST, SST, CONG	0	0	NO	A	E	I	NO	TD
		Hole 26"				Drilled Interval:			68 ft			Avg Time		1,50			Avg ROP	45,3 ft / hr				Net Time:	1,15 hrs	Net ROP:			59,1 ft / hr					
2	16"	CNLC	T117GW	117	2200618JH	3x18	0,746	447	332	5,90	56,3	6,5	51,1	2-12	80-120	0,25 / 0,31	325,26 / 324,33	200-500	100-500	0,0	0.0	Top Drive	U.T	CLYST, SLTST, SST, CONG	1	1	WT	A	E	I	NO	BHA
3	16"	CNLC	GS519-FMT4A	S123	P2012015	8x12 + 2x14	1,184	7092	6.645	28,25	235,2	44,0	151,0	2-38	80-100	0,31 / 41,70	324,33 / 80,15	550-1100	350-2800	0,0	0,0	PD 1100 X6 CA 16" Slick CC, PAD III	U.T, ORT, TIY	CLYST, SLTST, COAL, SST, SH	0	1	BT	S	X	I	CT	TD
		Hole 16"				Drilled Interval:			6977 ft			Avg Time		50,50			Avg ROP	138,2 ft / hr				Net Time:	34,15 hrs	Net ROP:			204,3 ft / hr					
4	12 ¼"	CNLC	S1955GD	S223	20230409	5x15 + 2x14	1,164	9410	2.318	39,70	58,4	51,0	45,5	2-35	40-80	41,70 / 39,61	80,15 / 80,03	650-1100	1500-3500	6,1	2,3	A962M 7:8/4.8 GT BH=1.5°; 12" Sleeve Stab	TIY	CLYST, SST, SLTST, CONG, CHT	4	3	RO	C	X	I	BT	PR
		Hole 12 ¼"				Drilled Interval:			2318 ft			Avg Time		51,00			Avg ROP	45,5 ft / hr				Net Time:	39,70 hrs	Net ROP:			58,4 ft / hr					
5	8 ½"	CNLC	GS616-FMT4A3	S222	P2012008	3x11 + 3x12	0,61	10414	1.004	15,30	65,6	19,5	51,5	5-25	80-110	39,61 / 29,00	80,03 / 80,19	380-450	1300-1850	0,0	0,0	PD 675 X6 Slick CC, PAD Type III, FR:26in	TIY, TEN, NAP	CLYST, SLTST, SST, SH, LMST	2	1	BT	C/S	X	I	CT	TD
		Hole 8 1/2"				Drilled Interval:			1004 ft			Avg Time		19,50			Avg ROP	51,5 ft / hr				Net Time:	15,30 hrs	Net ROP:			65,6 ft / hr					

Fig. 4. Actual drill bit usage record of well 65.

2.4 Wellbore Structure Design and Optimization to Reduce Drilling Costs

2.4.1 Several Wellbore Structures Commonly used in a Oilfield.

Based on years of drilling and development experience, directional wells in various oil fields of the block adopt two wellbore structures and three wellbore structures respectively according to the size of horizontal displacement and the difficulty of drilling construction. Horizontal wells in Block T generally adopt four or three wellbore structures, as shown in Figures 6.

Directional well with two wellbore structures:

Catheter: ø 339.7mm × 35m, establish circulation;

Surface casing: ø 244.5mm × 1800m, sealing a shale layer;

Production tail pipe: ø 177.8mm × 2900m, down to the target layer.

Three section wellbore structure for high angle and horizontal wells:

Catheter: ø 508mm × 35m, establish circulation;

Surface casing: ø 339.7mm × 1700m, sealing a shale layer;

Technical casing: ø 244.5mm × 2700m, sealing layer C;

Production tail pipe: ø 177.8mm (ø 168.3mm sand control pipe) x 3100m, down to the target layer.

Based on years of drilling and development experience, directional wells in various oil fields of the block adopt two wellbore structures and three wellbore structures respectively according to the size of horizontal displacement and the difficulty of drilling construction, as shown in Figures 6 Horizontal wells generally adopt a four or three opening wellbore structure, as shown in Figures 5

Three directional wellbore structures:

Catheter: ø 508mm × 35m, establish circulation;

Surface casing: ø 339.7mm × 1900m, sealing a shale layer;

Technical casing: ø 244.5mm × 2800m, sealing layer C;

Production tail pipe: ø 177.8mm × 3800m, down to the target layer.

Horizontal well four opening wellbore structure:

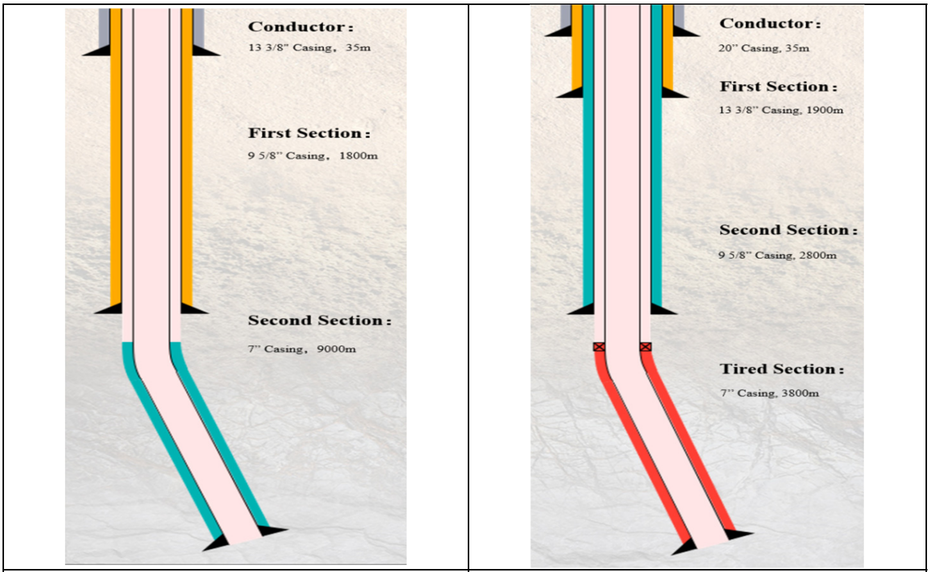
Catheter: ø 508mm × 35m, establish circulation;

Surface casing: ø 339.7mm × 1850m, sealing a shale layer;

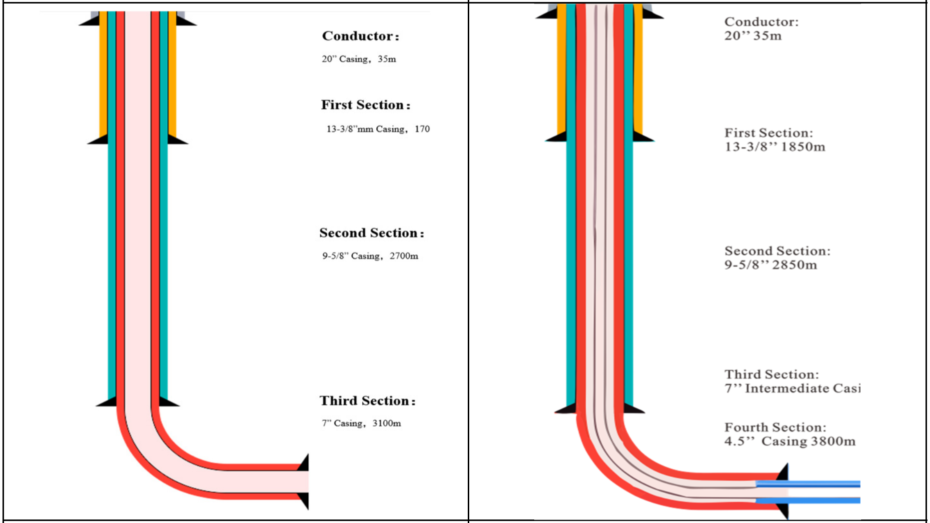
Technical casing: ø 244.5mm × 2850m, sealing layer C;

Technical tailpipe: ø 177.8mm × 3500m, down to the middle of the target layer;

Sand control screen tube: ø 114.3 × 3800m, horizontal section of oil reservoir.



Two section directional well structure | Three section directional well structure



Three section horizontal well structure | Four section horizontal well structure

Fig. 5. Schematic diagram of commonly used wellbore structures.

2.4.2 Optimization Practice of Well Body Structure in Oilfield A.

In the drilling engineering plan, conventional directional wells adopt a two hole wellbore structure, while high angle wells and horizontal wells adopt a three hole wellbore structure. The use of a simple wellbore structure in low difficulty wells increases drilling speed and reduces drilling costs. For difficult wells, a three hole wellbore structure is adopted to effectively control complex underground situations, reduce drilling accidents, and achieve safe and efficient drilling operations[11].

For example, in the M oil field, directional wells with a horizontal displacement of less than 1200 m underwent wellbore structure optimization, adopting a double opening wellbore structure, simplifying the casing sequence, achieving good results, shortening the well construction period, and reducing the well construction cost[12].

Well 24 is a three-stage J-shaped directional well with a horizontal displacement of 1338 meters and a three hole wellbore structure

Surface casing: ø 339.7 mm × 1532 m;

Technical casing: ø 244.5 mm × 2386.5 m;

Lining tube: ø 177.8 mm x 2852 m.

The drilling cycle of Well 24 is 12.29 days. The drilling cost is 2922325 US dollars.

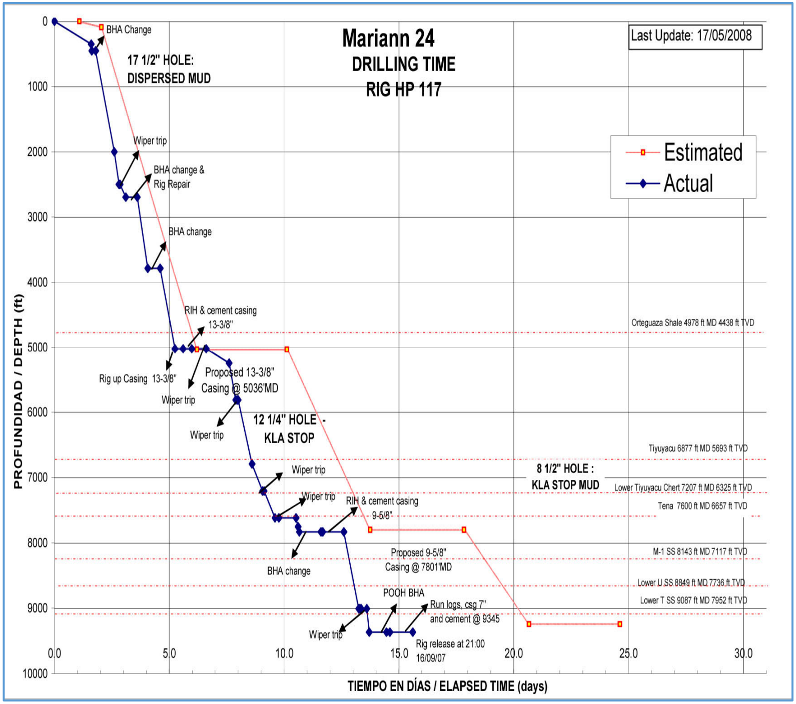
In the same oilfield, using the same drilling rig to complete well 29 is a three-stage J-shaped directional well with a horizontal displacement of 1287 meters and a two-stage wellbore structure:

Surface casing: ø 244.5 mm × 2103 m;

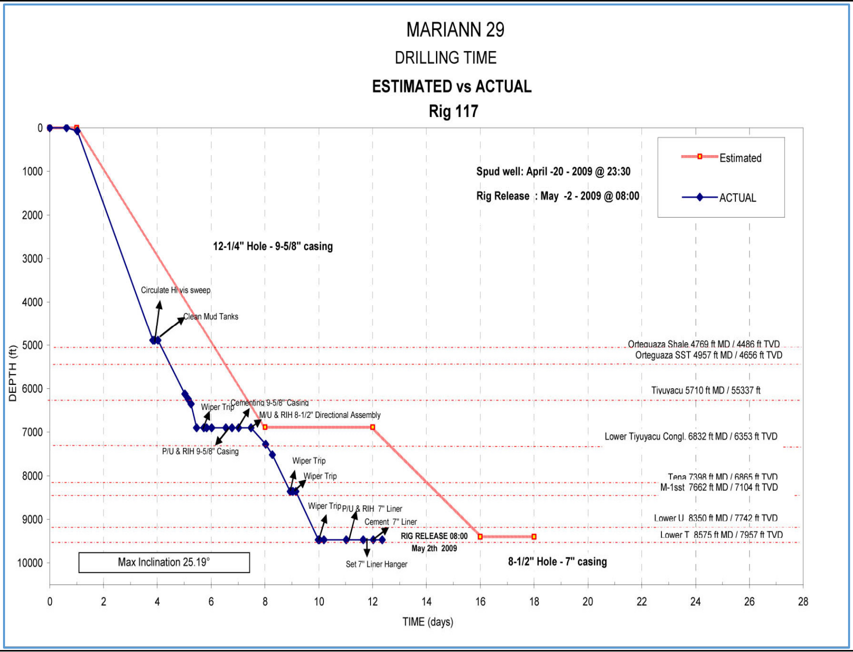
Production casing: ø 177.8 mm x 2886.5 m.

The drilling cycle of Well 29 is only 8.98 days. The drilling cost is 1810703 US dollars, a 38% reduction compared to the cost of building 24 wells.

Figures 6 show the progress curves of two wells.



Schedule of well 24.



Schedule of well 29

Fig. 6. Comparison of Progress between two wells before and after optimization of well structure.

The optimization and simplification of wellbore structure have been recommended and applied in various oil fields in Block T, achieving good results.

3 On Site Application Situation

The above research results have been applied in directional and horizontal well drilling in various blocks of A oilfield, effectively solving the problems of high drilling risks and multiple complex accidents, enabling economic and effective development of A oilfield, significantly improving drilling success rate and cementing quality rate, and bringing good economic and social benefits to the sustainable development of the oilfield.

4 Conclusion

(1) Solid free polymer drilling fluid containing calcium nitrate is used in the section above the coal seam, while G. without clay phase or low clay phase is used in the second section A. The P system uses a combination of two clay inhibitors, polyammonium and polyol, and a solid free oil soluble temporary plugging drilling fluid system is used during drilling in the oil reservoir section. Controlled the solid content,

slowed down the occurrence of shrinkage and mud wrapped drill bit phenomenon, successfully addressed the high hydration dispersion and shrinkage problems in mudstone formations, and thus achieved the goal of stabilizing the wellbore. Solved the problem of wellbore instability caused by shale collapse, while maximizing the protection of the reservoir[13].

(2) Through close cooperation between geology and engineering, advanced geological fine description theory is adopted, and advanced technologies such as geological guidance and rotary guidance are used in underground combination. The ability to control wellbore trajectory is greatly improved, which not only expands the field of exploration and development, but also provides guarantees for optimizing wellbore structure. By adopting advanced technology, the guide hole was successfully eliminated during horizontal well construction, significantly reducing drilling costs.

(3) Evaluate and optimize the performance of multiple PDC drill bits, optimize the structure of the drill bits, and form a series of PDC drill bit models suitable for the formation of this block, improving the cutting ability of the drill bits to the formation and increasing the mechanical drilling speed; Secondly, the tooth arrangement of the drill bit is optimized, especially the optimization of the retaining teeth, to improve the strength of the drill bit, avoid damage to the drill bit inside the casing or wear in high grinding formations, and improve the construction efficiency of the drill bit; The water hole of the drill bit has also been optimized. On the one hand, it improves the cleaning ability of the drill bit to avoid mud bags, and on the other hand, it enhances the hydraulic jet rock breaking ability of the drill bit water hole, greatly improving the mechanical drilling speed.

(4) In the drilling engineering plan, conventional directional wells adopt a two hole wellbore structure, while high angle wells and horizontal wells adopt a three hole wellbore structure. The use of a simple wellbore structure in low difficulty wells increases drilling speed and reduces drilling costs. For difficult wells, a three hole wellbore structure is adopted to effectively control complex underground situations, reduce drilling accidents, and achieve safe and efficient drilling operations. The optimization and simplification of wellbore structure have been recommended and applied in various oil fields in the block, achieving good results[14].

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