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The Bit Selection Research on LS101

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Abstract

The well LS101 has a deep subject reservoir. The ROP is low and drill bits are changed frequently because of high formation hardness and high rock abrasiveness. Rock breaking mechanism of PDC bit and cone bit is analyzed in this paper. The main factors which affect rock breaking efficiency of bits are provided. LS101 deep formation data provided by REED Hycalog and well logging information are analyzed and Lithological features of LS101 deep formation are gained. Referred to the realistic behavior of each drill bit in this well, the results of bits selection on LS block are recommended, and have the model significance for the future drilling in the same formation of this block.

Key words: LS101; Rock breaking mechanism; Lithology; Bit type selection

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INTRODUCTION

Well LS101 is a deep exploration well, which is located on the southwest of LS1 glutenite body. The main drilling purpose is to seek oil and gas to the West, and expand the oil and gas range of shahejie formation of well LS1. The planed depth is 4,400 m, and the actual TD is 4,465 m. It has a total of 170 drilling days from spud to TD.

During the deep formation drilling in this well, the drilling speed is too low due to the low rock breaking efficiency. Therefore, the drill bit selection on this block should be studied to improve the drilling speed and reduce the drilling cost.

1. ROCK BREAKING MECHANISM

1.1 Rock Breaking Mechanism of PDC Bit

(a) When PDC bit works in the formation with lower compressive strength, either for plastic rock or brittle rock, PDC bit teeth could enter into the rock with smaller WOB (weight on bit) and shear the rock, that's why the PDC bit is more effective than the roller bit which break rock by rolling;

(b) When the PDC bit is drilling in the strata with high compressive strength, under the same WOB, the teeth entering depth is small, the rock breaking quantity reduces, therefore, the rock breaking efficiency decreases.

(c) When the PDC bit is drilling in the strata with extremely high compressive strength of rock, under the same WOB, the PDC bit teeth are hardly to enter the rock, PDC bit can only break the rock by grinding, its rock breaking efficiency is greatly reduced, therefore, the drilling speed is greatly reduced.[1-4]

1.2 Rock Breaking Mechanism of Roller Bit

(a) When the compressive strength of rock is relatively low, the teeth of roller bit could enter the rock under a small WOB and produce volume breaking.

(b) When the compressive strength of rock is relatively high, the teeth of roller bit is hardly to enter the rock. The rock is mainly broken by the impact and crush of the teeth.

Through the analysis of rock breaking mechanism above, the author thinks that there are 2 main factors affecting rock breaking efficiency, namely the rock compressive strength and rock abrasiveness. The rock compressive strength affects the teeth entering depth of cone bit and PDC bit, while the rock abrasiveness affects the shear breaking capacity of drill bit. Therefore we studied on the lithology of this block.

2. LITHOLOGY ANALYSIS

We use TERRASCOP software of Reedhycalog Company to analyze the natural gamma ray and acoustic logging data of deep formation of well LS101. The lithology of deep formation in well LS101 is obtained:

2.1 Compressive Strength

For well LS101, Figure1 shows that the depth of 3,600 m is a cut-off point for the compressive strength, the upper formation's compressive strength is relatively low, at around 5,000 psi, which belongs to the soft stratum; and the compressive strength of 3,600-3,900 m has a certain degree of growth, between 5,000 and 10,000 psi, which belongs to soft to medium-hard formations; from 3,900 meters to the bottom, the compressive strength of strata increases significantly and has a larger variation, fluctuates in 10,000-25,000 psi, which belongs to medium-hard to hard formations.

2.2 Abrasiveness

As can be seen from Figure 1, the depth of 3,900 m is a cut-off point for the abrasiveness, the upper strata's abrasiveness changes greatly, remained in the range of 1-10, and below 3,900 m, the formation's abrasiveness increases, remain at around 10. Through the analysis of well LS101 logging data, formation quartz content below 3,900 m is very high, we can conclude that the rock has a high hardness and strong abrasiveness.

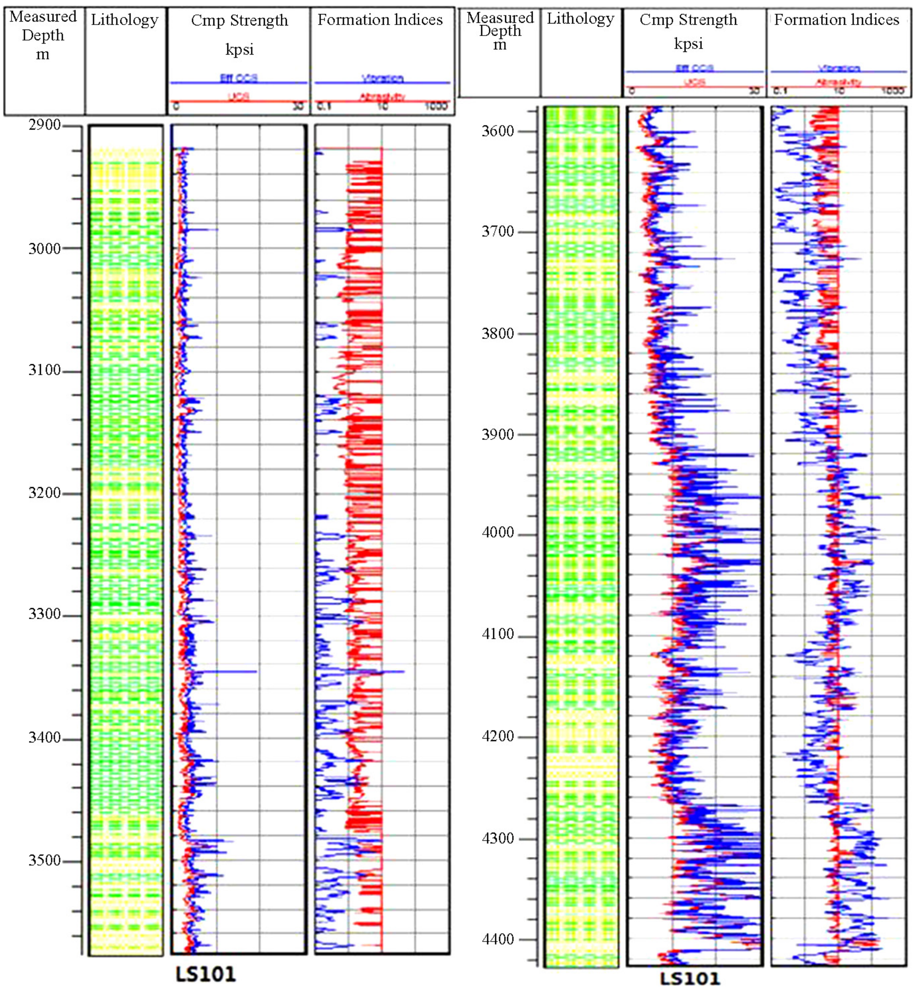

Figure 1
LS101 Lithology Analysis

3. FIELD PRACTICE

Based on the above analysis, we made a reasonable selection on the drill bit of LS101, there are 44 bits used in total including 5 coring bits. The using effect of bits in different well section was analyzed. The most accurate data "footage" and relatively accurate data "bit average ROP" were selected as a comparison index. Comparison results are shown in Table 1.

Table 1
Comparison Results of Drill Bit of Well LS101

Spud sequence	Formation	Bit mode	Quantity	Footage (m)	Average ROP (m/h)
First spud	Pingyuan ,minghuazhen group	P2	1	409	13.37
Second spud	Minghuazhen, guantao, dongying group, S1, S2, upper S3 section	P5361MC(5 bladders)	1	1893	23.91
	Middle S3 section	LHJ517G	4	285	1.28
		P5361MC(5 bladders)	2	42	0.64
		LHJ437G	2	298	2.22
Third spud	Lower S3 section	84KM245(6 bladders)	2	70	0.92
		HJ517	1	80	1.34
		PK5373MJ(5 bladders)	1	8	0.44
		LHJ447G	1	147	1.90
	S4 chunshang section	LHJ447G	2	186	1.43
		84KM245(5 bladders)	1	49	0.58
		MD6500	1	194	0.50
	S4 chunxia section	LHJ447G	5	368	1.1
		LHJ517G	10	317.7	0.95
	Lower S4 section	LHJ517G	5	94	0.51

4. BIT SELECTION ANALYSIS

4.1 Bit selection for Second Spud

4.1.1 Minghuazhen Group to Upper S3 Section

There are 9 Φ311.2 mm drill bits used in the second spud. P5361MC, a PDC bit, was used in the upper formation, the footage is 1,893 m, and the average ROP is 23.91 m/h, the maximum well angle is 0.69° within the footage. It drilled from Minghuanzhen group to the upper S3 section. These formation has a low compressive strength and abrasiveness, which is beneficial to PDC bit teeth to enter the formation. Therefore, PDC bit is recommended in this section.

4.1.2 Middle S3 Formation

Three kinds of drill bits, LHJ517, LHJ437 and P5361MC (5 blades), were used in the middle S3 formation. LHJ437G has the best using results, e.g. #9 bit, drilled from 2,629 m to 2,796 m, has a 167 m of footage, 61.17 h of actual drilling time, and 2.73 m/h of the average ROP. For using the results, LHJ517G takes second place and P5361MC has the worst effect. The main reason is: it is hard for the PDC bit to enter the formation under a small WOB, therefore, the ROP reduced significantly. In addition, there are a large number of interlayers in the formation, which lead to the severe formation heterogeneity and is not suitable for the PDC bit. When using a roller bit in this formation, due to the bigger WOB, the teeth of roller bit could enter the rock and produce volume breaking. Through analysis, LHJ437 bit is recommended in this section.

4.2 Bit selection for Third Spud

4.2.1 Lower S3 Formation

Four types of drill bits were tested in this formation, namely: 84KM245(6 blades), HJ517, PK5373MG (5 blades) and LHJ447G. The comparison of ROP is shown in Figure 2.

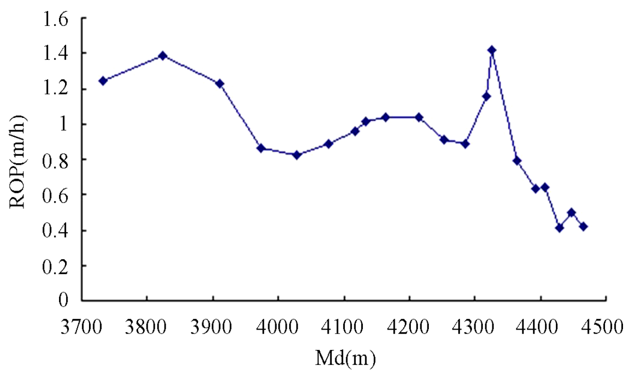

Figure 2
The Comparison of ROP in Lower S3 Formation

As can be seen from Figure 2, LHJ447G shows the highest ROP, HJ517 takes the second place, and two kinds of PDC bits drilled slowly. Therefore, LHJ447G is recommended.

4.2.2 S4 Chunshang Section

In this section a roller bit (LHJ447G) and two PDC bits (84KM245 and MD6500) were used and compared. Table 2 shows the penetration rate of LHJ447G is obviously higher than that of the other two PDC bits. E.g. #19 LHJ447G bit, drilled from 3,580 to 3,661 m, has an 81m of footage, 54.36 h of actual drilling time, 1.49 m/h of the average ROP.

4.2.3 S4 Chunxia Section to S4 Lower Section

The LHJ447G bit was used above 3,900 m, and the ROP reached more than 1.23 m/h, but LHJ447G and LHJ517G bits had poor using effect when drilling in the formation below 3,900 m. Based on the calculating results of REEDHycalog (shown in Figure 1), the rock compressive

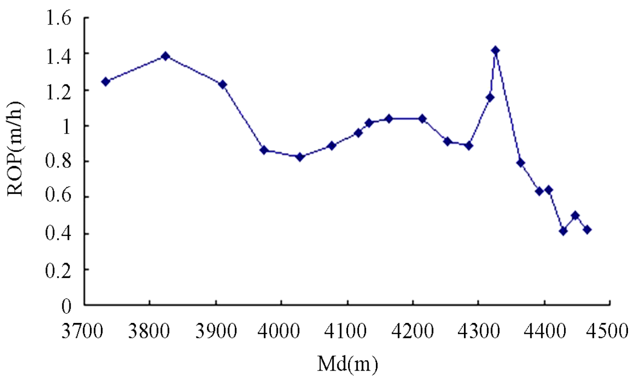

Figure 3
The Variation of Bit ROP With Depth

strength above 3,900 m is relatively low, belongs to soft formation. LHJ447G bit is suitable for the formation with low compressive strength and high drillability. Therefore it is fit for the formation above 3,900 m. The compressive strength of strata below 3,900 m increases significantly and has a larger variation, fluctuates in 10,000-25,000 psi, which belongs to medium-hard to hard formations. However, LHJ447G and LHJ517G bits are appropriate for the formation with low compressive strength. Therefore, it is unreasonable for bit selection below 3,900 m. It is suggested to select bit which is fit for medium-hard to hard formations. In addition, according to the analysis on the drilling cuttings, the rock of LS block not only presents high compressive strength but also shows a certain degree of plasticity, which belongs to the stiff-plastic formation. When drilling in this formation, the roller bit teeth should not be over long, because over long teeth will be broken or cracked by hard rock. Meanwhile the teeth should not be too small and dense, otherwise the roller bit could not produce enough crushing energy, and bit teeth are not easy to enter into the formation. For the plastic rock, the bit could produce enough breaking volume and high rock breaking efficiency only when the bit teeth could enter the rock.

CONCLUSION AND SUGGESTION

(a) Through the analysis of rock breaking mechanism, the compressive strength and rock abrasiveness are 2 main effects affecting rock breaking efficiency.

(b) The formation from minghuazhen group to upper S3 section presents a low compressive strength and abrasiveness, which are suitable for the use of PDC bit. In the middle S3 formation, a large number of interlayers exists, and the formation heterogeneity is severe, therefore, LHJ437G bit is selected.

(c) For the formation with lower compressive strength, S3 lower section, S4 chunshang section and S4 chunxia lower section, LHJ447G bit has a good using results. For S4 chunxia lower section and S4 lower section, it is necessary to carry out the research on the optimization of the drill bit, and it is suggested to select some drill bits which are suitable for drilling high compressive strength and hard formations.

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