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Well Control Case Study Analysis for Well U1-72 (En-Naga O Structure) Harouge Oil Operations, Libya

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Abstract

Well control and blowout prevention have become particularly important topics in the hydrocarbon production industry for many reasons. Among these reasons are higher drilling costs, waste of natural resources, and the possible loss of human life when kicks and blowouts occur. The case study of this project was selected from Harouge oil operations drilling history at En-Naga O prospect which is located in southwest of concession 72, due to volcanic activity in the past, which created carbon dioxide reservoir in Bahi formation, and due to dyke cross formations the gas moved to upper zones that's content high porosity and permeability. That's activity made the En-Naga O prospect one of the most difficult structure to be drilled due to abnormal pressure formation at loss circulation and fractured zones. This project is amid to study and to help in finding engineering solutions at drilling unstable formations En-Naga O prospect, which consists of high pressure zone and loss of circulation problems. Where the drilling cost of U1-72 raised up to approximately 4 times from the planned cost, due to high pressure and loss circulation problems while drilling. This study end up with very important recommendations as a lessons learned from this well practices, including mud weight should be designed properly at different hole intervals to control properly formation gas, casing setting depths should be reviewed to prevent hole problems and impose more control on the well geometry, and it's very important to apply proper particle size management selection for use loss circulation materials for achieving proper lost circulation zone sealing and treatments.

Keywords: Well control; drilling costs; mud weight; loss circulation.

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1. Study Area

The study well is located in Concession 72 which located 280km south of Ras Lanuf and is the most southerly concession in the Sirte Basin operated by HOO, see Figure .1. En-Naga O prospect where's located in southwest of concession 72, due to volcanic activity in the past, that's create carbon dioxide reservoir in Bahi formation, and due to dyke cross formations the gas moved to upper zones that's content high porosity and permeability. That's activity made the En-Naga O prospect one off the most difficult structure to be drilled due to abnormal pressure formation and the loss circulation; fractured zones see Figure **??**. This study is based on analysing of subsurface well logs, mud log, drilling report and geological information of well U1-72 I En Naga O filed. The Geology of area NC 72 based on wells drilled are consist of main local geological structures which consists of Eocene, see Figure **??**.

2. U1-72 Well Drilling History

The well was spudded on October 29, 2004 to Drilling target at 12,000 ft , Challenger Rig No 14 drilled this well to TD at 11,973 ft in 198 days. Only a very small percentage of CO_2 gas was detected at depth 6670 ft (- 5657 ft in Zelten Formation. CO_2 also exists along with the hydrocarbon gas while drilling Dahra and Beda Formations. While drilling Etel Formation only 10% of CO_2, while high amounts of

Hydrocarbon gas was recorded. Due of the Total loss circulation zones at depth 10,225 *ft* mud level continue decreases as the well hydrostatic pressure decreases, First CO_2 kick was encountered at 10,400 *ft* near top of Etel formation, mud weight was then increased from 12.5 *ppg* (6,720) *psi* to 14.2 *ppg* at 11,500 *ft* , then up to 14.75 *ppg* at *TD* 11,900 *ft*), at the end due to loss of circulation the operations cannot succeed to overcome the gas flow, therefore, preventing mud losses is the priority at drilling in this area to avoid huge drilling cost.

3. Detection of High Pressure Zone

The big challenge in this well that is to detect where the abnormal pressure formations existent. there's many of methods as drilling break and decreases in dc-exponent. The plot of rate of penetration verses depth, see Figure .5 that's shown more than one drilling breaks it shows the high formation pressure the first one about 9600 *ft*, which is the first detect of the abnormal pressure formation. D-exponent value was introduced in the mid-sixties to calculate a normalized penetration rate in relation to certain drilling parameters, see 3.1.

$$dexp = \frac{log\,(R/60N)}{log\,(12W/10D)} \tag{3.1}$$

Where:
R= rate of penetration, ft/hr
N= rotary speed, *rpm*
W= weight on bit, *lbs*
D= bit size, *ins*
dexp = D-exponent

4. Detect of Formation Pressure:

The formation pressure can be derived from the modified d-exponent, using a method proposed by Eaton (1976) using the equation 4.1:

$$\frac{P}{D} = \frac{\sigma ob}{D} - \left[\frac{\sigma ob}{D} - \left(\frac{Ph}{D}\right)\right]\left[\frac{dco}{dcn}\right]^{1.2} \tag{4.1}$$

Where
Pf/D= Fluid pressure gradient (psi/ft)
S/D= overburden gradient (psi/ft)
$(Ph/D)n$= "normal" hydrostatic gradient (psi/ft)
dco= observed dc at given depth
dcn= dc from normal trend

5. Detect of Fracture Pressure:

Hubbert and Willis 1972 They introduced an equation to determine fracture pressure:

$$Pff = \frac{\sigma ob + 2Pf}{3} \tag{5.1}$$

where,
Pff: formation fracture pressure, *psi*
σ_{ob} : overburden pressure, *psi*
Pf: formation pore pressure, *psi*
The estimated of pressure profile helps to drilling well more safely and less costly. By estimate the write mud weight, casing seats, and BOP limitation correctly, see Figure .7 .

6. Casing Seats Selection

The decision of when to stop drilling temporarily and cement casing in the well before proceeding with deeper drilling operations is a key decision in both the technical and economic success of a drilling venture. By adopt same hole casing sizes as the actual case is, Casing seats depth suggestion for this well on geology and pore/fracture pressure data see Figure .8 and Table .2. At the first and second casing strings installation there's no serious problems needs to change the mud actual planning, but for the remain three casing strings the planning mud weight change is necessary to make stability for the drilling hole from the formation average gradient and by using trip safety margin by 0.02 psi/ft. the Table .1 shows the mud weight suggestion planning and can comparing it with actual case in Figure .9.

7. Lost circulation zones

1. The estimation of pore pressure proper casing and mud design are not enough to put the well under control, that's because the main issues of drilling in Naga O area not solved.

2. This issues is the loss circulation of drilling and killing fluids. Packing theory is one of the techniques that could help in solving the loss of circulation problem.

3. When the drilling reach 10,400 *ft* depth the total loss circulation happened, that fluid loss make the hydrostatic column decreases progressively this made the hydrostatic pressure decreases too. At 10,440 *ft* kick accurate and stilled content to 11,970 *ft*

and that problem can't be solved without loss circulate zones treatment to remain the well stability.

4. The writer calculated the porosity from density and sonic log then corrects them by Vsh, and calculate the permeability form Yan (2001) equation 7.1.

$$K = 8.7096 \times 10^4 \times \frac{\emptyset^{5.78}}{Vsh^{1.37}} \tag{7.1}$$

1. By plotting the permeability versus depth can evaluate the loss circulate depth and can treat this zones. (As shown Figure .10). One of the most needed solutions to drill safely at this type of situations, are to find optimum treatment for loss of circulations to prevent any drop of the hydrostatic pressure in the hole. Preventing mud loss circulation zones should start with reduces mud weight to minimize mud loss rate, and prevent expanding of the natural fractures in the formation. But Etel formation which is the total mud loss zones is an inter beds of shale, sandstone, limestone and anhydrite. The shale zones need high Mwt to prevent shale collapse, so it's a big risk to reduce Mwt.

8. Recommended Treatment

The suggestion technique is to reduce mud loss while drilling, therefore the writer suggests using packing theory to block the fractures and the porous at the well wall and minimize the fractures or porous width. The packing theory or the bridging theory is a technique using to determine the most optimum particle size of LCM use for providing the most and optimum loss zone sealing, The main pore size can be estimated by equation 8.1 by using porosity and permeability of the formation.

$$D_{pore} = 4.6 \times \sqrt{\frac{K}{\emptyset}} \tag{8.1}$$

The theory of this rule been driven from analyzing the relations between the main pore size (D_{pore}) and the main LCM particle size (D_{50}) in order to Identify the (D_{50}/ D_{pore}) Ratio which able to achieve the most optimum sealing efficiency.
By applying Ben Younes packing roles using the following relations.
For invasion:

$$D_{\text{pore}} * 0.40 > D50 \tag{8.2}$$

For internal sealing and blocking:

$$D_{\text{pore}} * 0.40 \leq D50 \leq D_{\text{pore}} * 0.56 \tag{8.3}$$

for optimum sealing:

$$D_{\text{pore}} * 0.56 = D50 \tag{8.4}$$

for external sealing:

$$D_{\text{pore}} * 0.56 < D50 \tag{8.5}$$

The estimate particle size using Ben Younes rule by applying 56% from the pore size for optimum sealing to close the pores and minimize the loss circulation ratio. Prospect. Shown LCM the particle sizes required to use at curing loss circulation while drilling this well as shown at Table .2.

References

[1] Ben Younes, 2007 " investigations of new lost circulation Materials for site Basin Treatment" PhD thesis , Robert Gorden University, Uk.

[2] Lansing, Eaton I-69, Charlotte to I-96 and I96 Northwest of County: Environmental Impact Statement, United States.

[3] Wild Oil Well Tamed by Scientific Trick" Popular Mechanics, July 1934.

Figure .1: Location of Concession 72 on Libya map.

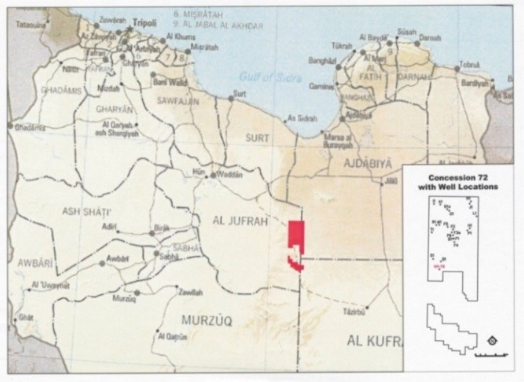


Figure .2: Migration of CO^2 from Bahi Formation to upper Zone.

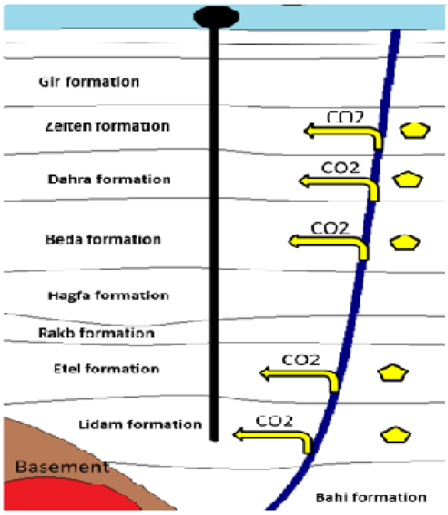


Figure .3: Stratigraphy of Concession72.

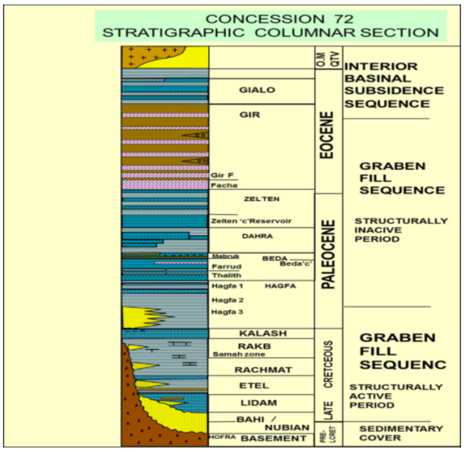


Figure .4: Drilling History for U1-72.

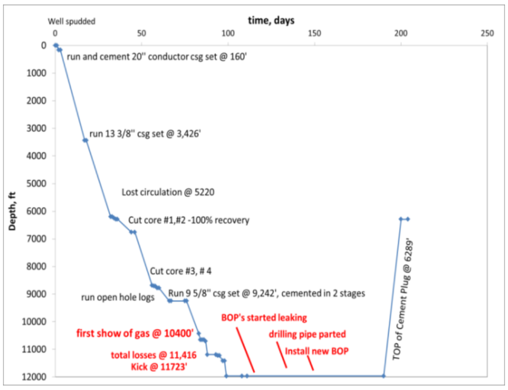


Figure .5: Plot of Rate of Penetration verses Depth Shows Drilling Break Zones

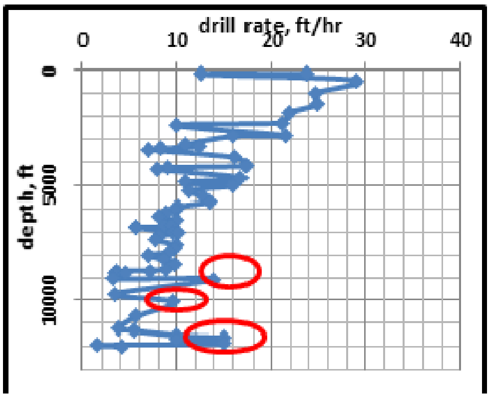


Table .1: Mud Weight Suggestion Planning

size inch		depth ft.	Mud property	
hole	casing	setting depth	Mud type	Mud weight, ppg
26	20	150-200	spud Mud	8.6-8.75
17 1/2	13 3/8	5000	low solids polymer	8.75-9.3
12 1/4	9 5/8	8400	LCM material additives	9.3-10.4
8 1/2	7	10400	LCM material additives	11.45-15.4
6	5	13000	LCM material additives	15.4-15.77

Table .2: Porosity, permeability, Dpore and LCMparticle Size of En-Naga O Structure.

Lithology	Well logs	porosity ave	permeability	pore size	*LCM* particle size
	Depth	ϕ_e	K	D_{pore}	
	ft	*v/v*	*Darcy*	*micron*	*Micron*
sandstone	10420	0.19	103.51	108.45	60.731781
	10470	0.20	65.84	84.25	47.179236
	10870	0.17	47.53	77.07	43.157405
Anhydrite	11510	0.15	82.64	107.04	59.940068

Figure .6: Plot of Dcexponent verses Depth

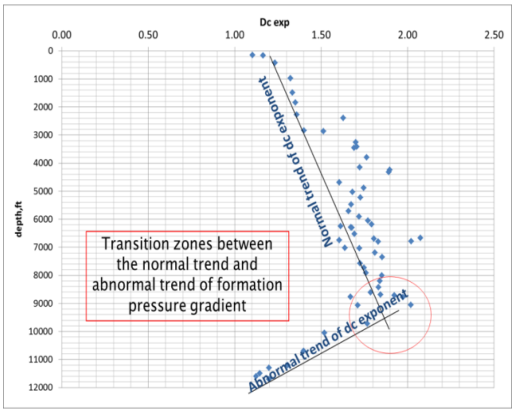


Figure .7: Plot of Formation, Hydrostatic and Fracture Pressure verses Depth for Well U1-72.

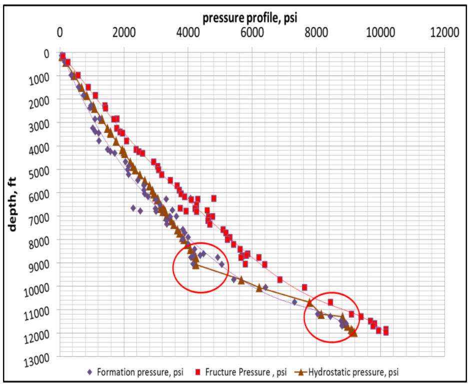


Figure .8: Casing Selection Design Seats for Well U1-72.

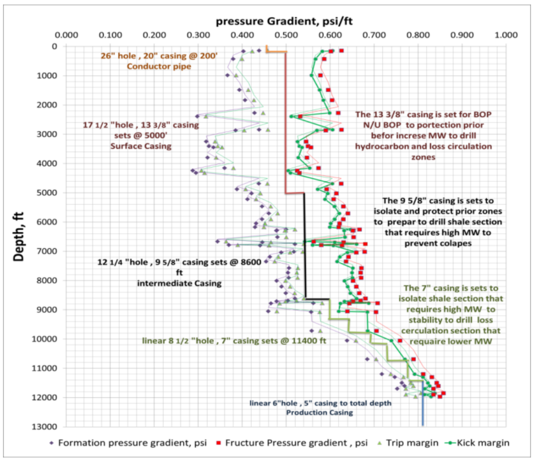


Figure .9: Mud Suggestion planning.

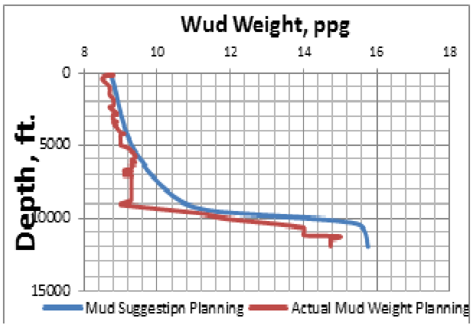


Figure .10: Plot for Permeability versus Depth for Well U1a-72

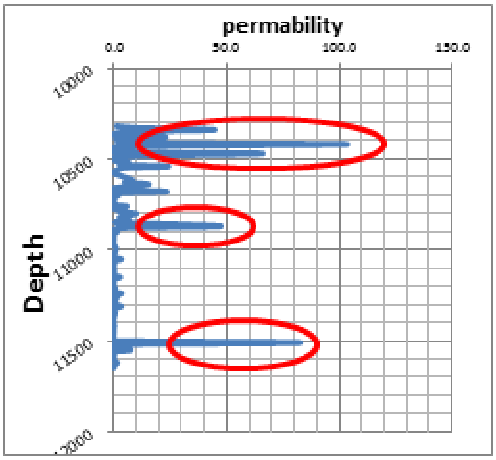


Figure .11: Packing theory.

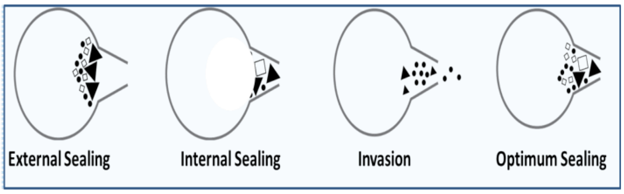
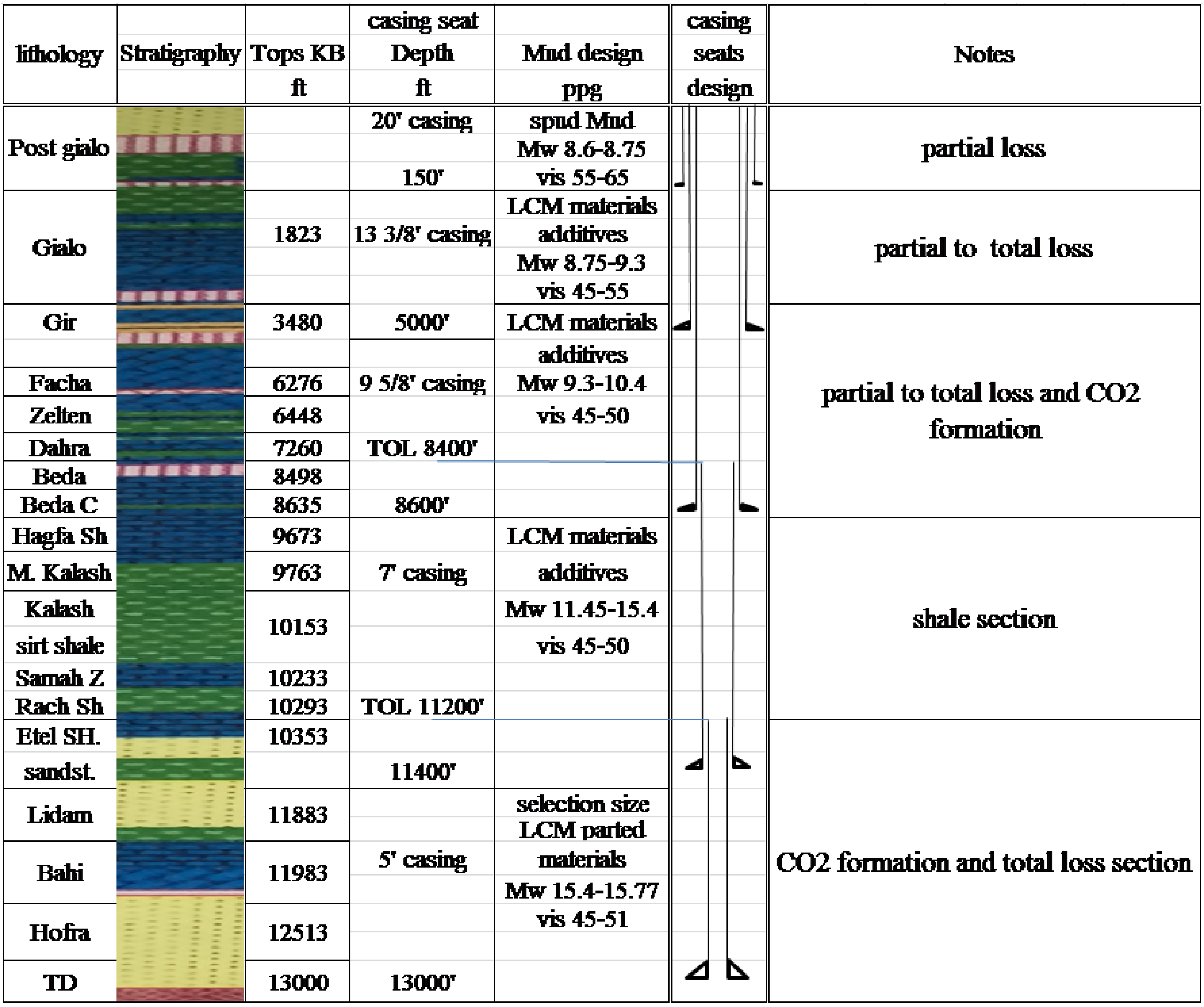


Figure .12: Casing Seats for Well U1-72.



lithology	Stratigraphy	Tops KB ft	casing seat Depth ft	Mud design ppg	casing seats design	Notes
Post gialo			20' casing 150'	spud Mud Mw 8.6-8.75 vis 55-65		partial loss
Gialo		1823	13 3/8' casing	LCM materials additives Mw 8.75-9.3 vis 45-55		partial to total loss
Gir		3480	5000'	LCM materials		partial to total loss and CO2 formation
				additives		
Facha		6276	9 5/8' casing	Mw 9.3-10.4		
Zelten		6448		vis 45-50		
Dahra		7260	TOL 8400'			
Beda		8498				
Beda C		8635	8600'			
Hagfa Sh		9673		LCM materials		shale section
M. Kalash		9763	7' casing	additives		
Kalash sirt shale		10153		Mw 11.45-15.4 vis 45-50		
Samah Z		10233				
Rach Sh		10293	TOL 11200'			
Etel SH.		10353				CO2 formation and total loss section
sandst.			11400'			
Lidam		11883		selection size LCM parted materials		
Bahi		11983	5' casing	Mw 15.4-15.77 vis 45-51		
Hofra		12513				
TD		13000	13000'			