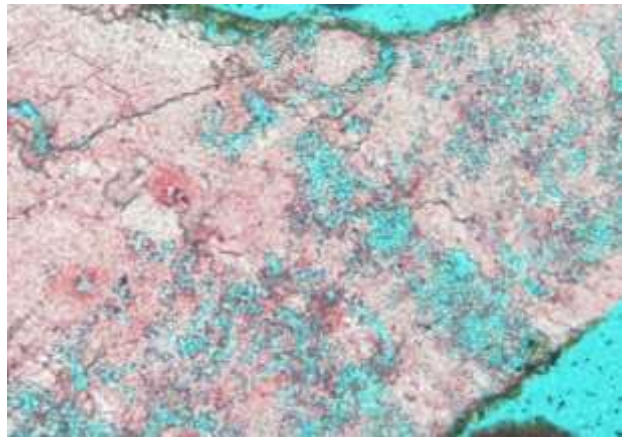
Some Points About Carbonate Reservoirs




Dr. Ahmed Salah

- Contents
- All Limestone Reservoirs Are Fractured????
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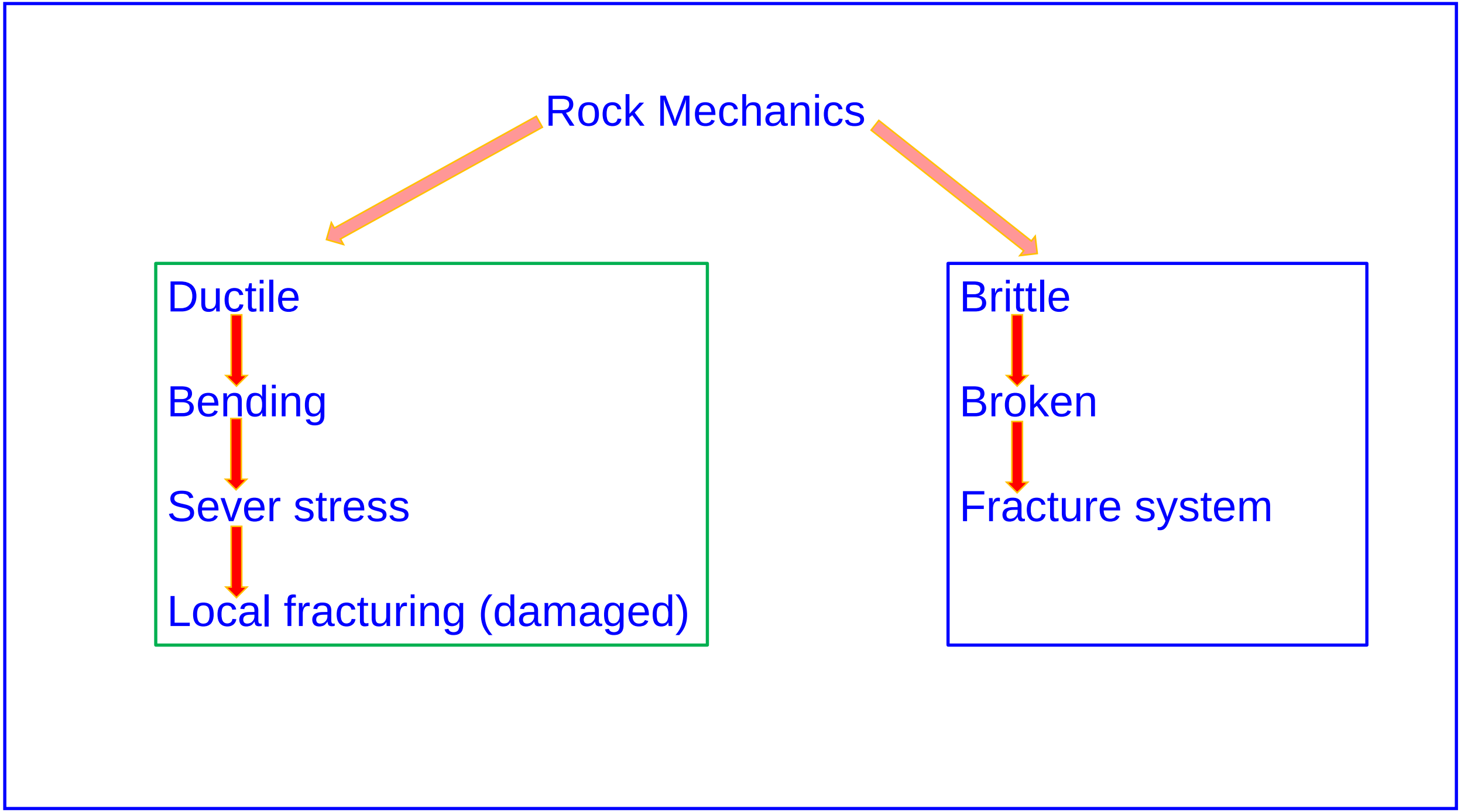
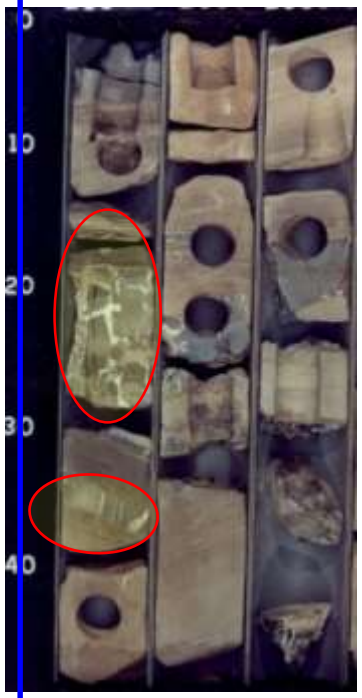
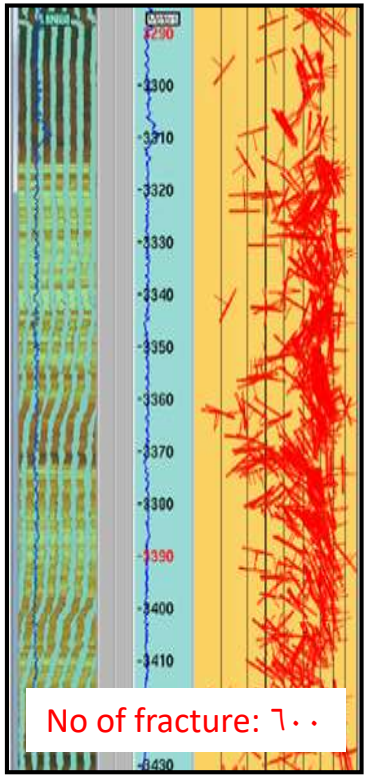
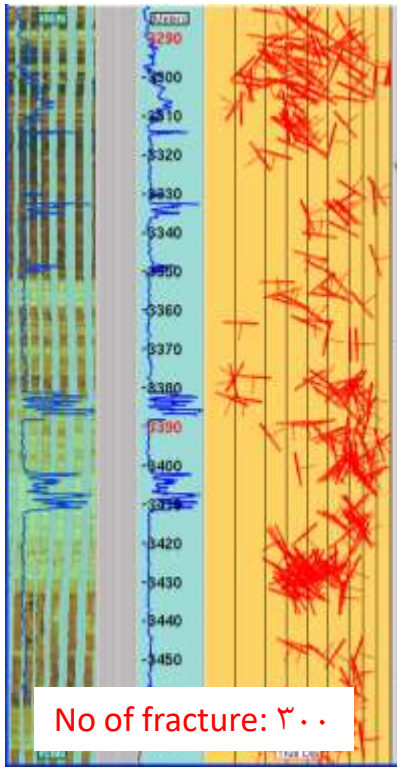

Rock Mechanics
Ductile
Bending
Sever stress
Local fracturing (damaged)
Brittle
Broken
Fracture system

Damaged reservoir

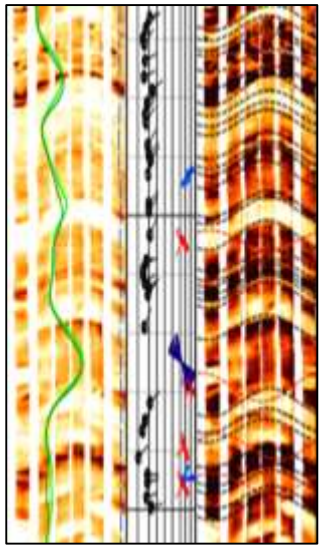


Fractured reservoir





Damaged reservoir



Few fractures

Fractured reservoir

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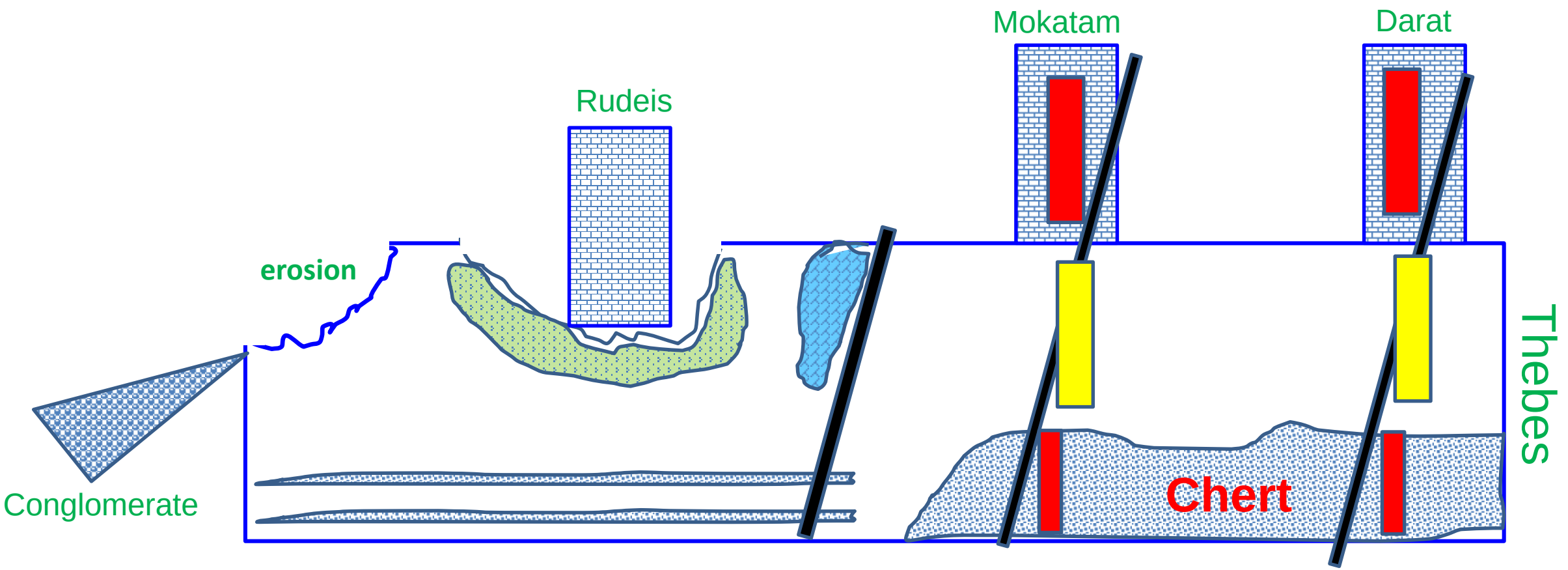
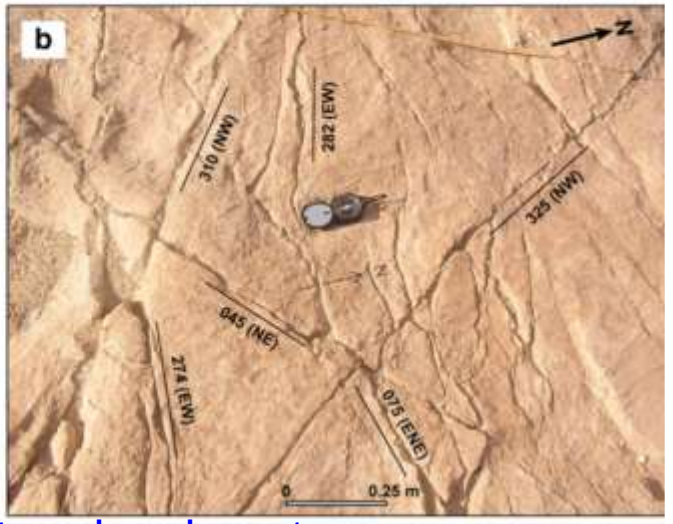
Eocene Reservoirs in GOS Province

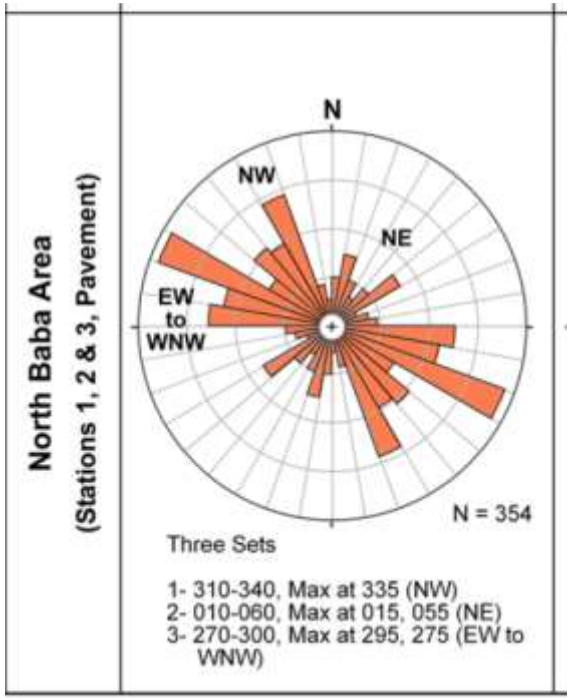


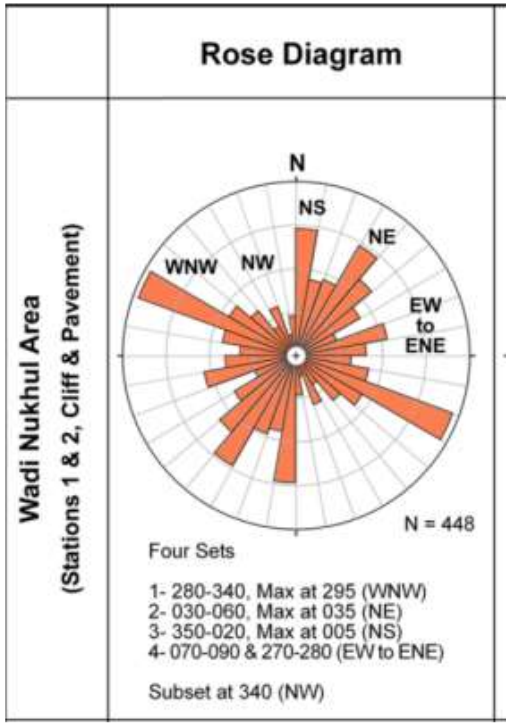
Limestone weathered surface



Thebes damaged reservoir

Darat fractured carbonate





Syn-rift conglomerate (Thebes _ derived)

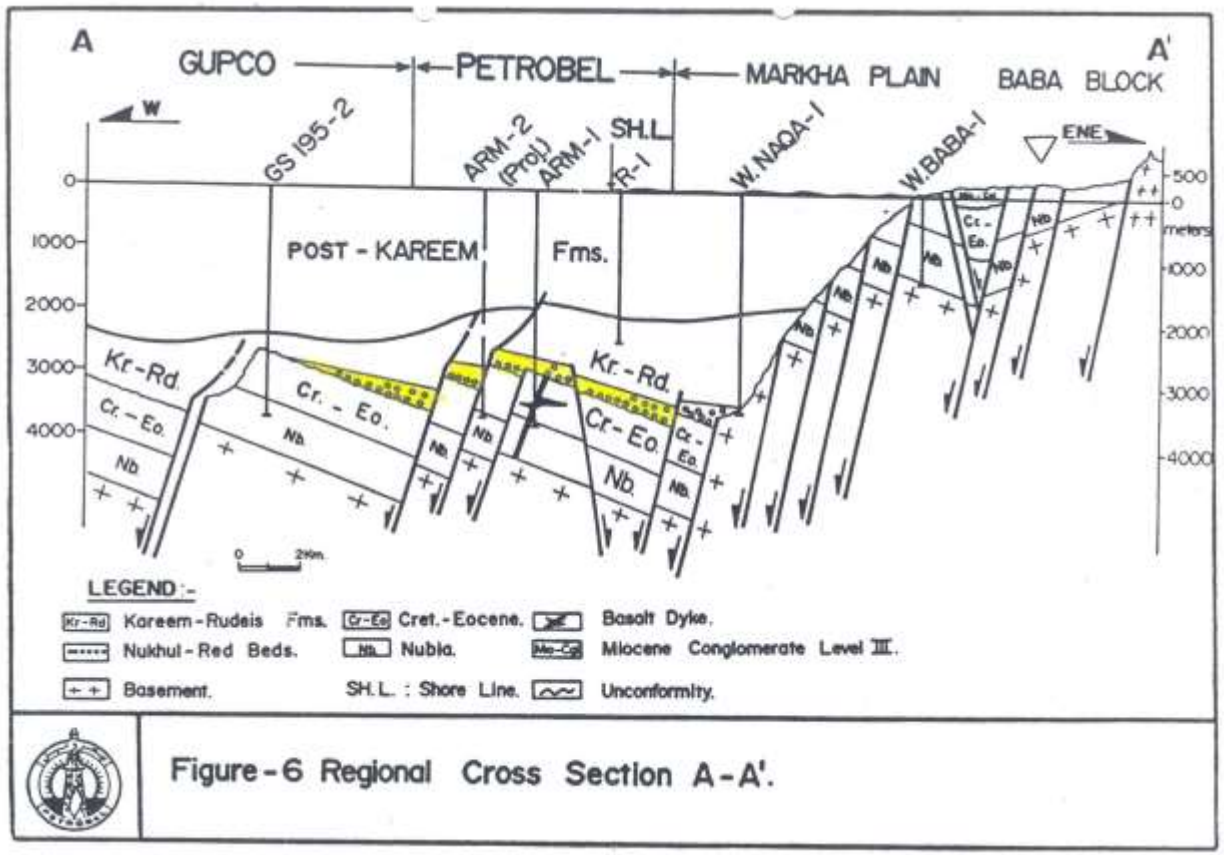
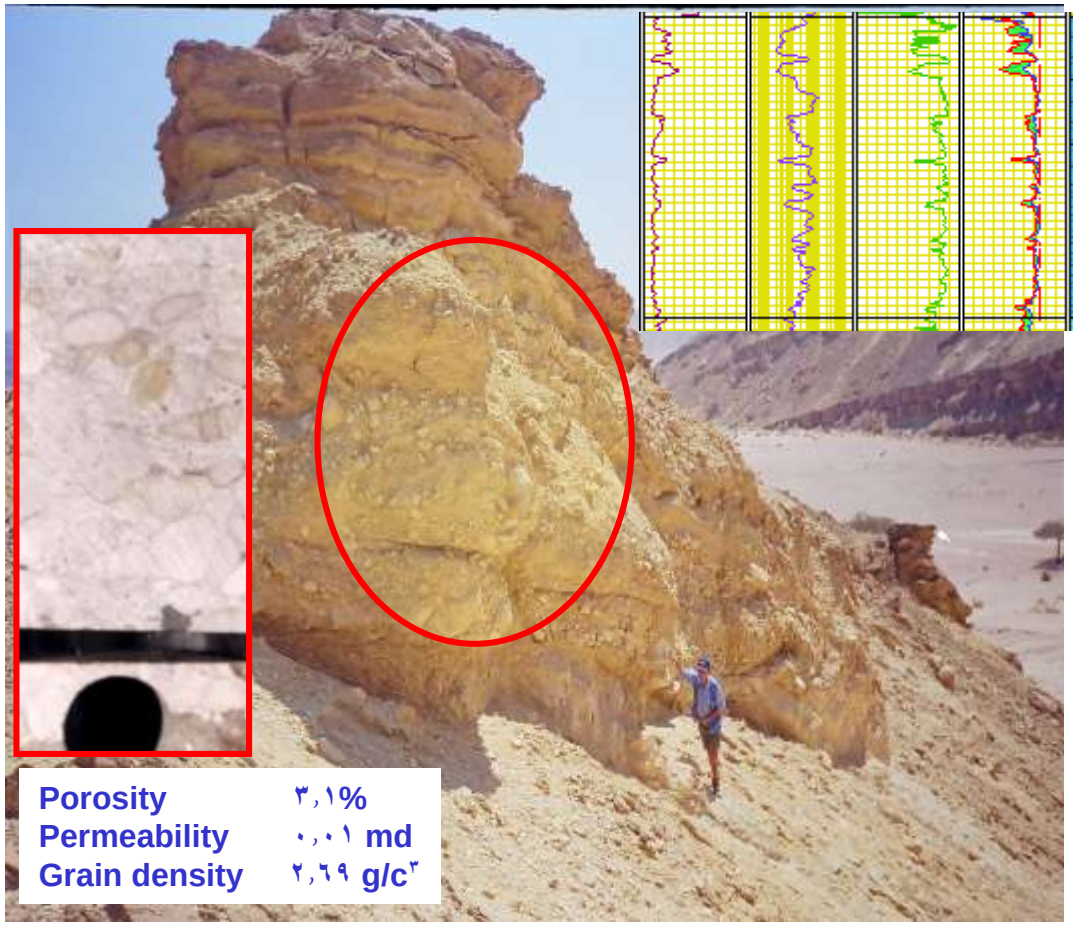
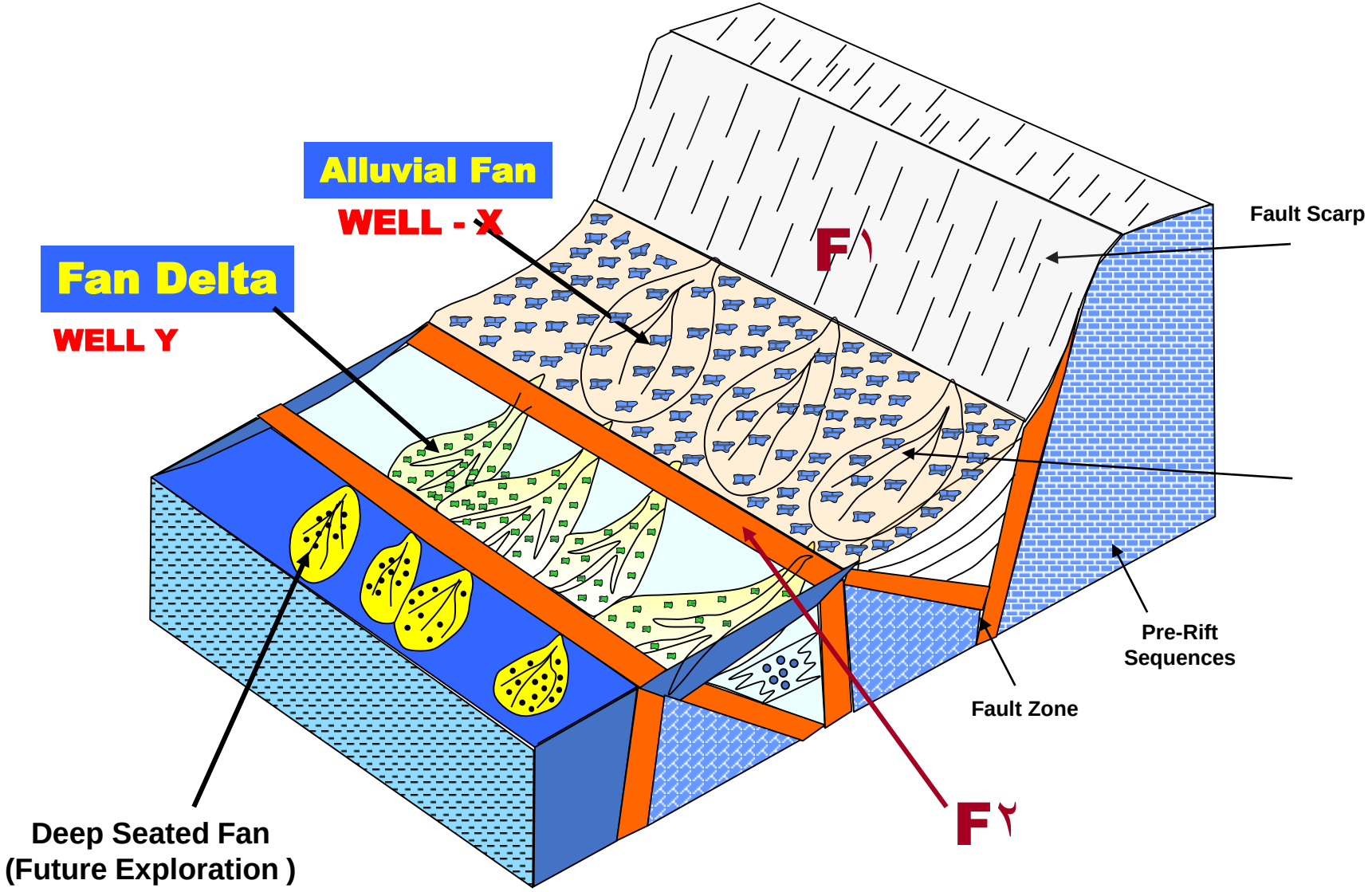


Figure - 6 Regional Cross Section A - A'.



DEPOSITIONAL MODEL OF SYNRIFT SEDIMENTS



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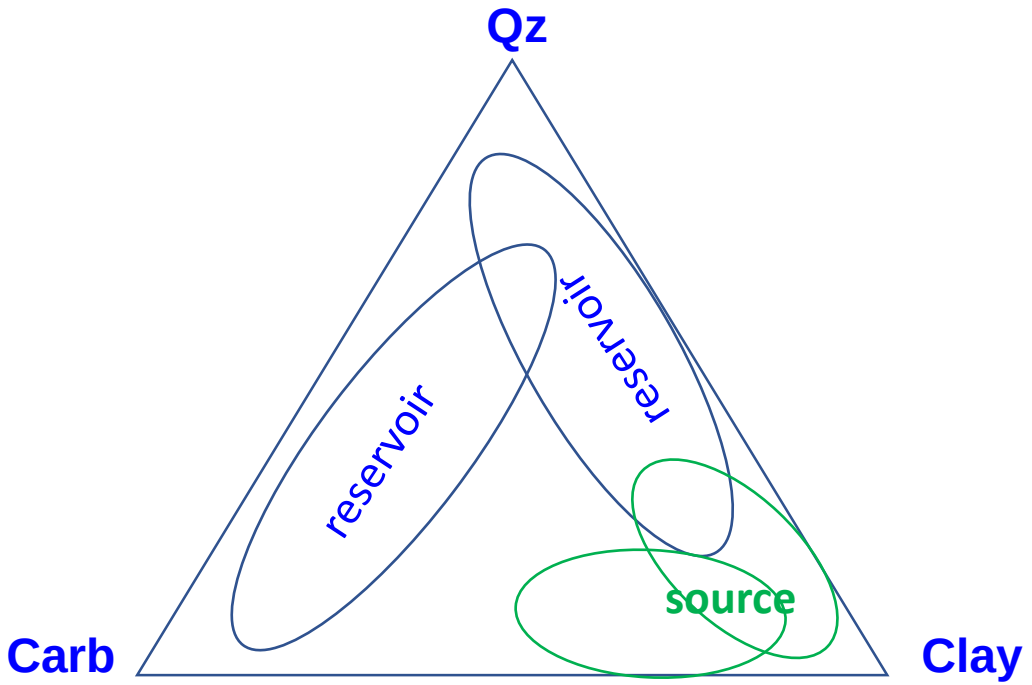
Shale is a size term, not a mineralogical term



Ternary diagram showing the distribution of shale-gas mineralogical contents

The main components are the Qz and Carb. Materials. SPE ١١٥٢٥٨

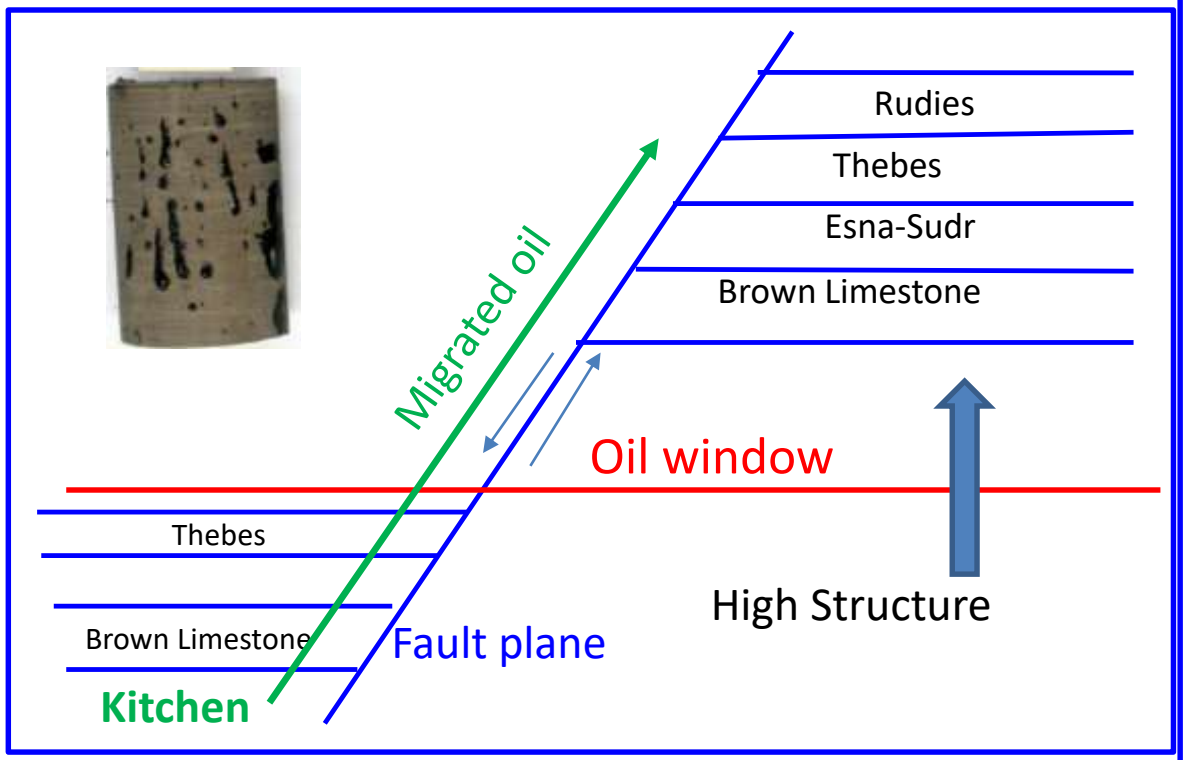
The mature oil is expelled from source below the oil window by the alteration of organic material into liquid oil which is associated with very high pressure, enough to exceed the rock capillarity and starts migration process.

The presence of immature source rock in structurally high position, that oil can not be produced because the ultralow perm and high viscosity.

To produce oil from source rock in high structure:

١. Additional porosity should be created by tectonic and/or diagenesis, before the oil expulsion from a source rock in the kitchen.

٢. The migrated oil will be accumulated in the additional created porosity and would be produced.



Rudeis oil: ٩٨% sourced from Brown limestone
٢% sourced from Thebes

Thebes oil: ١٠٠% Thebes oil
Zero % Brown Limestone

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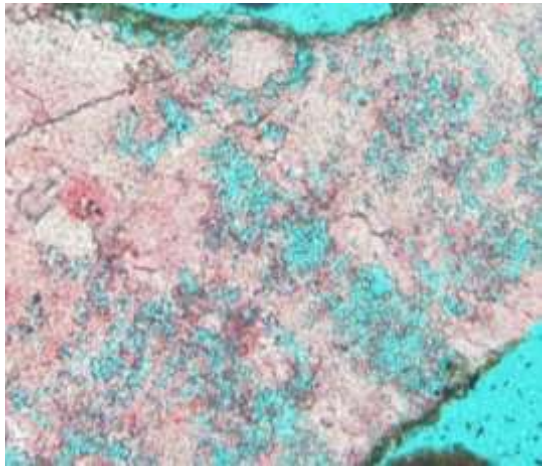
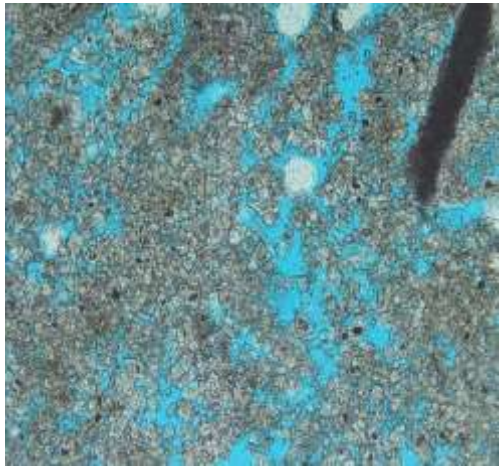
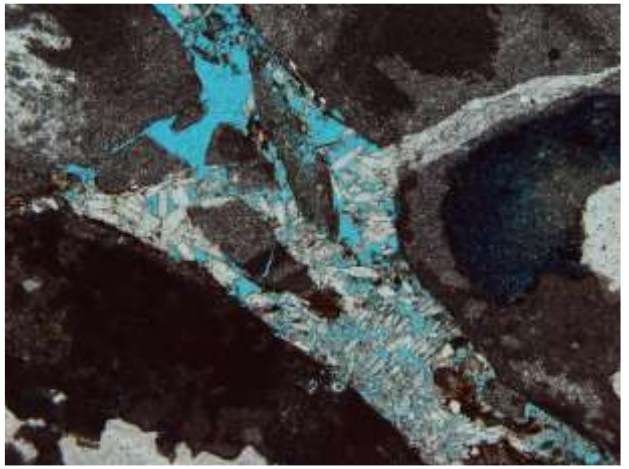
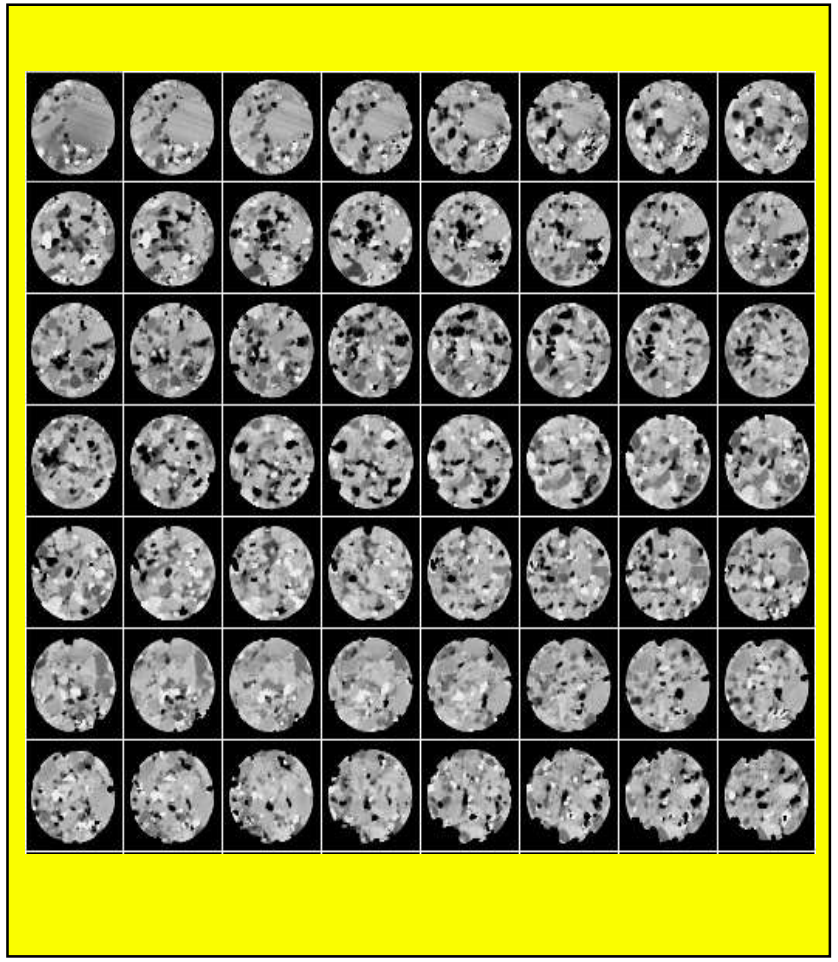
Carbonate Reservoirs Heterogeneity



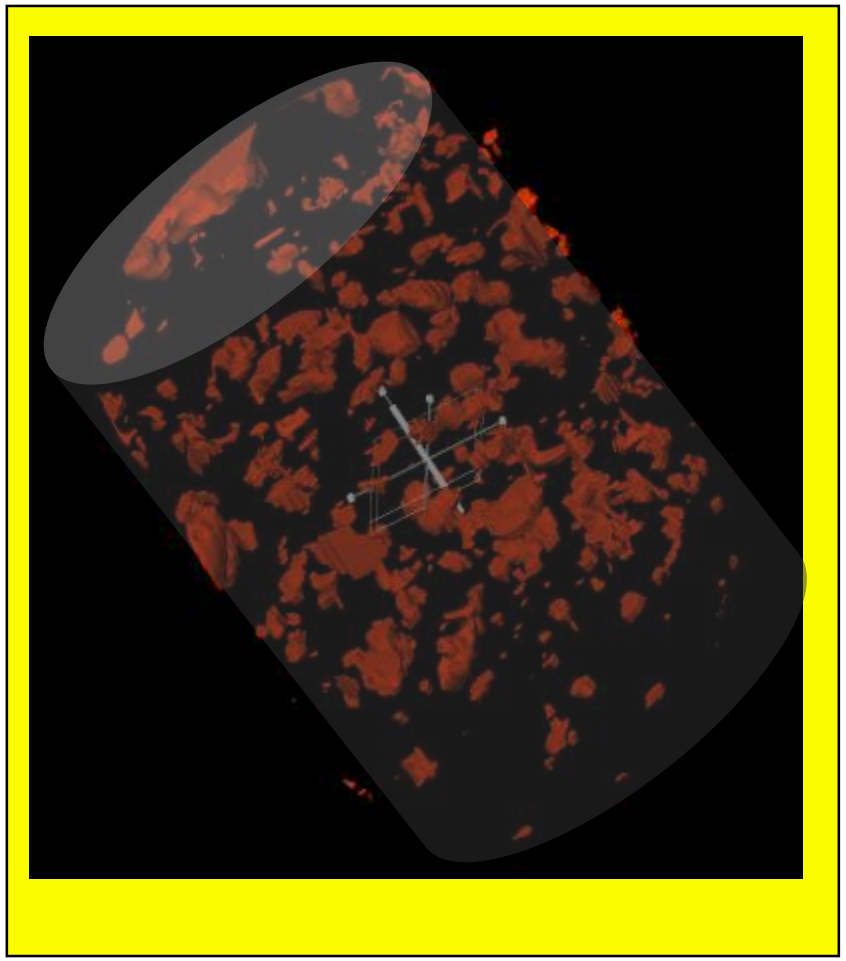


X-Ray Computed Tomography

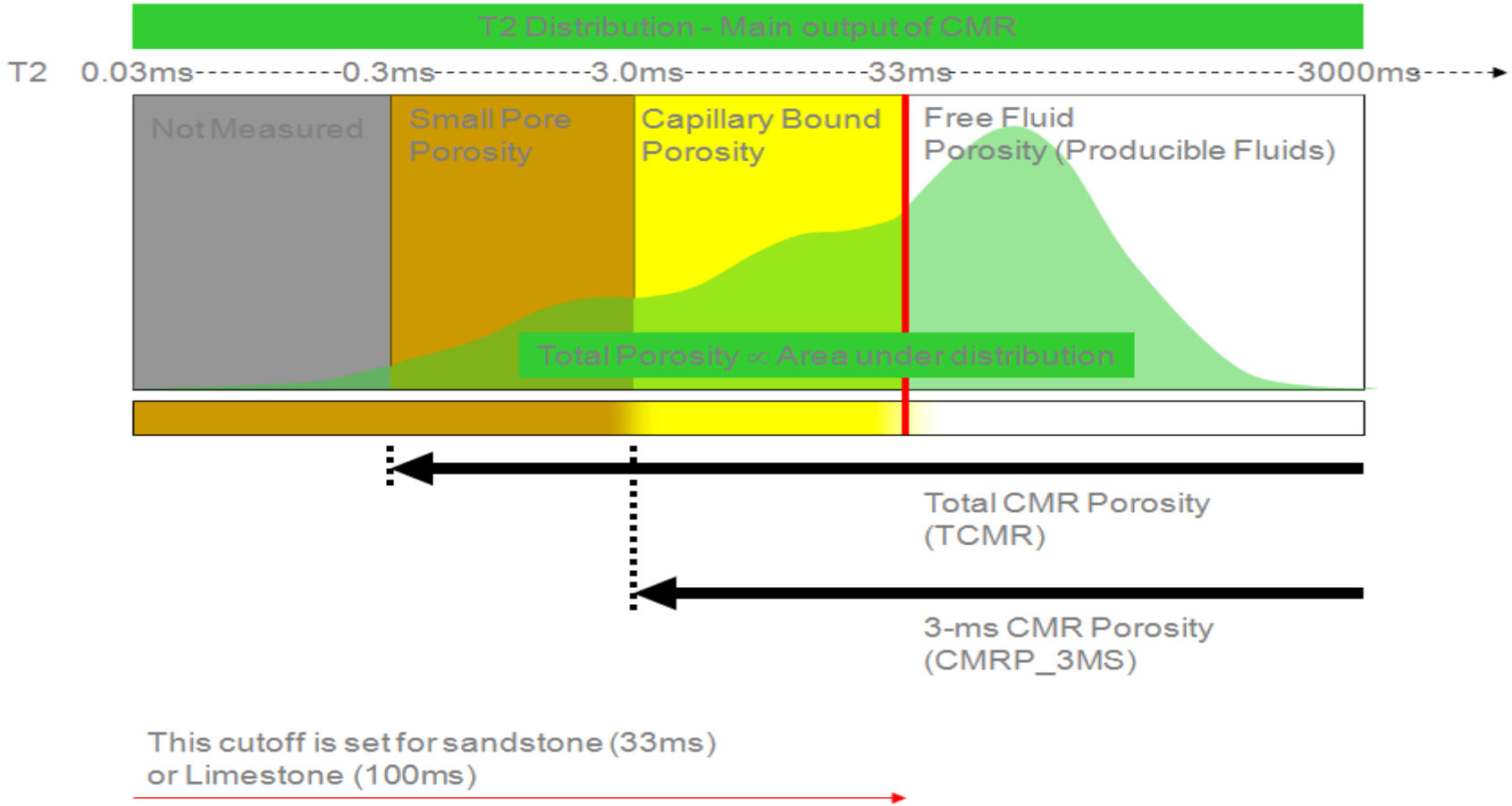


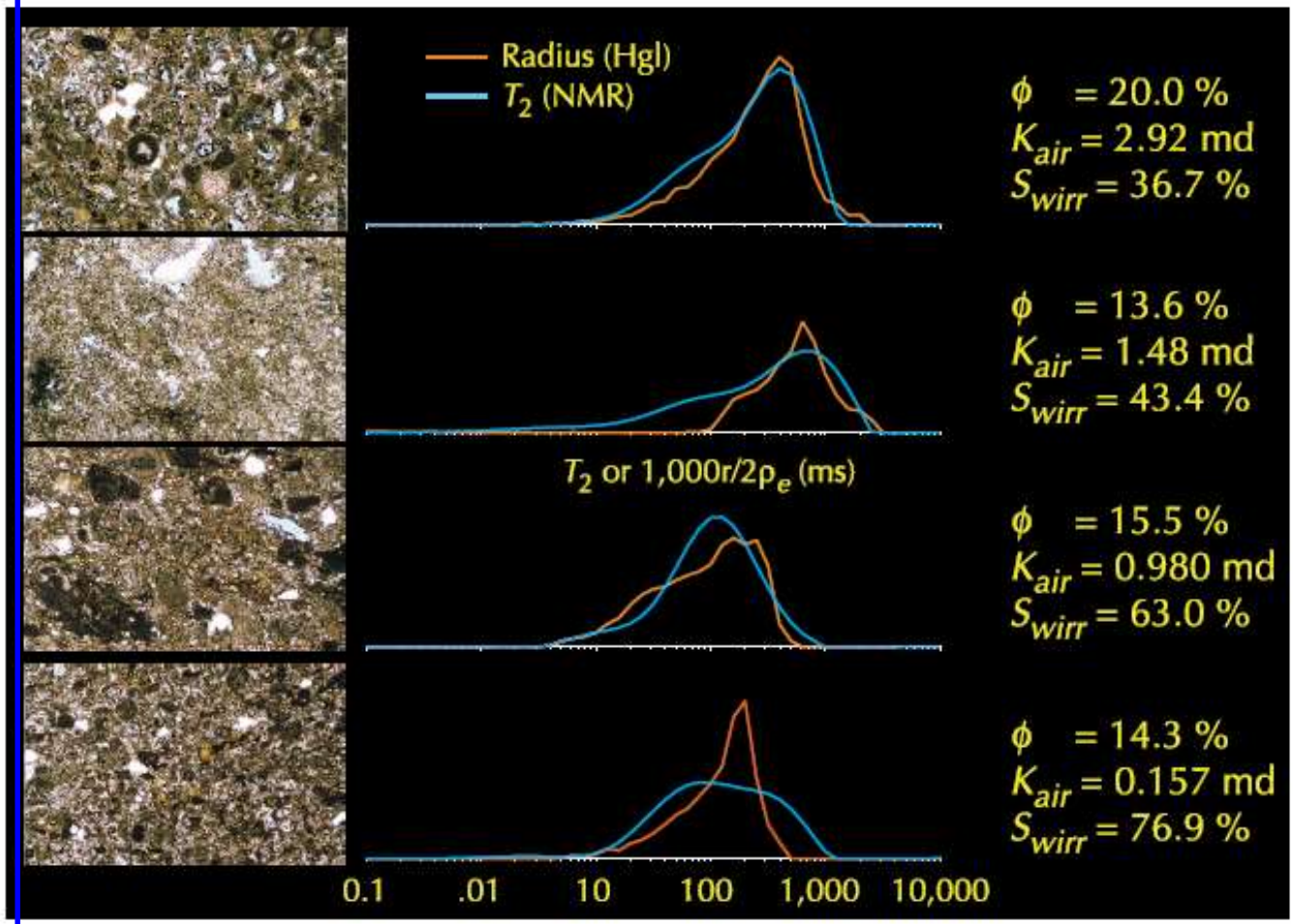
Traverse slices



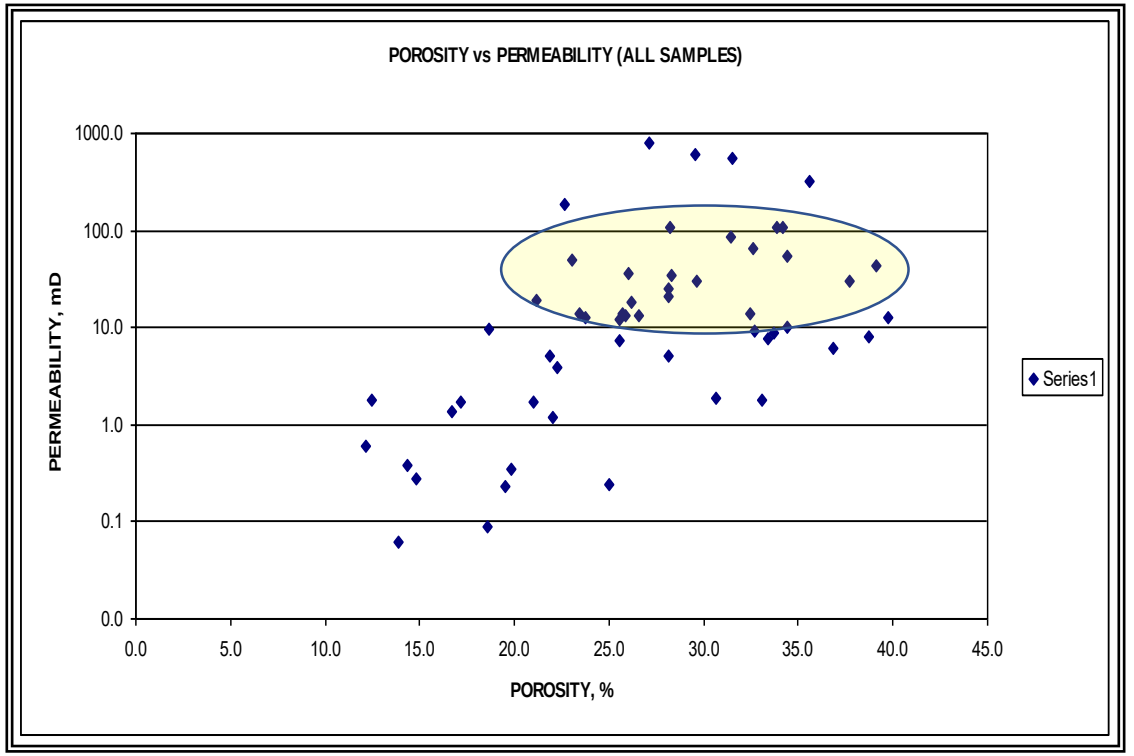
٣d construction of pore spaces

Porosity Partionning by NMR





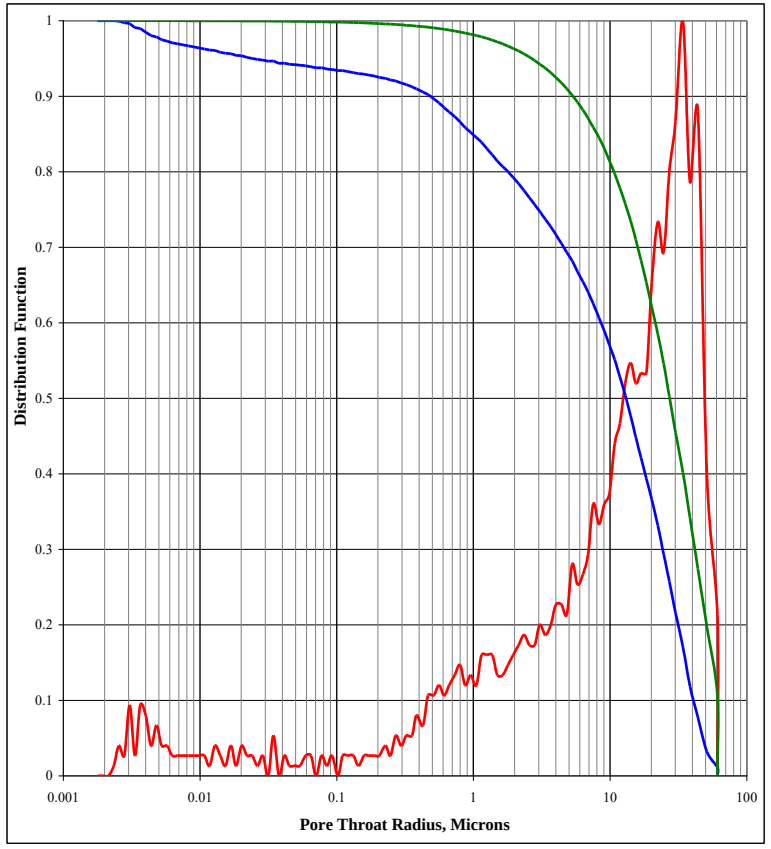
Carbonate Samples



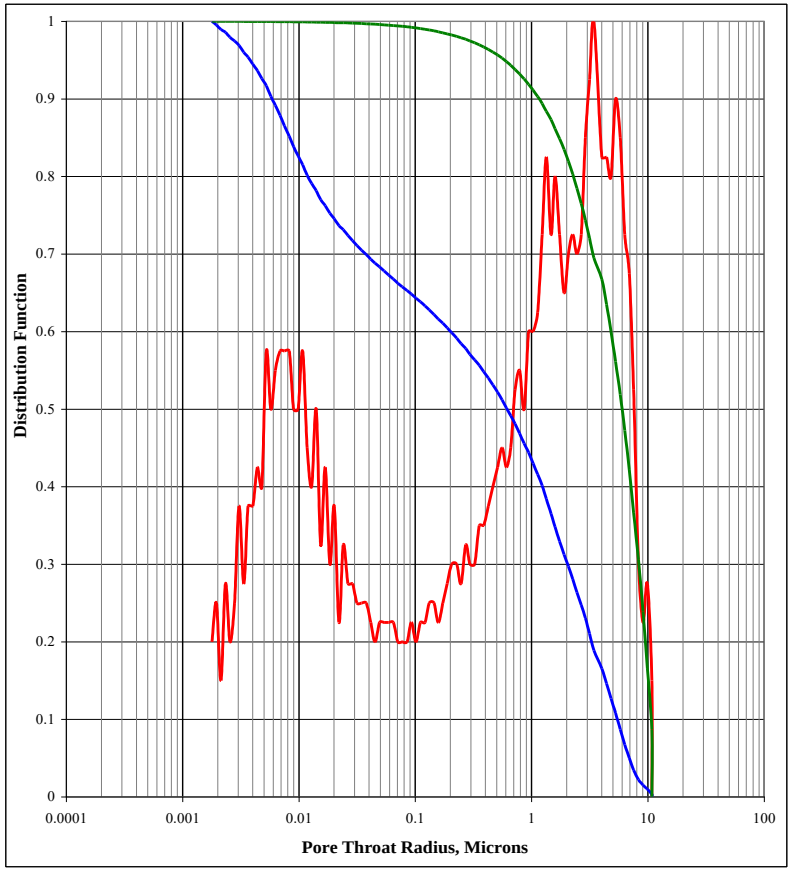
NMR Logging Principles and Applications, G. R. Coates, L. Xiao, and M. G. Prammer, ۱۹۹۹, pg. ۵۷

Rock Flow unit and Reservoir Productivity

AIR PERMEABILITY (mD) : 1296 **POROSITY:** 29.2%



AIR PERMEABILITY (mD) : 26.2 **POROSITY:** 29.6%

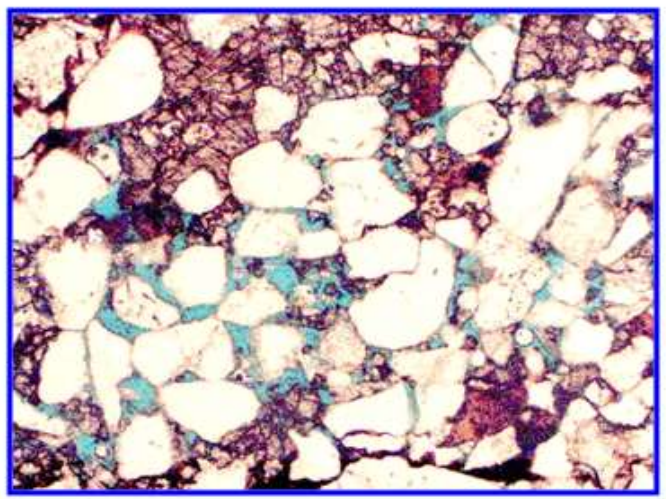


ROCK CHARACTERIZATION

SOLIDES

GRAIN

CEMENT

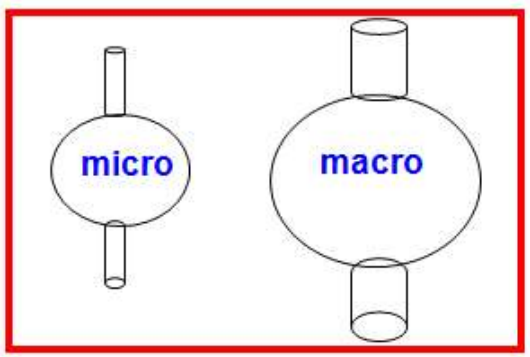


PORE NETWORK

MICRO PORES

LARGE PORES

PORE THROAT



ROCK TYPE

Unit Of Rock Deposited Under Similar Conditions

If it is experienced

✓Similar *Diagenetic* Processes Same **FLOW UNIT**
✓Different *Diagenetic* Processes Different **FLOW UNIT**

Resulting in a

Unique Poro-perm Relationship
Capillary Pressure Profile (Sw vs Depth)

FLOW UNIT is aimed to characterize the reservoir rock into

UNITS WITH UNIFORM PORE THROAT SIZE
DISTRIBUTION AND SIMILAR FLOW PERFORMANCE

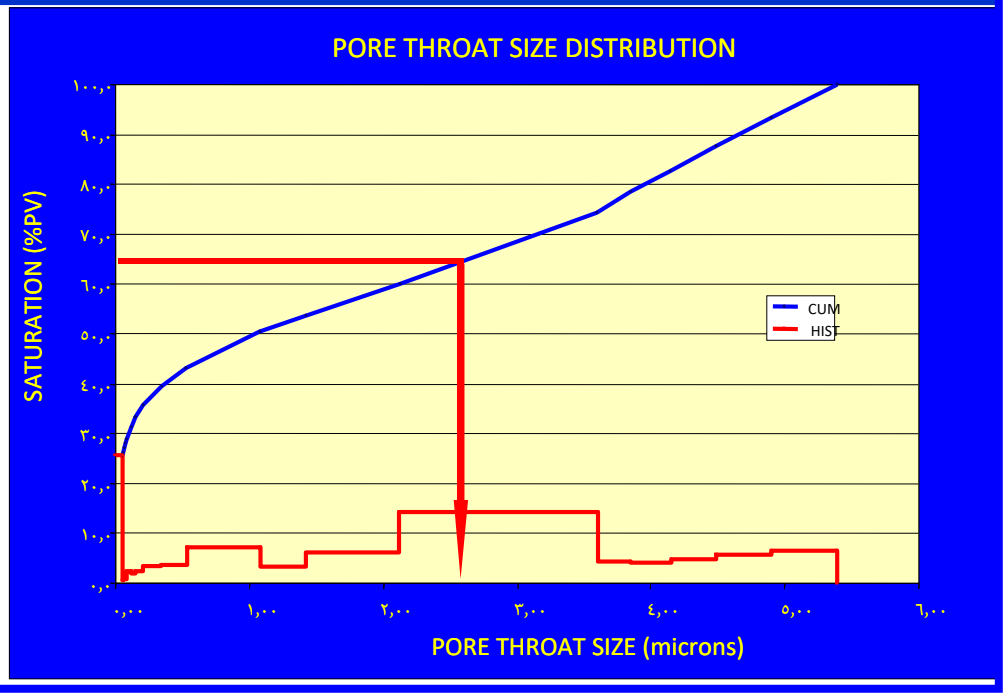
DETERMINE THE EFFECTIVE PORE THROAT SIZE THAT DOMINATES THE FLOW

R٣٥ =PORE THROAT RADIUS @ ٣٥%PORE VOLUME

$$\text{Log } R_{35} = ٠,٧٣٢ + ٠,٥٨٨ \text{Log (Kmd)} - ٠,٨٦٤ \text{Log (por \%)}$$ WINLAND EQUATION

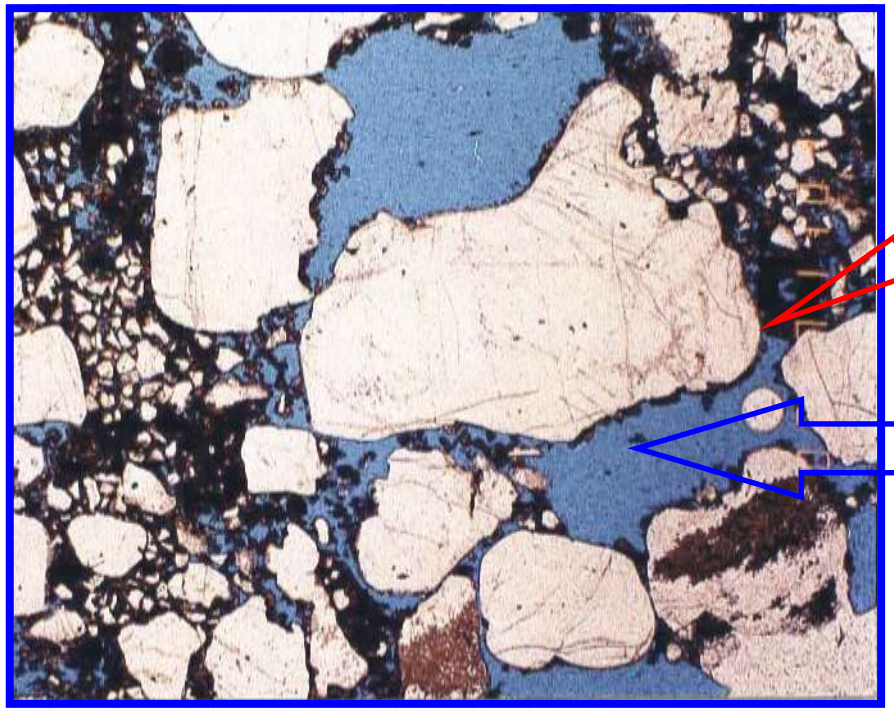
FLOW UNITS RANGES

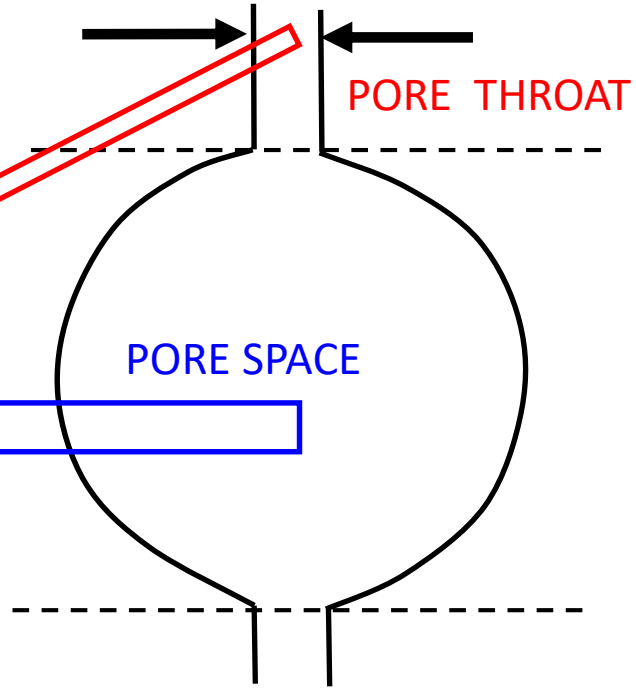
١-	MEGAPORT	R٣٥ >١٠
٢-	MACROPORT	١٠ < R٣٥ > ٢
٣-	MESOPORT	٢ < R٣٥ > ٠,٥
٤-	MICROPORT	٠,١ < R٣٥ < ٠,٥
٥.	NANOPORT	R٣٥< ٠,١



CAPILLARY PRESSURE BY MERCURY INJECTION

PORE-THROAT SIZE DISTRIBUTION





$$P_c = \frac{2 t \cos\theta}{r}$$

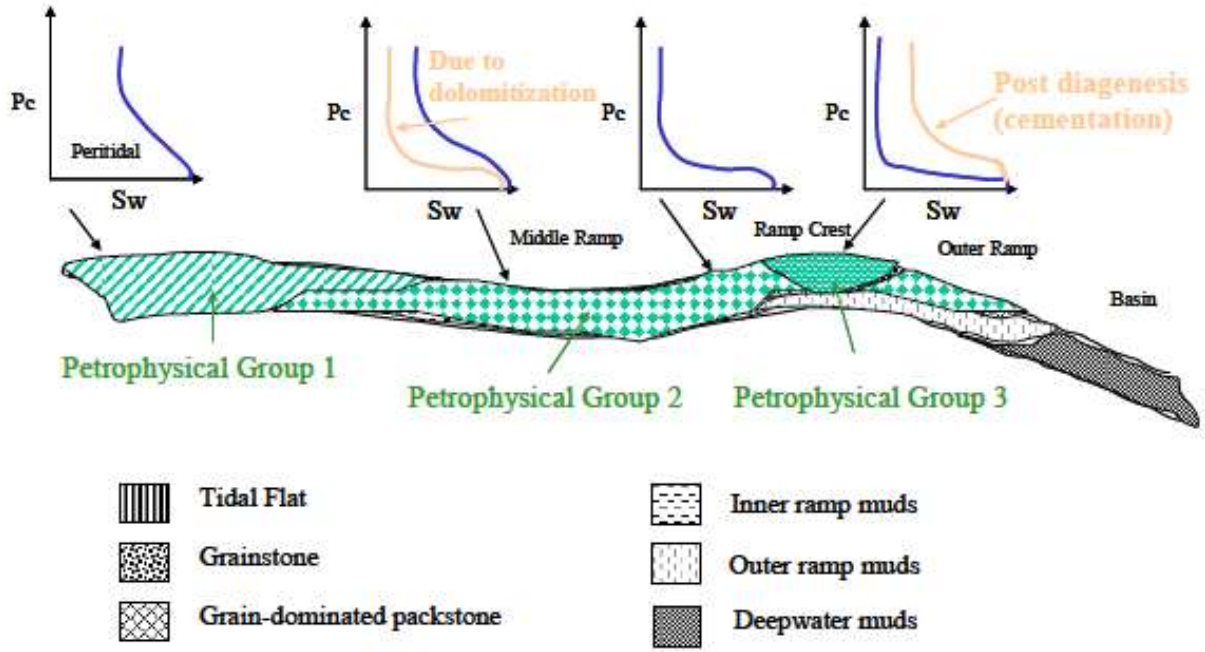
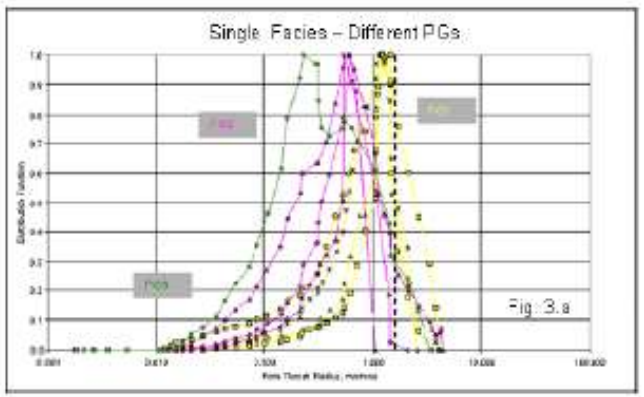
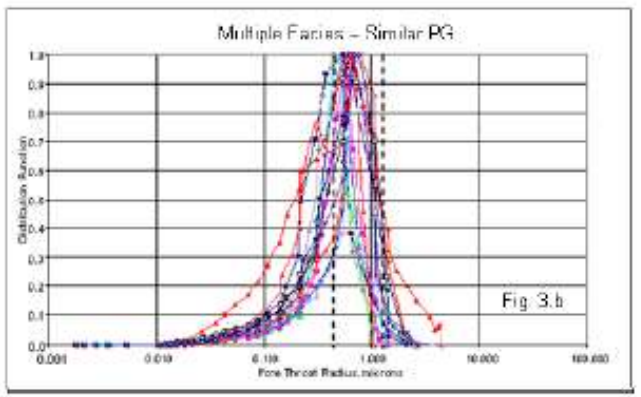


Figure 2b – The impact of diagenesis on the capillary pressure behaviour of different facies (Refer to Figure-2a).





Figures 3a & 3b – Impact of diagenesis on pore throat radius distributions of geological facies

Capillary Pressure

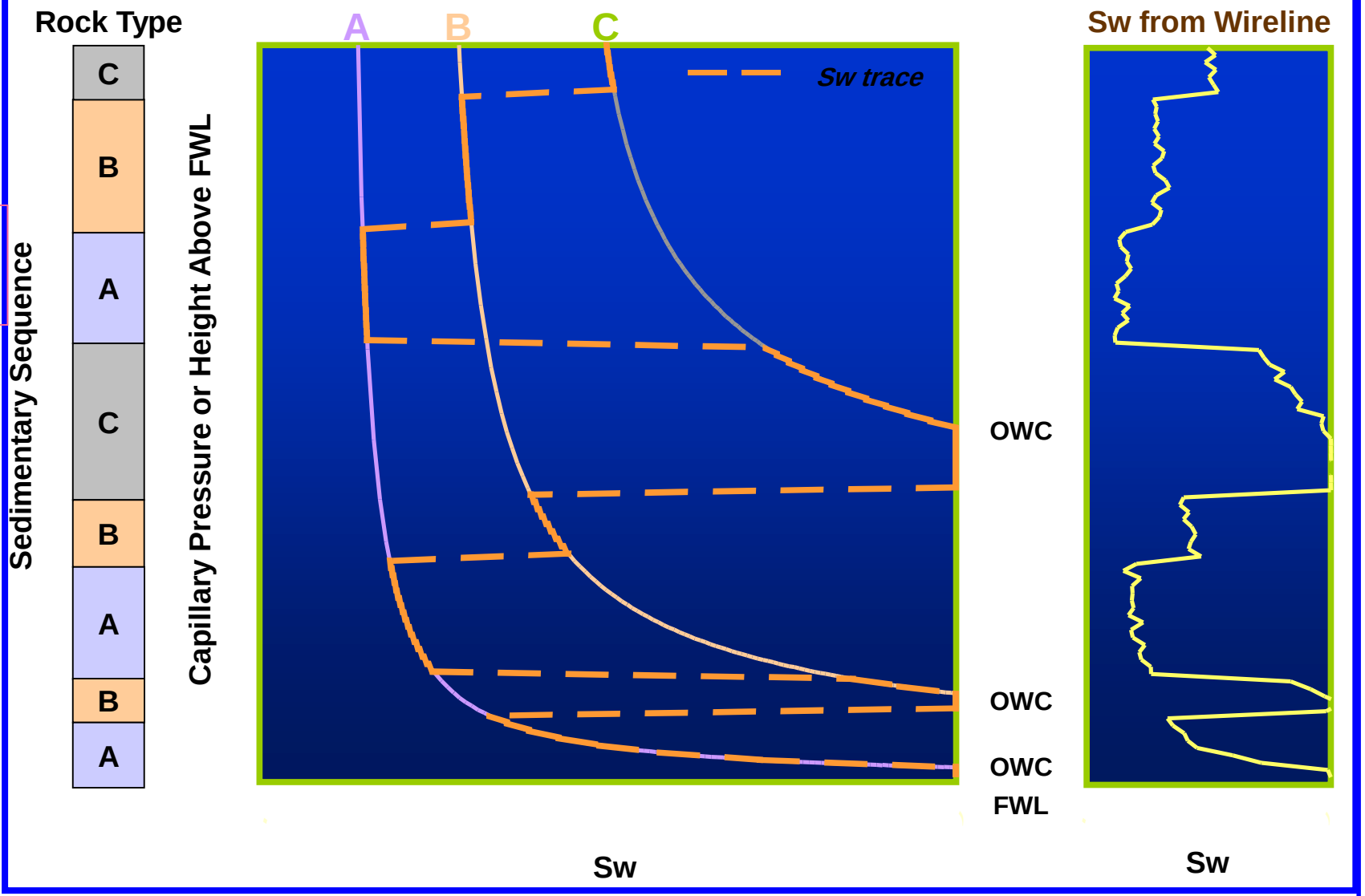
Fluid Property

Rock - Fluid Property

$$Pc = \frac{2\sigma \cos\theta}{r}$$

Rock Property (K & ϕ)

Sw Distribution by rock type concept



THE WETTABILITY CONTROL

DISTRIBUTION OF FLUIDS

RESERVOIR PERFORMANCE

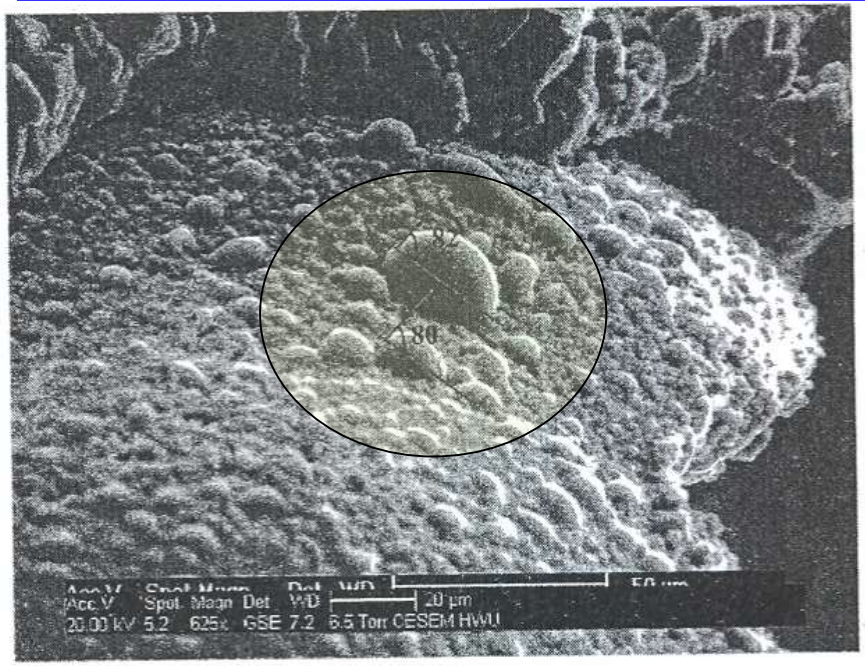
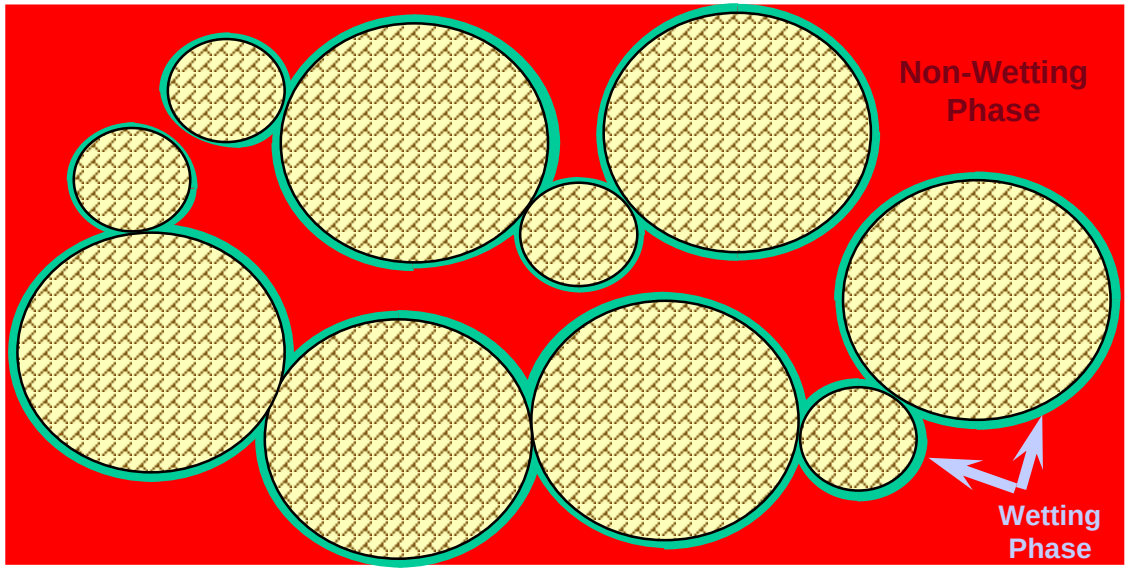
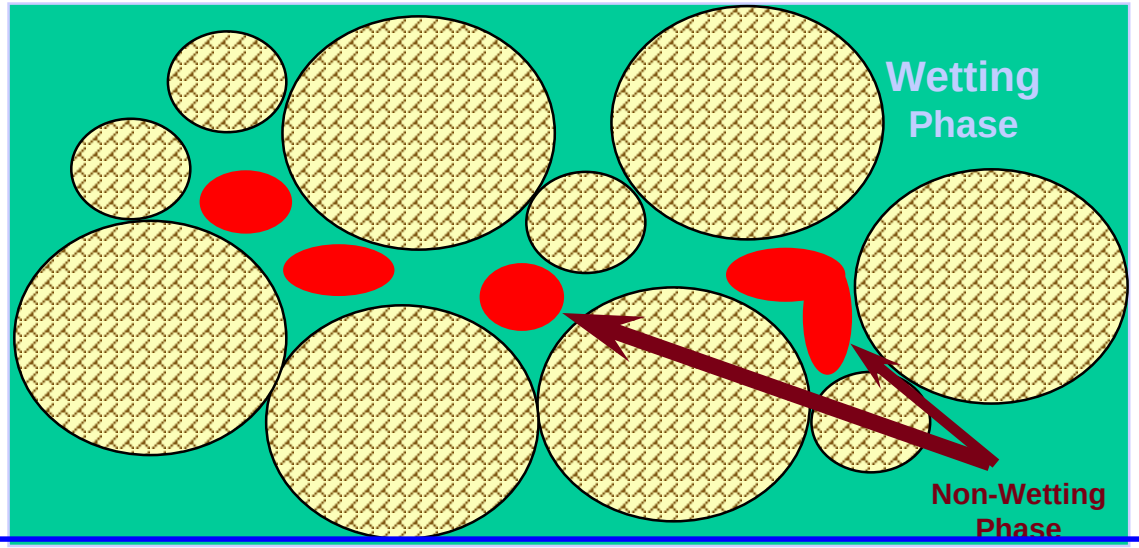


Figure 11: Arab-D carbonate rock. Appearance of water distribution and intermediate wetting characteristics of grains.

Wetting Phase Forms a Continuous Film on Rock



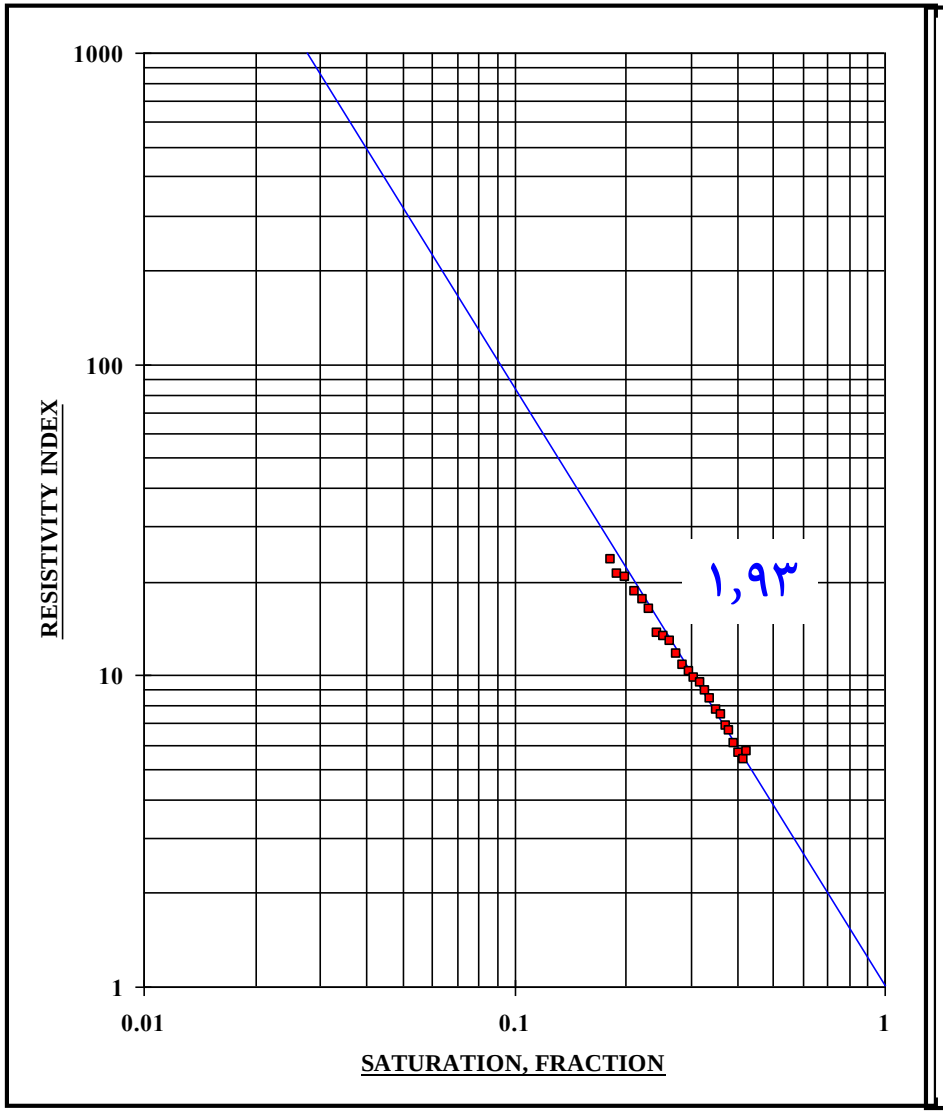
Non-Wetting Phase Becomes Discontinuous

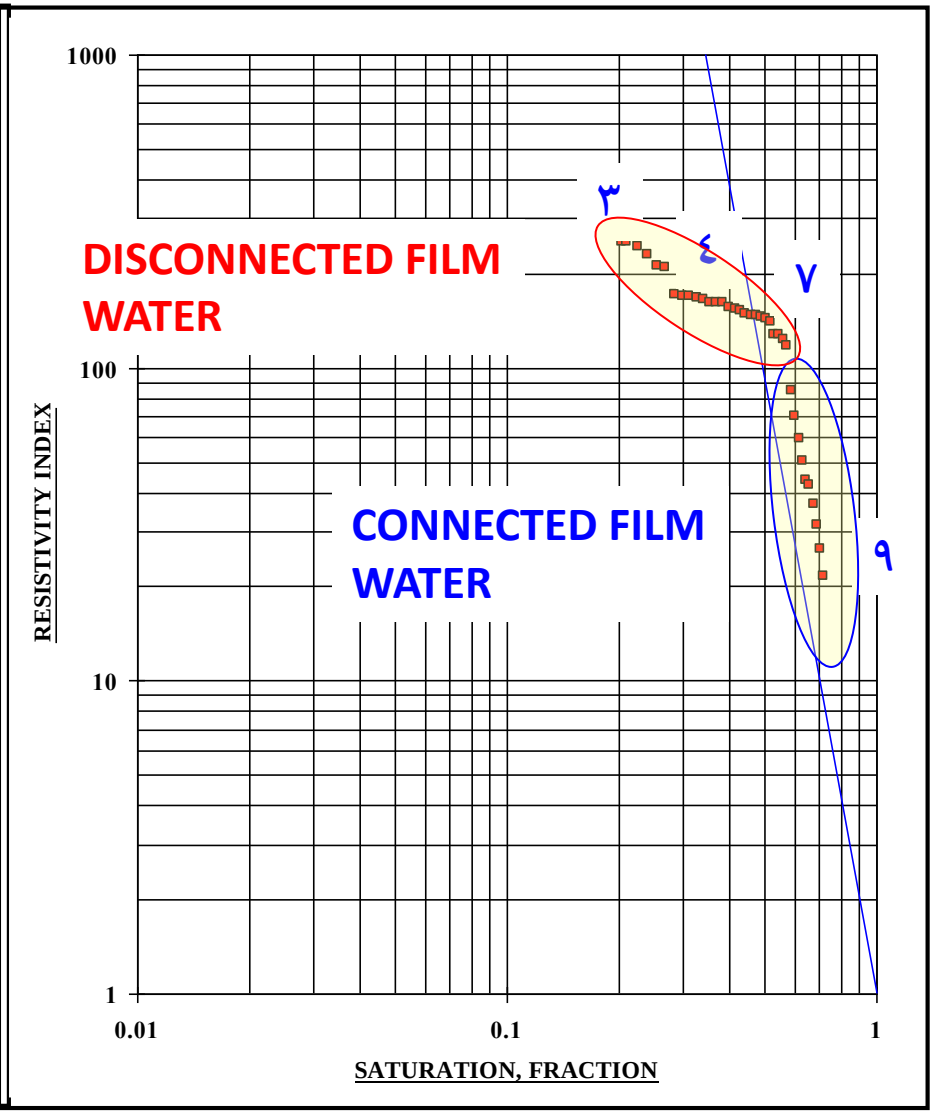


RESISTIVTY MEASUREMENTS

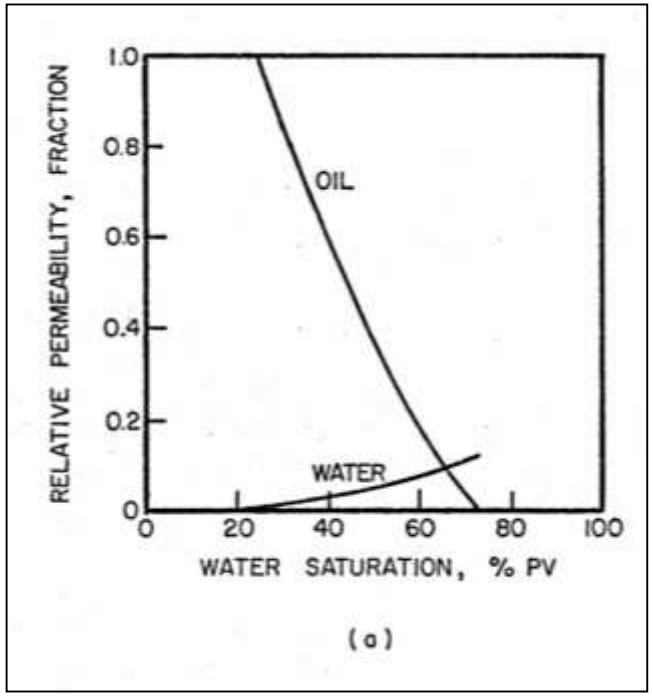
CLEANED-STATE SW-DECREASING

RESTORED-STATE SW-INCREASING



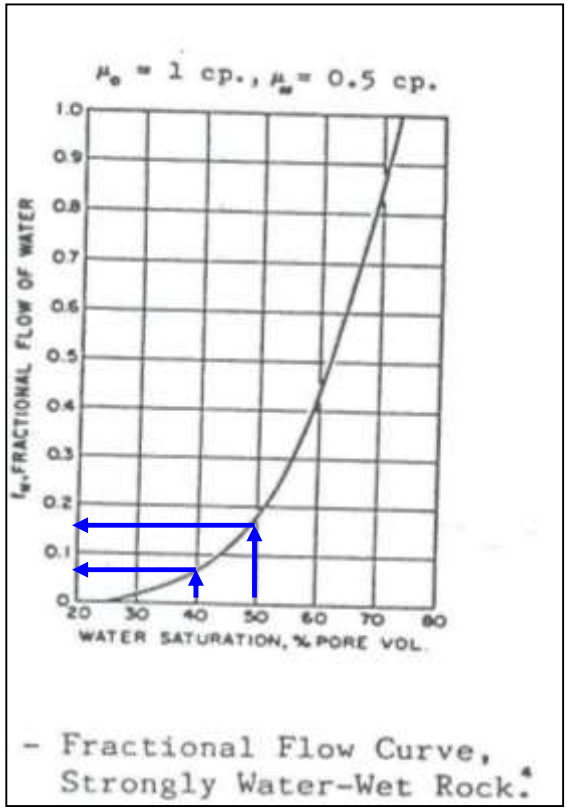


Relative Permeability



Strongly Water-wet

Water Cut



- Fractional Flow Curve, Strongly Water-Wet Rock.[4]

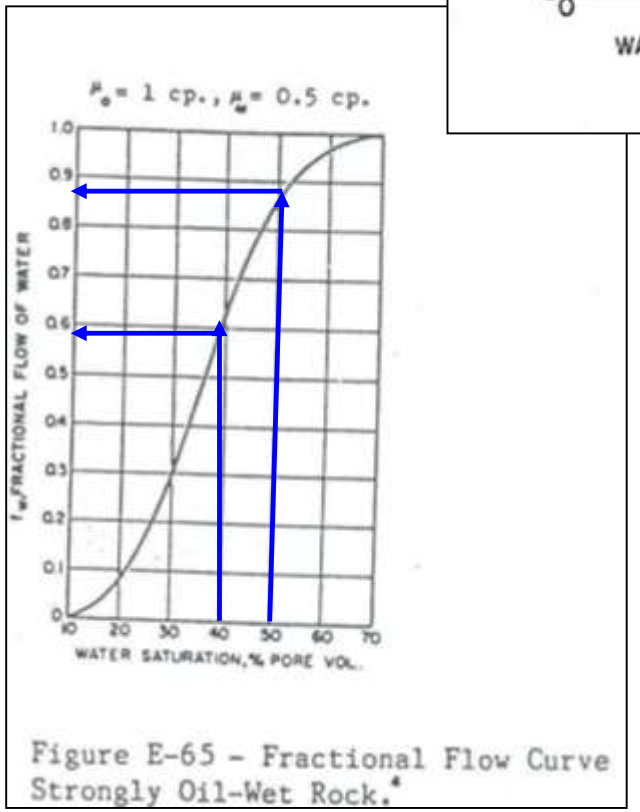
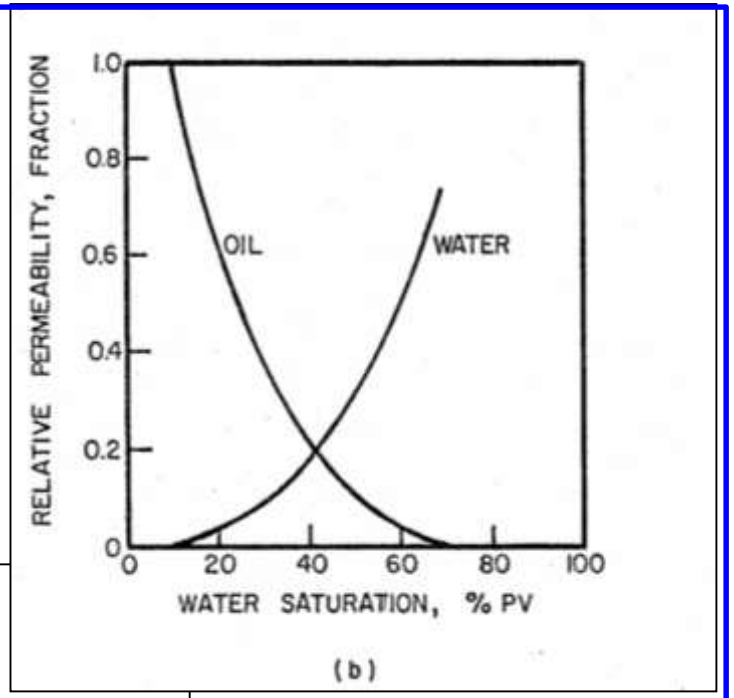


Figure E-65 - Fractional Flow Curve Strongly Oil-Wet Rock.[4]



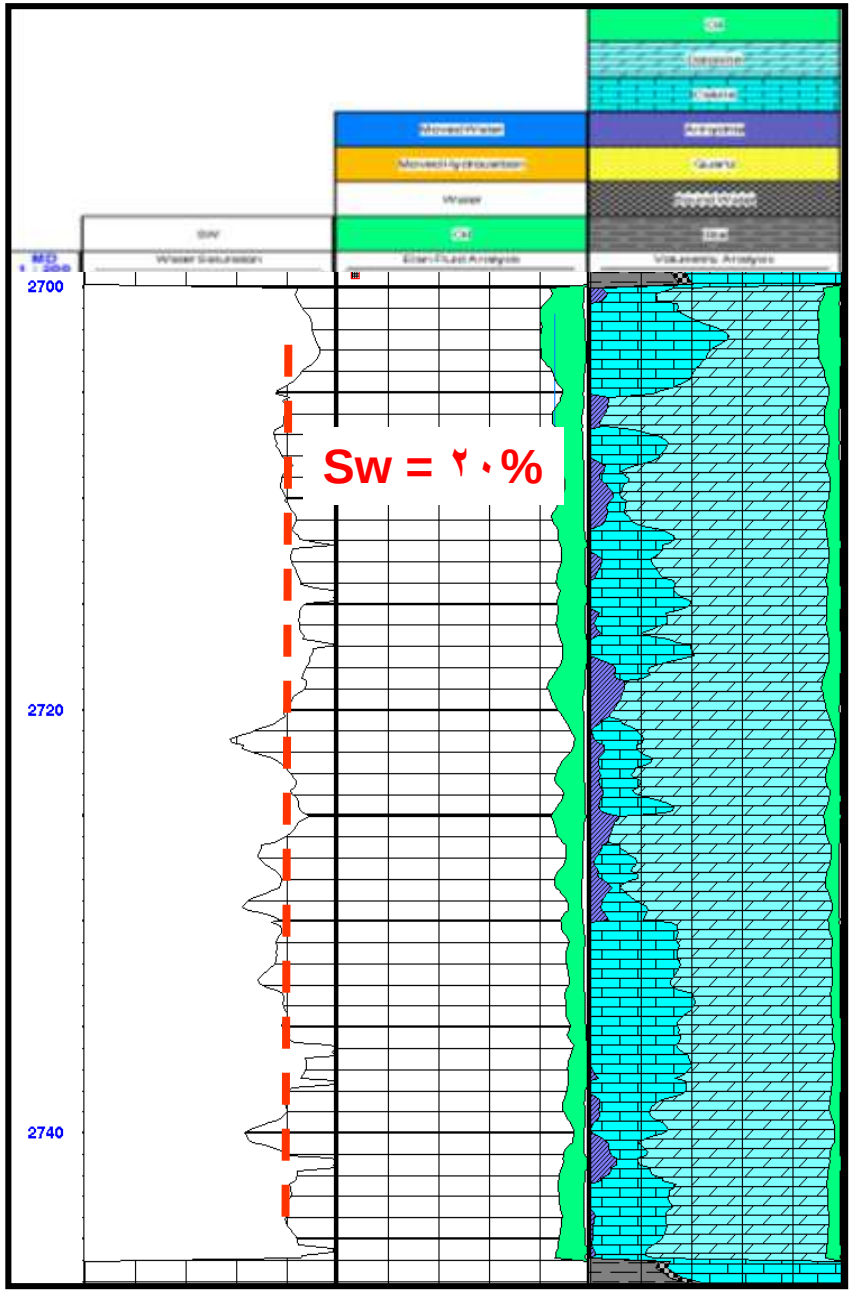
Strongly Oil-wet

Petrophysical evaluation

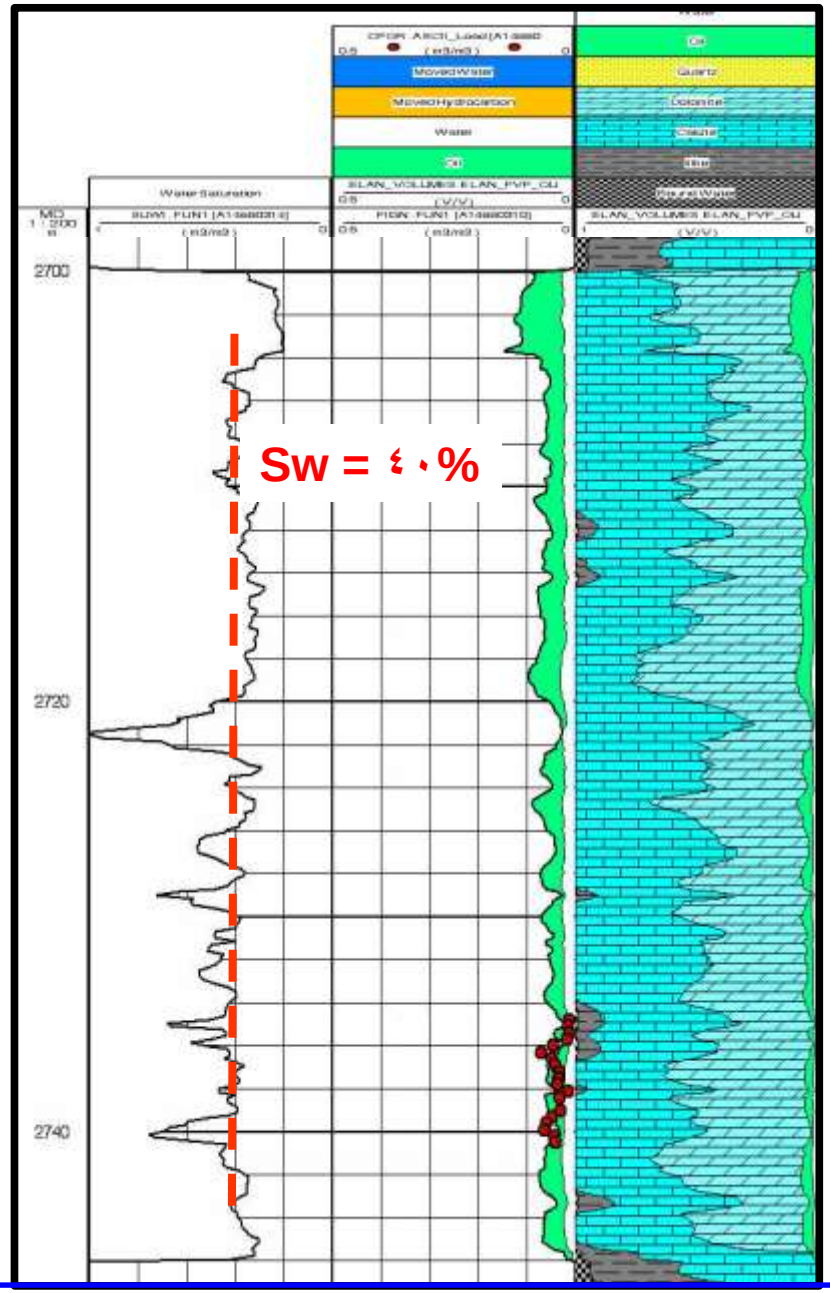
Mineral model

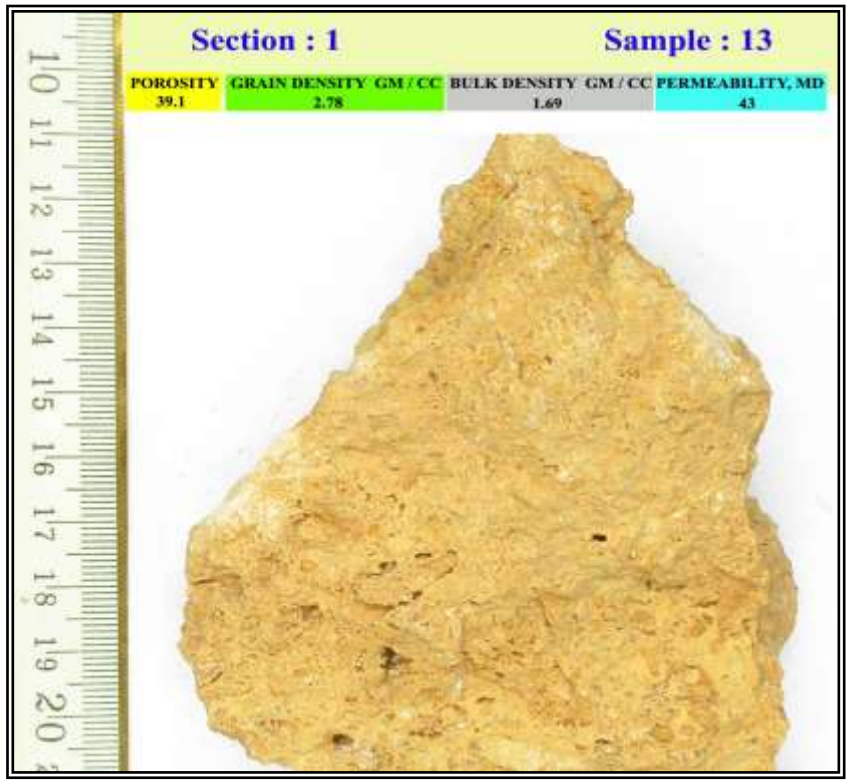
Grain Density ٢,٧٨ gm/cc

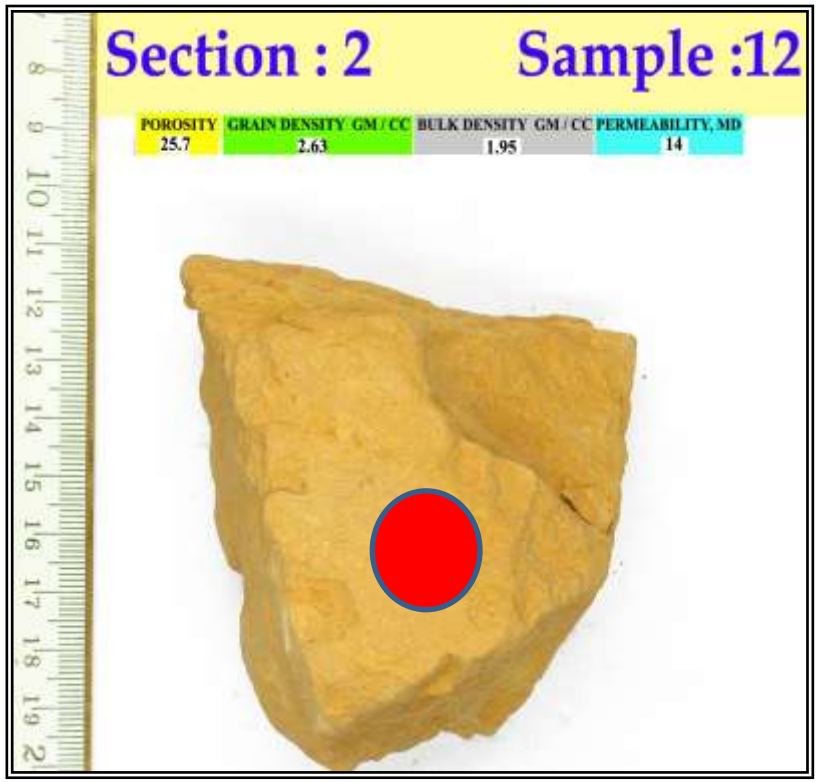
New

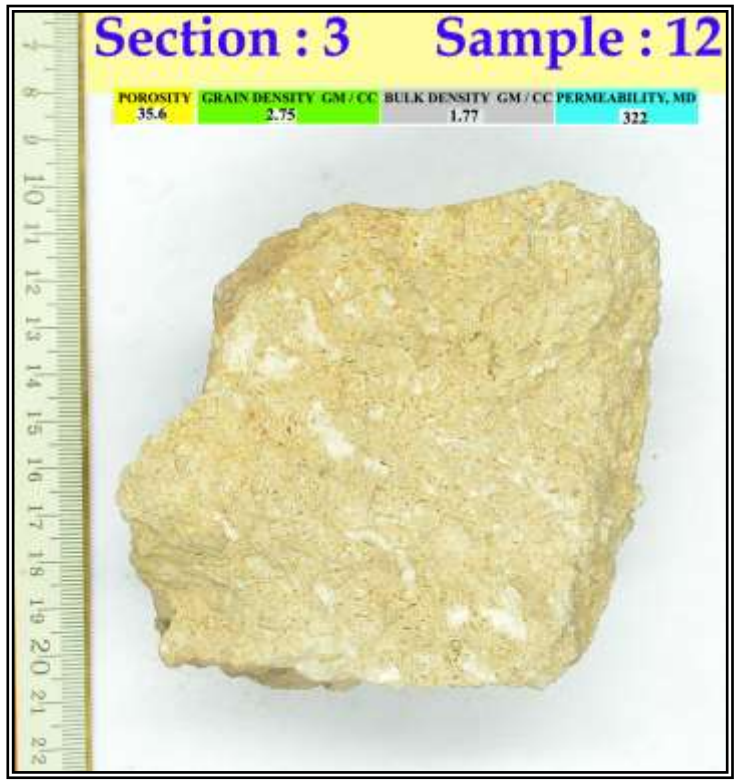


Old







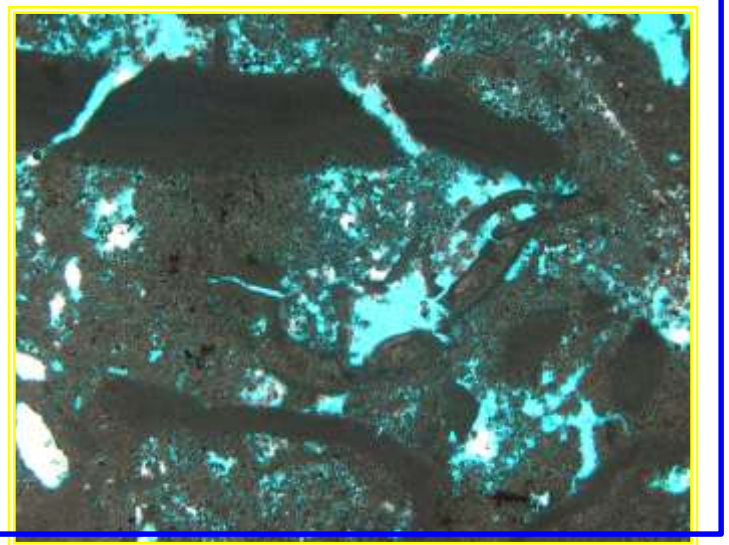


ALGAL-DOLOMICRITIC MUDSTONE-WACKESTONE

AV. POROSITY ٣١,٤%

AV. PERM ٦٥ **mD**

Av. Grain density ٢,٧٨ **gm/cc**



Carbonate Reservoir Heterogeneity and Water Production

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- Carbonate Reservoirs Productivity

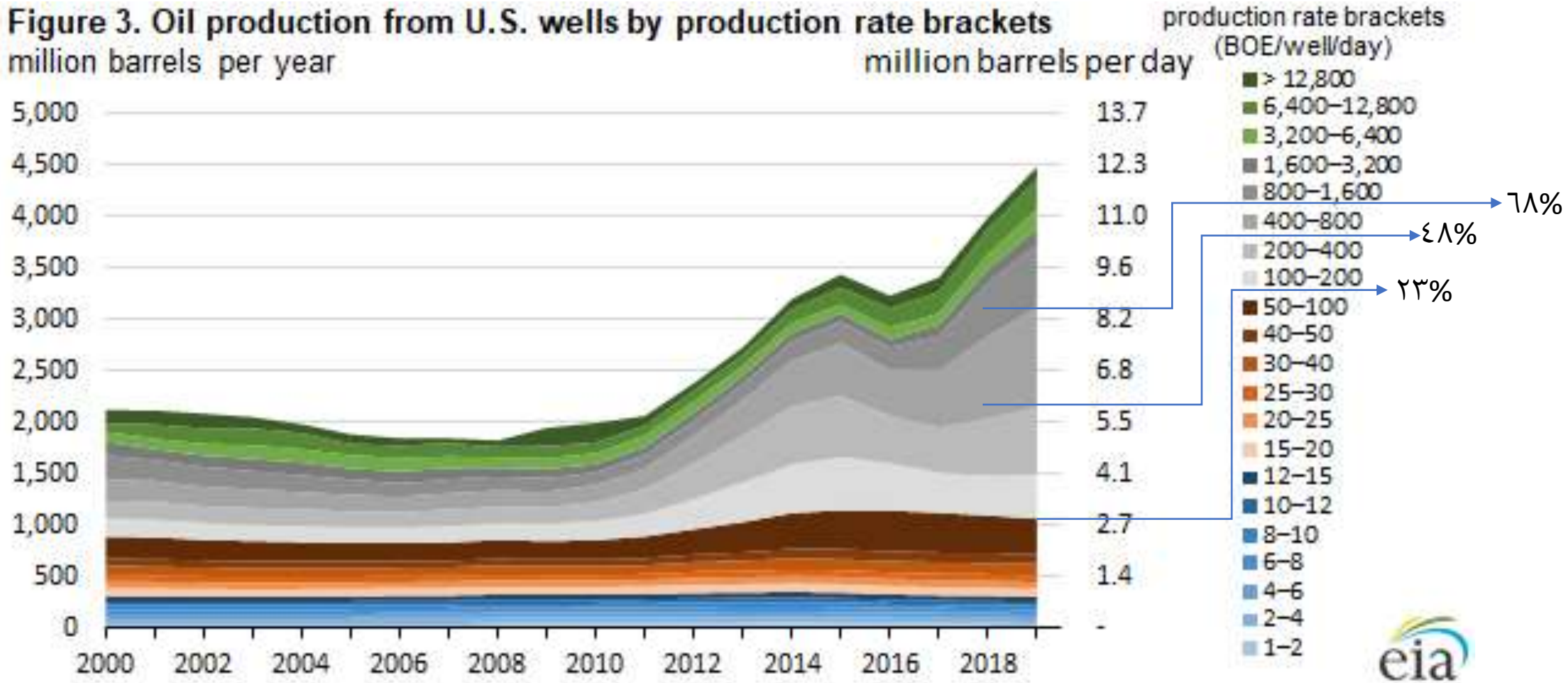
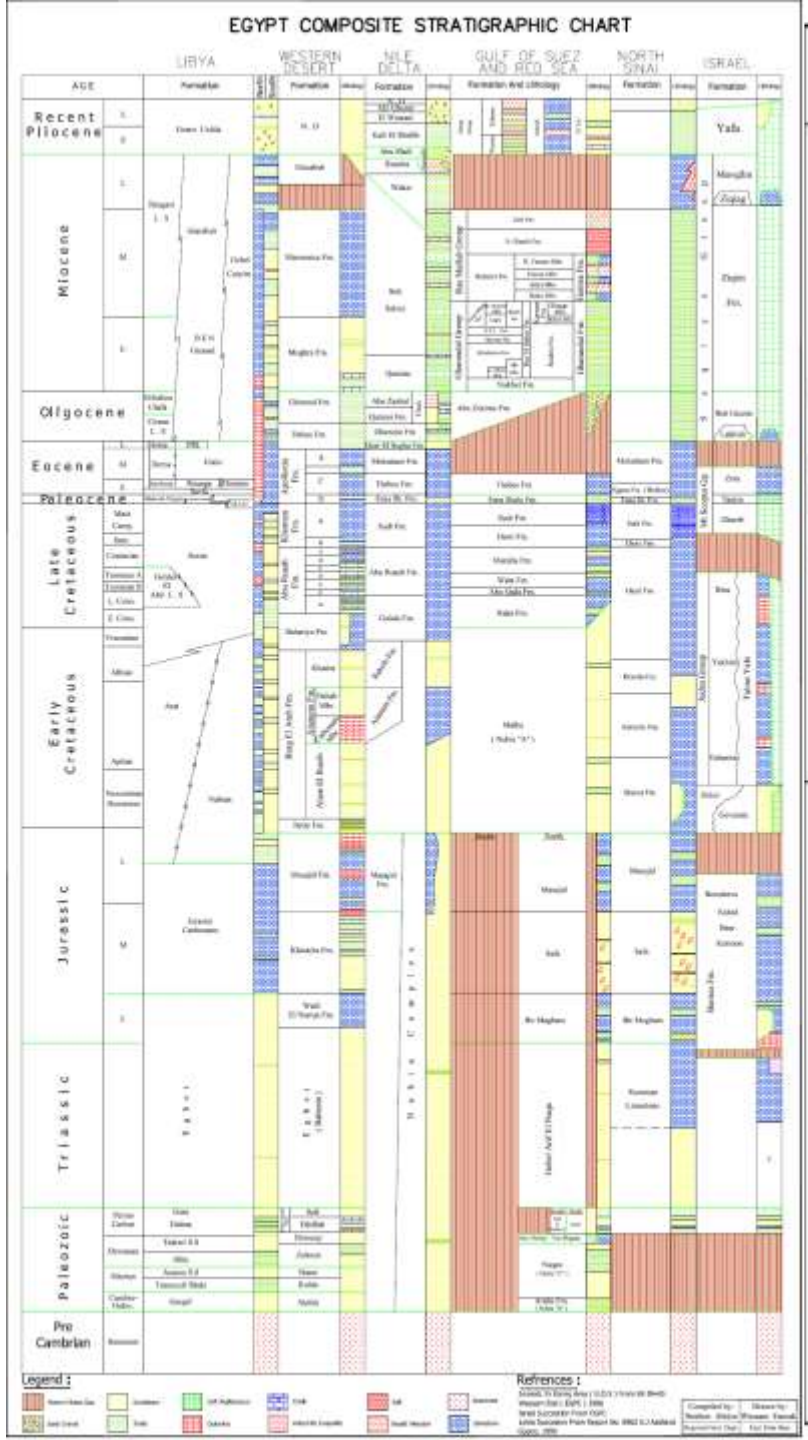


Figure 3. Oil production from U.S. wells by production rate brackets
million barrels per year
million barrels per day
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
13.7
12.3
11.0
9.6
8.2
6.8
5.5
4.1
2.7
1.4
-
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
production rate brackets
(BOE/well/day)
> 12,800
6,400–12,800
3,200–6,400
1,600–3,200
800–1,600
400–800
200–400
100–200
50–100
40–50
30–40
25–30
20–25
15–20
12–15
10–12
8–10
6–8
4–6
2–4
1–2
٦٨%
٤٨%
٢٣%
eia

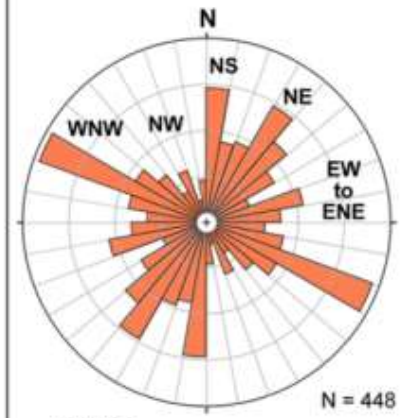
We have to respect the rock capability to produce more oil

Thank You



Rose Diagram

Wadi Nukhul Area (Stations 1 & 2, Cliff & Pavement)



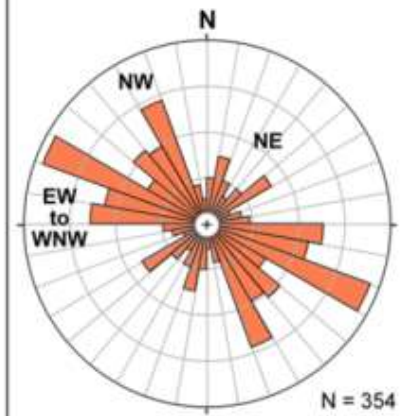
N = 448

Four Sets

1- 280-340, Max at 295 (WNW)
2- 030-060, Max at 035 (NE)
3- 350-020, Max at 005 (NS)
4- 070-090 & 270-280 (EW to ENE)

Subset at 340 (NW)

North Baba Area (Stations 1, 2 & 3, Pavement)



N = 354

Three Sets

1- 310-340, Max at 335 (NW)
2- 010-060, Max at 015, 055 (NE)
3- 270-300, Max at 295, 275 (EW to WNW)

Figure 1. U.S. total wells by production rate brackets

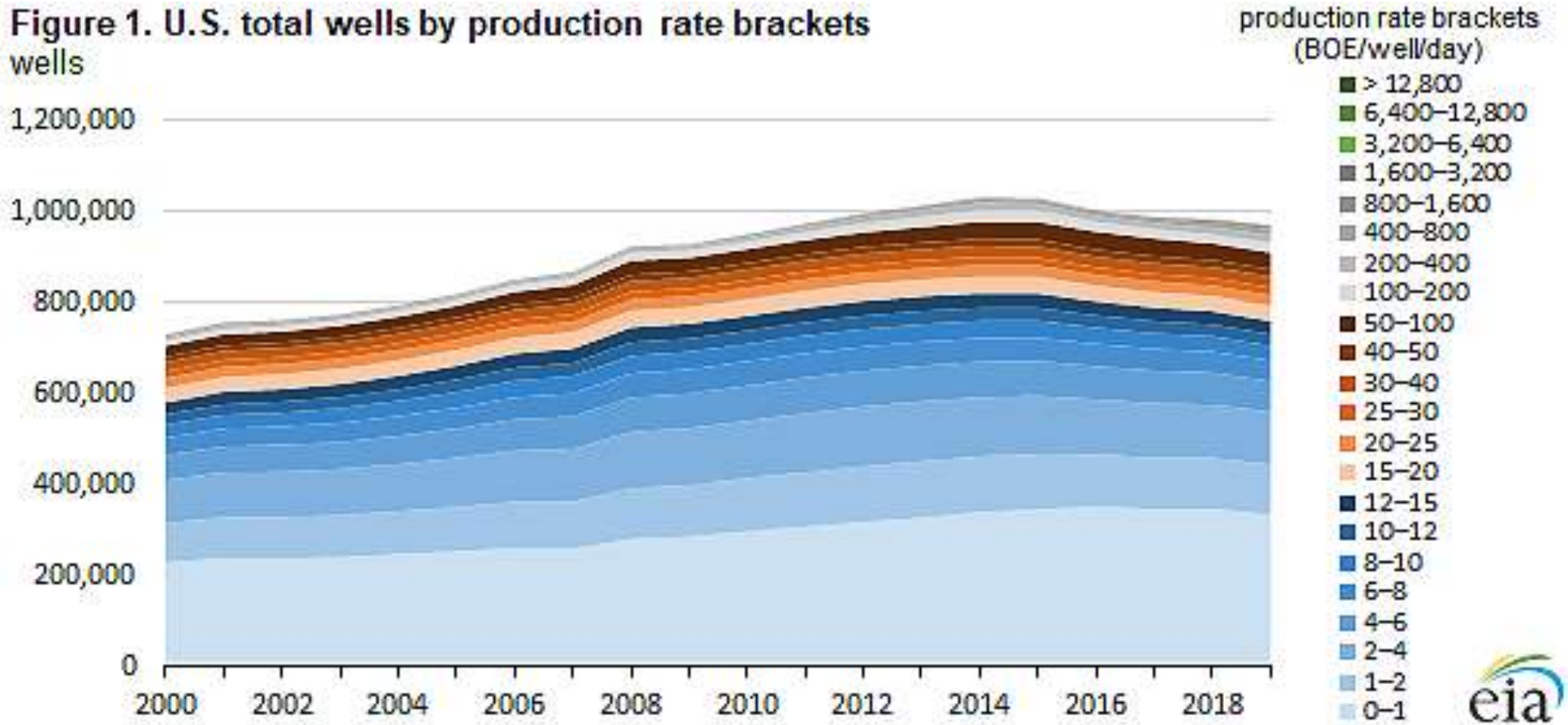


Figure 2. U.S. total horizontal wells by production rate brackets

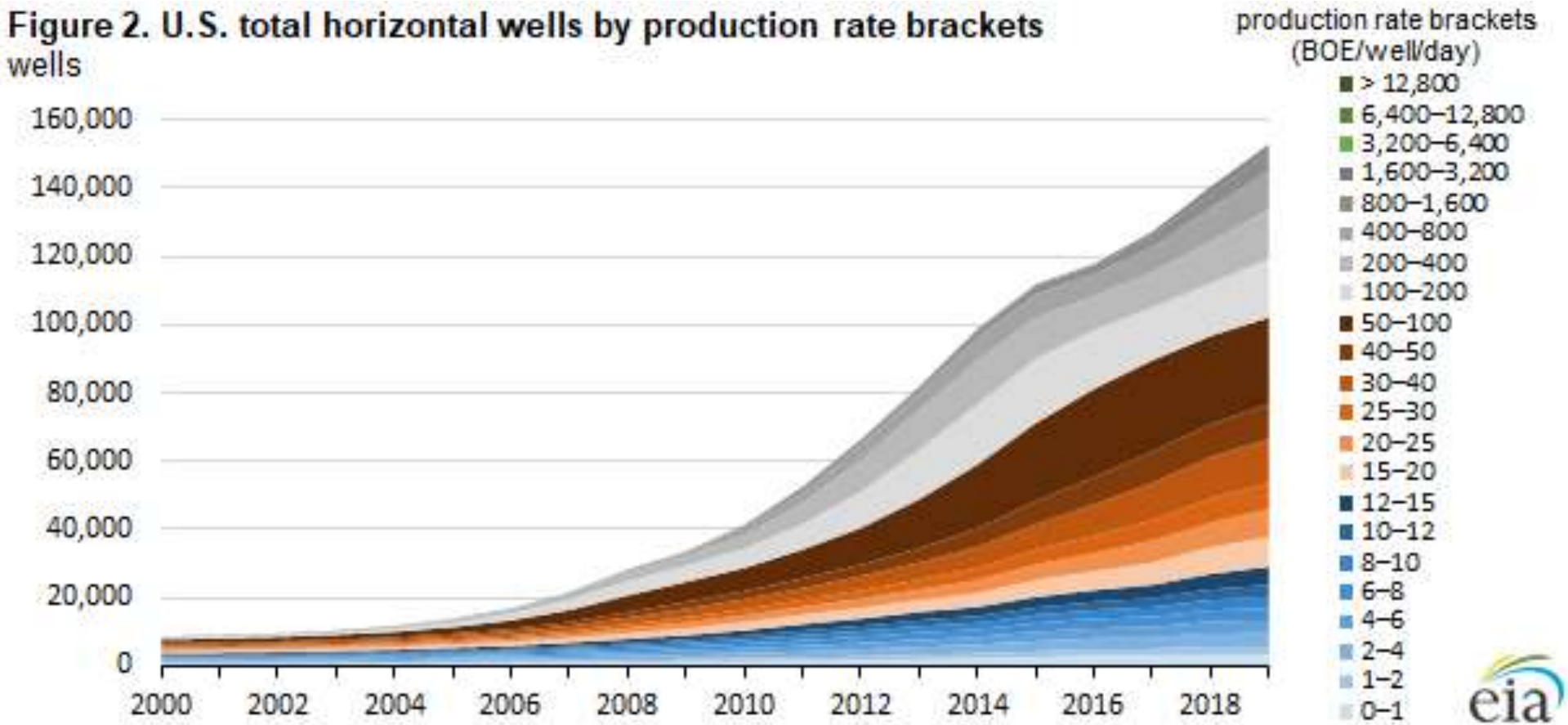
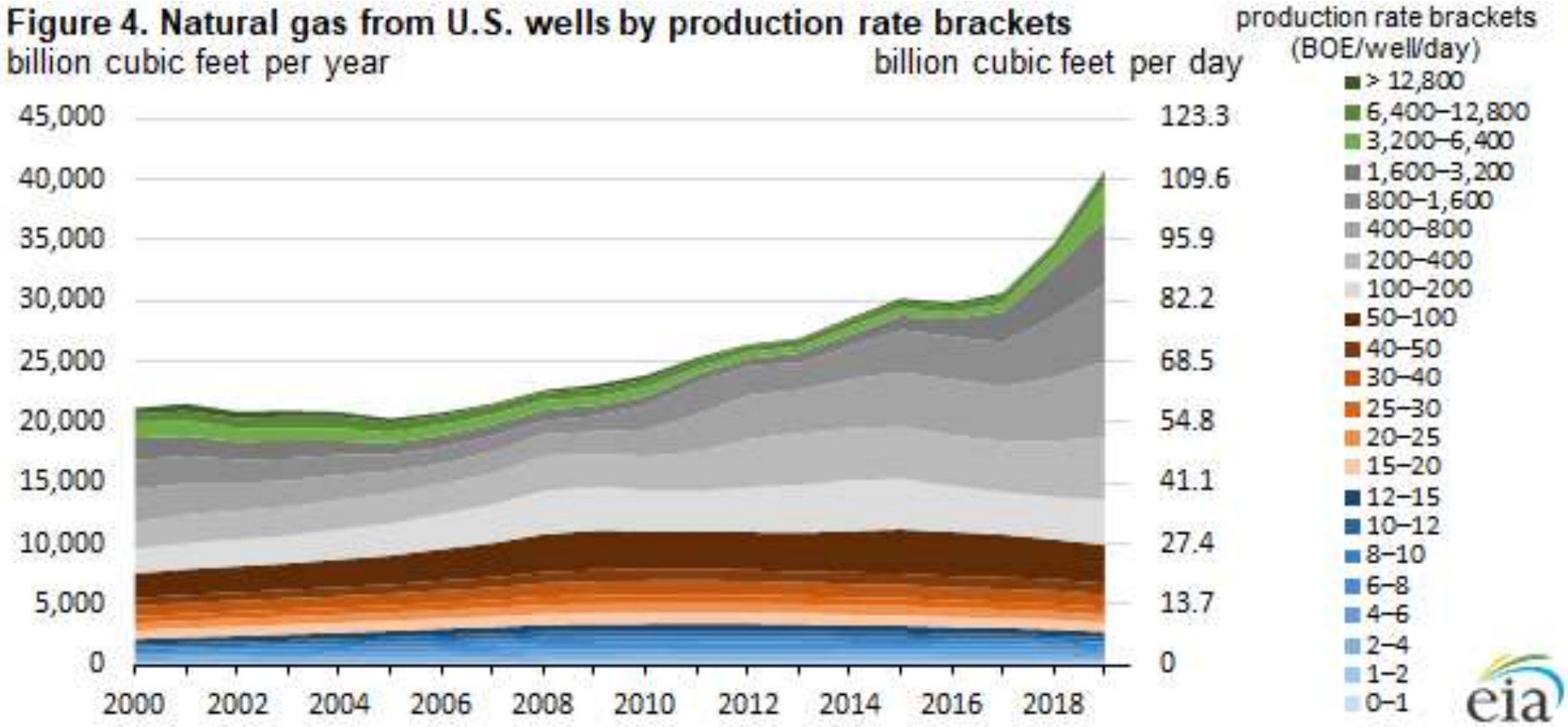
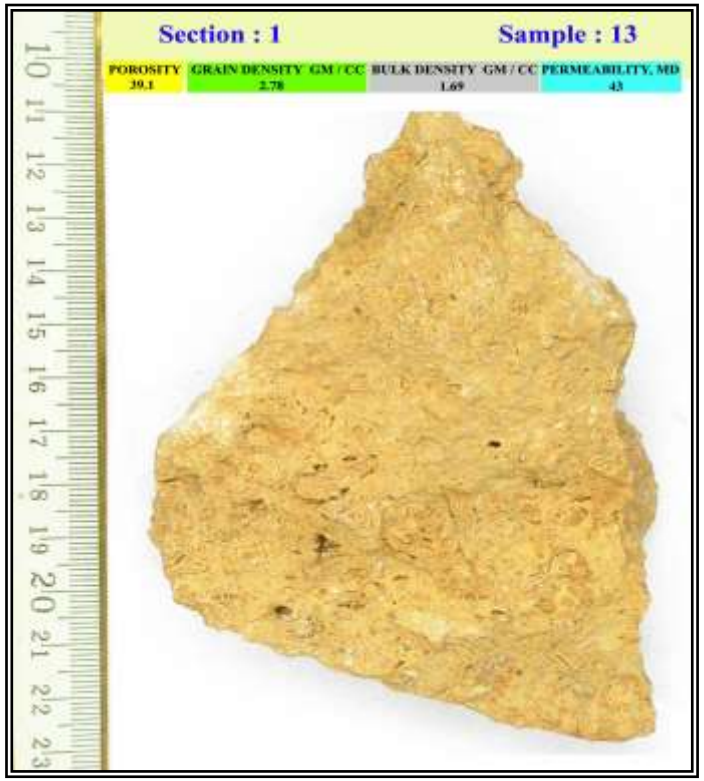
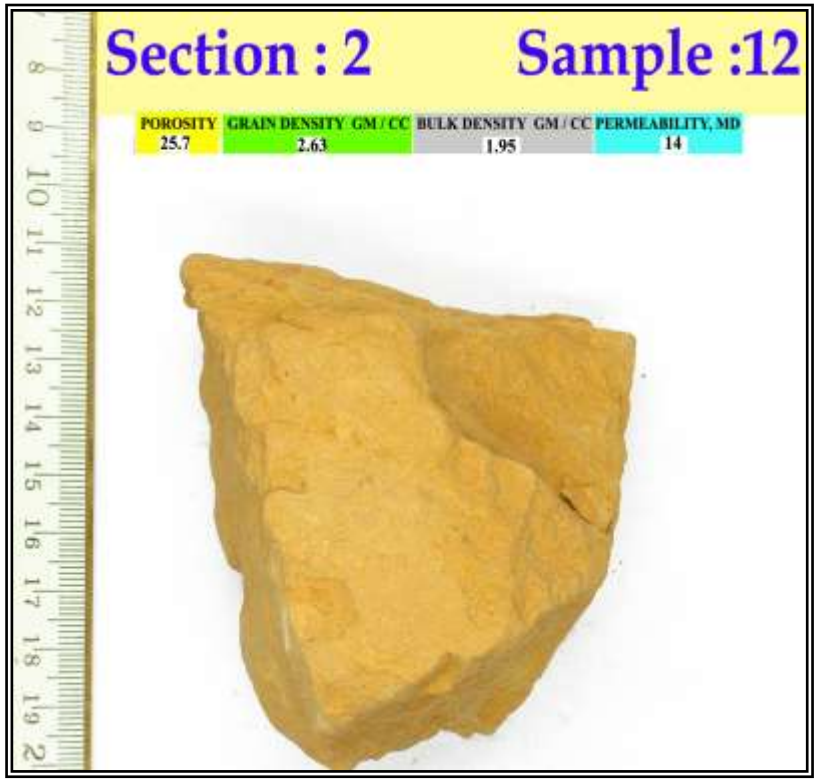
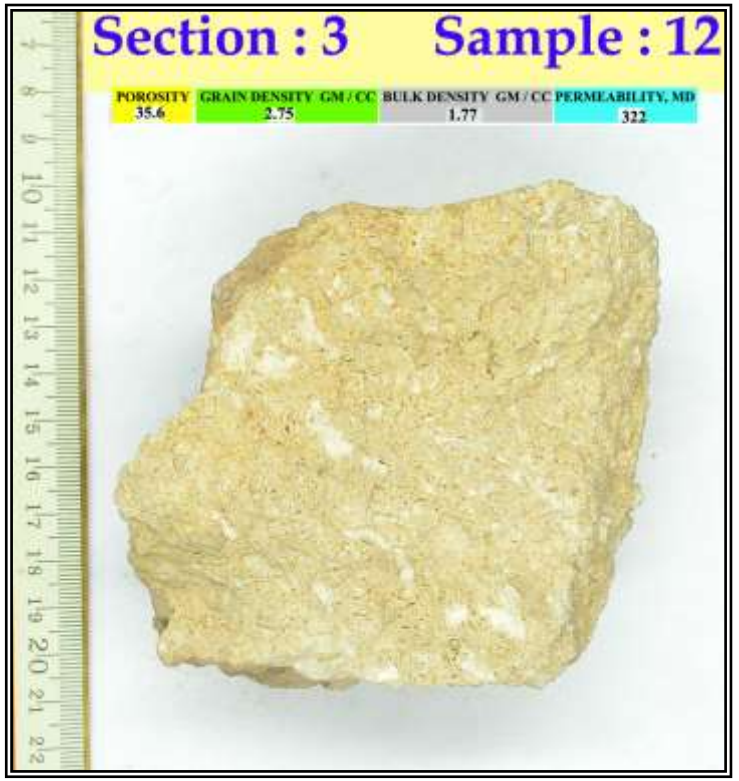


Figure 4. Natural gas from U.S. wells by production rate brackets







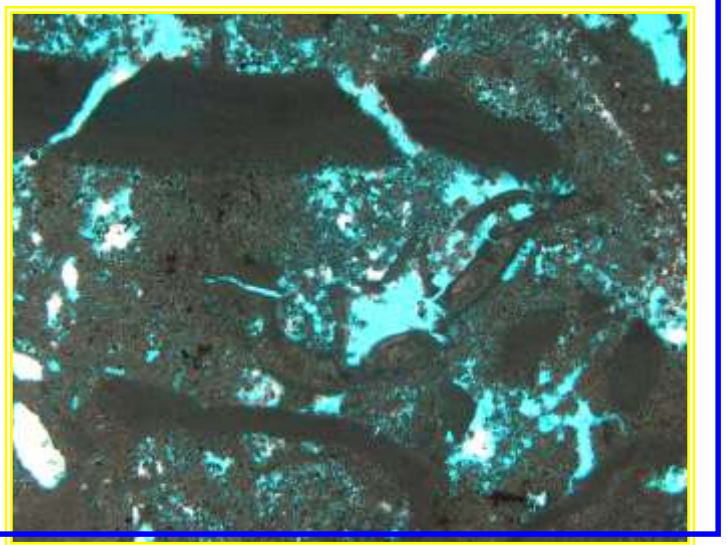


ALGAL-DOLOMICRITIC MUDSTONE-WACKESTONE

AV. POROSITY ٣١,٤%

AV. PERM ٦٥ **mD**

Av. Grain density ٢,٧٨ **gm/cc**



Some Points About Carbonate Reservoirs

Dr. Ahmed Salah