[PS]A Multidisciplinary Approach to Recognize and Predict the Role of Fractures in Maximizing Economic Recovery from Basement Reservoirs by Integrating Different Disciplines, Zeit Bay Field - Gulf Of Suez, Egypt*

Saber M. Selim[1] and Khaled M. Abdallah[2]

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*Adapted from poster presentation at AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012. Please see closely related article, "Pressure Regime Evaluation, Role, and Contribution in Well Planning and Formation Evaluation Process, Zeit Bay Fields - Gulf of Suez, Egypt", Search and Discovery article #40600.

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Abstract

Fractured reservoirs provide over 20% of the world reserves and production. However, few of these reservoirs are optimally developed. It is undeniable that the reservoir characterization modeling and simulation of naturally fractured reservoirs present unique challenges that differentiate them from conventional reservoirs which also means that they require unique solutions and strategies for optimum production.

Zeit Bay Field is considered the first field in the Egyptian Petroleum Sector that explored and produced oil from the fractured basement. This field is located in the southwestern offshore part of the Gulf of Suez. The field was discovered in June 1981 and started to produce commercially in December 1983. Hydrocarbons are produced from all the porous and permeable intervals from Hammam Faraun of the Belayim Formation down to Precambrian basement. These units are in complete hydraulic communication, making it one of the unique reservoirs.

In this study, the authors use all available data and various methods and techniques to construct a reservoir model for the basement reservoir of the Zeit Bay Field aiming to:

1) Identify and model a basement reservoir that predicts content and behavior of the wells.

2) Explain the past basement reservoir performance and predict its future performance.

3) Formulate a reservoir management policy and development plane of the field throughout its life with minimum expenditures.

1

A Multidisciplinary Approach To Recognize And Predict The Role Of Fractures In Maximizing Economic Recovery From Basement Reservoirs By Integrating Different Disciplines

ZEIT BAY FIELD GULF OF SUEZ , EGYPT

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ROXAR

A

Abstract

Fractured Reservoir Provide Over 20% Of The World Reserves And Production. Few Of These Reservoirs Are Optimally Developed.

It Is Undeniable That The Reservoir Characterization Modeling And Simulation Of Naturally Fractured Reservoirs Present Unique Challenges That Differentiate Them From Conventional One Which Also Mean That They Require Unique Solutions And Strategies For Optimum Production.

Zeit Bay Field Is Considered As The First Field That Explored And Produced Oil From The Fractured Basement In Egypt. So, The Authors Selected That Field To Produce 3D Fractures Modelling For That Type Of Reservoir .

B

Objectives

1- Demonstrate How Different Data Sets Can Be Integrated Into The 3D Static & Dynamic Models To Achieve & Obtain Better Reservoir Management To Obtain The Maximum Productivity From The Reservoir Units .

2- Identify & Construct Model Of Fracture Basement Reservoir To Predicts Content & Behavior Of Wells Using All Available Data & Applying Various Methods And Techniques.

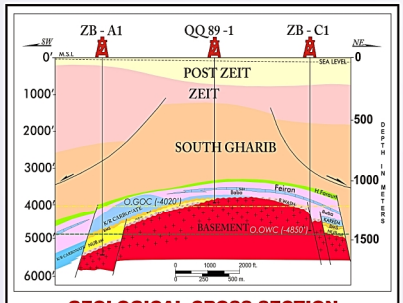
3- Formulate Reservoir Management Policy & Development Plane Throughout Field Life With Minimum Expenditures.

C

Field Highlights

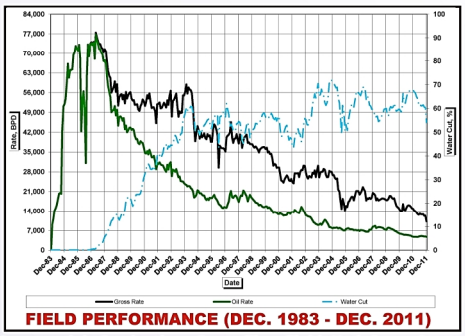
LOCATION MAP

Zeit Bay Oil Field Is Located In The South Western Part Of The Gulf Of Suez, Egypt. It Was Discovered In June, 1981.



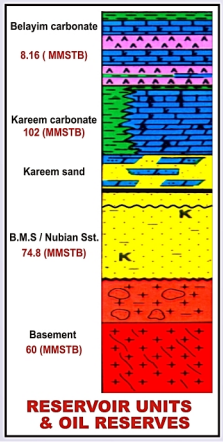
GEOLOGICAL CROSS SECTION

Structurally, It Is Interpreted As NE-SW Basement Relief Like Anticlinal Feature Bounded On All Sides By Major Normal Faults And Dissected By Many Cross Faults .



FIELD PERFORMANCE (DEC. 1983 - DEC. 2011)

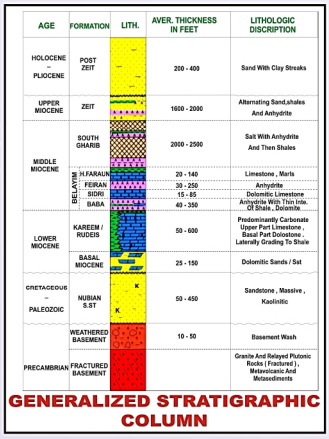
Commercial Production From The Field Had Been Started In December 1983 At Average Rate 20,000 Bbl/Day & Reached 80,000 Bbl/Day In 1986 .
Nowadays, The Production Became 5,000 Bbl/Day.



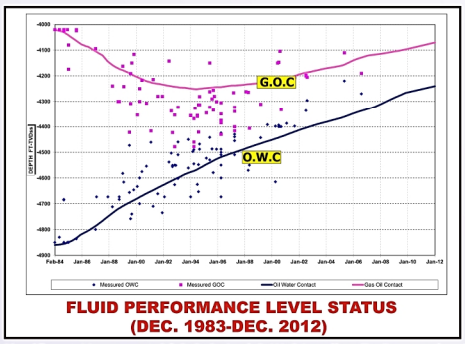
RESERVOIR UNITS & OIL RESERVES

It Has A Stratigraphic Sequence Similar To The Southern Part Of Gulf Of Suez With Multi Reservoir Units Of Different Ages.

These Unites Are In Complete Hydraulic Communication Making It One Unique Reservoirs .



GENERALIZED STRATIGRAPHIC COLUMN



FLUID PERFORMANCE LEVEL STATUS (DEC. 1983-DEC. 2012)

Significant Movement Of G.O.C. And O.W.C Leading To Decreasing In Oil Column And Declination In Reservoir Pressure Has Been Noticed Due To Long Time Of Productivity. Hence ,good Reservoir Management Of The Field Becomes Highly Rrequired.

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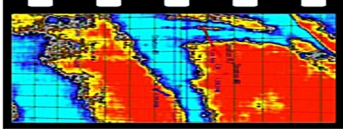
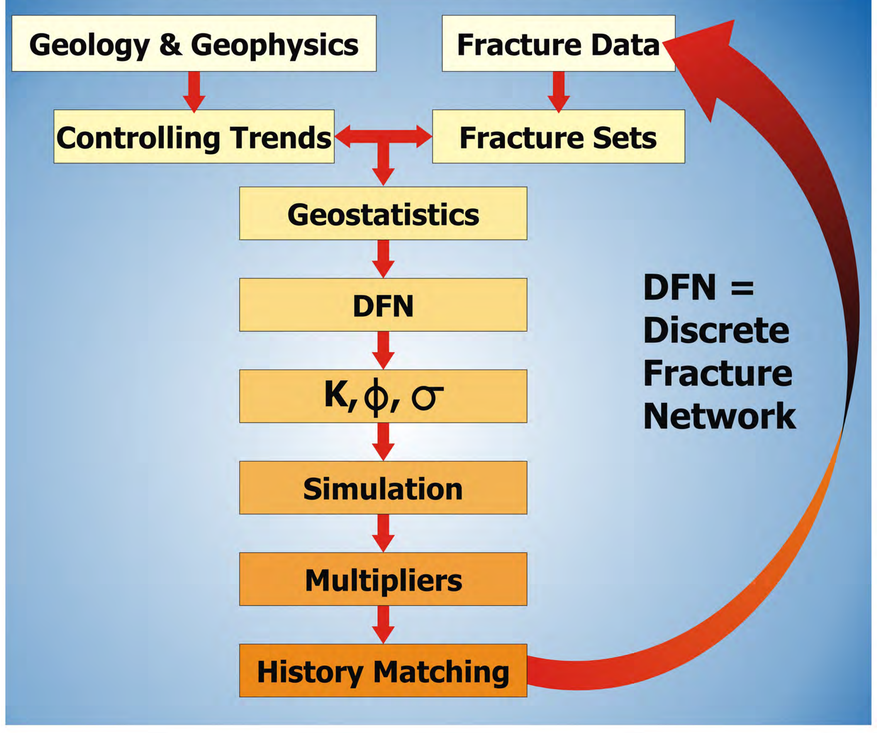
AAPG 2012 Annual Convention & Exhibtion

22-25 April
Long Beach , CA



2

Fracture Modelling Workflow in RMS

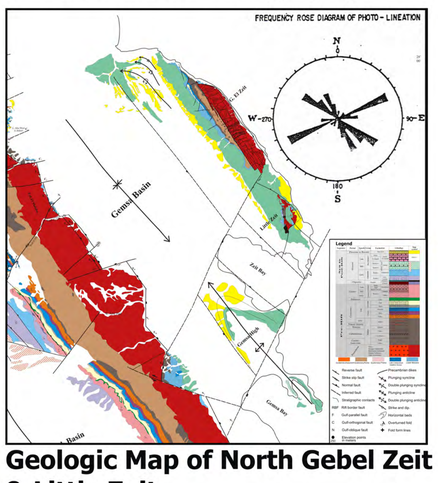


Geology & Geophysics

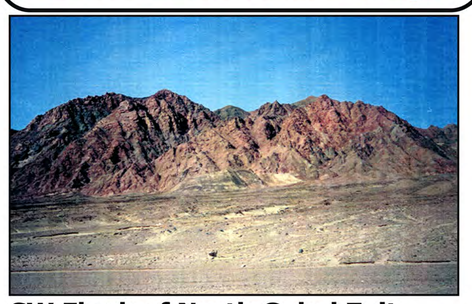
A Surface Basement Analogue Northern & Southern Gebel Zeit

Gebel Zeit Outcrops

Gebel Zeit located closely to the North of Zeit Bay Field. It was used as an analogue to simulate Zeit Bay Field structure and stratigraphy.



Geologic Map of North Gebel Zeit & Little Zeit

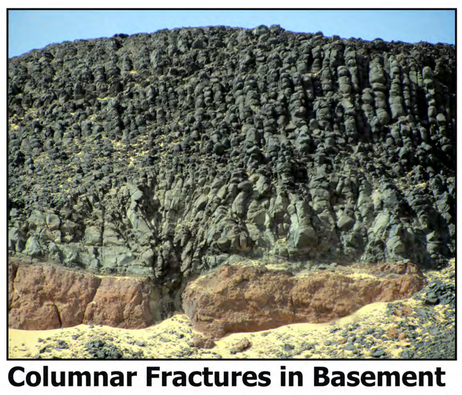


SW Flank of North Gebel Zeit shows 'pink' Prophyritic Granite with Jagged Topographic Expression.

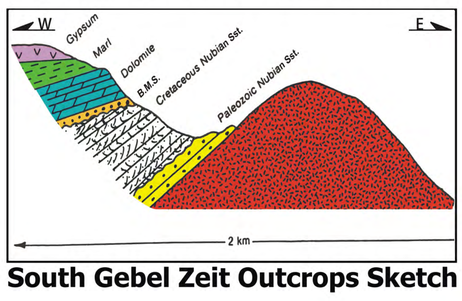
Vertical Fractures in Basement

Two Conjugate Widely Spaced Fractures in Gebel Zeit Granite

Rotated Orthogonal Joint Set Amplified By Subaerial Erosion. Prior To Block Faulting The Contraction Cooling Joints Were Vertical Or Sub-vertical And The Stress Relief Joints Were Horizontal Or Sub-horizontal.



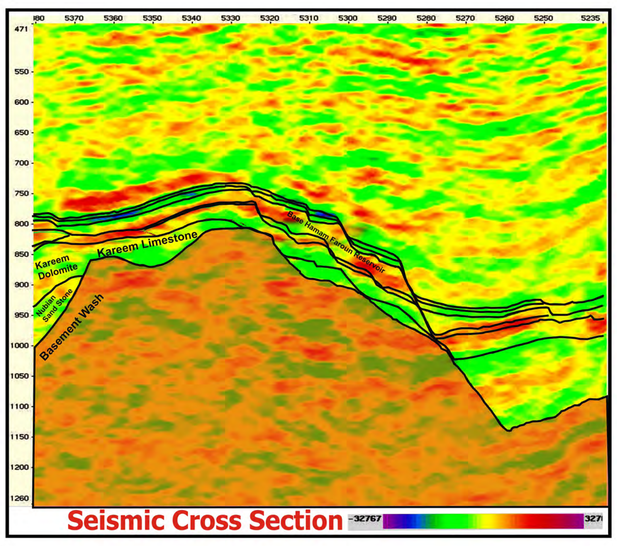
Columnar Fractures in Basement

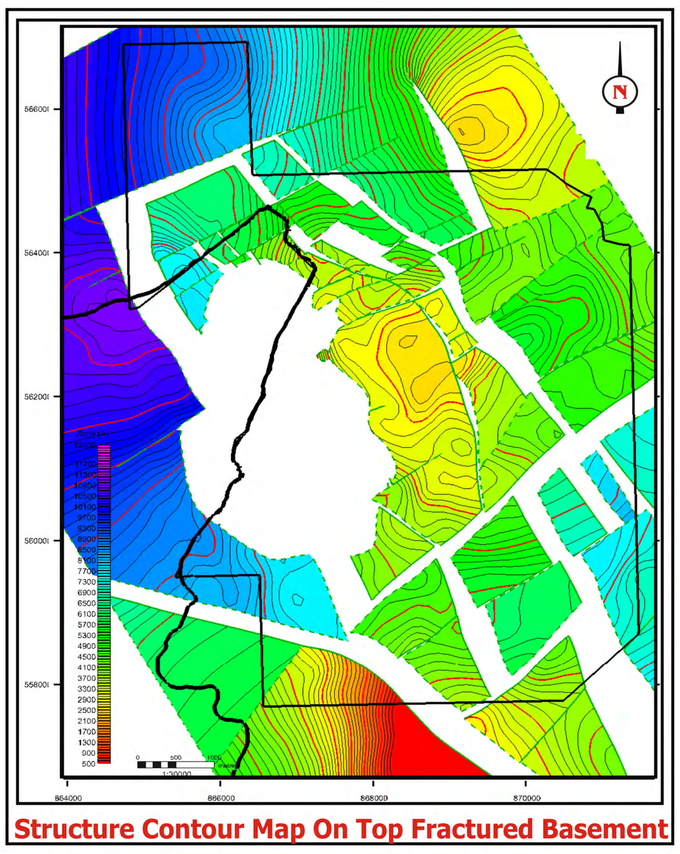


South Gebel Zeit Outcrops Sketch

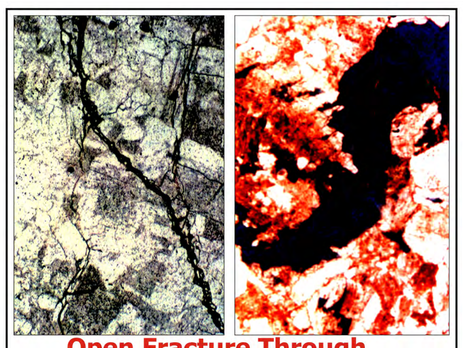
B Subsurface Basement in ZB Field

Seismic Interpretation & Mapping

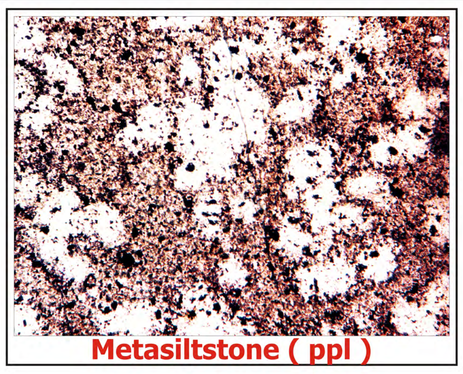




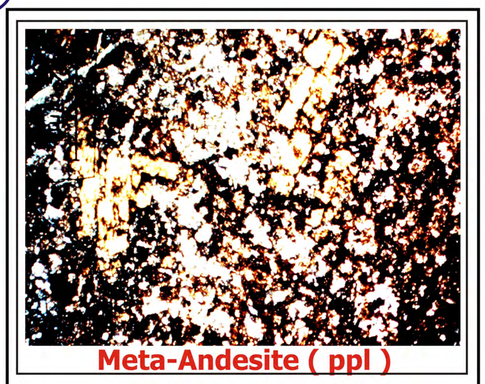
Types Of Basement



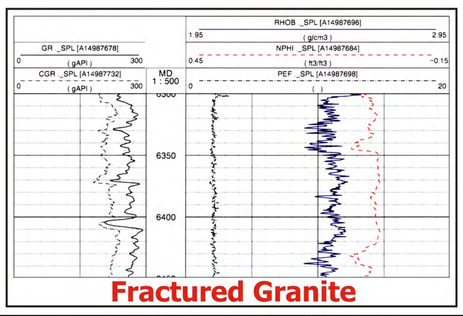
Open Fracture Through Feldspar Clusters (ppl)



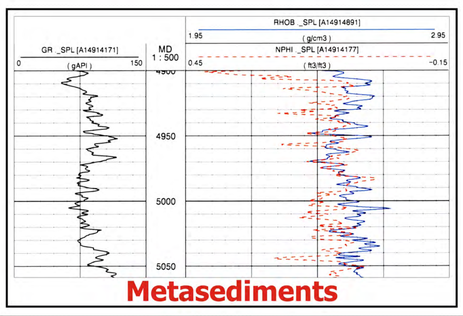
Metasiltstone (ppl)



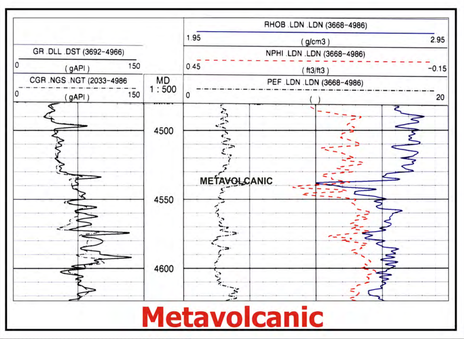
Meta-Andesite (ppl)



Fractured Granite



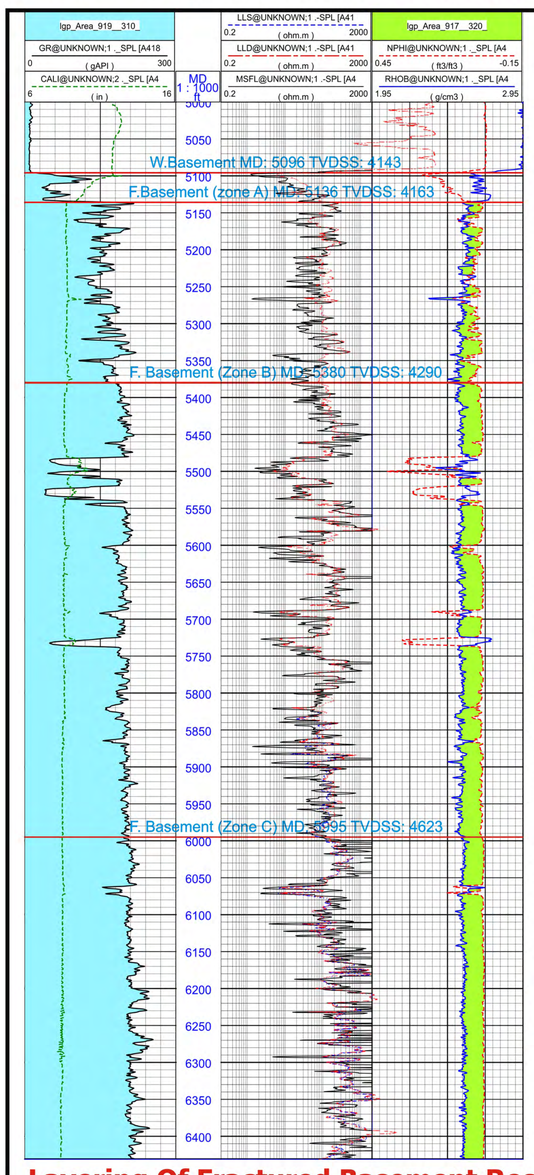
Metasediments



Metavolcanic

Layering of Basement Reservoir

Fractured Basement Reservoir Can Be Differentiated Into Layers Depending on Petrophysical & Petrographical Discrimination

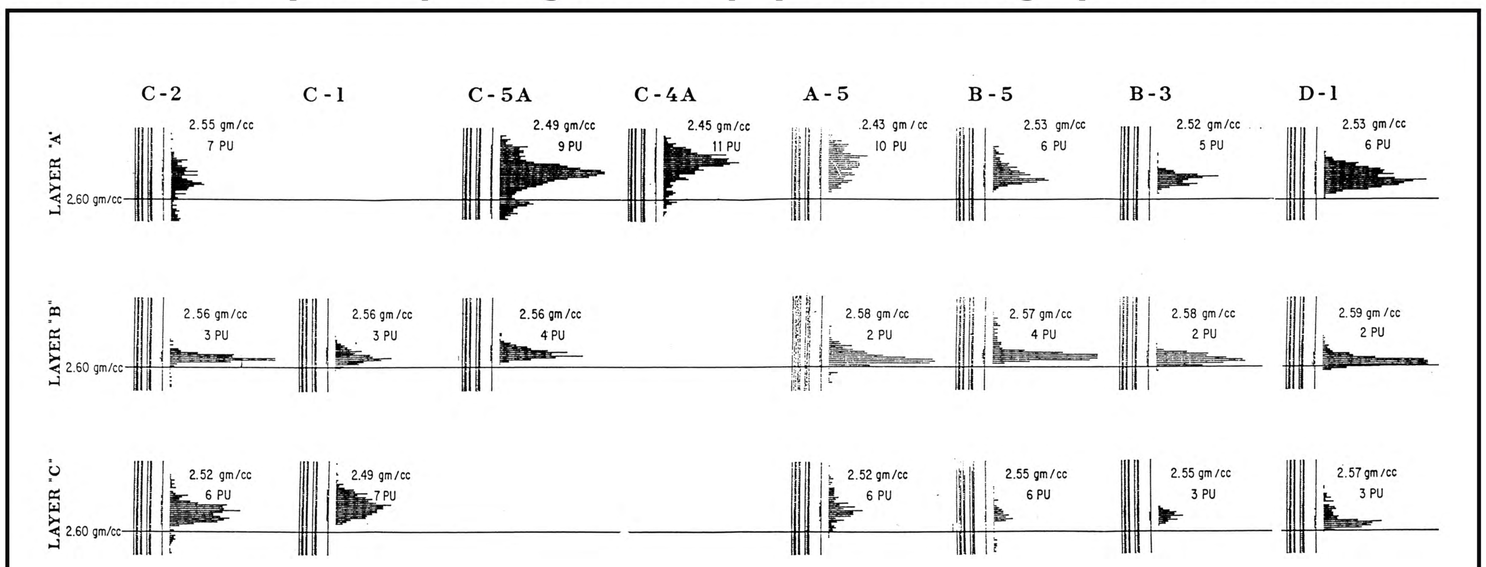


Hi Porosity
Low Density
(Pagmatite Granite)

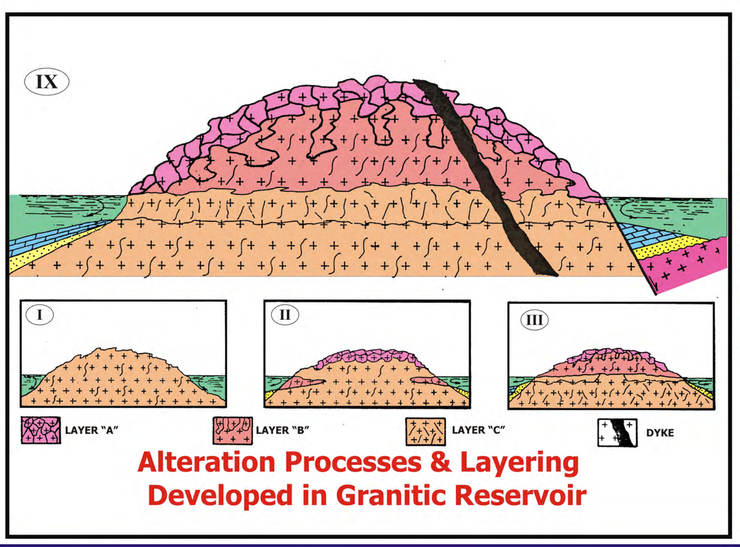
Low Porosity
Hi Density

Modrate Porosity
Low Density
(Alkli Granite)

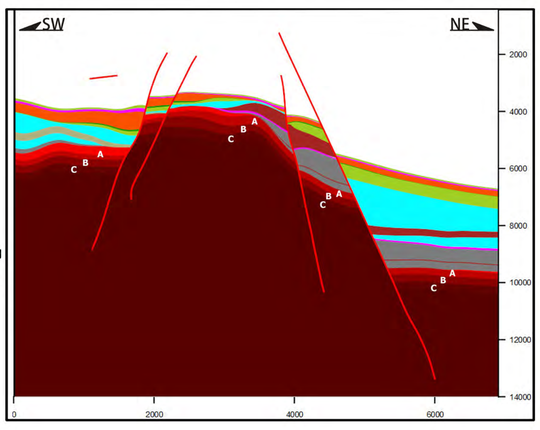
Layering Of Fractured Basement Reservoir Based on Neutron - Density Log Response



Histograms Showing The Variations in Bulk Density for Each Layer Reflecting the Variations in Porosity



Alteration Processes & Layering Developed in Granitic Reservoir



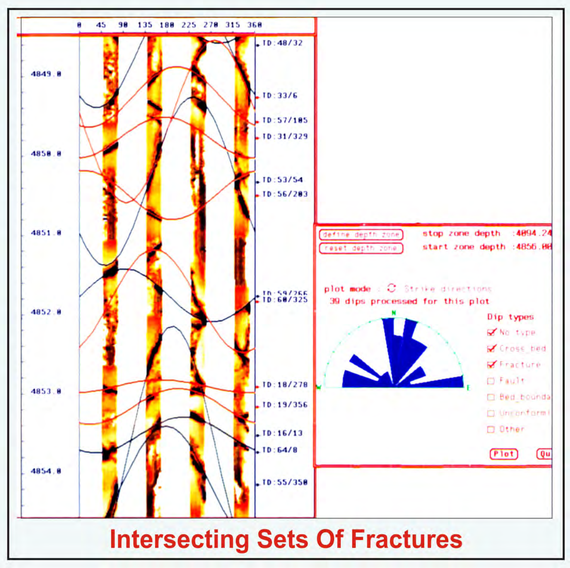
Geologic Cross Section Shown Layering Of Basement Reservoir

3

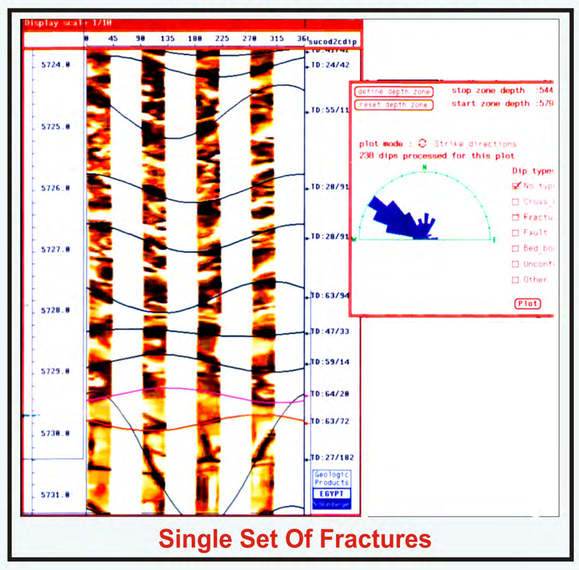
Fracture Trend Modeling

A — Fracture Analysis

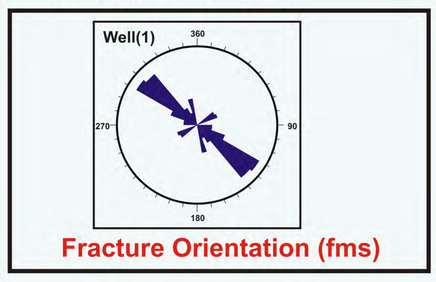
Fracture Micro Scanner (image Logs)



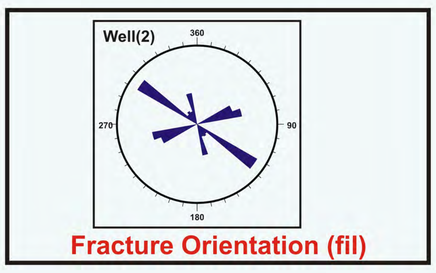
Intersecting Sets Of Fractures



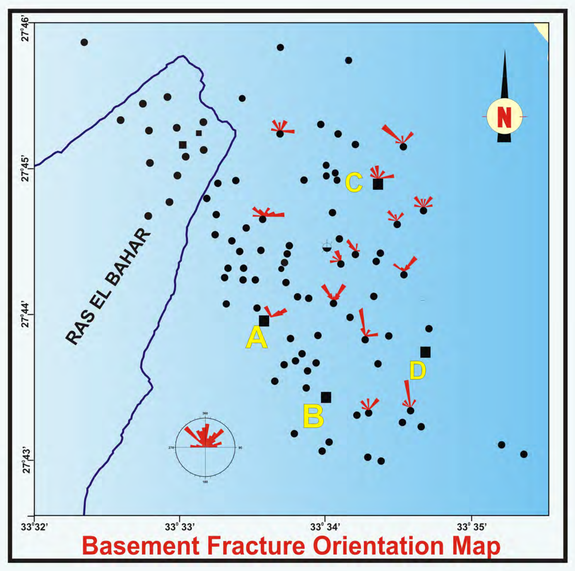
Single Set Of Fractures



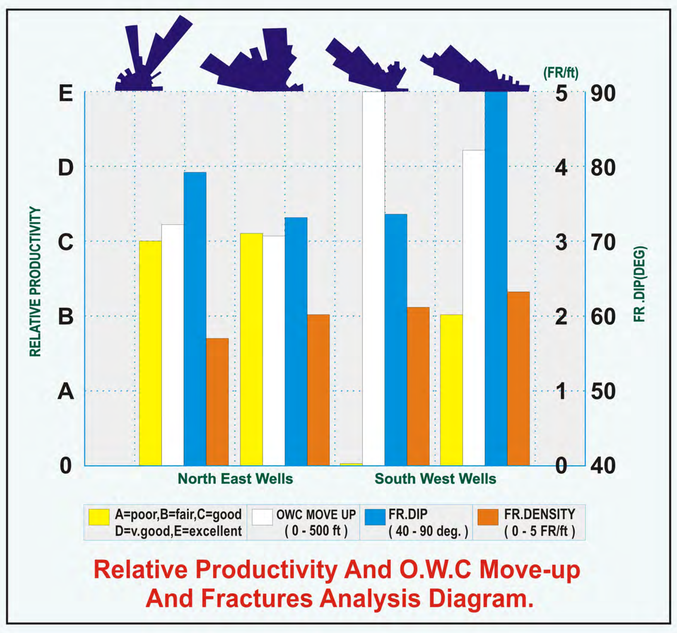
Fracture Orientation (fms)



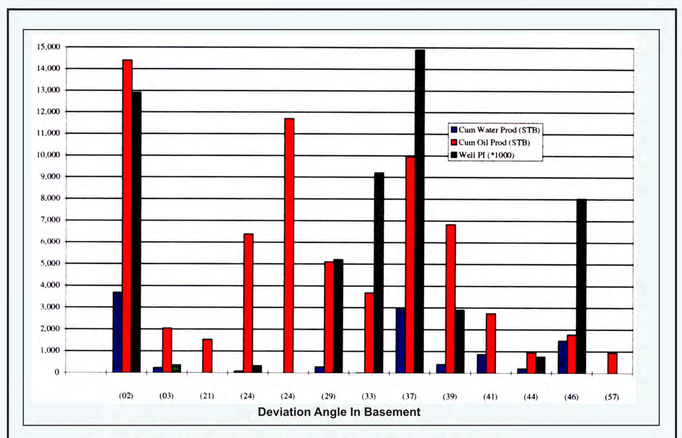
Fracture Orientation (fil)



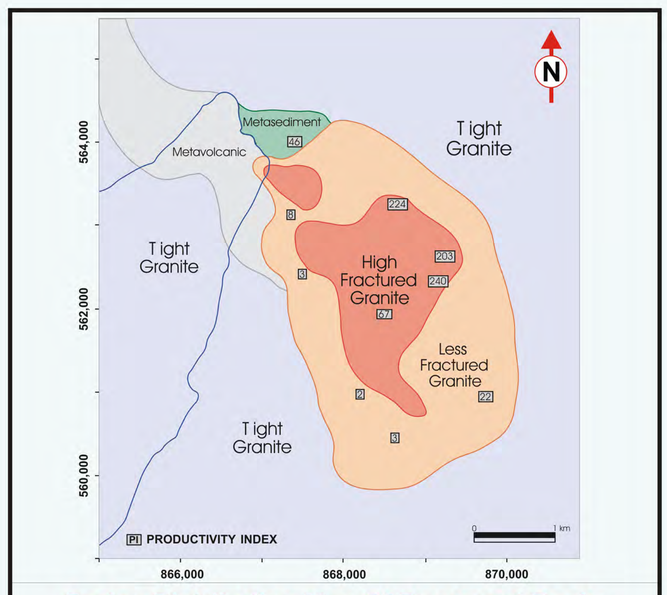
Basement Fracture Orientation Map



Relative Productivity And O.W.C Move-up And Fractures Analysis Diagram.



Well Deviation Angle With Production Performance

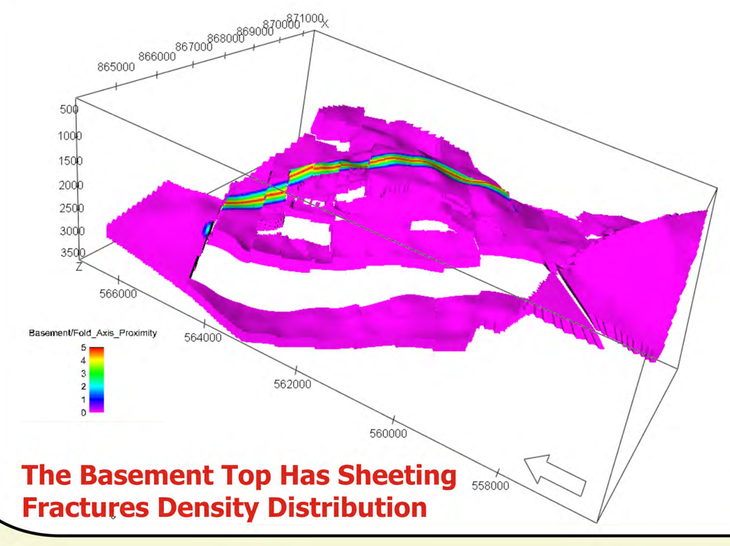


Facies Distribution Map Of Basement Rocks

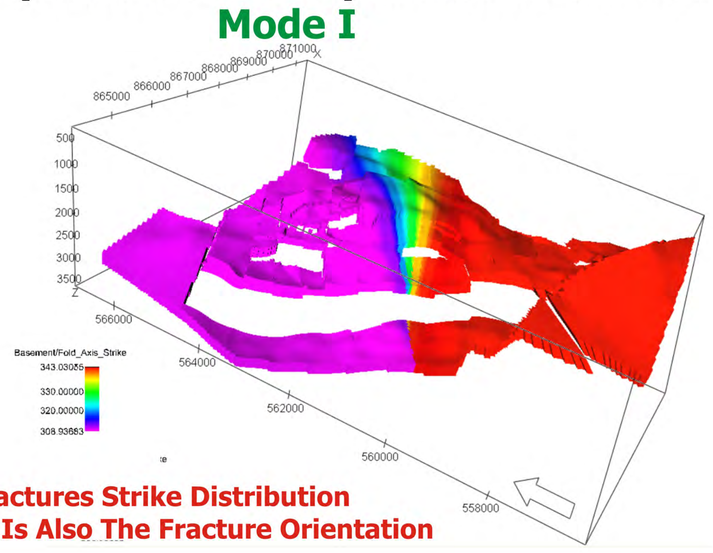
B — Fracture Types

1 — Sheeting Fractures (Fracture Density Is Set To 5 Fracture / Meter)

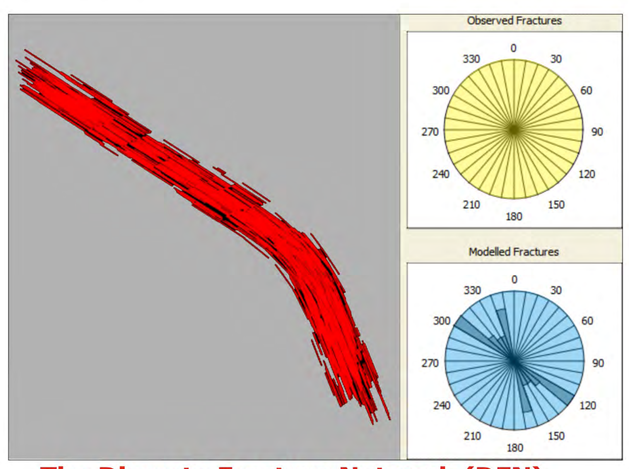
Mode I



The Basement Top Has Sheeting Fractures Density Distribution



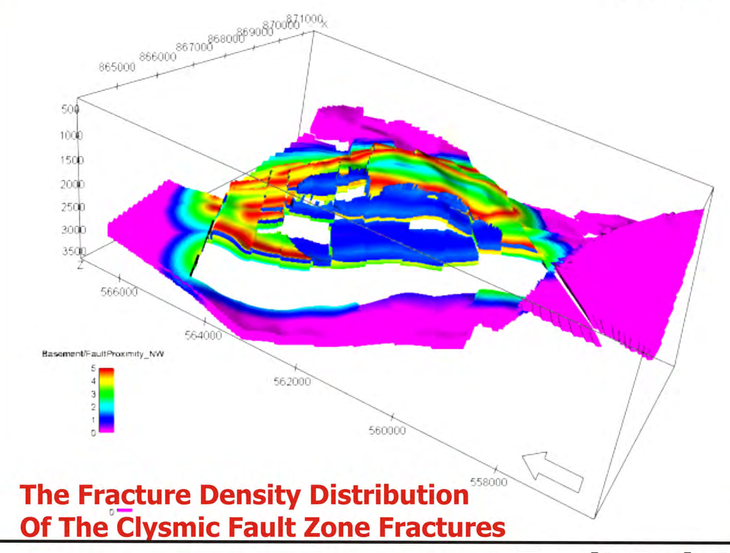
The Fractures Strike Distribution Which Is Also The Fracture Orientation



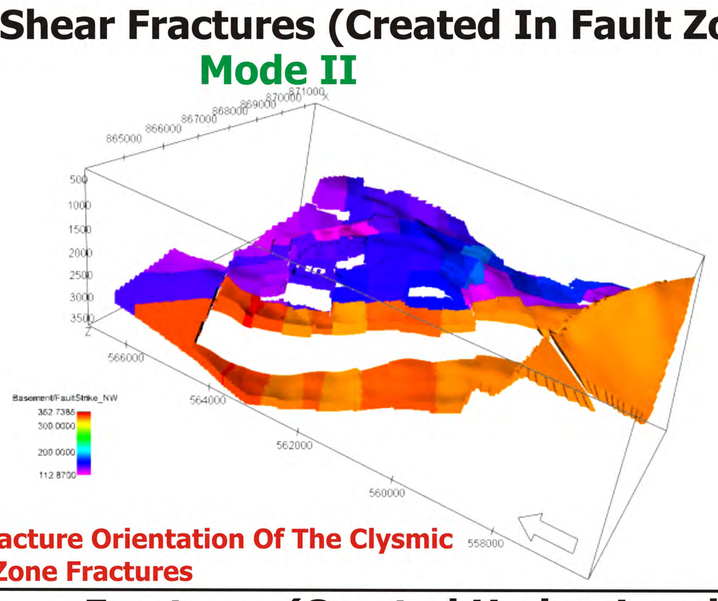
The Discrete Fracture Network (DFN) Of Sheeting Fractures

2 — Fault Zone Shear Fractures (Created In Fault Zone)

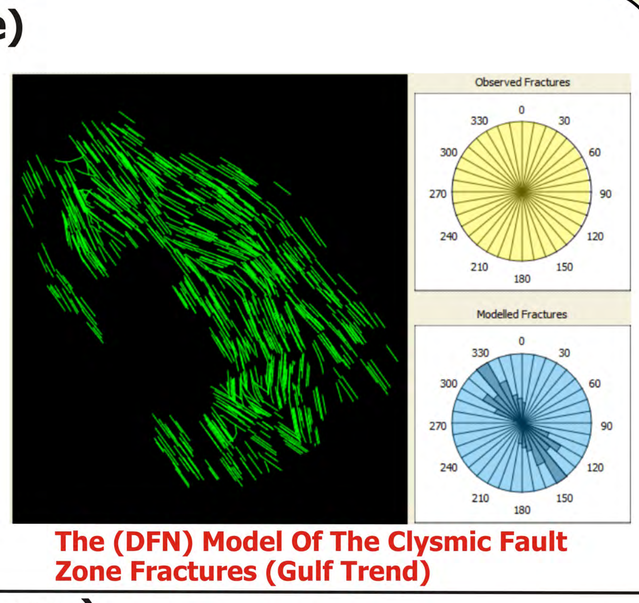
Mode II



The Fracture Density Distribution Of The Clysmic Fault Zone Fractures



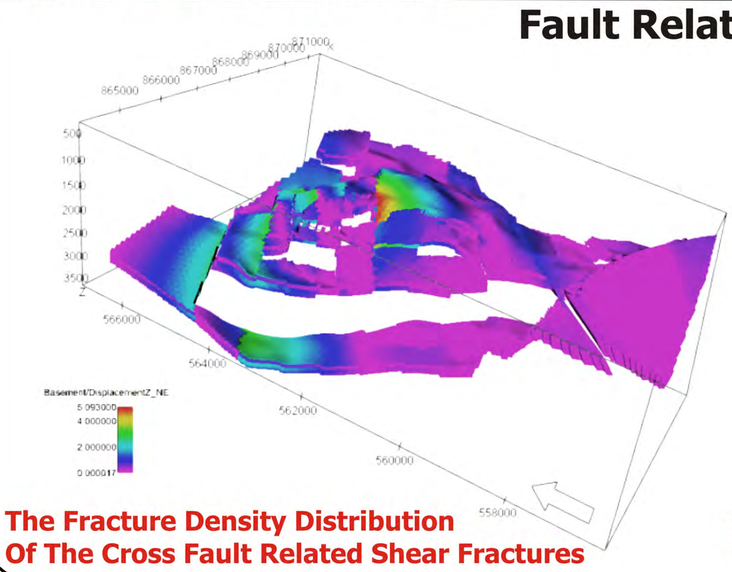
The Fracture Orientation Of The Clysmic Fault Zone Fractures



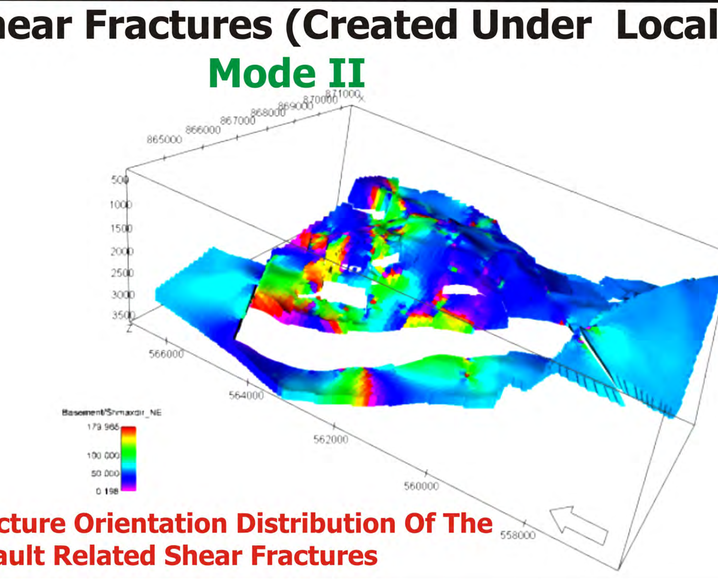
The (DFN) Model Of The Clysmic Fault Zone Fractures (Gulf Trend)

Fault Related Shear Fractures (Created Under Local Stress)

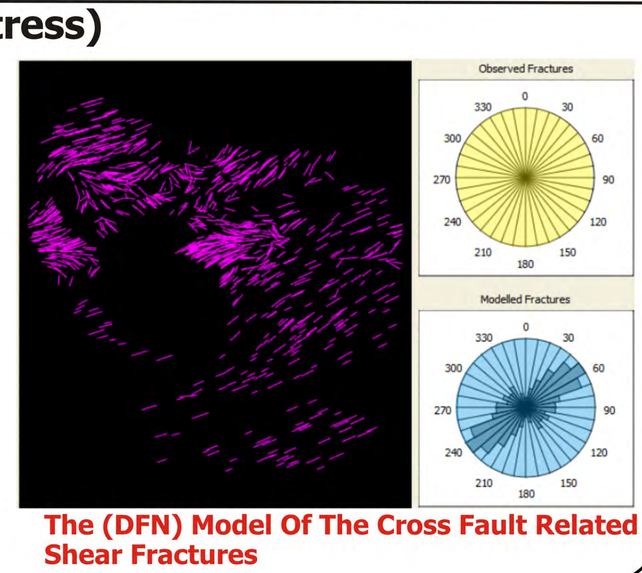
Mode II



The Fracture Density Distribution Of The Cross Fault Related Shear Fractures



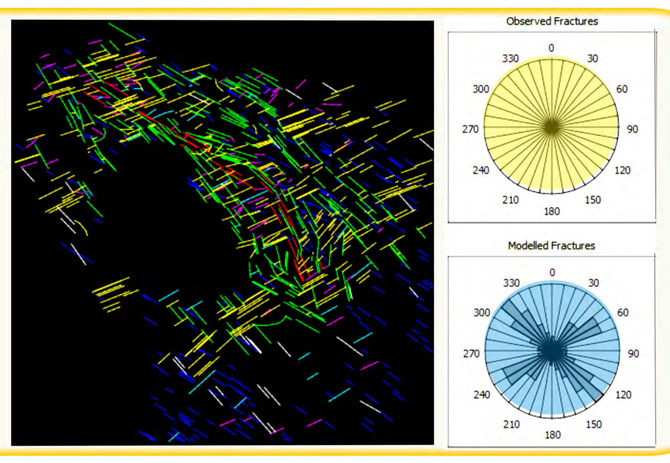
The Fracture Orientation Distribution Of The Cross Fault Related Shear Fractures



The (DFN) Model Of The Cross Fault Related Shear Fractures

C — DFN Model Of All Fracture Sets

The DFN Model of All Fracture Sets Show Two Main Fracture Orientation Trends, NW - SE Trending (Gulf Trend) & NE - SW Trending Fractures (Aqaba Trend). The Uplifting Events Created The Clysmic Faults and The Lateral Compression Created The Cross Faults.

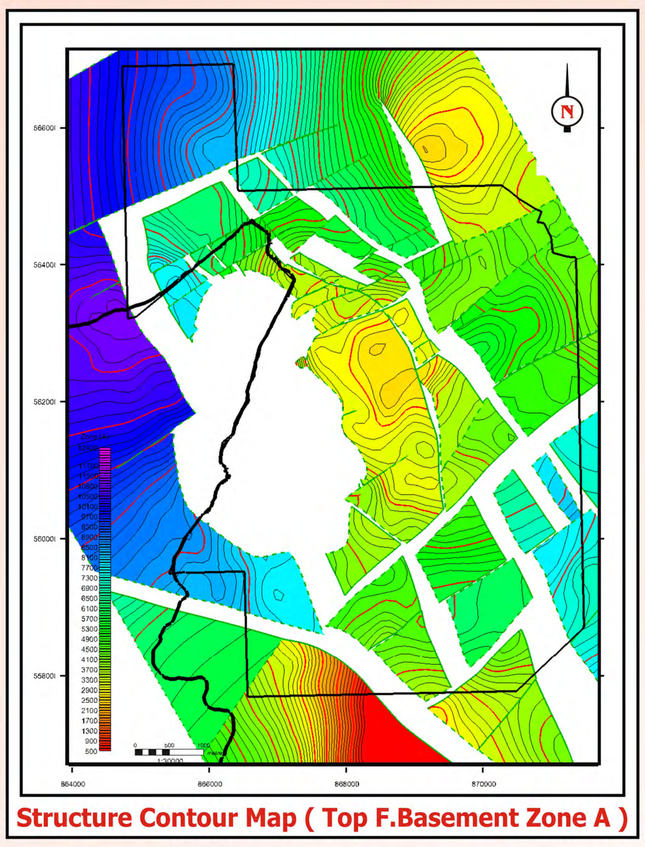


4

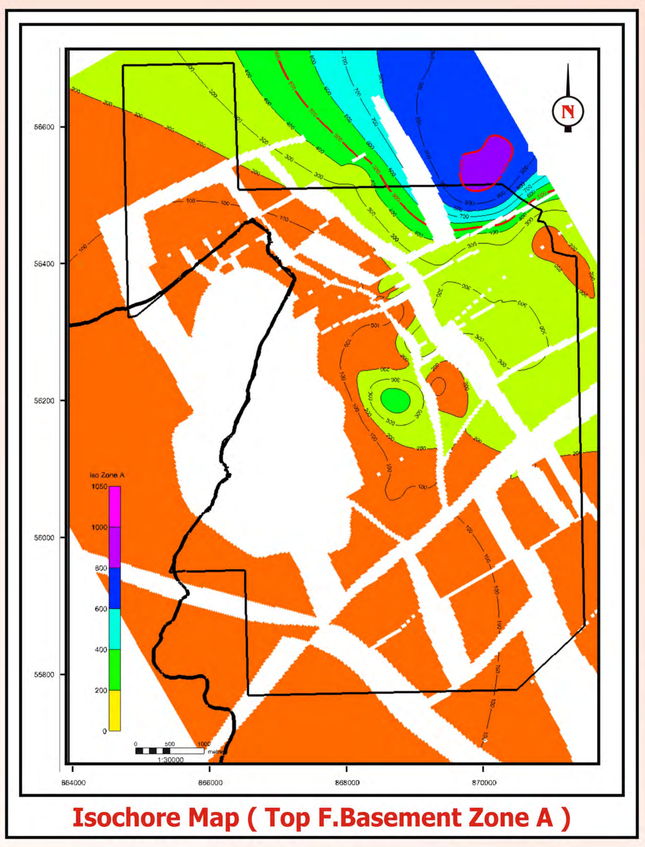
Basement Reservoir Modelling

Basement Reservoir Was Selected to Illustrate The Fracture Reservoir Modelling Workflow in RMS Including Structure Modelling (Horizons & Faults) Geological & Simulation Grids Building Static Reservoir, Attributes Population (Matrix Porosity , Permeability & Water Saturation) and Fracture Modelling Including (Fracture Trends, DFN & Fracture - Related Reservoir Attributes.)

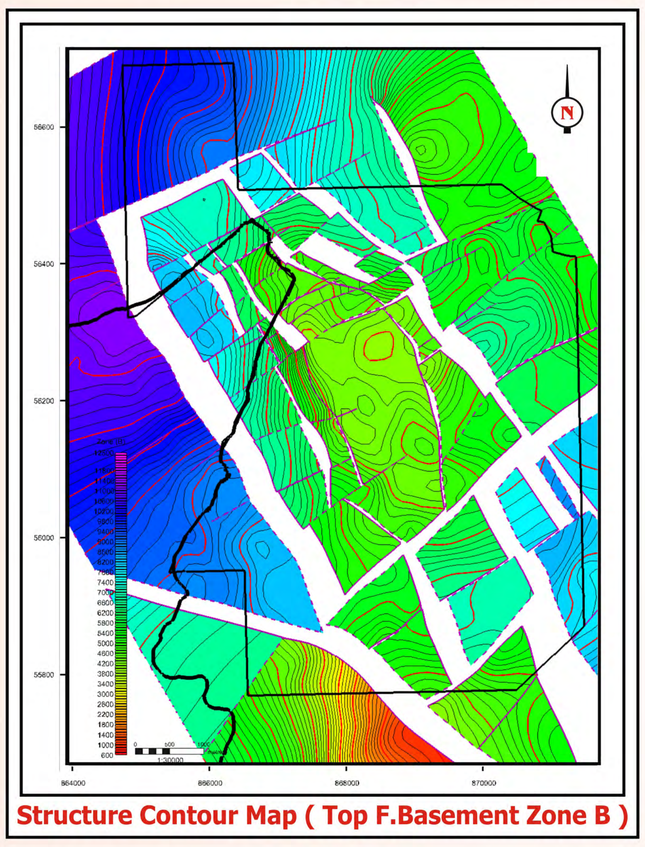
A Structure Modelling



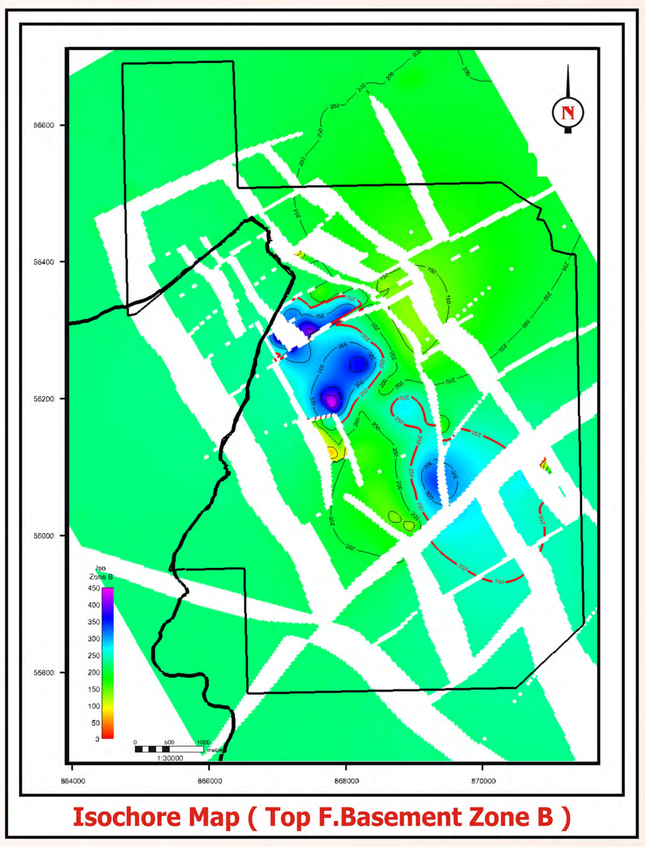
Structure Contour Map (Top F.Basement Zone A)



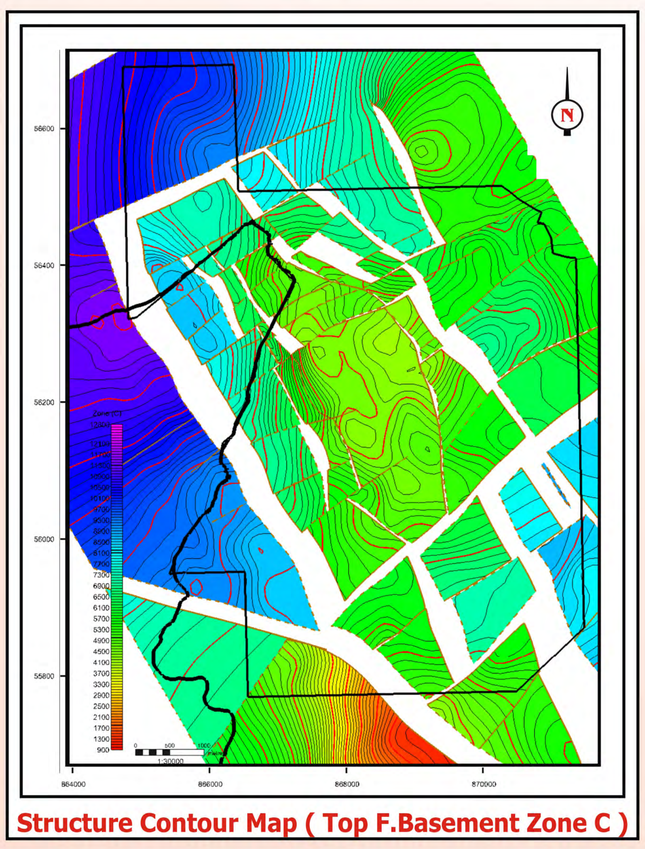
Isochore Map (Top F.Basement Zone A)



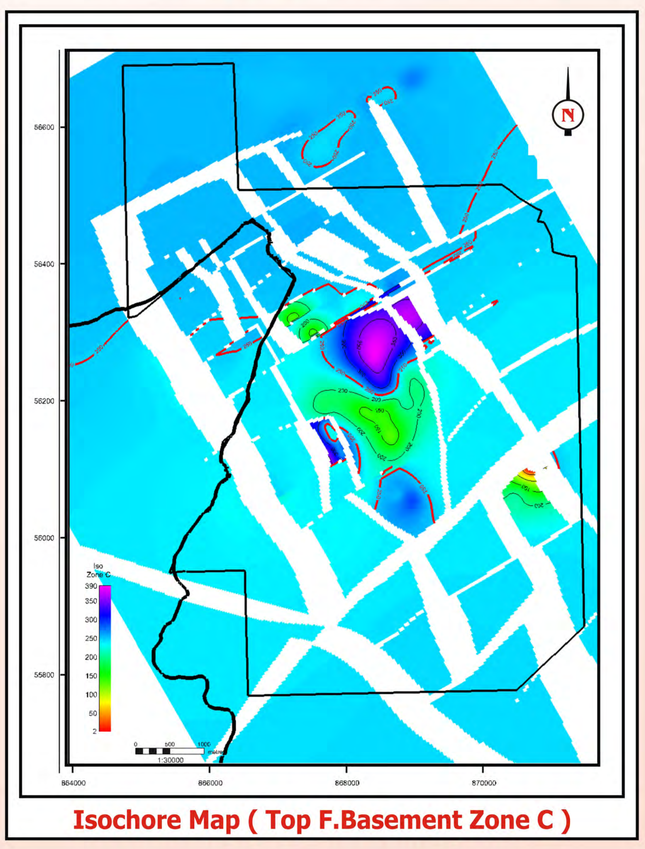
Structure Contour Map (Top F.Basement Zone B)



Isochore Map (Top F.Basement Zone B)

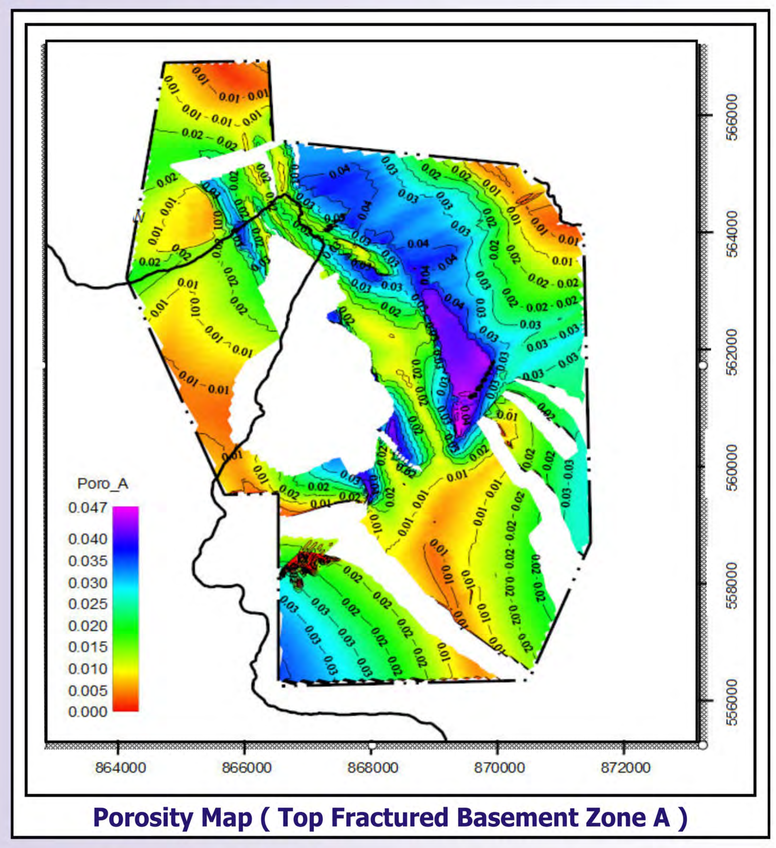


Structure Contour Map (Top F.Basement Zone C)

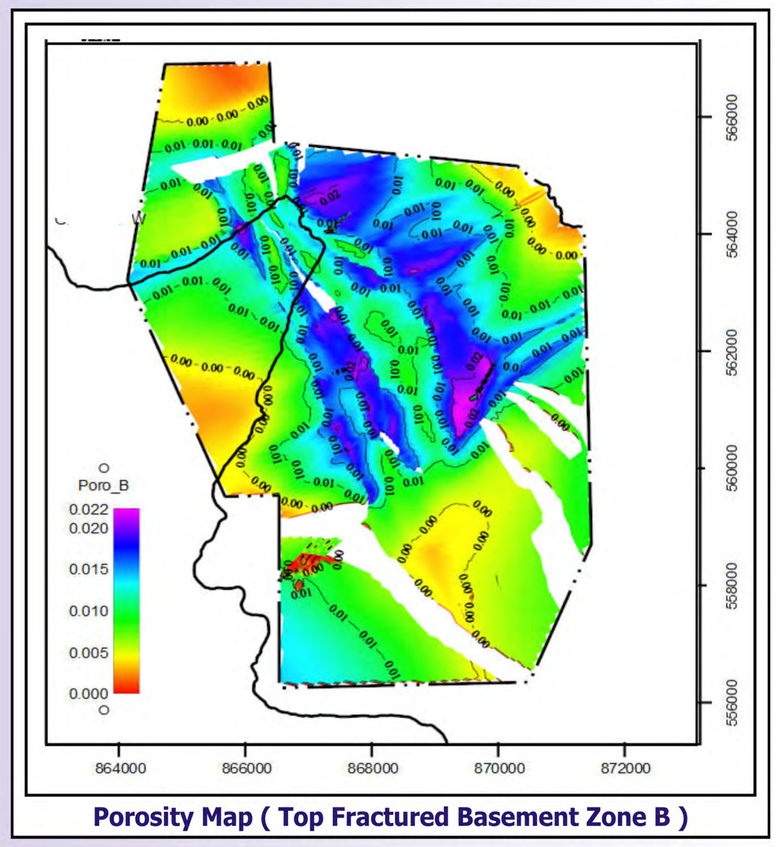


Isochore Map (Top F.Basement Zone C)

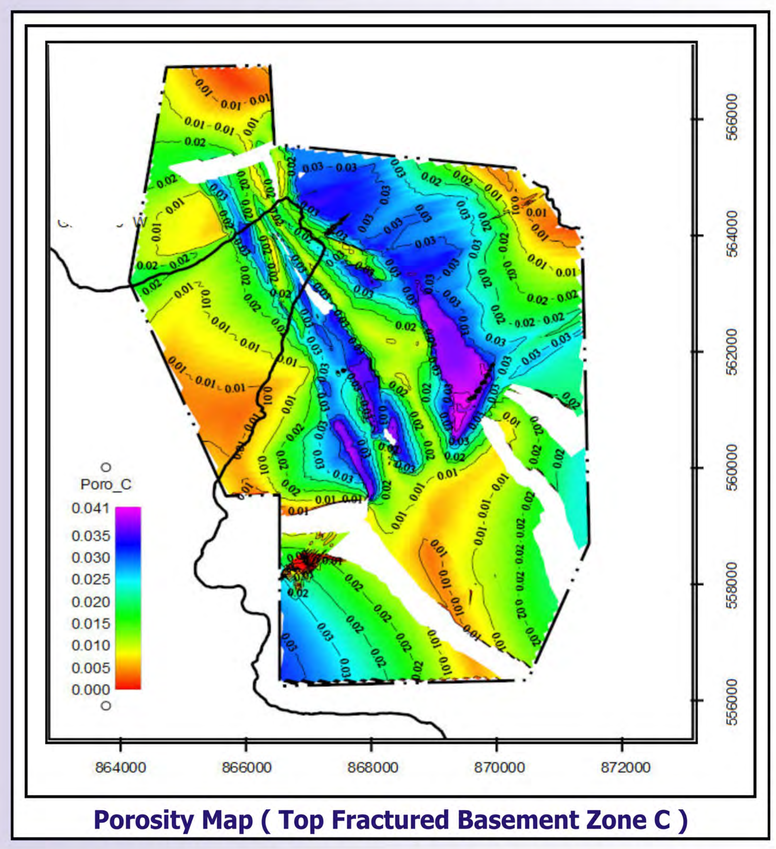
B Petrophysical Modelling



Porosity Map (Top Fractured Basement Zone A)

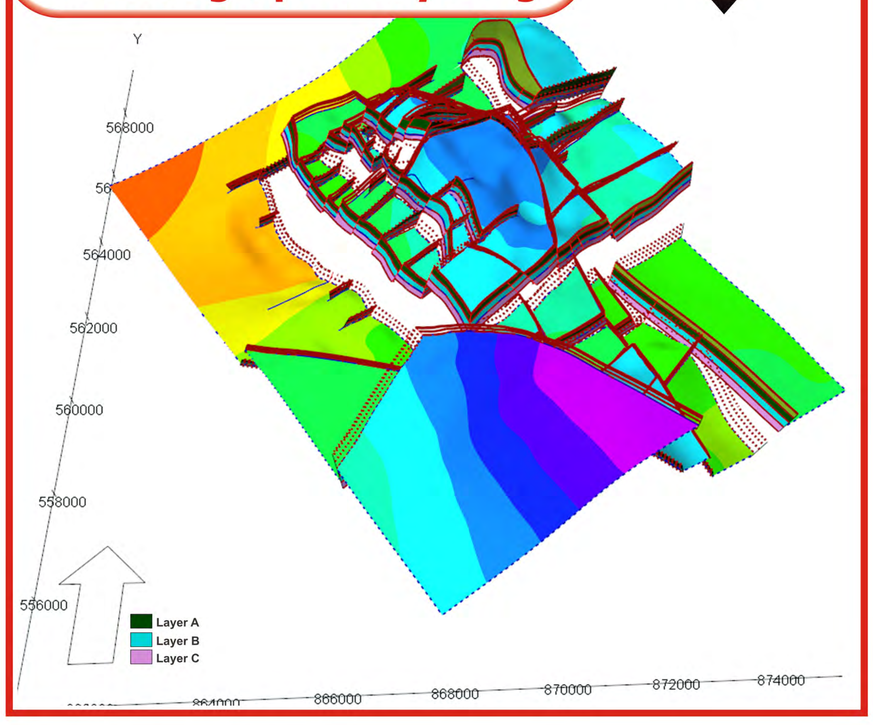


Porosity Map (Top Fractured Basement Zone B)

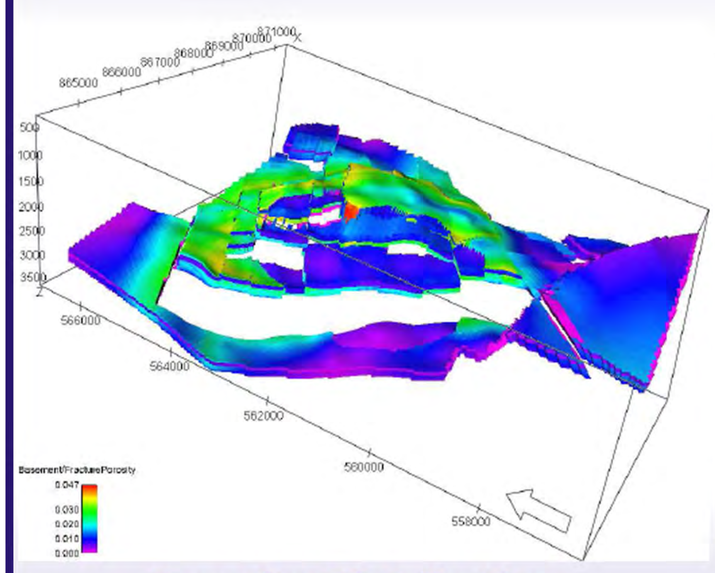


Porosity Map (Top Fractured Basement Zone C)

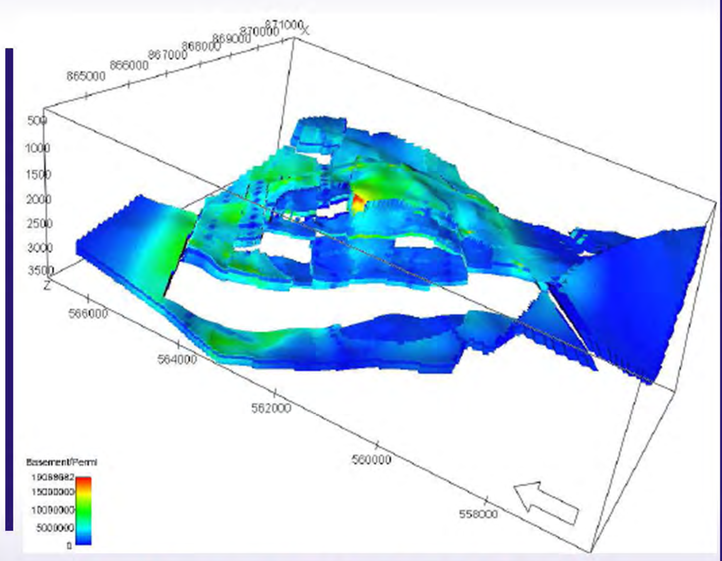
3D Basement Structure & Stratigraphic Layering



Property Distribution Modelling



Porosity Distribution

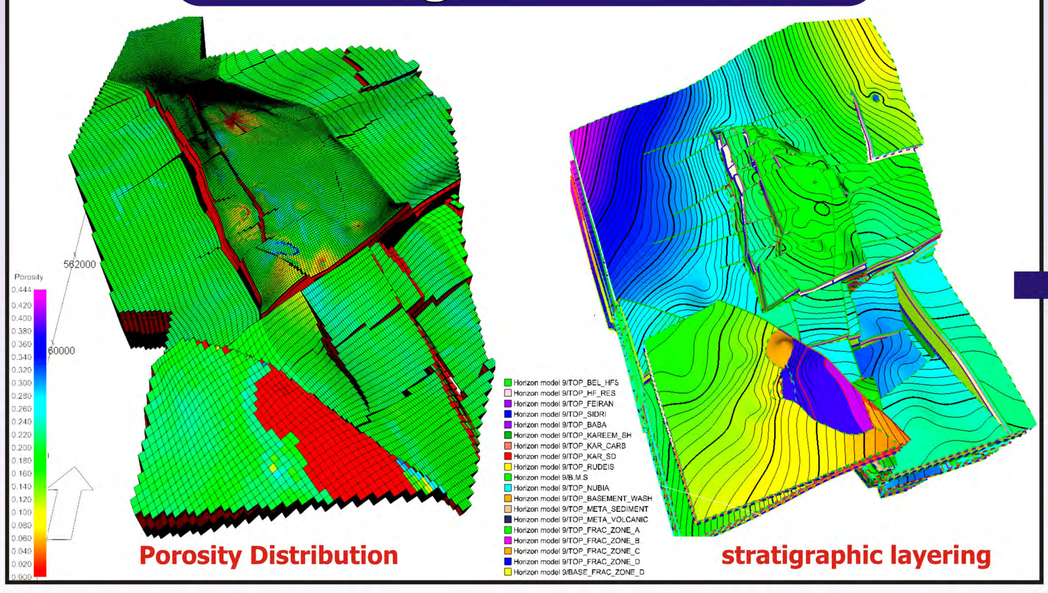


Permeability Distribution

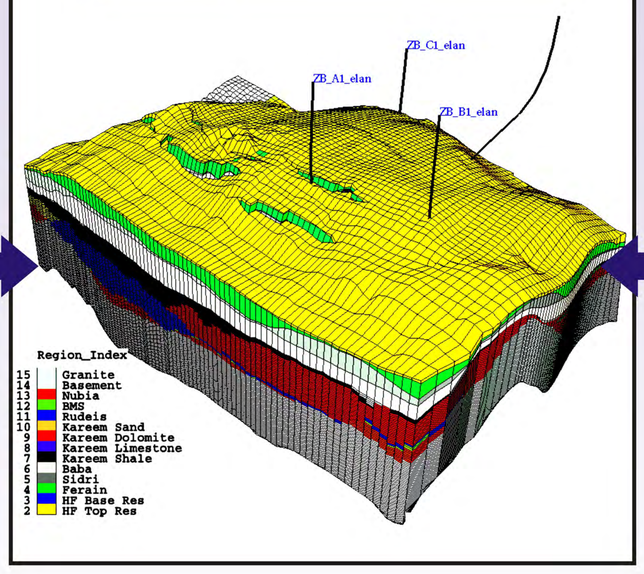
5

History Match

3D Geological Static Model



3D Dynamic Model



Reservoir Engineering

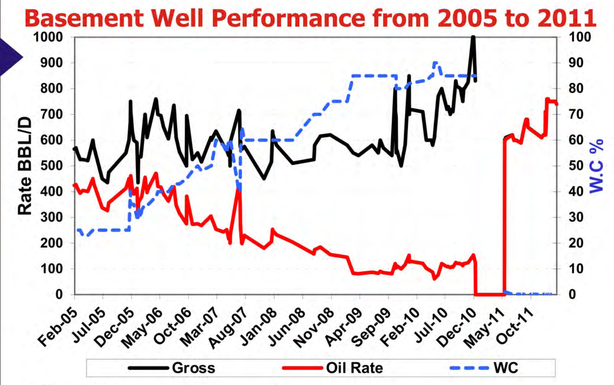
Engineering Data

- Original Hydrocarbon in Place Estimation.
- Reserves and Ultimate Recovery Estimation

Production Data

Past Performance Analysis

Basement Well Performance from 2005 to 2011



- History Match
- Future Performance Prediction

The Fracture Model is in Incorporated Within 3D Geological Static Model for Simulation Purpose in Order to Get Better History Match.

Results & Conclusion

1. The Authors Built 3D Structure And Fracture Models Of Fracture Basement For Zeit Bay Field Using All The Available Data.

2. To Achieve That, Different Techniques And Methods Had Been Applied And Different Software Had Been Used .

3. The Study Reveals The Following Facts:-

- Zeit Bay Area Had Been Affected By Two Main Tectonic Events:-

1) Ancient Uplifting Event (Created An Extensional Environment).
2) More Recent Compression Event From The Gulf Of Suez (Created A Strike-slip Environment).

- The Fracture Types Related To The Two Events Are, Sheeting Fractures , Fault Zone Fractures And Fault - Related Shear Fractures.

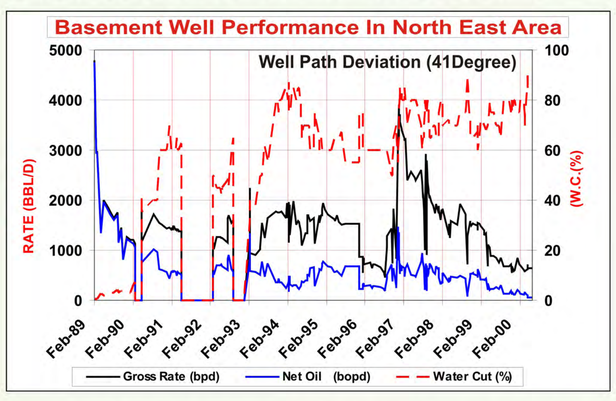
- Fractures Are Brittle Discontinuities In The Rock Matrix Arranged In Regular Networks . Fracture Networks Present Regularities & Can Be Predicted Away From Data Points . A Fracture Set Is Defined By (1) Orientation (strike / Dip) (2) Density / Spacing (3) Aperture / Mineralization (4) Size (length / Height) (5) Type (6) Origin / Age / Truncations & (7) Connectivity. Fractures Are Commonly Measured From Well Core Image Logs And Outcrop Analogues . Other Sources Can Be Used To Quantify Fractures Scales Such As Well Tests And Mud Loss Measurement.

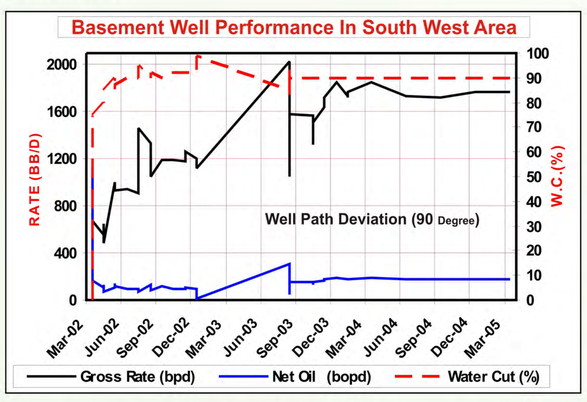
- 3D Fracture Trends Can Be Built & Calibrated Against Fracture Density (from Wells) Or Well Test Permeability Values . Areal Fracture Trends Include (1) Regional / Zone Trends (2) Curvature Trend ,(3) Proximity To Fault & (4) Elastic Dislocation .Other Trends Include (1) Facies Trend And (2) Depth Trend . The Calibrated Trend Models Can Be Co-simulated With Well Observations Directly To Generate 3D Fracture Distributions.

- The Fracture Model Should Be Modified For The Simulation Purpose In Order To Get Better History Match.

Recommendations

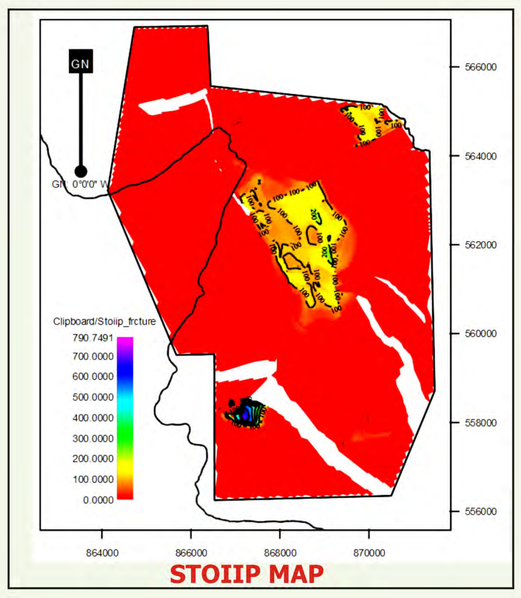
Many Factors Should Be Taken Into Consideration In Dealing With **Fractured Basement** Productivity In Zeit Bay (The Productivity Index,Movement Of Oil-Water Contact Upward , Fractures Dip Intensity & Orientation) In Addition To Well Path Deviation.



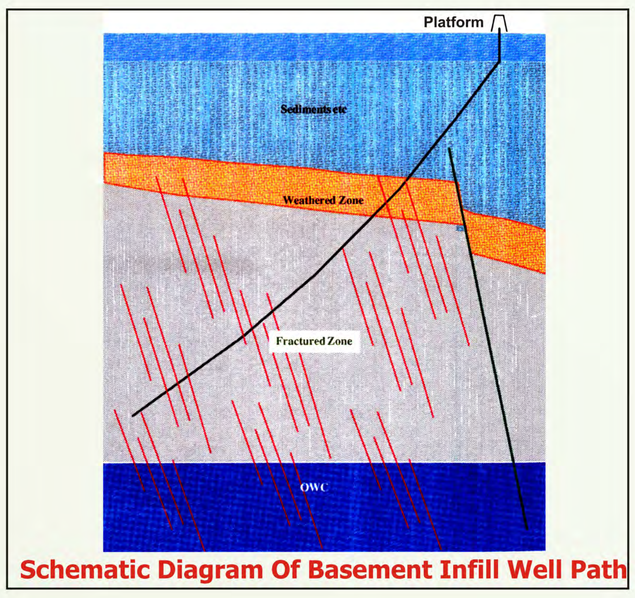


Based Upon The Above Factors , The Optimal Locations For Infill Wells To Be Drilled Are In The South East & North East Portions Of The Field As They Have High Productivity Index , 60 Degree Fracture Dip In Conjugate Set & Slow Movement Of Oil - Water Contact Upward .

Well Deviation Design Is **Recommended** To Be At 30 - 40 Degree In Order To Penetrate Maximum Fracture Sets. Hence, Maximum Oil Productivity Can Be Aevchdei



STOIIP MAP



Schematic Diagram Of Basement Infill Well Path

Acknowledgment

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