

CEMENTATION FACTOR AND CARBONATE FORMATION PROPERTIES  
CORRELATION FROM WELL LOGS DATA FOR NASIRIYA FIELD

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CORRELATION FROM WELL LOGS DATA FOR NASIRIYA FIELD

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**DEDICATION**

*To almighty Allah (SWT), for the favours granted me throughout the course of my studies*

*And to my parents, for their blessing, and my dearest wife, for her patience and endurance for supporting me from the beginning to the end of my stud*

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## ABSTRACT

The cementation factor has specific effects on petrophysical and elastic properties of porous media. A comprehensive investigation of carbonate rock properties which have an interlock with the cementation factor was done through core analysis and well log data. Five wells in Nasiriya oilfield, which is one of the giant fields consists of the carbonate reservoirs in the Middle East were used in this study. The study was made across the Mishrif and Yamamma carbonate formations in the Nasiriya oilfield. Neurolog software (V5, 2008) was used to digitize the scanned copies of available logs while Interactive Petrophysics software (IP V3.5, 2008) was used to determine the properties of studied formations. The average cementation factor values were calculated from the *F-PHI* plot and Gomez methods and compared with Pickett method. Petrophysical and dynamic elastic properties were determined from well logs. In this study, a new approach was introduced to obtain correlations of cementation factor to petrophysical and dynamic elastic properties of Mishrif and Yamamma formations. An artificial neural network platform was used to determine these correlations depending on the determined properties of studied formations. The neural network model used two different training algorithms; Gradient Descent with Momentum and Levenberg–Marquardt. Results show that the plot of average core data and calculated data from IP software of porosity and permeability gave a good correlations coefficient of  $R^2 = 0.86034$  to  $0.94303$ . Generally, cementation factor values obtained from all methods are found to be less than two. In addition, cementation factor values also increased with increasing depth of the studied formations. An efficient performance and excellent prediction of cementation factor have been obtained with less than  $10^{-4}$  and  $10^{-8}$  mean square error from both artificial neural network models. Three saturation models were used to estimate water saturation of carbonate formations, which are simple Archie equation, dual water model and Indonesian model. The Indonesian water saturation model recorded the lowest percentage error in comparison with water saturation of core samples, and the water saturation in Yamamma formation was higher than in the Mishrif formation. The accurate determination of a cementation factor gives reliable saturation results.

## ABSTRAK

Faktor penyimenan mempunyai kesan yang spesifik terhadap sifat-sifat petrofizik dan sifat-sifat keanjalan media berliang. Kajian menyeluruh terhadap sifat-sifat batuan karbonat yang saling mengunci dengan faktor penyimenan telah dilaksana menggunakan data analisis teras dan log telaga. Lima buah telaga di medan minyak Nasiriya, yang merupakan satu daripada medan gergasi yang terdiri daripada reservoir karbonat di Timur Tengah telah digunakan dalam kajian ini. Kajian dilakukan merentasi formasi karbonat Mishrif dan formasi karbonat Yamamma di medan minyak terbabit. Perisian Neurolog (V5, 2008) telah diguna untuk mendigitkan salinan log. Perisian Petrofizik Interaktif (IP V3.5, 2008) pula diguna untuk menentukan sifat-sifat formasi yang dikaji. Purata nilai faktor penyimenan dikira daripada plot  $F-PHI$  dan kaedah Gomez, dan seterusnya dibandingkan dengan kaedah Pickett. Sifat-sifat petrofizik dan sifat-sifat keanjalan dinamik ditentukan daripada log telaga. Dalam kajian ini, suatu pendekatan baharu telah diperkenalkan untuk memperoleh korelasi antara faktor penyimenan dengan sifat-sifat petrofizik dan sifat-sifat keanjalan dinamik formasi Mishrif dan formasi Yamamma. Suatu platform rangkaian neural tiruan diguna untuk menentukan korelasi ini yang bergantung kepada sifat-sifat formasi kajian yang dikaji. Model rangkaian neural terbabit menggunakan dua algoritma latihan yang berbeza; Turun Cerun dengan Momentum dan Levenberg-Marquardt. Hasil kajian menunjukkan bahawa plot data purata keliangan dan kebolehtelapan teras dan data keliangan dan kebolehtelapan yang dikira daripada perisian IP menghasilkan pekali korelasi yang baik, iaitu  $R^2 = 0.86034-0.94303$ . Nilai faktor penyimenan yang diperoleh daripada semua kaedah adalah kurang daripada dua. Nilai ini meningkat dengan bertambahnya kedalaman formasi yang dikaji. Prestasi yang efisien dengan ramalan faktor penyimenan yang baik berjaya diperoleh daripada kedua-dua model rangkaian neural tiruan, dengan masing-masing ralat min kuasa dua adalah kurang daripada  $10^{-4}$  dan  $10^{-8}$ . Tiga model ketepuan digunakan untuk menganggar ketepuan air dalam formasi karbonat, iaitu persamaan ringkas Archie, model air duaan, dan model Indonesia. Model Indonesia mencatatkan peratusan ralat yang paling rendah berbanding dengan ketepuan air daripada sampel teras, dengan ketepuan air dalam formasi Yamamma adalah lebih tinggi daripada formasi Mishrif. Penentuan faktor penyimenan yang jitu boleh menghasilkan ketepuan yang tepat.

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## LIST OF SYMBOLS

$a$	-	Tortuosity factor
$A_c$	-	Total cross sectional area
$B$	-	Bias value
$B.C$	-	Biot's constant
$c$	-	Fitting parameter
$C_b$	-	Bulk compressibility
$C_e$	-	Clay conductivity
$C_\sigma$		Conductivity of the fully brines saturated rock
$C_r$	-	Rock matrix compressibility
$C_t$	-	Conductivity of non – invaded zone
$C_w$	-	Conductivity of formation water
$C_{wb}$	-	Conductivity of bound water
$C_{we}$	-	Equivalent conductivity of the waters in pore space
$C_{LLD}$	-	Conductivity of the deep logs
$C_{LLS}$	-	Conductivity of the shallow logs
$d_i$	-	Diameter invasion
$DT$	-	Interval transit time
$E$	-	Young modulus
$F$	-	Formation resistivity factor
$F_S$	-	Apparent formation resistivity factor from sonic log
$F_{xo}$	-	Apparent formation resistivity factor in flushed zone

$f$	-	Activation function
$g$	-	Gradient of error surface
$GR_{min}$	-	Minimum gamma ray response (API unit)
$GR_{max}$	-	Maximum gamma ray response (API unit)
$H_1$	-	Hydrogen index, mineral 1
$H_2$	-	Hydrogen index, mineral 2
$H_{mf}$	-	Hydrogen index, mud filtrate
$I_{sh}$	-	Shale index
$I$	-	Number of neuron of input layer
$J$	-	Number of neuron of first hidden layer
$K$	-	Permeability
$K_n$	-	Number of neuron of second hidden layer
$K_B$	-	Bulk Modulus
$L$	-	Actual length of the core
$Le$	-	Length of the conducting channel
$m$	-	Cementation factor
$n$	-	Saturation exponent in Archie equation
$N$	-	Time step
$n^*$	-	Archie saturation exponent for shaly sands
$P$	-	Neural Network input vector
$P_c$	-	capillary pressure
$P_d$	-	Displacement pressure
$PR$	-	Poisson's ratio
$q$	-	Flow rate
$Q_v$	-	Cation exchange capacity in meq/ml pore volume
$R_{deep}$	-	Formation resistivity from deep resistivity log device
$R_{t_{irr}}$	-	Formation resistivity at irreducible water saturation
$R_{LLD}$	-	Resistivity deep Laterolog tool



$R_{LLS}$	-	Resistivity shallow Laterolog tool
$R_{mfe}$	-	Equivalent resistivity of mud filtrate
$R_{msfl}$	-	Formation resistivity from micro-spherical log device
$R_{MSFL}$	-	Resistivity from micro-spherical tool
$R_O$	-	Resistivity of the fully brine saturated rock
$RP$	-	Effective pore radius
$R_{SFL}$	-	Resistivity from spherical focus log
$R_{sh}$	-	Shale resistivity
$R_t$	-	True formation resistivity with water saturation $S_w$
$R_w$	-	Formation water resistivity
$R_{wa}$	-	Apparent formation water resistivity
$R_{we}$	-	Equivalent resistivity of formation water
$R_{xo}$	-	Flushed zone resistivity
$R_Z$	-	Resistivity water in invaded zone
$S_w$	-	Water saturation (fraction of pore volume)
$S_{WE}$	-	Effective water saturation
$S_{wb}$	-	Bound water saturation
$S_{wi}$	-	Irreducible water saturation
$S_{WT}$	-	Total water saturation
$S_{xo}$	-	Water saturation in flushed zone
$T_1, T_2$	-	Temperatures (°F)
$T_f$	-	Formation temperature (°F)
$T_O$	-	Surface temperature
$T_{pl}$	-	Measured values of propagation time (dB/m)
$T_{pm}$	-	Matrix propagation time (dB/m)
$T_{pw}$	-	Water propagation time (dB/m)
$ts$	-	Pore shape factor
$V_{cl}$	-	Clay volume

$V_{dcl}$	-	Dry clay volume
$V_p$	-	Compressional velocity
$V_s$	-	Shear wave velocity
$V_{sh}$	-	Shale volume
$V_w$	-	Bulk volume of formation water.
$V_{wb}$	-	Bulk volume of bound water.
$w$	-	Weight value
$z$	-	Number of neuron of output layer

### GREEK SYMBOLS

$\rho_b$	-	Bulk density log reading
$\rho_D$	-	Bulk density
$\rho_g$	-	Grain density gm/cc
$\rho_m$	-	Mud density (lb/gal)
$\rho_{ma}$	-	Apparent matrix density
$\rho_{mf}$	-	Mud filtrate density
$\gamma$	-	Gamma ray index bulk density ( $\rho_D$ )
$\Delta t$	-	Interval Transit Time
$\Delta t_f$	-	Fluid transit time $\mu\text{sec}/\text{ft}$
$\Delta t_{ma}$	-	Apparent matrix transit time $\mu\text{sec}/\text{ft}$
$\Delta t_p$	-	Compressional transit time $\mu\text{sec}/\text{ft}$
$\Delta t_s$	-	Shear wave transit time $\mu\text{sec}/\text{ft}$
$\sigma$	-	Interfacial Tension
$\delta$	-	Backpropagation error
$\eta$	-	Learning rate

**LIST OF ABBREVIATIONS**

API	-	American Petroleum Institute
ANN	-	Artificial Neural Network
BHT	-	Bottom Hole Temperature
Bp	-	Back propagation
BVW	-	Bulk Volume Water
CEC	-	Cation Exchange Capacity
CMR	-	Compensating Magnetic Resonance
CNL		Compensated Neutron Log
GrC	-	Corrected Gamma Ray
CPI	-	Computer Processed Interpretation
DST	-	Drill Stem Test
FCL-CL	-	Ferro Chrome Lignite - Chrome Lignite
F-Foc	-	Resistivity formation factor from Focke method
FFNN	-	Feed Forward Neural Network
F-Gom	-	Resistivity formation factor from Gomez method
EPT	-	Electromagnetic Propagation Tool
FDC	-	Formation Density Compensated
GR	-	Gamma Ray
GUI		Graphical User Interfaces
ILD	-	Deep Induction Laterolog

ILDC	-	Corrected Induction Laterolog
INOC	-	Iraqi National Oil Company
IP	-	Interactive Petrophysics
$K_{CORE}$		Permeability from Core Samples
$K_{CPI}$		Permeability from Computer Processed Interpretation
K-SLB	-	Permeability from Schlumberger model
K-Timur	-	Permeability from Timur model
LDT	-	Litho- Density Log
m-DE	-	Cementation factor from ANN model for dynamic elastic
m-Pet	-	Cementation factor from ANN model for Petrophysics
m-Foc	-	Cementation factor from Focke method
m-Gom	-	Cementation factor from Gomes Iteration
MD	-	Measured Depth
MSE	-	Mean square error
MSFL	-	Micro Spherical Focused Log
MSFLC	-	Corrected Micro Spherical Focused Log
NGR	-	Natural Gamma Ray
NMR	-	Nuclear Magnetic Resonance
PHI		Total porosity
NPHI	-	Neutron Porosity log
NPHIC	-	Corrected Neutron Porosity log
$NPHI_{clay}$		Neutron log reading in 100% shale
OWC	-	Oil Water Contact
$PHI_{CPI}$	-	Porosity from computer processed interpretation
$PHI_{CORE}$	-	Porosity from core samples
PHID	-	Porosity from density log
$PHI_{DN}$		Porosity from density – neutron cross plot
$PHID_{sh}$		Apparent density porosity in 100% shale

PHIE	-	Effective porosity
PHI <sub>EPT</sub>		Porosity from EPT – log
PHIS	-	Porosity from sonic log
PHIX	-	Porosity from neutron -density log
PSP	-	Pseudo Spontaneous Potential
RFT	-	Repeated Formation Tester
RHOB	-	Bulk Density
RHOBC	-	Corrected Bulk Density
RTKB	-	Rotary Table Kelly Bushing
SFL	-	Spherical Focused Log
SNP	-	Side-well Neutron Porosity
SP	-	Spontaneous Potential
SSP	-	Static Spontaneous Potential
Sw-Arch	-	Water saturation from Archie model
Sw-Dual	-	Water saturation from Dual water model
Sw-Ind	-	Water saturation from Indonesian model
Sw-Sim	-	Water saturation from Archie model
TVD	-	True vertical depth
VCL-GR	-	Clay volume from gamma ray log
VCL-N	-	Clay volume from neutron log
VCL-ND	-	Clay volume from neutron-density log
VCL-R	-	Clay volume from resistivity log
VCL-SD	-	Clay volume from sonic-density log
VCL-SP	-	Clay volume from spontaneous log
V.R	-	Input compressional-shear wave velocity ratio in the ANN model
V <sub>p</sub> /V <sub>s</sub>	-	CPI compressional-shear wave velocity ratio

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## CHAPTER 1

### INTRODUCTION

Carbonate rocks reservoirs usually consist of various kinds of grains, lime mud, and carbonate cement. A petroleum carbonate reservoir is a porous medium that is sufficiently permeable to permit fluid flow through it. In the presence of interconnected fluid phases of different density and viscosity, such as water and hydrocarbons, the movement of the fluids is influenced by gravity, viscosity and capillary forces. The fluids separate, therefore, in order of density when flowing through a permeable stratum is arrested by a zone of low permeability, and, in time, a petroleum reservoir is formed in such a trap (Peters, 2011).

In petroleum carbonate reservoirs; there are many forms of heterogeneity in rock properties. Petrophysical parameters such as; porosity, permeability, cementation factor, resistivity formation factor and fluid saturation are the most important parameters for evaluating oil reservoirs in order to estimate the original oil in place and flow patterns to optimise production of a reservoir. The evaluation of logging data in most carbonate reservoirs still a challenging task in the present days which need to specify of efforts and capitals to avoid incorrect interpretation (Kadhim *et al.*, 2015). The incorrect interpretation leads to lost hydrocarbon zones or incorrect selection for the perforated intervals, as a result, lost time and money.

Middle East carbonate reservoirs contain giant oil and gas reservoirs, since their reserve are more than 500MMbbl (Bia and Xu, 2014), such as Mishrif, Yamamma, Shu'aiba, Asmari, Ilam and Sarvak, which cover around 50% percent of hydrocarbon reserves in the world (Naomi and Standen, 1997). This ratio will increase when reservoirs in other regions are depleted, and then the Middle East



carbonate formations will become the main resource of oil and gas reserve (Kadhim *et al.*, 2013). After World War I, carbonate reservoirs became important to the petroleum industry, when exploration drilling resulted in the discovery of major oil reserve in carbonate rocks in the Middle East (Chilingarian *et al.*, 1992).

Fluid flow through heterogeneous carbonate reservoirs is a substantially different process from the flow through the less heterogeneity sandstone reservoir. This variation is largely cause to the fact that carbonate rocks tend to have a more complex pore system (i.e the interrelationships among depositional lithologies, the geometries of depositional facies, and diagenesis) than sandstone (Chilingar *et al.*, 1979; Mazullo, 1986; Xu *et al.*, 2012). Carbonate reservoirs have highly heterogeneous layers in nature. Therefore, on the basis of the dominant rock type carbonate reservoirs are divided into layers in order to define average values and trends of petrophysical parameters in these reservoirs (Kadhim *et al.*, 2013).

Archie in 1942 is the first researcher, who had discernment for the porosity exponent ( $m$ ). Archie introduced an empirical relationship between porosity, and formation resistivity factor ( $F$ ), the porosity exponent used in the description of this correlation that could has a valuable application to quantitative studies of electrical well logs. Physically, the  $m$  factor is a measure of the degree of cementation and consolidation of the rock. Therefore, it is called cementation factor (Guyod, 1944). The  $m$  factor is the most important parameter for applying the petrophysical characterization, because its effect on the calculation of water saturation ( $S_w$ ),  $F$  factor, tortuosity ( $a$ ) of the pore geometry to current flow, surface area of composite particles, and porosity (Ransom, 1974; Ransom, 1984; Polido *et al.*, 2007).

Water saturation interpretation from conventional logs are encountered many difficulties that lead to misleading of information such as; the impact of diagnosis and rock wettability variations in Archie's parameters ( $m$ ,  $n$ , and  $a$ ) is difficult to quantify throughout the reservoir, and errors in reading of logging tools due to high environmental impact while drilling and run logging tools in open whole sections (Cassou *et al.*, 2007; Liu and Ford, 2008).

The accurate calculations of petrophysical and dynamic elastic properties in carbonate formations are the most challenging aspects of well log analysis. Many empirical correlations and equations have been derived and developed over the years based on known physical principles, which are used to find carbonate rock properties (Archie, 1942; Coates and Dumanoir, 1973; Hagiwara, 1984; Watfa and Youssef, 1987; Salazar *et al.*, 2008; Kadhim *et al.*, 2015). Practically, the formation water resistivity ( $R_w$ ) estimates from spontaneous potential (*SP*) log. Deep induction log (*ILD*) or deep lateral log (*LLD*) usually measured the true resistivity of the formation ( $R_t$ ). Density, neutron, and sonic logs are used to calculate the porosity. Well logs and core data analysis can be used to estimate the saturation exponent ( $n$ ) and cementation exponent. There are many correlations were developed to calculate permeability ( $K$ ) from porosity logs (Lucia, 2007; Peters, 2011).

Depositional carbonate rocks consist mainly of loose irregular calcite grains, during deposition of carbonate rocks, there are many physical and chemical processes will take place over time that will change these rocks. One of the most important processes that take place during deposition is called cementation. Cementation will significantly influenced the compressional and shear wave velocities and other dynamic elastic properties of carbonate rocks. In addition cementation also impacts the grain surface and the grain contacts will become stiffer sediment. The compressional and shear wave velocities can be determined by interval transit time (*DT*) from the sonic logs. The dynamic elastic properties; Bulk modulus, Young modulus, and Biot's Constant can be determined when the compression wave velocity ( $V_p$ ) and corrected bulk density values are available (Entyre, 1989; Lucia, 2007; Jackson, *et al.*, 2008; Kadhim *et al.* 2013).

Due to complexity and highly nonlinearity of carbonate reservoirs properties as well as there are many input variables related cementation factor with petrophysical and dynamic elastic properties, no close mathematical model that can describe the behaviour of this relationship. Artificial neural networks (*ANN*) technique has been implemented, because of their cost - effective, easy to understand and ability to learn from examples, which found in many applications to estimate variable that usually cannot be measured in linear modelling (Amnah, 2009). The *ANN* has become increasingly popular in the petroleum industry. Many

practical applications of the *ANN* have been used for quantitative analysis of reservoir properties from well logs (Huang *et al.*, 1996; Huang and Williamson, 1997; Zhang *et al.*, 2000), where the *ANN* approach is shown to be a simple and accurate alternative for converting well logs to common reservoir properties such as porosity and permeability.

Overall, due to the large variation of petrophysical and dynamic elastic properties of carbonate reservoirs, petrophysical evaluation of these reservoirs is important in predicting their behaviour. Well logs are considered one of the main sources of data for the geological and petrophysical parameters of reservoir formations. Cementation factor is one of the most important parameters because the accurate determination of it should be improved the saturation value and consequently oil in place calculation.

## 1.1 Problem Statements

The value of  $m$  factor has been assumed constant for each type of rocks in numerous studies of formation evaluation (Kadhim *et al.*, 2013). Previous studies of the Nasiriya (*NS*) oil field too, assumed the  $m$  factor is constant with depth, that increases the uncertainty in calculating water saturation value, and as a result there was a mistake of hydrocarbon reserve calculation, as well as inaccurate detection of perforation zones.

Since carbonate reservoirs are heterogeneous in nature, therefore the behaviour of petrophysical and elastic properties of these reservoirs is a high non-linear. The correlation between cementation factor and petrophysical properties of carbonate reservoirs such as;  $K$ ,  $PHI$ , and  $F$  factor is provided in this study based on the conventional well logs, analysis of core samples data, and *NS* oilfield reports. Moreover, a new interpretation approach for the relation between dynamic elastic properties for instance; compressional-shear velocity ratio ( $V_P/V_S$ ), Poisson's Ratio ( $PR$ ), Bulk modulus ( $K_B$ ), Young's modules ( $E$ ), and Biot's Constant ( $BC$ ) is introduced using *ANN* platform.

The artificial network model is used as an efficient technique as predictor, especially in carbonate formations when the nature is complex and highly non-linearity, that cause no close conventional mathematical model can describe the behaviour of this process without assumptions. Furthermore, the model can be considered faster by integrating graphical user interfaces (*GUI*) and more accurate by added mean square errors calculations in comparison with traditional ones such as Gomes and Pickett methods.

## 1.2 Objectives of Study

1. To determine petrophysical properties of carbonate formations from well logs data and compare with available core data results.
2. To determine the dynamic elastic properties of carbonates formation from sonic log data.
3. To calculate cementation factor for various depth of formation by using Pickett, Gomez and *F-PHI* plot methods.
4. To determine new correlations between the cementation factor and petrophysical and dynamic elastic properties for carbonates formation by using a new approach of *ANN* model.
5. To determine the water saturation for various depth of carbonate formation from Archie, dual water and Indonesian models.

## 1.3 The Scope of Study

1. Mishrif and Yamamma carbonate formation of the *NS* oilfield are used as a case study. Available well logs and core data are provided from five studied wells in this field.

2. Convert the available copies of logs to digitals using Neura-log software (NL, V5, 2008) and validated using Origin Pro8 software based on correlation coefficient ( $R^2$ ) and standard error ( $SE$ ).
3. Interactive Petrophysics software (IP V3.5, 2008) was used to determine the petrophysical and dynamic elastic properties of the carbonate rocks in the studied area, and validated with properties from core data.
4. Gomez and  $F$ - $PHI$  plot methods were used to determine the cementation factor for the studied carbonate formation, and compared and validated with Pickett method.
5. An Artificial neural network model was trained using Gradient Descent with Momentum and Levenberg – Marquardt algorithms.
6. An artificial neural network model was used to develop a new correlation between cementation factor and petrophysical properties ( $K$ ,  $PHI$ , and  $F$ ) and with dynamic elastic properties ( $V_P/V_S$ ,  $PR$ ,  $K_B$ ,  $E$  and  $BC$ ) of the studied carbonate formation and compared with Pickett method.
7. Mean square error ( $MSE$ ) and correlation coefficient ( $R^2$ ) were used to determine the cementation factor prediction performance by  $ANN$  model, and compared with previous studies, such as (Aifa *et al.*, 2014; saljooghi and hezarkhani, 2014)
8. Three water saturation models (Archie, dual water and Indonesian) were used to determine water saturation in various depths of the studied carbonate formation, and validated with saturation data from core samples.

#### **1.4 Significance of Research and Contributions of the Present Study**

Cementation factor is one of the most important parameters, which has the specific effect to rock properties. Therefore, the accurate determination of this factor should be improved the accuracy of water saturation values, and consequently oil in place calculation. Moreover, accurate determination of water saturation profile with depth leads to avoiding mistakes in the detecting of perforation zones, that means save money and time. The contribution to be made in this study involves:

1. With a new developed correlations between cementation factor and carbonate rock properties, more accurate formation cementation factor can be determined by knowing the carbonate reservoirs petrophysical and dynamic elastic properties.
2. More accurate water saturation for various depths of carbonate formation can be determined.
3. Establishment of a new and more accurate petrophysical and dynamic elastic properties data for studied formation.
4. Developed an artificial neural network model can be used to establish the cementation factor from properties of carbonate formation by using graphical user interfaces (*GUI*).

## **1.5 Area of Case Study**

NS oil field is located on the Arabian platform, in a gently folded zone, west of the Zagros fold belt as shown in Figure 1.1. A thick platform (Yammama formation) develops in the north of Arabian Gulf, passing to north-east to Balambo formation. During Barremian, the erosion of the Arabian shield introduced a lot of clastic sediments (Zubair formation) into the basin, invading part of the former shelf area. After the widespread deposition of anhydrite facies (Hartha formation.), carbonate depositional conditions re-establish in response to generalized transgressed events.

The last sedimentary cycle is represented by shallow shelf limestone (Shuaiba formation) gradually passing eastward to basin deposits where shale and marl accumulate (Sarmond formation). NS-1, NS-2, NS-3, NS-4, and NS-5 are studied wells in the NS oil field which is considered as a giant oil field in the southern of Iraq as shown in Figure 1.2. Also, it is characterized by carbonate reservoirs. NS oil field has reserves in Late Cretaceous Mishrif limestone reservoir, and Early Cretaceous Yammama limestone reservoir as shown in Figure 1.3, (Repsol Company, 2008). Mishrif reservoir contains water oil contact (*WOC*) at depth 2064m, while in Yammama formation, the *WOC* at depth 3390m (INOC,

1985). The lithological column of the NS oil field is provided by Iraqi National Oil Company (INOC) in 1985, in the final drilling report of the NS-3 oil well as shown in Table 1.1.



**Figure 1.1** : Satellite images for NS oil field location



**Figure 1.2** : Location maps of the studied wells

**Table 1.1** : Lithological column from the Sulaiy to Upper Faris formations in the NS-3, (INOC, 1985)

No	Formation	Top (m)	Bottom (m)	Main Lithology	Thickness (m)
1	Upper Fars	surface	296	Mudstone and sandstone	296
2	Lower Fars	296	376	Shale and anhydrite	80.0
3	Gereibi	376	426	Dolomite and anhydrite	50.0
4	Dammam	426	667	Limestone, dolomite and anhydrite	241
5	Russ	667	732	Anhydrite and dolomite	65.0
6	Umm Rradhuma	732	1174	Anhydrite and dolomite	441
7	Tayarat	1174	1244	Dolomite	70.0
8	Shiranish	1244	1443	Shale and limestone-clayey	199
9	Hartha	1443	1625	Limestone and dolomite	182
10	Sa'di	1625	1790	Cretaceous-limestone	165
11	Tannuma	1790	1862	Shale	72.0
12	Khasib	1862	1910	Shale-clayey	48.0
13	Kifl	1910	1929.5	Shale-clayey	19.5
14	Mishrif	1929.5	2101	limestone	171.5
15	Rumaila	2101	2148	Limestone-clayey	47.0
16	Ahmadi	2148	2251.5	Shale and clay	103.5
17	Maudud	2251.5	2412	Cretaceous-limestone	160.5
18	Nahr Umr	2412	2529.5	Shale, limestone and sand	117.5
19	Shu'aiba	2529.5	2592	Dolomite	62.5
20	Zubair	2592	3097	Sandstone and some shale	505
21	Ratawi	3097	3197	Limestone-clayey and some shale	80.0
22	Yammama	3177	3403.5	Limestone	226.5
23	Sulaiy	3403.5	3440.5	Limestone	17.5



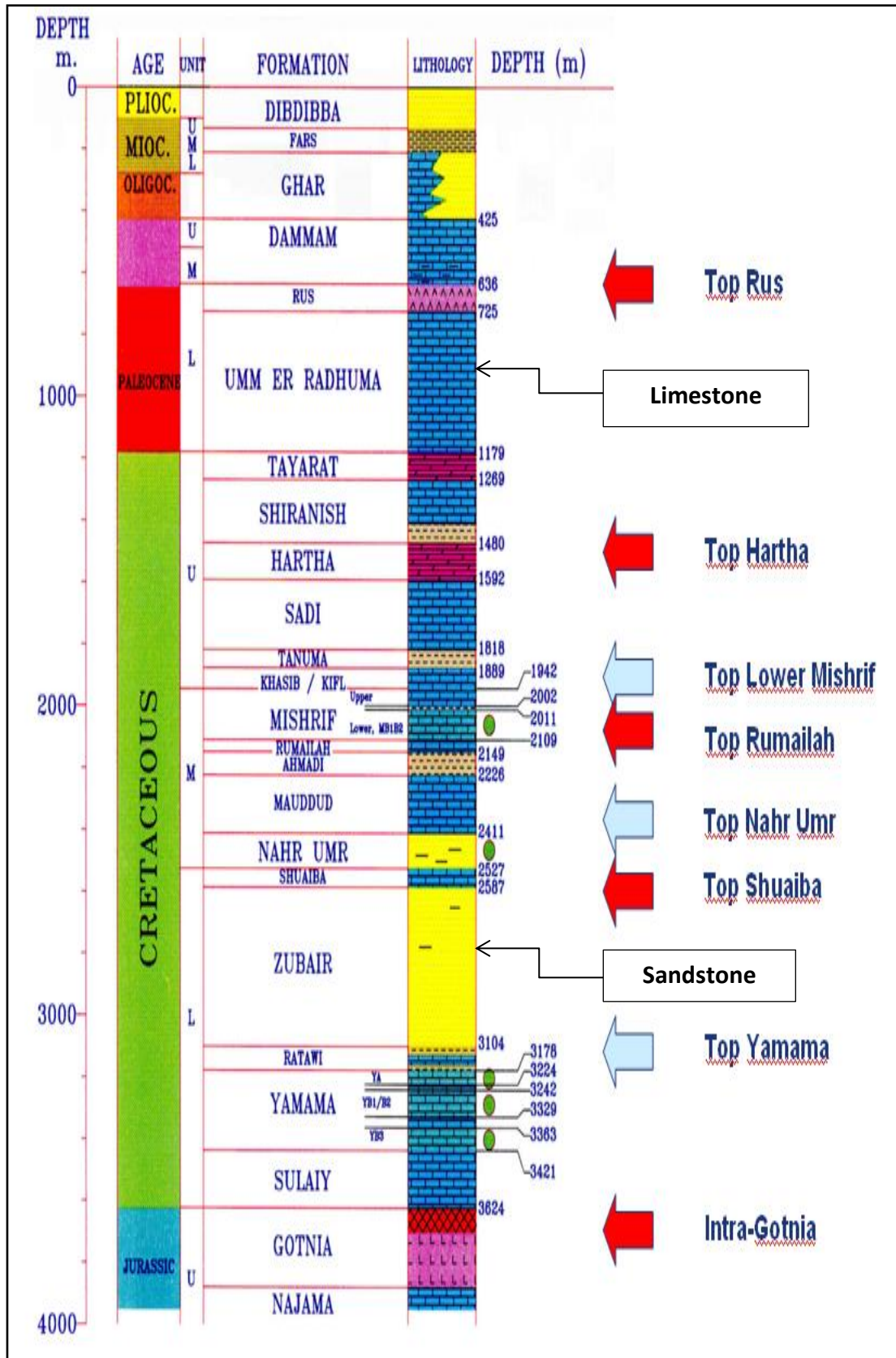


Figure 1.3 : Stratigraphy of NS oil field formations (Repsol Company, 2008)

## 1.6 Thesis Outlines

The present thesis is divided into five chapters. Chapter 1 describes a background of the study and motivation of the research is being explained to give a basic overview of the problem statement, research objectives, significant, contribution and scope of the study. This chapter also explains the area of the case study. Chapter 2 reviews the cementation factor, petrophysical and dynamic properties and their calculations. The theory and application of artificial neural are also proposed in this phase. Previous studies of correlations between cementation factor and porosity, resistivity formation factor, permeability, and acoustic velocities are introduced in this chapter.

Chapter 3 shows the research methodology diagrams and the steps of parameters calculation as well as structure of artificial neural network model. Chapter 4 illustrates the results and discussion of petrophysical properties, cementation factor, dynamic elastic properties, and water saturation. The cementation factor calculation from petrophysical and dynamic elastic models are introduced by *ANN* technique, and the verification of results has been done in each step of the calculation. This is followed by the conclusion and recommendations of future works in Chapter 5.

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