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Estimation of rock strength from sonic log for Buzurgan oil field: A Comparison study

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Abstract

It is very difficult to obtain the value of a rock strength along the wellbore. The value of Rock strength utilizing to perform different analysis, for example, preventing failure of the wellbore, deciding a completion design and, control the production of sand. In this study, utilizing sonic log data from (Bu-50) and (BU-47) wells at Buzurgan oil field. Five formations have been studied (Mishrif, Sadia, Middle lower Kirkuk, Upper Kirkuk, and Jaddala) Firstly, calculated unconfined compressive strength (UCS) for each formation, using a sonic log method. Then, the derived confined compressive rock strengthens from (UCS) by entering the effect of bore and hydrostatic pressure for each formation. Evaluations the result of compared rock strength generated from two wells for the same formation and match the bottom and top of this formation in two wells.

Based on the obtained results, a good agreement between values of unconfined compressive strength from well (50) and well (47) that used real along of drilling section. The net results of the match between rock strength for wells (BU-50, BU- 47) of five formations; Mishrif, Sadia, Middle lower Kirkuk, upper Kirkuk, and Jaddala were 97, 87, 96.5, 97, 86 %, respectively

Keywords: drilling, unconfined rock strength, sonic log

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1- Introduction

The value of rock strength for each foot of the well, from the surface to the bottom of the hole, is very difficult to be achieved. For example, it is difficult to get the safe density for drilling fluid during the drilling of the different formations to avoid instabilities of the wellbore and when design the program of casing [1]. It is very essential for a drilling engineer to know all the data associated with the strength of rock along the well because the production of sand during extraction of oil is also great degree depending on lithology of reservoir or strength of the rock. Also, the penetration rate and wear of bit largely depend on the value of rock strength, where an increase in strength of rock led to increased wear of drilling bits and decreased penetration rate which increases the cost of drilling [2].

Several methods are used to calculate the strength of rock for each foot during the drilling process. First, we can calculate the strength of rock directly in the lab via a mechanical method on cutting or cores. In addition, the strength of rock can be calculated from log data which achieved during the drilling process by using sonic log along the well [3]. Finally, it can be calculated from the model of drilling, where utilizing data of drilling such as weight on bit, rotary speed and other drilling parameters for finding the mechanical properties of the rock. These drilling parameters can be obtained through the drilling process of the well for each foot [4].

The main objective of this study is to calculate the value of the strength of the rock from the sonic log model where this value is called the unconfined compressive strength. After that, the study used value of unconfined compressive strength to calculate confined compressive strength for each well by depends on pore and hydrostatic pressure [5].

2- Calculation Unconfined Compressive Strength

The use of sonic velocity log to calculate rock elastic properties are well established. Many correlations were presented between sonic travel time and rock strength or a grouping of different logs [6], [7]. Rock strength depends mainly on lithology. The rock strength was high for the rocks with low porosity or low traveling time. The equation used in this study is show below [4].

$$S_{os} = \left(\frac{1}{K_1(\Delta t_c - K_2)^2} + 2\right) * \frac{1}{145} \quad (1)$$

Where:
Δtc : time of traveling.
S_{0S} : Rcock strength in case (UCS)
k_1, k_2 are constants
K1 = 5.15*10-8
K2 = 23.87

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3- Calculating Confined Compressive Strength of Rock

Unconfined compressive rock strength (UCS) that calculated from sonic log do not use in the apply model so should calculate the confined compressive rock strength (CCS) from (UCS) for any well or formations in the same field when we want to use the rate of penetration model. Confined compressive strength (CCS) calculation depends on hydrostatic and pore pressure because the drilling model use confined rock strength and the value of rock strength, which got from sonic model do not contain on the effect of the difference between hydrostatic pressure and pore. Rock strength is the chief element of the drilling models [8].

$$S = S_o\left(1 + a_s P_e^{b_s}\right) \quad (2)$$

S: (CCS) in MPa, So: (UCS) in MPa, P_e different between pore and hydrostatic pressure.
(a_s,b_s) are fitting constants showing in Table **1**.

Table 1. Chip Hold-down Permeability Coefficients [9]

Formation	Permeable	Impermeable
P_e	P_h-P_p	P_h
a_c	0.00497	0.0141
b_c	0.757	0.470
c_c	0.103	0.569
a_s	0.0133	0.00432
b_s	0.577	0.782

4- Results

The results of this work are presented for two wells (BU-47); (Bu-50) wells. The results are listed in the following figures (1 to 5) studies formation. These formations include Mishrif, Sadia, Middle lower Kirkuk, upper Kirkuk, and Jaddalla formations.

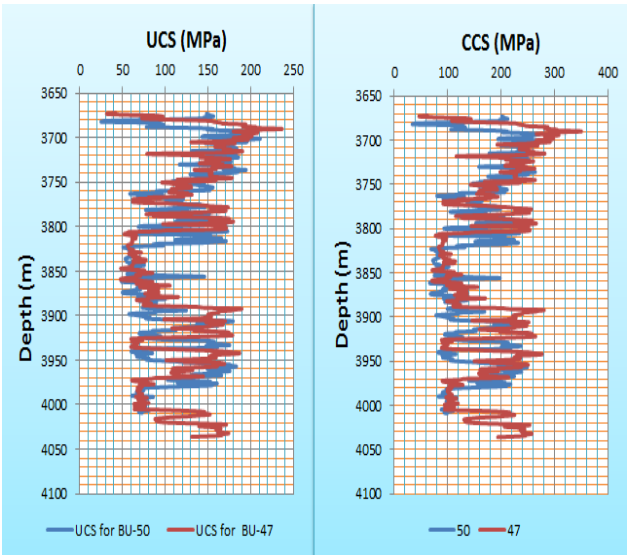

Fig. 1. Comparison the values of UCS and CCS between (BU-50) and (Bu-47) wells for Mishrif formation

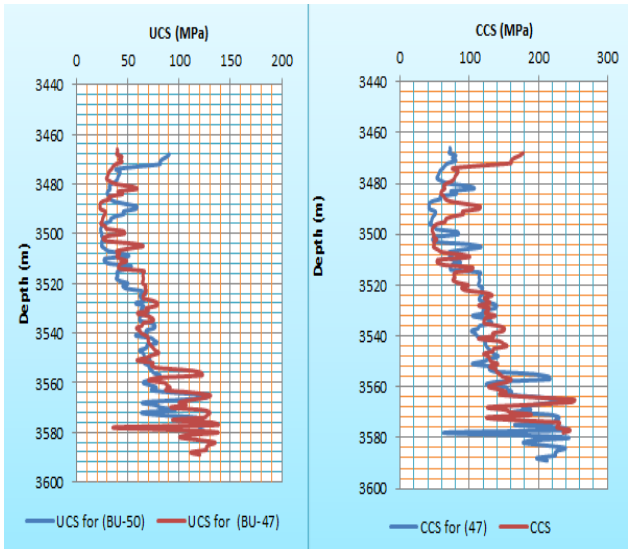

Fig. 2. Comparison the values of UCS and CCS between (BU-50) and (Bu-47) wells for Sadia formation

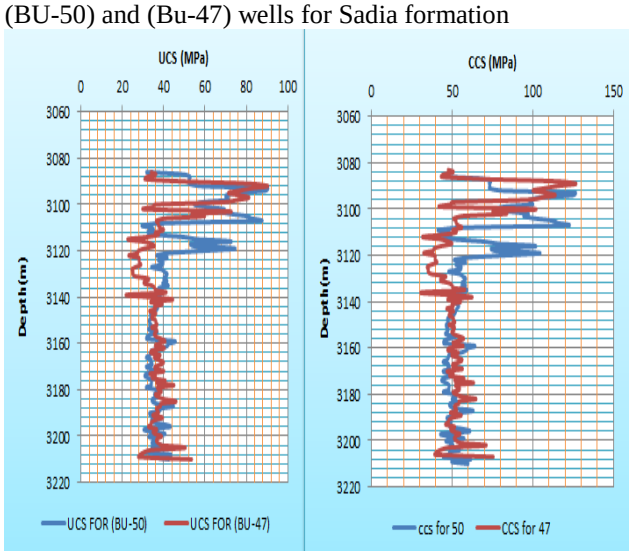

Fig. 3. Comparison the values of UCS and CCS between (BU-50) and (Bu-47) wells for Middle lower Kirkuk formation

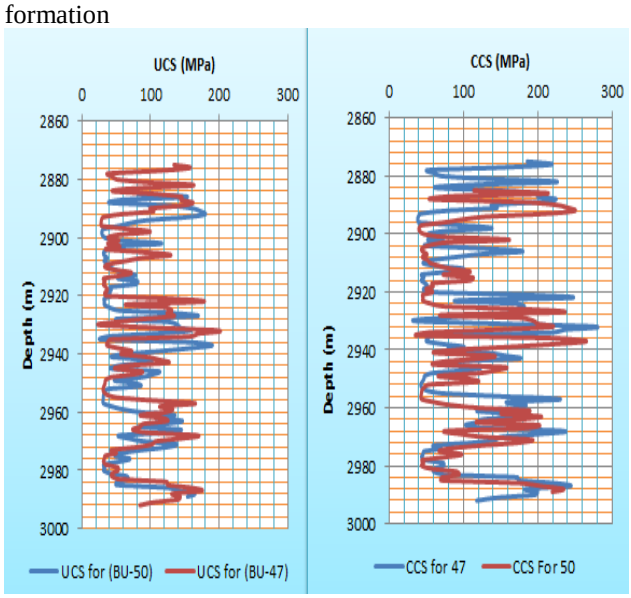

Fig. 4. Comparison the values of UCS and CCS between (BU-50) and (Bu-47) wells for Upper Kirkuk formation

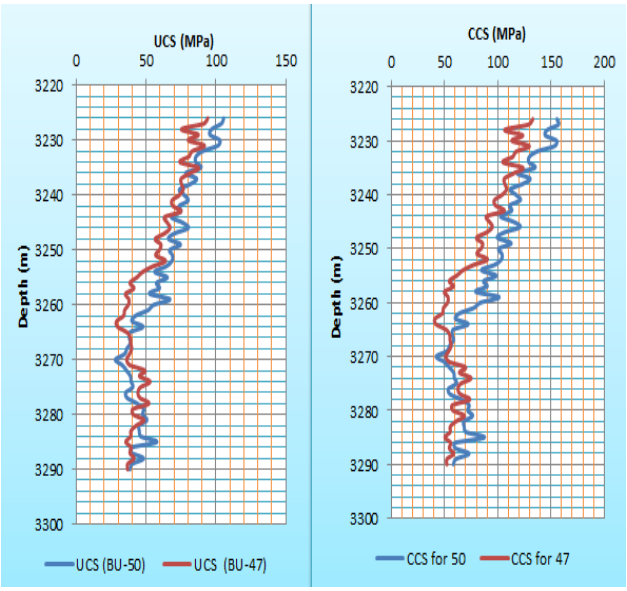

Fig. 5. Comparison the values of UCS and CCS between (BU-50) and (Bu-47) wells for Jaddala formation

5- Discussion

Figures (1 to 5) represent the comparison between (BU-50), (BU-47) for the unconfined compressive rock strength that is calculated from the measuring sonic log with confined compressive rock strength which calculated from UCS with depth. The difference between confined rock strength and unconfined rock strength depend on the value of hydrostatic and pore pressure. When the value of the difference between pore and hydrostatic pressure is very high that led to increasing differences between unconfined and confined compressive strength for each formation. It can be noticed that there is an only slight difference between the values of unconfined and confined compressive rock strength in upper Kirkuk formation. Mishrif, Sadia Middle lower Kirkuk has a high difference between unconfined confined compressive rock strength because there is a high difference between the hydrostatic and the pore pressure.

The values of rock strength changed with depth, because of varying in the lithology with depth. In addition, it can be noticed the value of rock strength increases with depth. This increase in depth led to rising the rock strength. The rock strength in mishrif formation was higher than all formations because it is the deeper formation. The value of match for unconfined compressive strength between (BU-50) and (BU-47) for five formations (Mishrif, Sadia, middle lower Kirkuk, upper Kirkuk and Jaddala) was (97%, 87%, 96.5%, 97%, 86%) respectively.

6- Conclusions

The values of unconfined compressive rock strength that obtain from (BU-50) well using sonic log tool have a very good match with the value of unconfined compressive rock strength which determined from (BU-47) well for all formations.

In addition, the difference between the values of confined and unconfined depends on the value of hydrostatic pressure for the same formation in two wells. The value of unconfined compressive rock strength mainly rose with increasing depth.

Nomenclatures

Symbol	Definition
a_c	chip hold-down coefficient, dimensionless
a_d	drag-bit lithology coefficient, dimensionless
a_s	rock-strength lithology coefficient, dimensionless
b_e	chip hold-down coefficient, dimensionless
b_d	drag-bit lithology coefficient, dimensionless
b_s	rock-strength lithology coefficient, dimensionless
c_c	chip hold-down coefficient, dimensionless
P_e	effective differential or confining pressure, psi
P_h	mud column hydrostatic pressure, psi
P_p	pore pressure, psi
S	confined rock strength, psi
S_o	unconfined rock strength, psi

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تقدير مقاومة الصخرة من التسجيل الصوتي لحقل البزركان النفطي :دراسة مقارنة

الخلاصة

من الصعب جداً الحصول على قيمة قوة الصخور على طول حفرة البئر. قيمة قوة الصخور التي تستخدم لإجراء أنواع مختلفة من التحليل على سبيل المثال منع فشل جدار البئر ، وتحديد تصميم الاكمال ، والتحكم في إنتاج الرمال. في هذه الدراسة يتم استخدام بيانات التسجيل الصوتي لحقل البزركان النفطي ، وطبقت هذه الدراسة على الابار التالية (BU-47) (BU-50) . أولا ، حساب قيمة قوة الضخرة بدون تاثير ضغط عمود الطين و ضغط التكوينات والتي يطلق عليها ب (UCS) لكل تكوين من التسجيلات الصوتية اثناء الحفر . ان نتائج قوة الصخرة التي يتم الحصول عليها بتطبيق نموذج التسجل الصوتي لا تحتوي على تاثير ضغط عمود السائل وكذلك ضغط التكوين ولا يمكن استخدامها في تطبيق معادلات نماذج الاختراق لذلك يتم حساب قوة الصخرة (CCS) من قيمة (UCS) بالاعتماد على ضغط التكوين وضغط عمود السائل اثناء الحفر . وللتاكد من نتائج قوة الصخرة تم المقارنة بين قوة الصخرة لبئرين ومعرفة مدى التطابق بينهما .

بناءا على النتائج التي تم الحصول عليها ، هناك تطابق جيد بين قيم قوة الصخرة التي تم حسابها من الابار(BU_50), (BU-47) بالاعتماد على التسجيلات الصوتية. حيث ان قيمة تطابق النتائج بين قوة الصخور لخمس تكوينات والتي هي Mishrif, Sadia, Middle lower Kirkuk, upper Kirkuk, Jaddal كانت(97٪ ، 87٪ ، 96.5 ٪، 97 ٪، 86٪) على التوالي