

## "Reservoir Characterization and Management, Role and Contribution in Improving Hydrocarbon Productivity Zeit Bay Field – Gulf of Suez, Egypt"

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### Summary :

The study aims to describe how different geological and petrophysical data sets were integrated to describe the Reservoir Units of any field. In this study the authors emphasized on describing the Carbonate Reservoir Characterization Model of the Kareem / Rudeis Carbonate Reservoir Zeit Bay field, Gulf of Suez, Egypt. The concepts depositional environment, faulting, and original truncation ..... etc for Zeit Bay Field had been used. Also, the study aims to assign likely porosity and permeability values and ranges for Carbonates zones. Outputs from this study were used to characterize and set development scheme for the Carbonate Reservoir.

### Introduction :

Reservoir characterization plays an important role in defining, in a comprehensive manner, the details distribution of reservoir rocks and fluids content with the ultimate goal of a reservoir management scheme. Reservoir management aims to provide facts, information and knowledge necessary to control production operations and to optimally develop any oil field by obtaining the maximum possible economic recovery from the reservoir units. The reservoir characterization model embodies the integration of the technical disciplines of the exploration, reservoir engineering production and financial and usually accomplishes prior to or contemporaneously with the development phase of the oil field. Existing test and production data are also used to develop a better understanding of reservoir dynamics and to improve the depositional model of the reservoir.

The Modeling helps in:

- 1) Maximizing the profitability from the hydrocarbon reserves.

- 2) Identifying the reservoir unit that predicts the content and the production behavior of wells.
- 3) Matching the past reservoir performance and predict the future performance.
- 4) Formulating a plan for the development of the reservoir units in the field.

### General Outline about Zeit Bay Field :

Zeit Bay field is an oil field located in the southwestern offshore part of the Gulf of Suez, some 65 km north of Hurghada and 85 km south of Ras Gharib. The field extends to the onshore and is combined with General Petroleum Company's Bahar North –East field. (fig.1)



Fig (1) Zeit Bay Location Map

The field was discovered in June 1981 through the drilling of the Exploratory well "QQ 89-1" which was drilled in the crestal part of the structure and considered as gas producer well. In October, 1981 another well "QQ 89-2" was drilled 2 km south and down dip from well QQ 89-1. This well recorded the underlying oil-leg with an oil water contact at 4850 feet sub-sea.

Structurally, Zeit Bay field is interpreted as a NW–SE basement relief like anticline feature. This anticlinal feature is however, dissected into several fault block panels by two main fault systems. A set of NW–SE trending faults affecting the western and eastern flanks. Another set of W–NW/E–SE trending fault system affecting the northeast flank. Some of these faults die out at/ or near top Belayim except the extreme bounding faults. In addition to the northeast and southwest blocks there are a parallel narrow elongated rectangular high blocks down stepping away from the above triangular horst blocks. (fig.2 & 3)

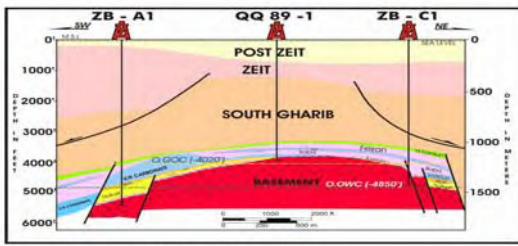


Fig (2) Main Geological Cross Section of Zeit Bay Field

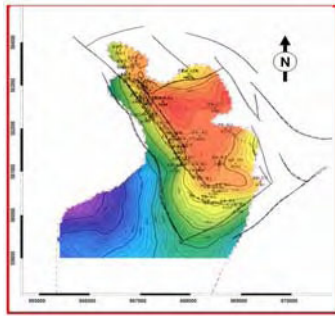


Fig (3) Structure Contour Map on Top Kareem/Rudeis

The stratigraphic succession of the field is similar to the sequences presented elsewhere in the southern part of Gulf of Suez basin. The field is characterized by the presence of two different types of Miocene facies. These Miocene sediments are unconformably underlain by Paleozoic to Mesozoic Sandstone of Nubia facies which cover unconformably the Pre-Cambrian basement rocks. (fig.4)

AGE	FORMATION	LITH.	AVER. THICKNESS IN FEET	LITHOLOGIC DESCRIPTION
HOLOCENE	POST ZEIT		200 - 400	SAND WITH CLAY STRIATA
	ZEIT		1000 - 2000	ALTERNATING SAND, SHALES AND SANDSTONE
UPPER MIOCENE	SOUTH GHARIB		2000 - 2300	SALT WITH SANDSTONE AND TIER SHALES
	H. FARAFRAUN		20 - 140	LIMONITE SANDS
	YEMAM		30 - 200	SANDSTONE
LOWER MIOCENE	KAREEM/RUDEIS		50 - 600	PRODOMINANTLY CARBONATES UPPER PART SANDSTONE LOWER PART SANDSTONE LITHOLOGICALLY UNSTABLE
	BASAL MIOCENE		25 - 100	SOLVENTIC SANDS (SH)
	NUBIAN SANDSTONE		50 - 400	SANDSTONE, MASSES, FACULATIC
PALEOZOIC	BEACHED		10 - 50	BASINMENT WELLS
	FRACTURED			SHALTS AND NO. LIT. PLTING SHALES, SANDSTONES, SANDSTONES, SANDSTONES

Fig (4) Generalized Stratigraphic Coloum of Zeit Bay Field

Oil-in-place is mainly localized over the western flank of the field comprising several reservoir units in complete hydraulic communication, making it one of the unique reservoirs. Hydrocarbons are produced from all the porous and permeable intervals from Belayim Formation down to Pre-Cambrian fractured basement. (fig.5)

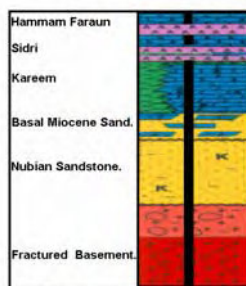


Fig (5) Reservoir Units of Zeit Bay Field

The commercial field production has been started in December 1983 with average daily rate 20000 BOPD and reached with the maximum rate at 80.000 BOPD in 1986. Nowadays, the daily production is about 10.000 BOPD (fig.6)



Fig (6) Zeit Bay Field Performance (From 1983 To 2003)

### GEOLOGICAL EVALUATION:

The Kareem/Rudeis carbonates reservoir is volumetrically the largest reservoir unit in the field, containing approximately 50% of the total reserves. An oil rim map for Kareem/Rudeis carbonate has been constructed (fig.7).

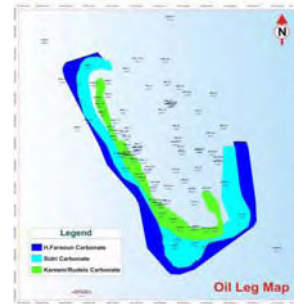


Fig (7) Oil Rim Map for Carbonates of Zeit Bay Field

This Map shows that the most of the current oil reserves are located in the south of the field and along the western edge of the main field structure assuming the field fluid contacts as 4200 and 4500 ft.TVDss for gas and oil contacts respectively.

The Kareem/Rudeis carbonate reservoir overlies the Basal Miocene sand. It attains a maximum thickness of 600 ft. and pinches out laterally on the crestal part of the structure. The Belayim evaporites form the vertical seal of the carbonates. The Kareem/Rudeis strata show deep water shales on the flanks and carbonate on the crest (fig.8).

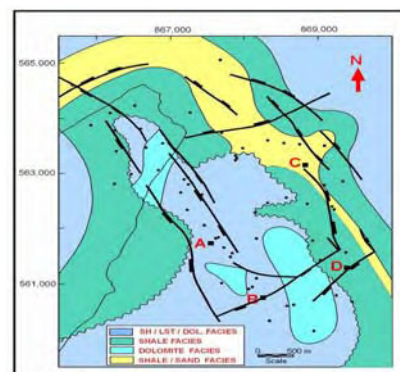


Fig (8) Kareem/Rudeis Facies Map

The Geological evaluation is based on the mapping and Petrographical examination of the cored intervals of Kareem/Rudeis Carbonates. This examination revealed that this reservoir is largely determined by diagenetic controls. The sediments were originally limey and with varying contents of skeletal debris.

### Petrographical Analysis

The Petrographical analysis divided this carbonate into **Four zones** (from top to bottom) as follows:-

#### 1) Zone I:- Wackstone - Packstone (Foraminiferal Limestone)

This facies is recorded in the upper part of Kareem/Rudeis Carbonate and consists of organic fossil remains embedded within lime mud matrix (micrite). (fig.9)

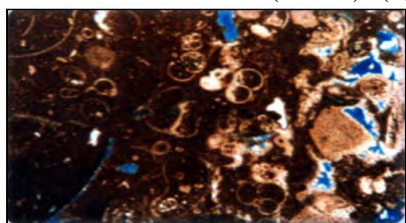


Fig (9) Wackstone-Packstone (Zone I)

#### 2) Zone II:- Wackstone (Algal Dolostone)

This facies is represented by red algal fragments embedded in dolomitic groundmass. (fig.10)

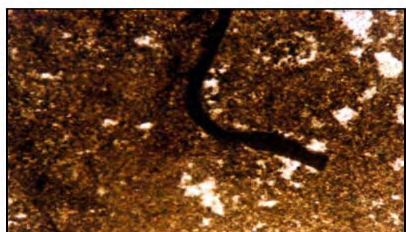


Fig (10) Wackstone (Zone II)

#### 3) Zone III:- Anhydritic Wackstone (Anhydritical Algal Dolostone)

This facies is represented by increasing the anhydrite content as well as the biogenic remains embedded in dolomitic groundmass. (fig.11)

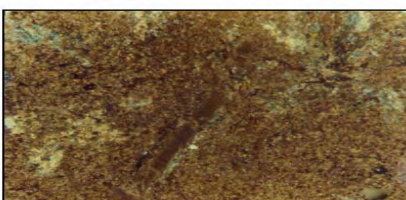


Fig (11) Anhydritic Wackstone (Zone III)

#### 4) Zone IV:- Sandy Wackstone (Sandy Algal Dolostone)

This facies consists of algal dolostone with presence of terrigenous quartz grains of medium to fine sand size at the lower part. (fig.12)

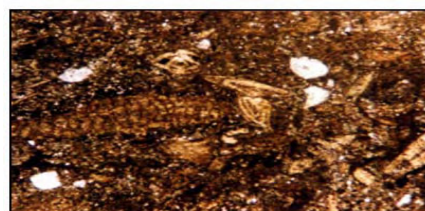


Fig (12) Sandy Wackstone (Zone IV)

### Digenesis

The Petrographical Examination of Carbonates revealed that this reservoir is largely determined by diagenetic processes as recrystallization, dolomitization, dissolution pressure solution and filling.

#### Pore spaces

Many types of pore spaces were identified within this carbonates.

##### a) Bimoldic cavities

The cavities are developed as a result of dissolution processes acting on the organic matter embedded in Wackstone-Packstone facies. (fig.13)

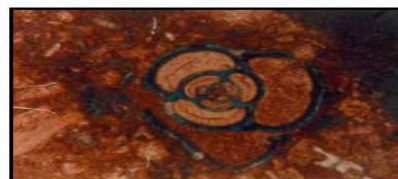


Fig (13) Bimoldic Cavities

##### b) Vuggs

They are developed through the dissolution of the dolomite and the anhydrite crystals during the post depositional variation. (fig.14)

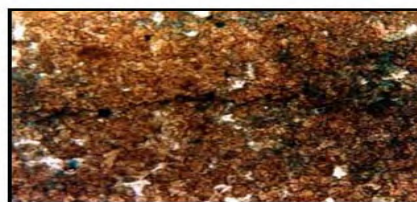


Fig (14) Vagular Pore-space

##### c) Intercrystalline Type

This type is developed through aggregating recrystallization in diagenetic processes. (figs 15-16)



Fig (15) Intercrystalline Pore-spaces

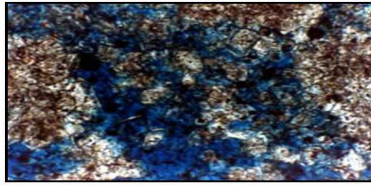


Fig (16) Large Dolomitic Lattice Crystals (Solution Porosity in Blue Colour)

d) **Fracture and micro fractures**

Compaction and pressure solution lead to creation of micro fractures in carbonate rock called stylolitic structure. (fig.17)

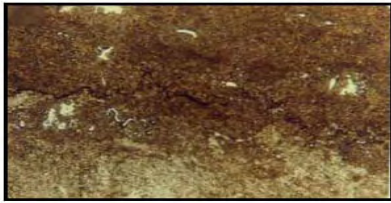


Fig (17) Stylolitic Structure

The Isochore thickness maps of the four reservoir sub zones have been constructed. These maps revealed the presence of two loops of carbonate for all the reservoir zones trending NW-SE. This trend is the same fault trend indicating that carbonate development is structurally controlled. Zone I of Carbonate attain a maximum thickness of 400 ft. in the south loop fig (18).

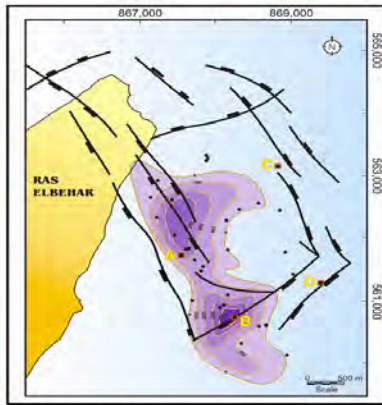


Fig (18) Isochore Map of Kareem/Rudeis Limestone (Zone I)

Zone II and III attains maximum thickness of 200 ft. within the two loops fig (19).

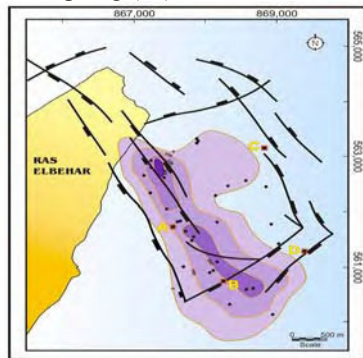


Fig (19) Isochore Map of Kareem/Rudeis Low Gamma Ray Dolomite (Zone II & III)

Zone VI attains a maximum thickness of 200 ft. within the two loops. It has the best reservoir parameters and achieves the best production performance. (fig. 20)

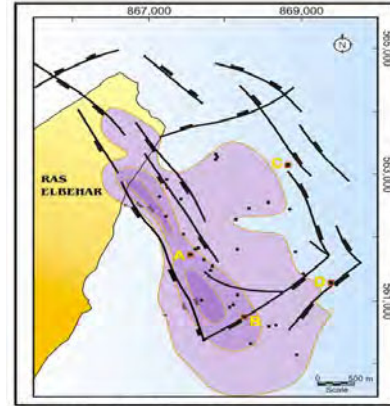


Fig (20) Isochore Map of Kareem/Rudeis High Gamma Ray Dolomite (Zone IV)

**PETROPHYSICAL EVALUATION:**

The petrophysical evaluations have been made using ELAN software. This program gives a quantitative determination of porosity, hydrocarbon saturation and mineral volume fractions.

The petrophysical analysis of the Kareem/Rudeis reservoir was done using the available electric logs and core data. The carbonate facies can be distinguished into several facies, as shown in the correlation chart (Fig.21).

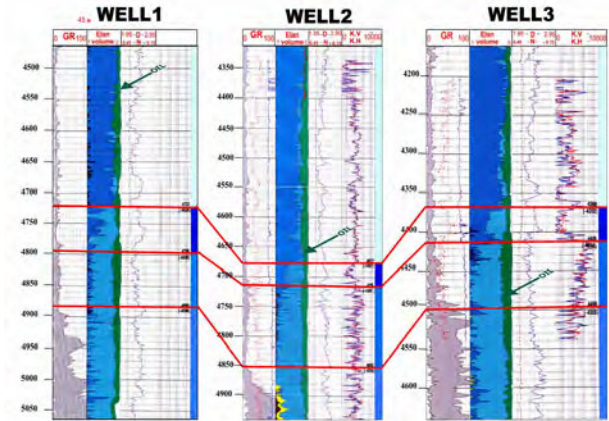


Fig (21) Correlation Chart for Kareem/Rudeis Carbonate Using ELAN, E-Logs & Core Data

The upper part is a limestone body which is developed as separate mound along the western flank. The dolomite facies which underlain the limestone is considered as a secondary dolomite derived by dolomitization processes from original deposited limestone. This dolomite/dolomitic limestone facies can be subdivided into three zones. The upper one is a transitional dolomitic limestone characterized by the presence of algal dolomite while the second one is represented by presence of anhydrite content with low gamma ray. The lower dolomite is characterized by a relatively high gamma ray with sand content.

Porosity/Density cross plots figs (22-25) allowed identification for the above mentioned four sub zones. The uppermost zone (zone I), is moderate porosity limestone.

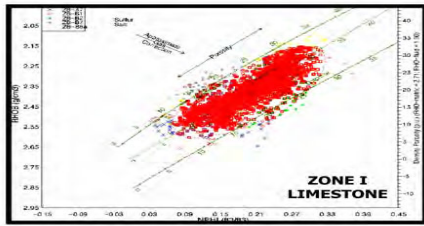


Fig (22) Neutron/Density Cross-plot Limestone (Zone I)

Zone II is identified on the cross plot as dolomitic limestone of better reservoir parameters than zone I.

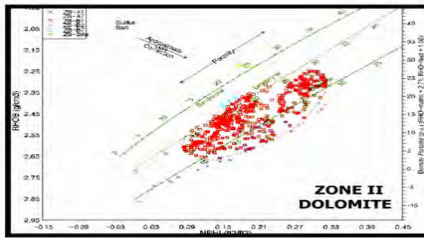


Fig (23) Neutron/Density Cross-plot Dolomite (Zone II)

Reservoir zone III is clearly identified on the porosity/Density cross plot as anhydritic dolomite.

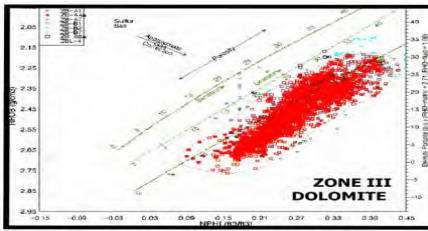


Fig (24) Neutron/Density Cross-plot Dolomite (Zone III)

The fourth reservoir sub zone is the most porous dolomite with high GR due to larger dolomite lattice crystals and described as sandy dolomite (fig. 16).

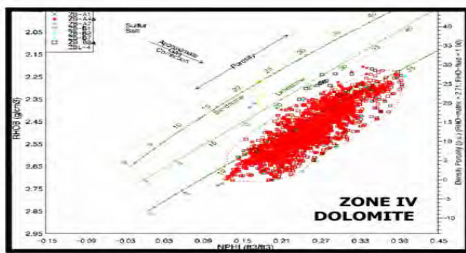


Fig (25) Neutron/Density Cross-plot Dolomite (Zone IV)

As shown on the reservoir zonation, the porosity, sedimentological and ELAN interpretation represent perfect match to well identify the four sub-zones.

Porosity/permeability cross plots and porosity distribution maps of carbonate zones were also constructed (fig.26-28). These cross plots show different linear relations fit with the carbonate zonations. On the porosity /permeability cross plot a limestone zone I with relatively moderate porosity, low permeability is identified. Low GR dolomite (Zone II and III) with moderate reservoir parameters exist. The best reservoir carbonate (Zone IV) of high GR, high porosity and permeability is identified.

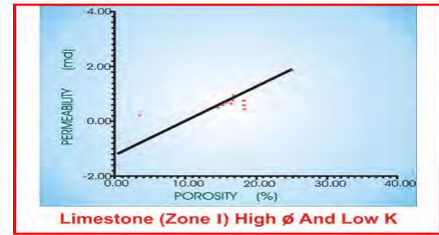


Fig (26) Porosity/Permeability Cross-plot Limestone (Zone I)

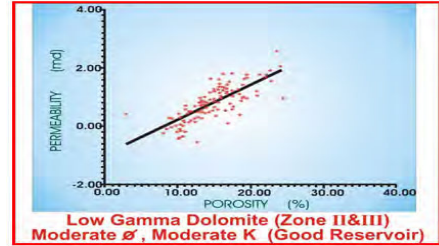


Fig (27) Porosity/Permeability Cross-plot Dolomite (Zone II & III)

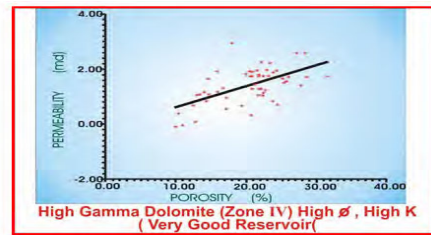


Fig (28) Porosity/Permeability Cross-plot Dolomite (Zone IV)

The porosity distribution maps show high porosity values on the structural high which indicates higher dolomitization process in the crestal part of the structure. Both isochore thickness and porosity distribution trends (NW-SE) are matched. (fig.29-31)

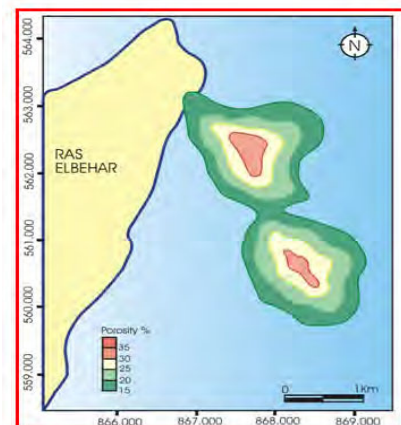
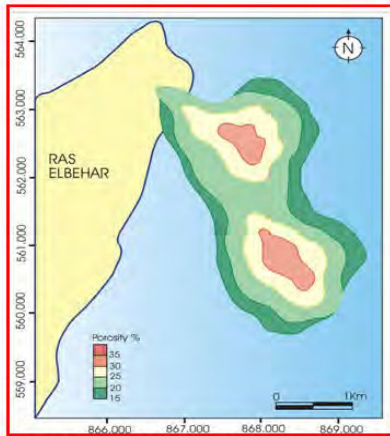
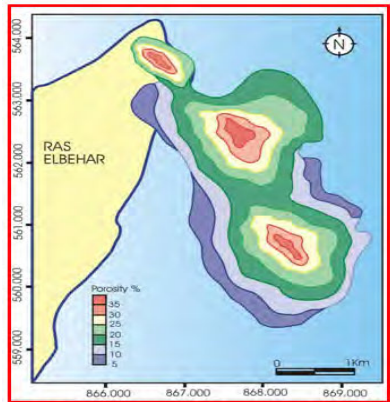


Fig (29) Porosity/Distribution Map Limestone (Zone I)

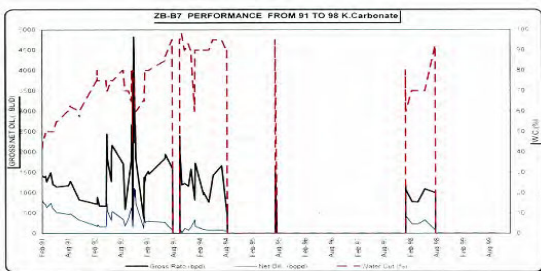


**Fig (30) Porosity/Distribution Map Dolomite (Zone II & III)**

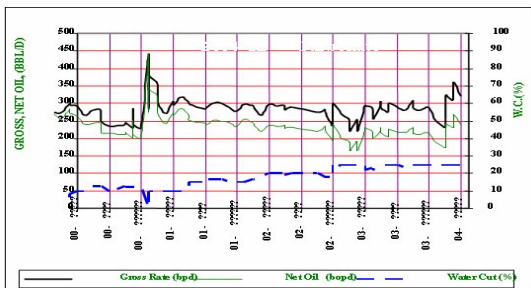


**Fig (31) Porosity/Distribution Map Dolomite (Zone IV)**

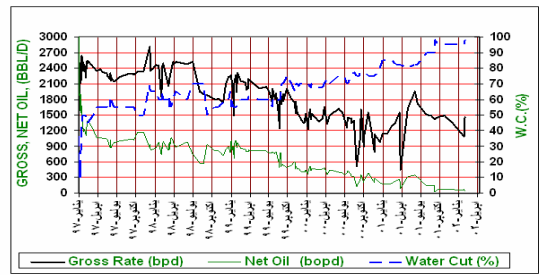
Gross/net/oil and W.C % figures were plotted against time, (Figs.33, 34, 35). The best production performance is clearly related to oil produced from Zone IV



**Fig (32) Production Performance of Limestone (Zone I)**

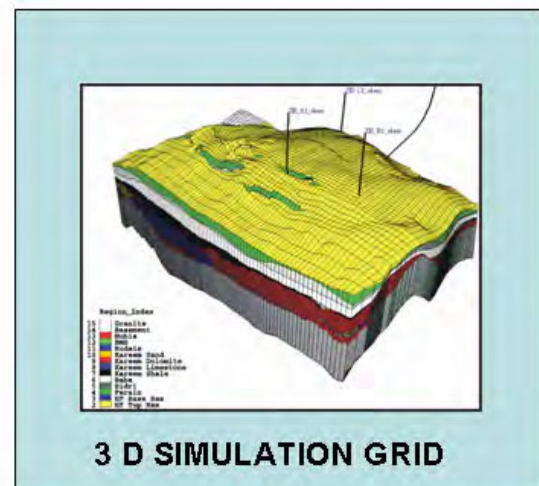
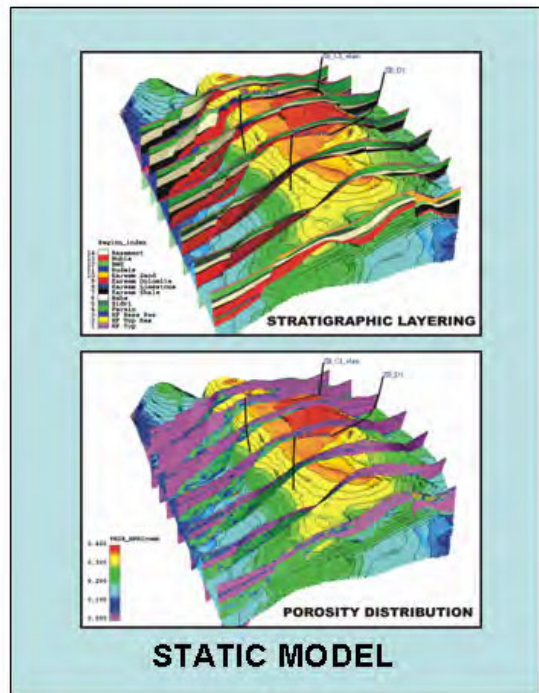


**Fig (33) Production Performance of Dolomite (Zone II & III)**



**Fig (34) Production Performance of Dolomite (Zone IV)**

The whole porosity, permeability, isochore distribution were input into the 3D static model (on RMS) and dynamic model (ECLIPS) to run history match and production predictions, (Fig.35).



**Fig (35) Kareem/Rudeis Carbonate Modeling**

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### **Conclusions and Recommendations:**

- Based on Petrophysical, sedimentological analysis the Kareem/Rudeis carbonate is described as a heterogeneous reservoir, divided into lower dolomite with high GR response (Zone IV), Middle Dolomite with low GR response (Zone II and III) and upper fossiliferous limestone (Zone I).
- The lower dolomite has porosity about 25% and permeability ranging from 100-280 md. It is considered as very good reservoir unit.
- The Middle dolomite has porosity about 20% and permeability ranges from 10-180 md. It is considered as good reservoir unit.
- The upper limestone has good porosity (about 20%) and low permeability. Stimulation jobs are recommended to produce oil from this Zone.
- It is recommended to drill infill wells in the lower dolomite than any of the other reservoir zones.
- Most of the current reserves are setting in the southern part of the field.
- Drilling of horizontal geosteered wells can drain oil reserves of thin dolomite pay zones.
- Integration of Petrographical, sedimentological analysis in combination with the wireline logs and core data allows good reservoir characterization and modelling.

### **Acknowledgment:**

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