Reservoir Characterization Using Bore Hole Logs and Core data for Neag-1, -2 and -3, Western Desert. Egypt

THESIS

Submitted to award the degree of

DOCTOR OF PHILOSOPHY OF SCIENCE IN GEOPHYSICS

By

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بِسْمِ اللّهِ الرَّحْمَنِ الرَّحِيمِ

إِنَّ الَّذِينَ ءامَنوا وَعَمِلُوا الصّٰلِحٰتِ إِنّا لا نُضيعُ أَجرَ مَن أَحسَنَ عَمَلًا (30)

صدق الله العظيم سورة الكهف

Verily, as for those who believed and did righteous deeds, certainly We shall not make the reward of anyone to be lost who does his (righteous) deeds in the most perfect manner

Approval Sheet

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List of Abbreviations

Ka,	absolute permeability
P_b	bouncy pressure
V_b	bulk volume of the sample
P_C	capillary pressure
BQv	cation Exchange capacity
m	cementation factor
C_t	conductivity
θ	contact angle
R_t	deep resistivity
DEN	density log
ρ_w	formation water density
ρ_{hc}	formation hydrocarbon density
g	gravitational acceleration constant
F	formation factor
GR	gamma ray log
V_g	grain volume
h	height above free water level
λ	lambda
J (sw)	leverett J-function
T_{ma}	matrix transit time
r_{50}	median pore throat size
a	Archie multiplier
C	compaction multiplier
NEU	neutron log
K	permeability
Ø	porosity

r_{35}	pore throat radius
P_f	pore filling minerals
PEF	photoelectric Factor log
r	radius of pore aperture as capillary tube
R_{sh}	resistivity of shale
n	saturation exponent
σ	surface tension
TS	thin section
τ	tortuosity
ΔT	transit time
Sgr	specific surface area for a porous media
Fs	shape factor
Sw	water saturation
V_{sh}	volume of shale
R_w	water resistivity
XRD	x-ray diffraction

ABSTRACT

An integrated petrophysical study for the Bahariya reservoir using bore hole logs and core data. The Bahariya formation has a high economic importance in north western desert as hydrocarbon bearing rocks which varies in origin and architecture from fluvio-marine to shallow marine sediments. It belongs to the Cenomanian (Upper Cretaceous) in age. North east Abu Gharadig fields NEAG-1, -2 and -3 exhibit structural and stratigraphic processes features characterizing the Bahariya reservoirs.

Both lithological and mineralogical variations are detected in the Bahariya reservoir rocks while, the laboratory measurements such as porosity, grain density, electrical resistivity, permeability and capillary pressure were carried out for 380 core sample showing wide petrophysical data ranges which requires more investigations related to pore spaces, storage capacity and flow capacity of the Bahariya formation. Thin sections and X-ray diffraction technique are carried out for fifty seven representative samples. Significance relations between pore filling mineralogy and both porosity and permeability are investigated and classified as permeability zonation according to total pore filling minerals.

Graphical method is used for characterizing the types of hydraulic flow units of Bahariya samples into four groups; each group is controlled by a certain volume of fluid flow and incremental pore sizes. High degree of heterogeneity on pore scale is indicated from mercury injection capillary pressure (MICP) measurements. The effective pore radius (r_{35}) calculated from MICP is investigated and correlated with the hydraulic flow units of the Bahariya reservoir providing type of fluid flow and size

of pore throats, A consistent relationship is calculated among porosity, permeability and pore throat size (r_{35}).

The electrical resistivity data of the Bahariya samples were obtained, while formation resistivity factor (F), cementation factor (m), cation exchange capacity (CEC), mounce potential (ϕ) and saturation exponent (n) were calculated. Significant relations between formation resistivity factor and both porosity and permeability are performed; while cation exchange capacity and mounce potential are found to be strongly dependent on clay filling minerals specially kaolinite. The saturation exponent (n) and cementation factor (m) are strongly correlated while unique interrelation is characterizing the Bahariya rocks for clean and shaley sands. Each type is identified by core samples or by studying open hole logs on the way to evaluate and interpret the hydrocarbon potentiality from electrical resistivity measurements.

The hydraulic conductivity of the studied Bahariya samples characteristic of pore system is classified into micro-pores, meso pores and macro pores as per Winland classification. Coefficients of correlation of micro-meso pores and macro pores showed clear differences in porosity, permeability, residual oil saturation and pore throat radius (r_{35}) which are used to address the water saturation in transition zone function of the capillary pressure.

Coefficients of both hydraulic and electrical conductivity are identified while several mathematical formulas have been developed to predict some petrophysical parameters showing the higher coefficient of correlations. The obtained formulas can be used for predicting the permeability from bore hole logs and characteristics of net pays

thicknesses, reservoir quality and electro-facies. They calibrated from enhanced bore hole images for high shale content streaks.

The workflow in the present work is helpful to start the evaluation process with porosity and permeability to provide the other parameters as formation resistivity factor (F), cementation factor (m), saturation exponent (n) and interpret the hydrocarbon potential to fulfill a robust capillary and bound water calculation. Many petrophysical models have been performed to be used for reservoir evaluation and characterization.

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