Cairo University

A GLOBAL INTEGRATED MODEL FOR A TIME-DEPENDENT WELLBORE STABILITY PREDICTION

By

Mostafa Magdy Elsayed AbdelHafiz

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
PETROLEUM ENGINEERING

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Under the Supervision of

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A Global Integrated Model for A Time-Dependent Wellbore Stability Prediction

Key Words:
Wellbore stability; Mechanical Earth Model; Rock Mechanics; Safe Mud window; Optimum well trajectory

Summary

This work presents an integrated wellbore stability model using well log data and a time dependent poroelastic model. An iterative approach was build using MATLAB to determine the optimum wellbore trajectory and safe mud window. Mechanical Earth Model was constructed using log data. Wellbore stresses were determined using the poroelastic constitutive model. Modified Lade Criterion was used to determine the failure conditions of the wellbore walls. The results of the developed model were validated against actual well log data from Gulf of Suez, Egypt.

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Dedication

This thesis is dedicated to: The sake of Allah, my Creator and my Master, my great teacher and messenger, Mohammed (May Allah bless and grant him), who taught us the purpose of life; My great parents, who never stop giving of themselves in countless ways, my undergraduate professors and teachers, who lead me through the valley of darkness with light of hope and support, my friends who encourage and support me, All the people in my life who taught me anything useful, I dedicate this research.

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Nomenclature

$\emptyset$	Porosity
$\Delta Pr_t^{\sim}$	Pore pressure function in time
ΔT	Temperature difference
Δt_c	Sonic Compressional time slowness
Δt_{log}	Sonic Compressional time slowness from sonic log
Δt_{norm}	Sonic Compressional time slowness from normal compaction trend line
Δt_s	Sonic shear time slowness
$\Delta\sigma_r\ (r,t)$	Induced radial stress
$\Delta\sigma_\theta\ (r,t)$	Induced shear stress
as	Blanton and Olson material constant
bs	Blanton and Olson material constant
c	Diffusion coefficient
C	Hydraulic diffusivity coefficient
C1'	Blanton and Olson constant calculated at XLOT depth
C2'	Blanton and Olson constant calculated at XLOT depth
Co, UCS	Uniaxial compressive strength
c_t	Rock Total Compressibility
d	Depth (km)
DSI	Dipole sonic Imaging
E	Young’s Modulus
f	Depth compaction factor
g	Gravitational acceleration
G	Shear Modulus of elasticity
GPa	Giga Pascal
I_1”	First invariants stress
I_3”	Third invariants stress
I_{sf}	Shear Failure Index
k	Absolute permeability
L^{-1}	Laplace inversion

LWD	Logging While Drilling
m	Hoek Brown material constant
mD	Mille Darcy
MD	Measured Depth
MPa	Mega Pascal
MPa	Mega Pascal
n	Modified lade parameter
$P_{e\text{-}\Delta}$	Pressure difference between minimum horizontal stress and pore pressure of formation
ppg	Pounds per gallon
P_r	Pore pressure
P_{rn}	Normal pore pressure
p_w	Borehole pressure
r	Radius of investigation
R_b	wellbore rotational tensor
R_s	Geographic rotational tensor
R_w	Wellbore radius
s	Hoek Brown material constant
S_{geo}	stress tensor in the geographic coordinate
Sh	Minimum horizontal stress calculated from XLOT
So	Rock cohesion
S_{org}	Original stress tensor
S_{wb}	Wellbore stresses tensor
t	Time
TD	Total depth
T_o	Tensile strength
TVD	True vertical depth
v	Poisson’s ration
v_{fast}	Poisson’s ration from fast shear wave
Vp	Sonic compressional velocity
v_{slow}	Poisson’s ration from slow shear wave
z_w	Water depth
α	Biot’s contestant

δ	Wellbore azimuth
εtec	Tectonic strain
η	poroelastic coefficient
θ	Position around wellbore
λ	Lame's First parameter
μ	Fluid viscosity
ρ_b	Bulk density
ρ_w	Water density
σ_h	Minimum horizontal stress
σ_H	Maximum horizontal stress
$\sigma_h{}'$	Effective minimum horizontal stress
σ_{m2}	Mean normal stress
σ_{max}	Maximum principal stress
σ_{min}	Minimum principal stress
σ_r	Radial stress
σ_{rr}	Radial stress around the wellbore
σtec	Techtronic stresses
σ_{tmax}	Maximum principal stress
σ_{tmin}	Minimum principal stress
σv	Vertical stress
$\sigma_v{}'$	Effective vertical stress
σ_x	Normal Stress in X direction
$\sigma_x{}^{\circ}$	Original Stress in X direction
σ_y	Normal Stress in Y direction
$\sigma_y{}^{\circ}$	Original Stress in Y direction
σ_z	Normal Stress in Z direction
$\sigma_z{}^{\circ}$	Original Stress in Z direction
σ_{zz}	Axial Stress around the wellbore
σ_θ	Hoop stress (Tangential stress)
$\sigma_{\theta\theta}$	Tangential stress around the wellbore
τ_{oct}	octahedral shear stress
τ_{rz}	Shear stress in rz plane
$\tau_{r\theta}$	Shear stress in r θ plane