Screened Opportunities in Regional Context

GPC Workshop

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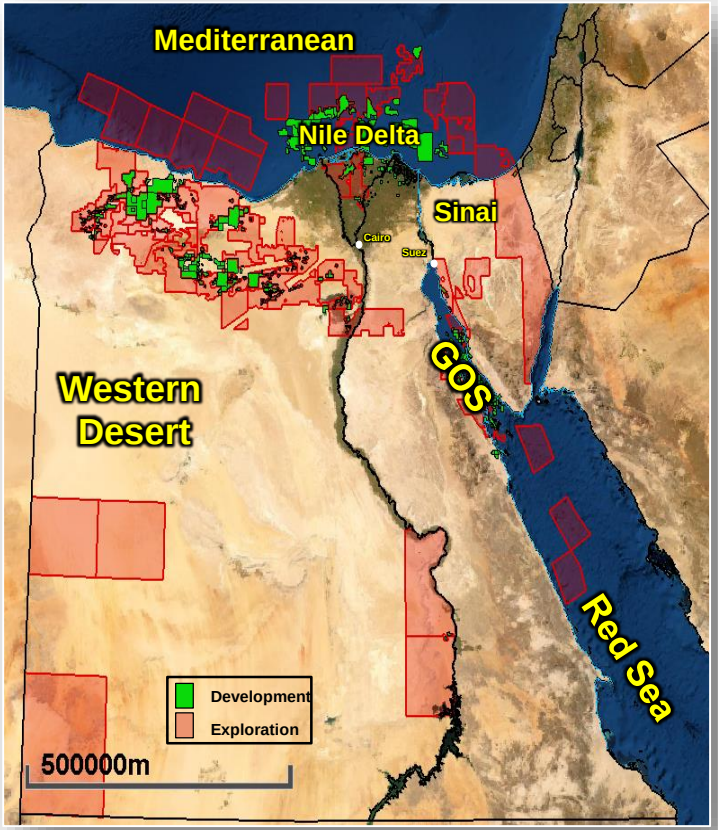
Outline

- Introduction
- Unlocking potentiality of Brown Fields
- Regional Examples
- Summary

Introduction

- Oil was first found as a surface seepage in Gemsa area, GOS in 1868
- Gemsa D-1 was the first exploratory well in 1886
- Drilled wells > 15K wells
- Maximizing the reserves and production requires new Ideas



GOS Depth Structure Maps

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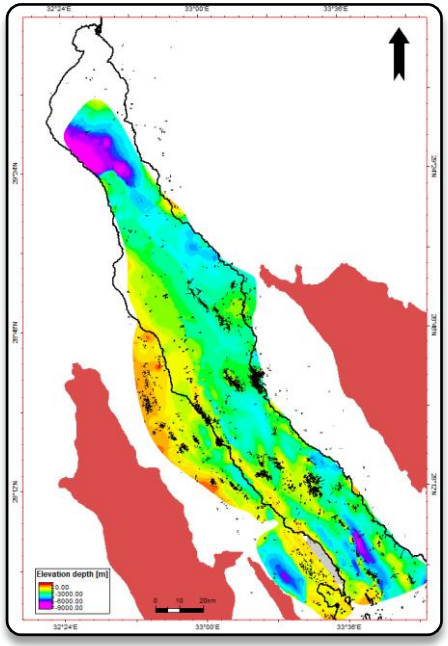
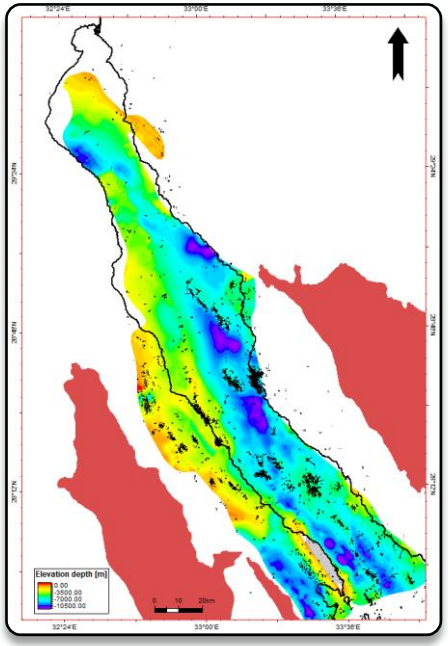
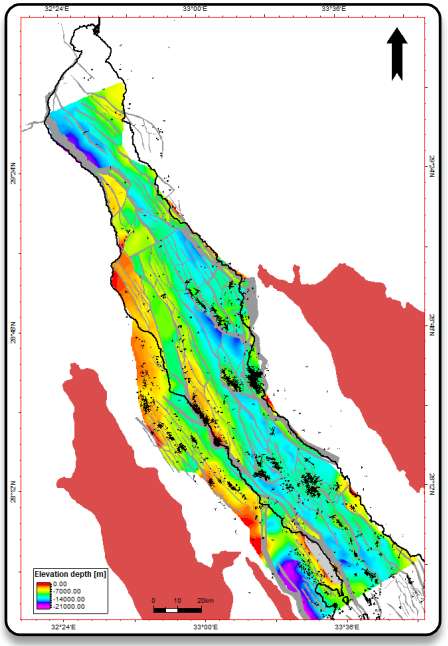
Near Zeit



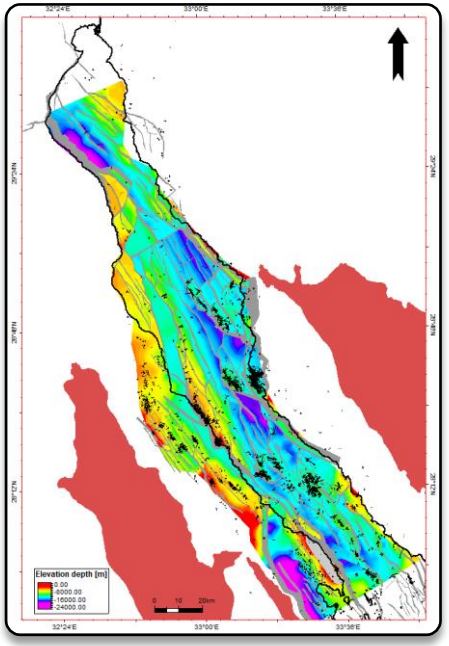
Near Belayim



Near Thebes ?



Near Nubia



- GOS Regional Maps Showing major Fault trends & Depocenters.

Unlocking Potentiality of Brown Fields

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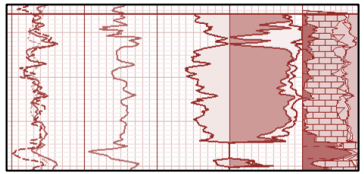
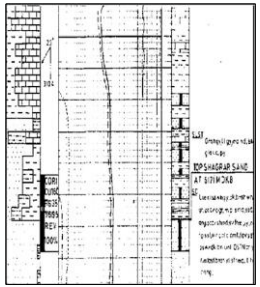
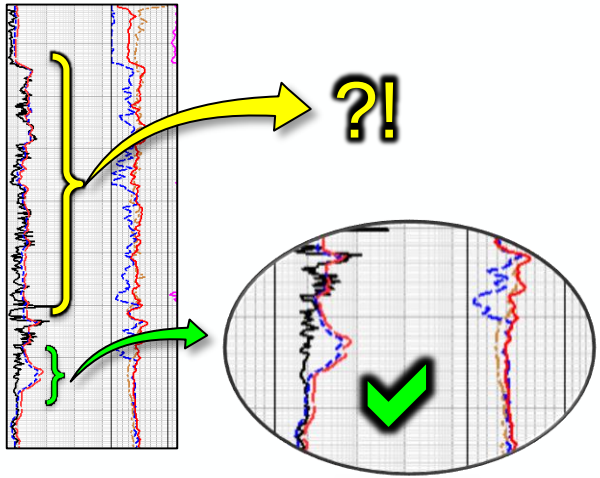
Re-Evaluation of Brown fields

- Wells screening
- Petrophysical re-evaluation
- Modern techniques
- Updated integrated Concepts

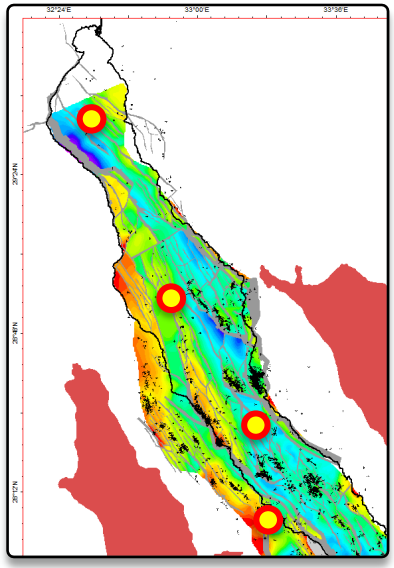


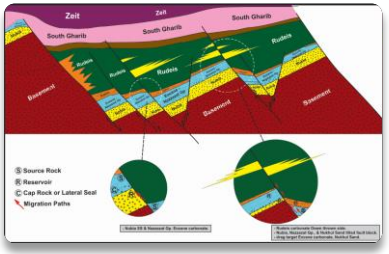


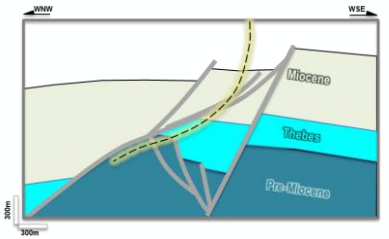


NFE and discoveries in Brown Fields

- Subtle Structural Traps
- Different trap type







Stratigraphic Column for GOS and WD

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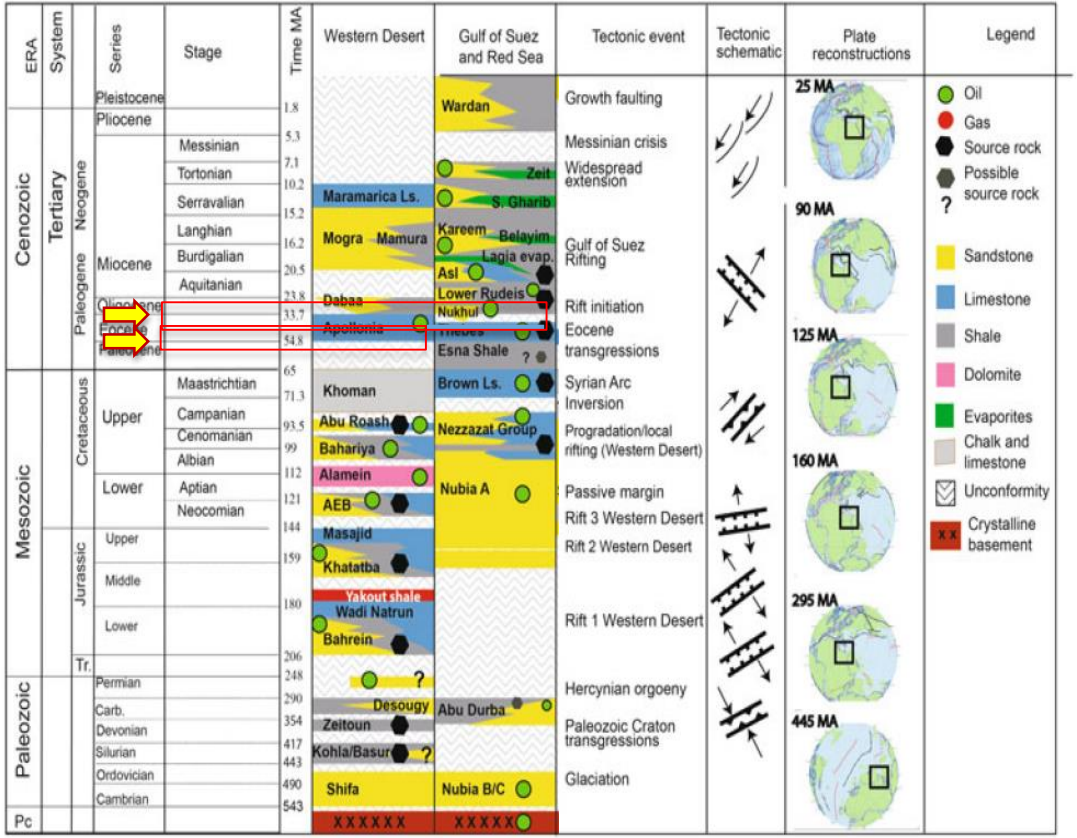
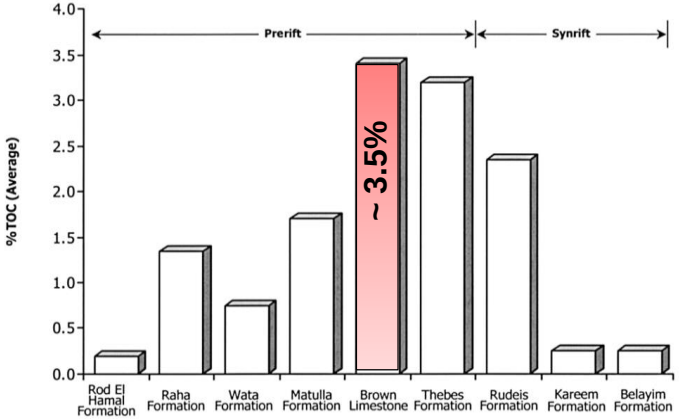
- Gulf of Suez and Western Desert includes wide range of reservoir and source rock units
- Many Reservoirs producing conventionally but the subtle hydrocarbon exists in the unconventional reservoirs
- Screening out via surgical selection for two main unconventional HC bearing rock units concluded in Abu Roash **F** and **B**rown Limestone
- **L**ow **R**esistive **P**ay also considered as a vital concept that could not be ignored to maximize the reserve and finding new discoveries



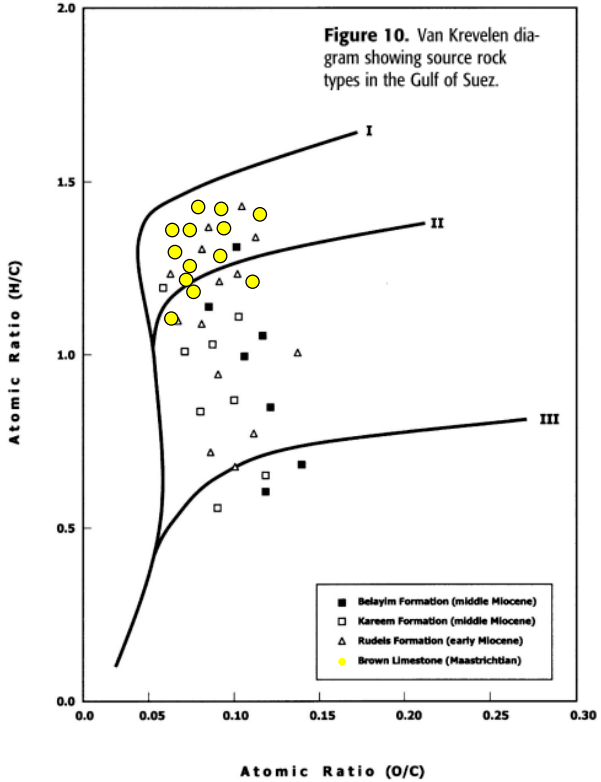
Main stratigraphic units in GOS and WD prolific Basins (modified after Dolson 2020)

Brown Limestone (Gulf of Suez)

- Late Campanian
- Marine outer sublittoral
- Conformably overlies the Matulla Formation
- Limestone with interbeds of highly calcareous shale. Cherty i/p and argillaceous i/p, with high organic matter
- TOC ~ 3.5% (up to 11%)



Average organic carbon content (%TOC) upper Cretaceous, Eocene, and Miocene formations in GOS



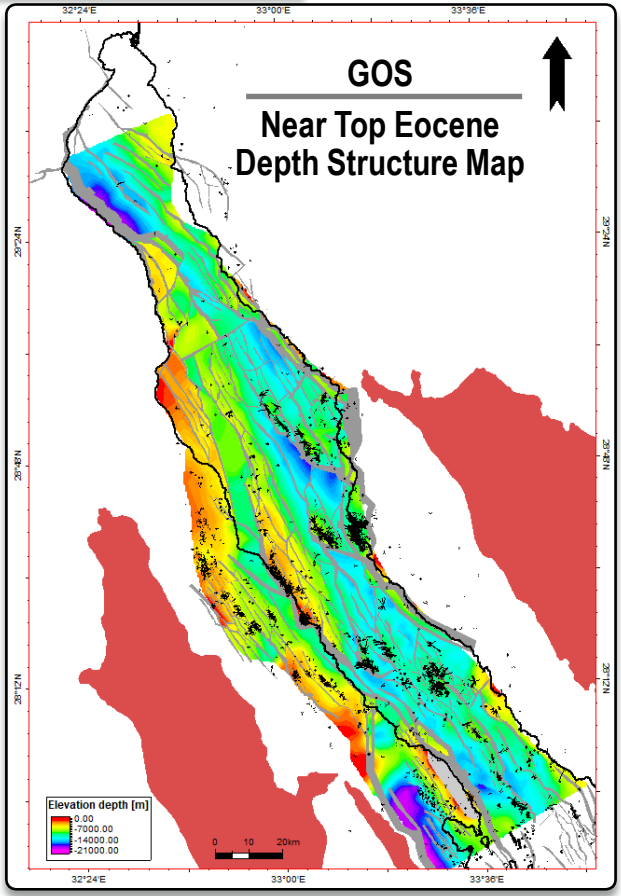
Van Krevelen diagram showing source rock types in the GOS Alsharhan, 2003

Brown Limestone (Gulf of Suez)

- Brown Limestone considered the main source rock in GOS
- It plays an important role in the petroleum system of the GOS
- It is characterized by uncertainty due to the complexity of various lithologies, and lateral facies variations.

Challenges in Evaluation:

- Resistivity is very high due to organic matter so the calculated water saturation is very low.
- Limited number for conventional cores and sidewall cores.
- No enough data about the cementation (m), saturation exponent (n), and grain density.
- Absence of advanced tools such as image and NMR in most cases.



Stratigraphic Correlation for Brown Limestone

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N

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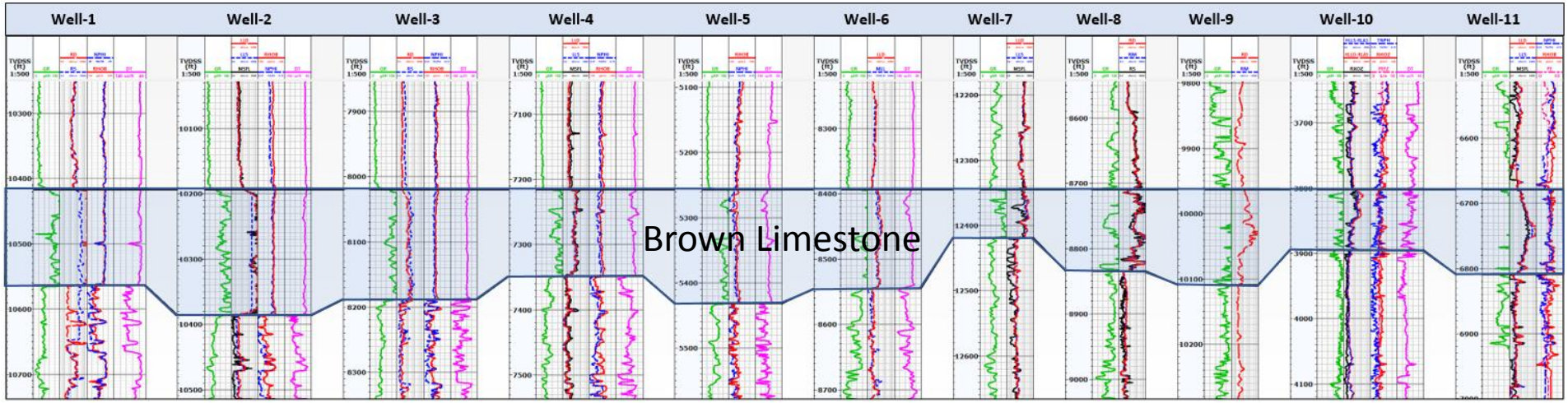
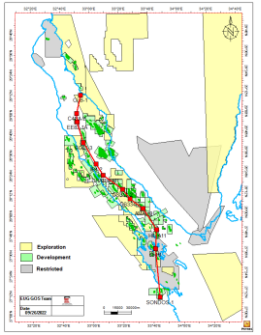


- Eleven wells in one correlation from north to south Gulf of Suez.
- Brown Limestone was penetrated in several wells.



Abu Roash “F” (Western Desert)

- Abu Roash F member is the main source rock in Abu Gharadig basin.
- AR/F is a transgressive Carbonate cycle bounded by 2 regressive clastics cycles (AR/E above & AR/G below).

Abu Roash F act as reservoir in two cases

Self-Charged Reservoir	• Act as mature source rock with fractured system to preserve produced oil
Conventional Fractured reservoir	• Not mature source rock need migrated hydrocarbon to be stored in its fractures

Abu Roash “F” Characteristics

- ***Source Rock***

  Rich Mature **-**Type I / II, High TOC (6 wt.%), High HI 750, widely distributed over Abu Gharadig basin

- ***Microfacies***

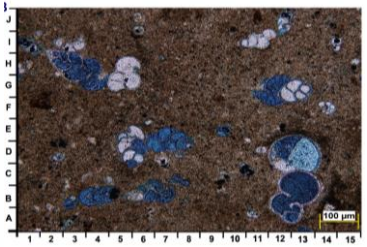
  Packstone to wackstone with large amount of micrite matrix

- ***Reservoir quality***

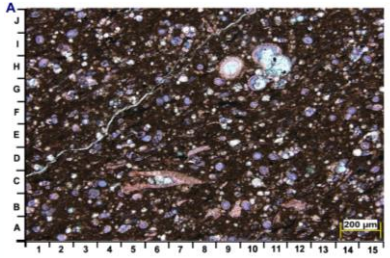
  Average porosity 8 % up to 18 %.

  Low matrix permeability (0.001-8 md).

  Production is generally believed to be associated with the fracture system

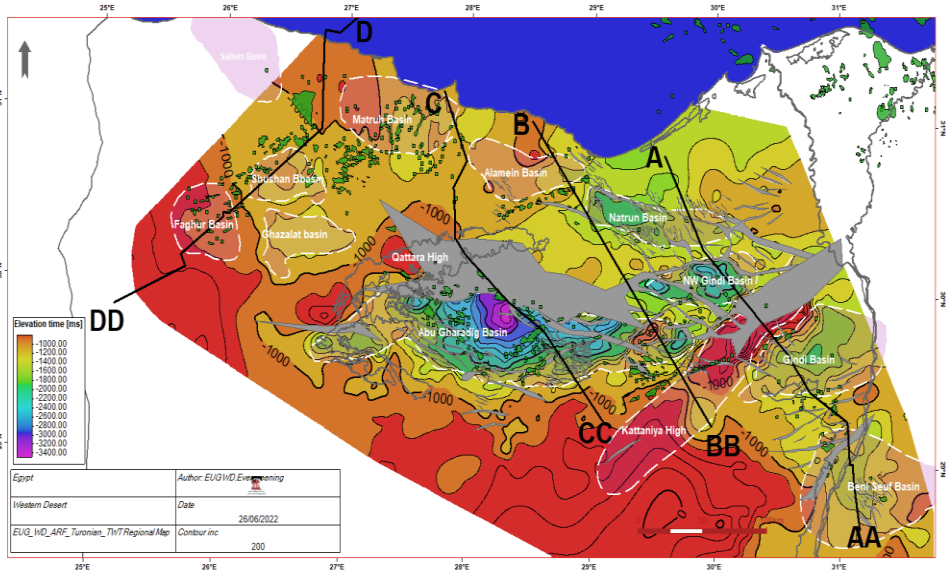


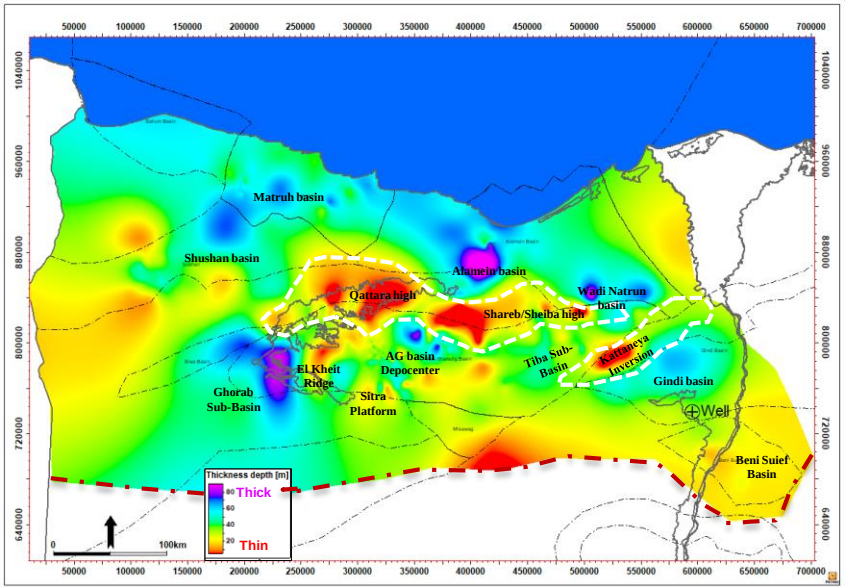
Wackstone



Packstone

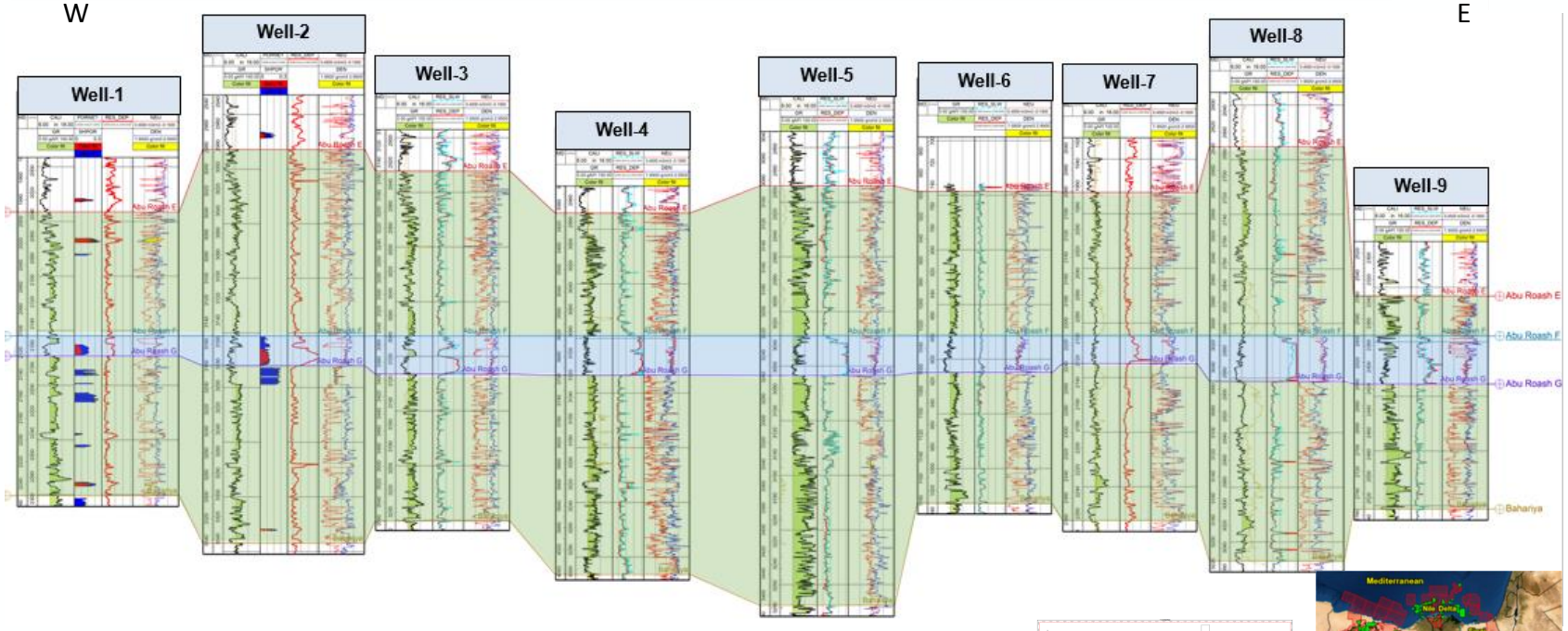
Abu Roash (F) Depth Structure & Isopach Maps

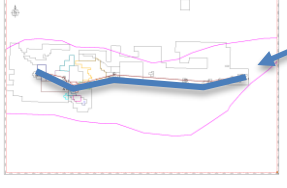


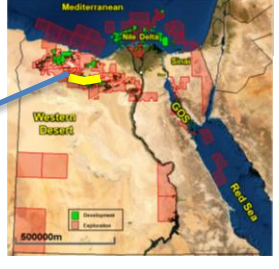


- AR/F almost covering whole North Egyptian Western Desert.
- Mapping for AR/F rock unit helps to recognize the depocenters of ARF and the areal distribution.
- Abu Gharadig and Alamein basin considered the most prolific basin contains thicker ARF.

Stratigraphic Correlation for Abu Roash (F), WD







- AR/F almost penetrated by all drilled wells in WD

Well-1 (Brown Limestone)

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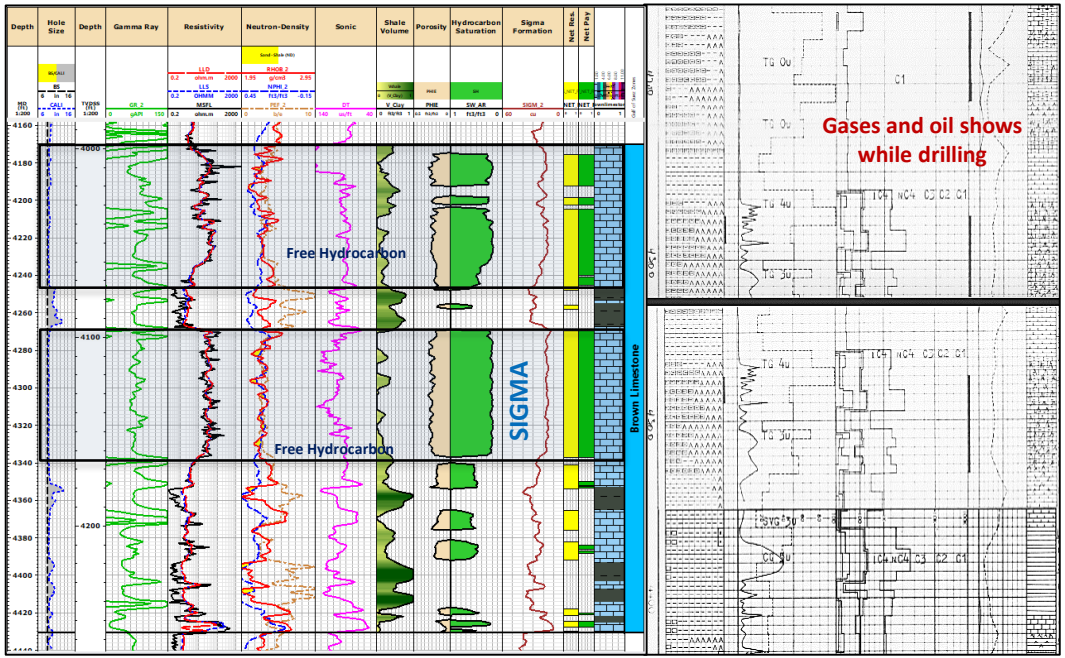

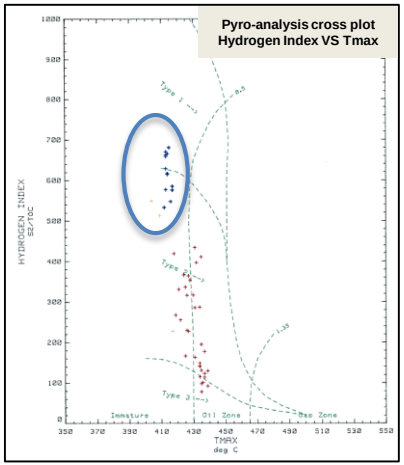

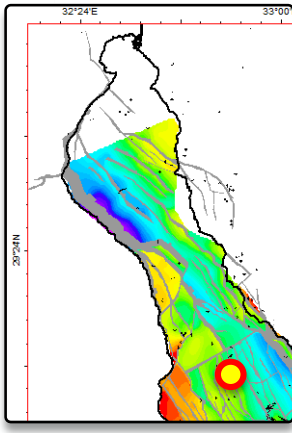

Source Rock Evaluation							Free Hydrocarbon	
Depth	TOC	S2	Tmax	S2/TOC	S3/TOC	S3	S1	S1/(S1+S2)
ft	%wt	mg/g	degc	HI	OI	mg/g	mg/g	PI
4170	4.16	27.66	414	665	70	2.91	3.1	0.1
4190	7.13	58.81	411	825	23	1.67	14.62	0.2
4200	7.05	44.28	413	628	45	3.19	8.02	0.15
4220	7.44	69.61	414	936	32	2.4	10.17	0.13
4230	6.19	28.02	414	614	47	2.88	5.68	0.13
4290	4.96	33.74	415	680	47	2.31	9.16	0.21
4320	4.63	30.65	413	662	47	2.16	9.12	0.23
4350	4.11	27.06	413	658	72	2.95	3.18	0.11

- RST Sigma was run to determine the water saturation for the Pre-Miocene sand while production, and SIGMA was recorded for Brown limestone (non-perforated) and indicated also the presence of hydrocarbon.

Brown Limestone (3997' TVDSS-4256' TVDSS)

- ✓ LST: Dk bn, lt bn, occ/crm-lt gy bn, sft-md hd,, mic--crypxln, very arg, pin point porosity **cherty-hi cherty up to 40 %, dull yel fluor with slow to medium fast** lt yel strmg cut, lt brn yellow residual ring
- ✓ High gases while drilling.

Free Hydrocarbons

Significant S1 values indicate the presence of very large quantities of **free hydrocarbons**.

Maturity

Both Tmax and vitrinite reflectance results indicate that the analysed interval is **immature** with respect to hydrocarbon generation.

Geochemical Analysis

FM	Br.LST
Interval (ft.)	3997-4256 TVDSS
Gross Thickness (ft)	258
Net Reservoir (ft)	170
Possible Net Pay (ft)	135
Avg. PHIE (%)	22
Avg. SW (%)	23

Well-2 (Brown Limestone)

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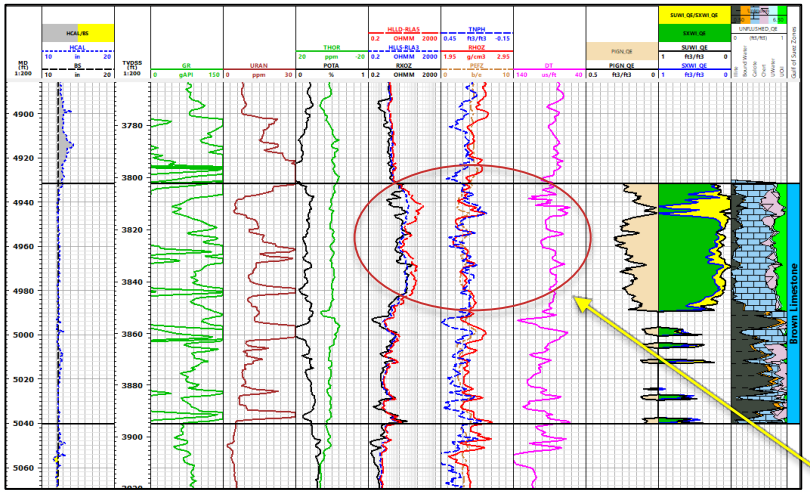
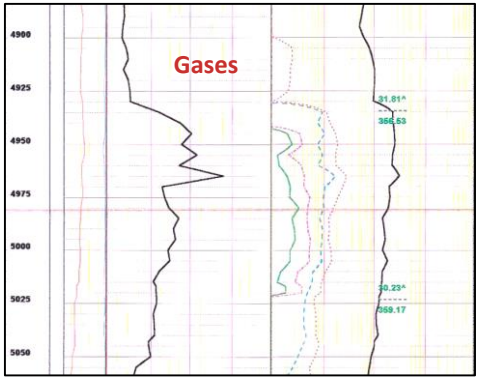
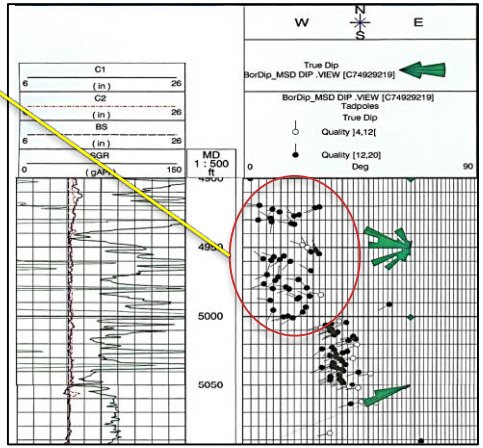
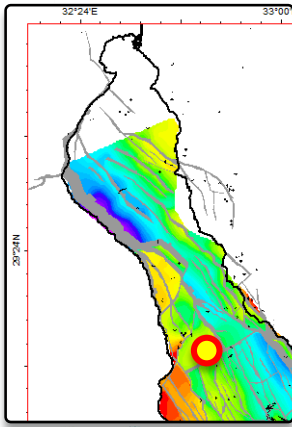
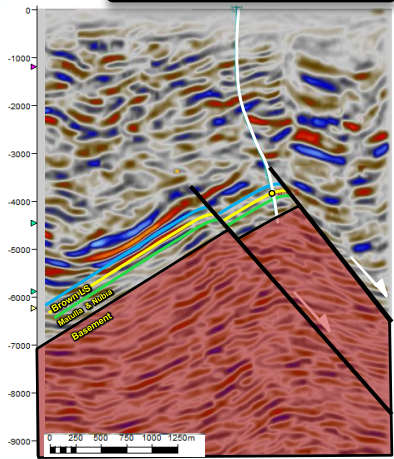








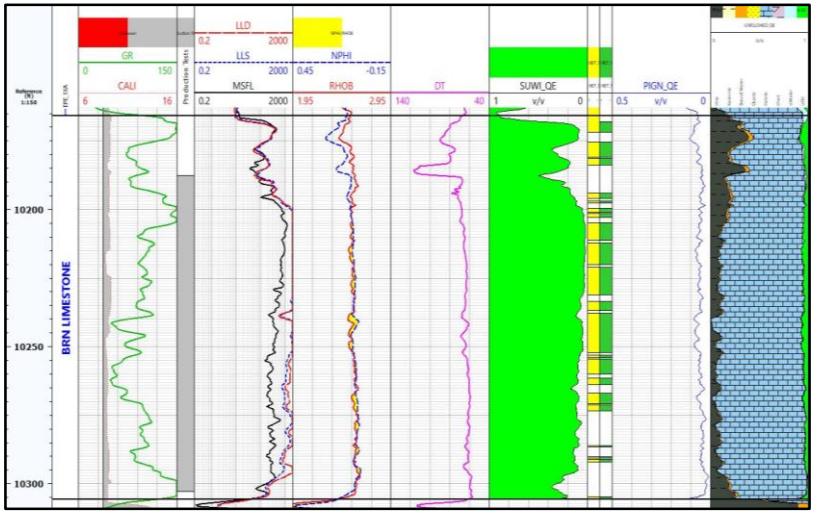


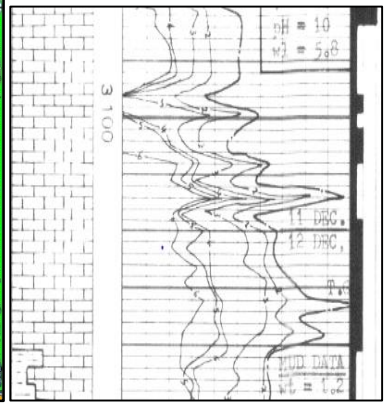
FM	Br.LST
Interval (ft.)	3802-3895 TVDSS
Gross Thickness (ft)	93
Net Reservoir (ft)	55
Net Pay (ft)	50
Avg. PHIE (%)	19
Avg. SW (%)	14

Brown Limestone (3802' TVDSS-3895' TVDSS)

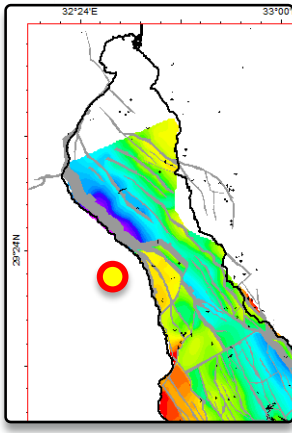
- ✓ LST: Bn, dk bn, lt bn, occ/bn gy, md hd, occ/sft, fn-crypxln, arg, cherty-hi cherty, w/ostan@ pts, chert up to 40 %, bn-dk bn, occ/lt bn w/sharp edges.
- ✓ High gases while drilling.
- ✓ Deformation on the top part.

Well-3 (Brown Limestone)





DST
Recovered 5 bbls of oil with 14.2 API after acid stimulation



- The well was drilled on 1989.

<u>Brown Limestone</u> (10165'-10305' TVDSS)

- LST: Dk bn-brn, lt brn-lt creamy wh, md hd-hd, v f xln, w arg. mat, w/tr chrt, Dark brown, very heavy oil droplets.

<u>Geochemical Analysis:</u>

- Indicated the presence of migrated hydrocarbon.
- The kerogen is immature to marginally mature, based on vitrinite reflectance measurements ranging from 0.54 % to 0.62 %.

<u>Log Analysis</u>

- Avg. porosity 8 % and avg. SW 12 %

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (m)	Sample Type	Gross Lithologic Description	TOC* (wt %)
3117 **(10226')**	ctgs	60% mdst-sh; dk brn, dk gy-brn, v calc, carb, hd-frm, mod fss, ostn 40% ls; brn blk, wh, mic xln, occ chky, arg, occ carb, hd-frm, ostn	3.21
3135 **(10285')**	ctgs	Ls; dk gy-brn, brn blk, m-dk gy, mic xln, occ chky, arg, carb, anq, hd-frm, ostn Pres-sh; dk gy-olv, dk gy, mica?, occ sl pyr, occ sl slty, calc, sl fos?, hd-frm, mod fss-fss; cht; dk brn, ang, trnsl-op, hd; mdst-sh; dk brn, dk gy-brn, v calc, carb, hd-frm, mod fss, ostn	1.67

Well-4 (Brown Limestone)

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Brown Limestone (7960’ TVDSS-8225’ TVDSS)

- LST: lt bn, dk bn, dol i/p, cherty i/p arg.
- Oil shows: Lt bn, oil stain, pale yellow fluor.

Geochemical analysis suggested that:

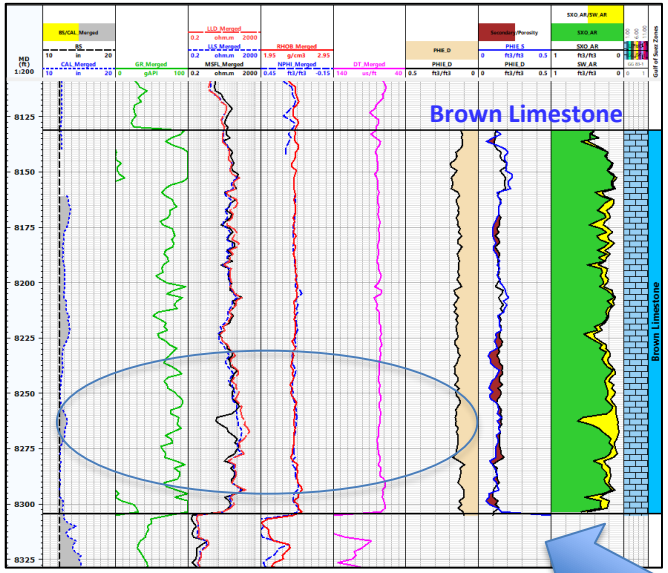
- The Brown limestone is mature
- The source quality of the brown limestone is excellent (oil-prone)
- Vitrinite Reflectance 0.73 %
- TOC: 2.9-4.2 %

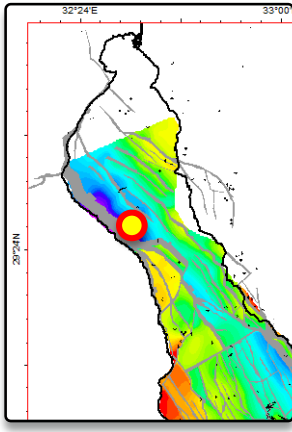
RFT Data

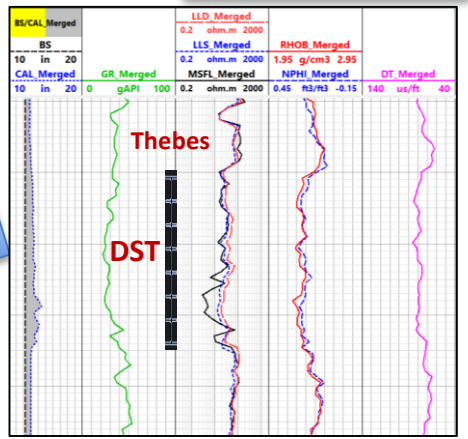
- Two RFT Point in Brown Limestone-Tight Formation
- Nine RFT in Thebes-Tight Formation

DST

- Thebes formation was tested and recovered 1100 BOPD with acid stimulation.



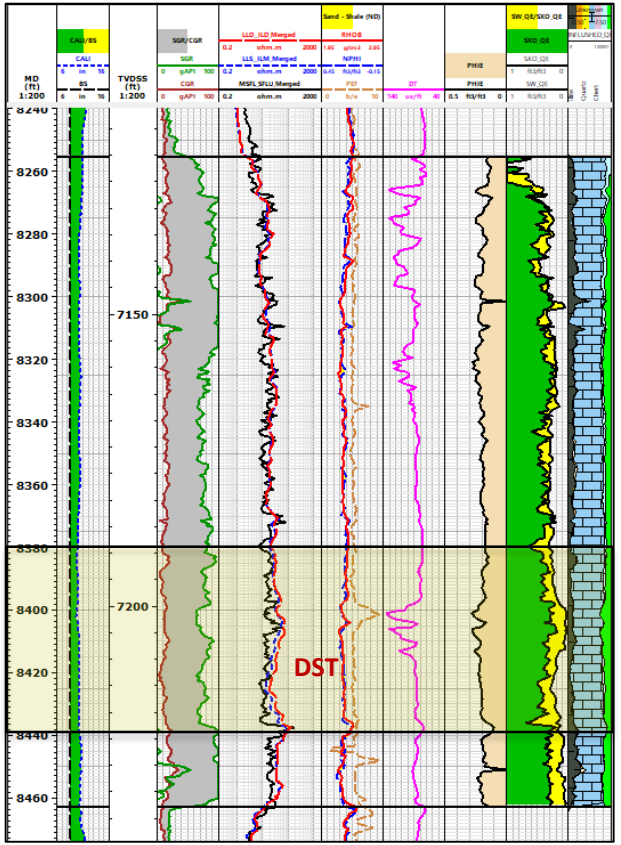


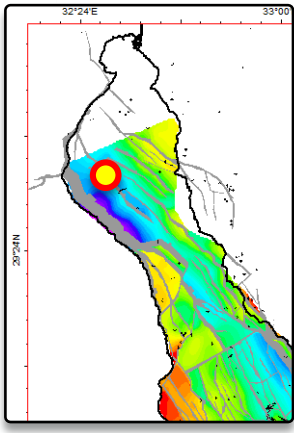


Well-5 (Brown Limestone)

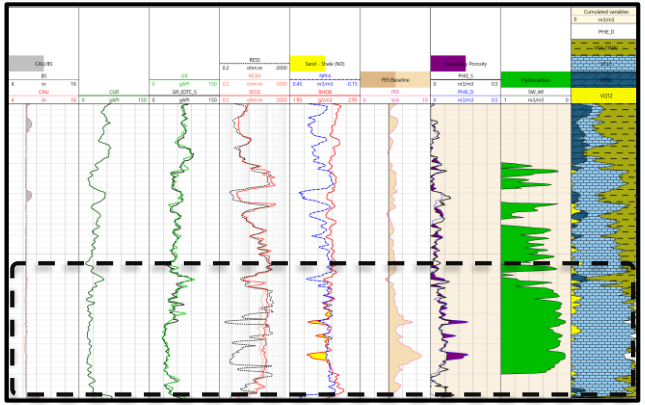
<u>Brown Limestone</u> (7122’ TVDSS-7234’ TVDSS)

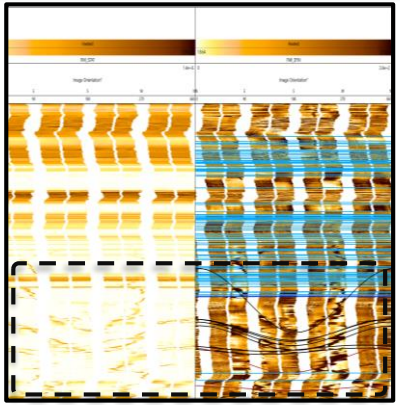
- LST: Lt-dk bn, frm, arg., kerogenous, oil shows from 8280’ to 8460’: 50 to 100 % very dull gold fluorescence, trace patchy oil stain.
- The well was drilled on 1989.
- From log analysis, avg. PHIE 20 % and avg. SW 25%.
- Brown limestone was tested and recovered only 10 gallons oil after acidized with estimated 20-25 API.

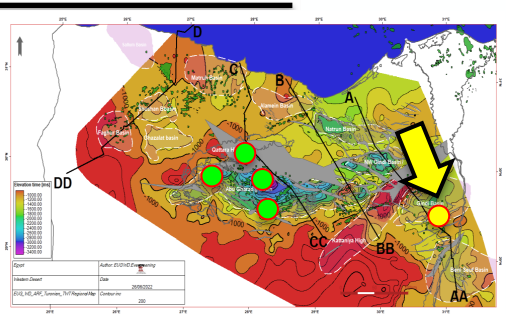




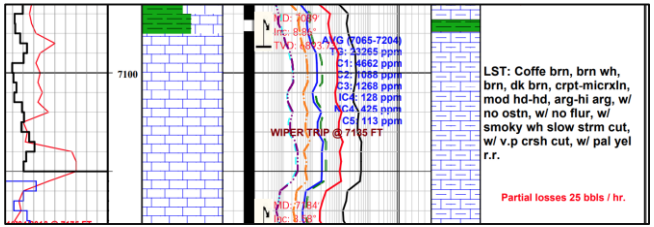
Well-6 (AR/F)



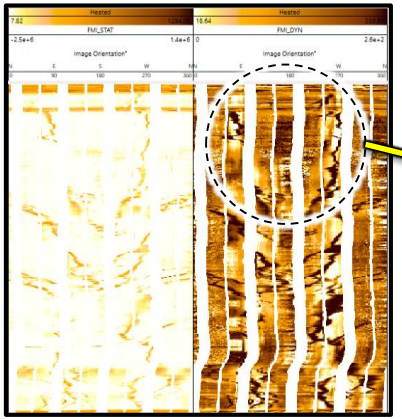


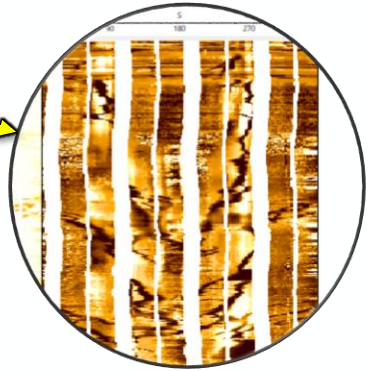


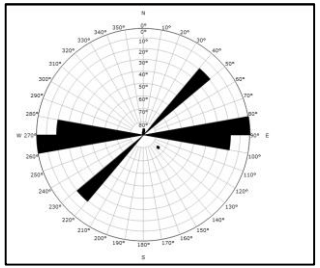
AVG.POR	AVG.SW	Possible Net pay
10 %	12 %	32 ft



Oil and Gas shows

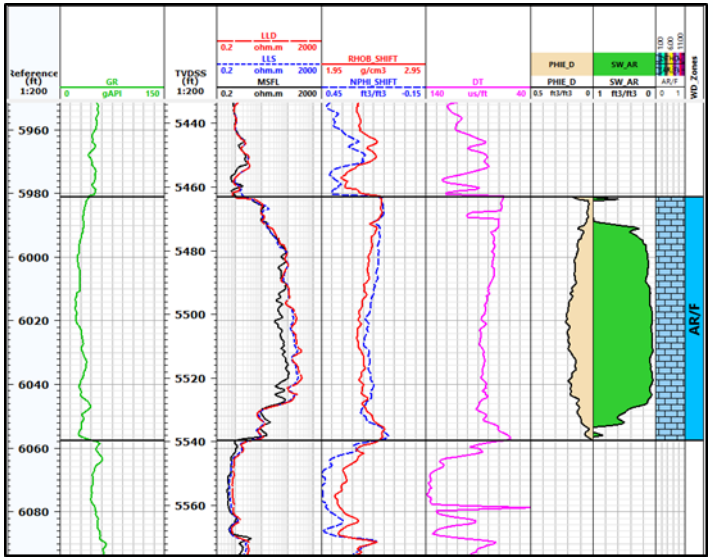


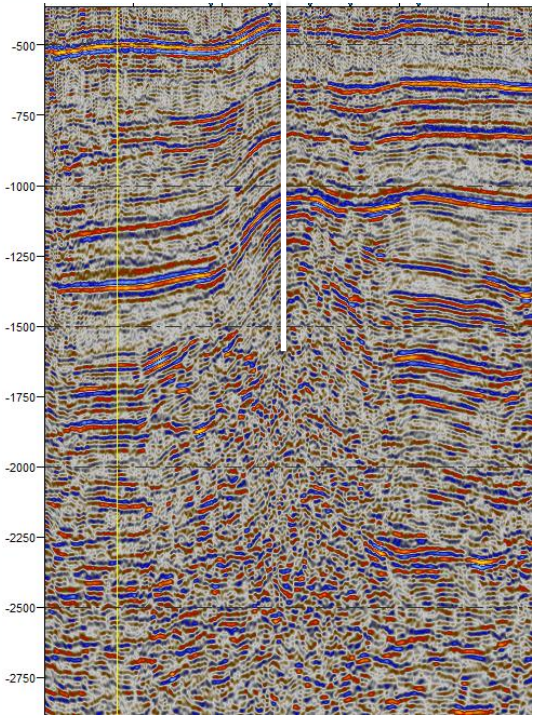


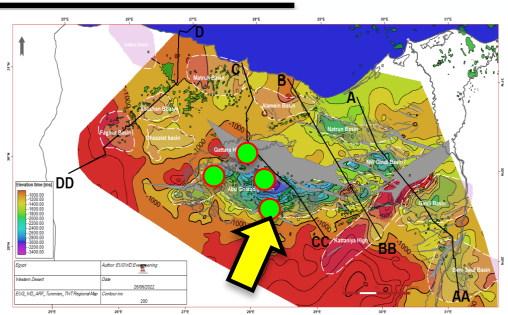


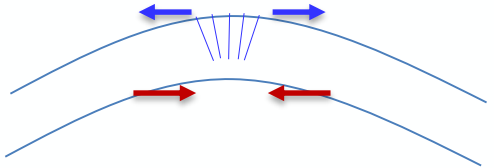
- Fractured potential zone with high resistivity separation & several conductive fractures.
- Two sets of conductive fractures encountered in this well: 1- NW-SE 2- E-W

Well-7 (AR/F)









AVG.POR	AVG.SW	Possible Net pay
14 %	15 %	58 ft

- Structural related Reservoir Enhancement
- Test >400 BBL after acid stimulation without applying modern technologies like Fracking

Low Resistivity Pay (LRP)

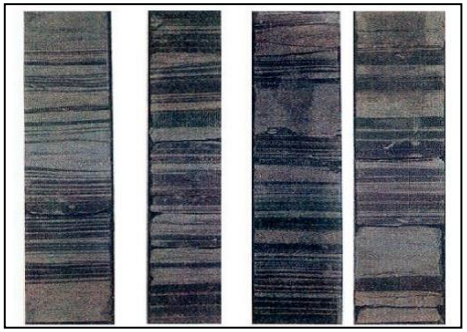
- **LRP:** Low resistivity formation is defined as having an apparent deep resistivity value of less than 5 ohm-meters (Gandhi et al 2011).

- A number of factors have found to act on the logging to produce low resistivity or low contrast pays. In Moore (1993), Darling and Sneider cite the following causes:

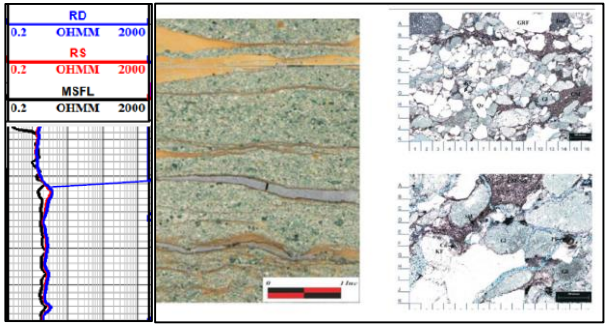
  1. Bed Thickness
  2. Grain Size
  3. Mineralogy
  4. Clay Distribution
  5. Water Salinity

- The problems with Low Resistivity reservoirs is firstly the resistivity data interpretation of the formation evaluation shows high water saturation but in reality even water free hydrocarbon can be produced from the well.

- Evaluating low-resistivity pay requires interpreters to discard the notion that water saturations above 50% are not economic.



A core through a laminated interval.(Source: IHRDC)



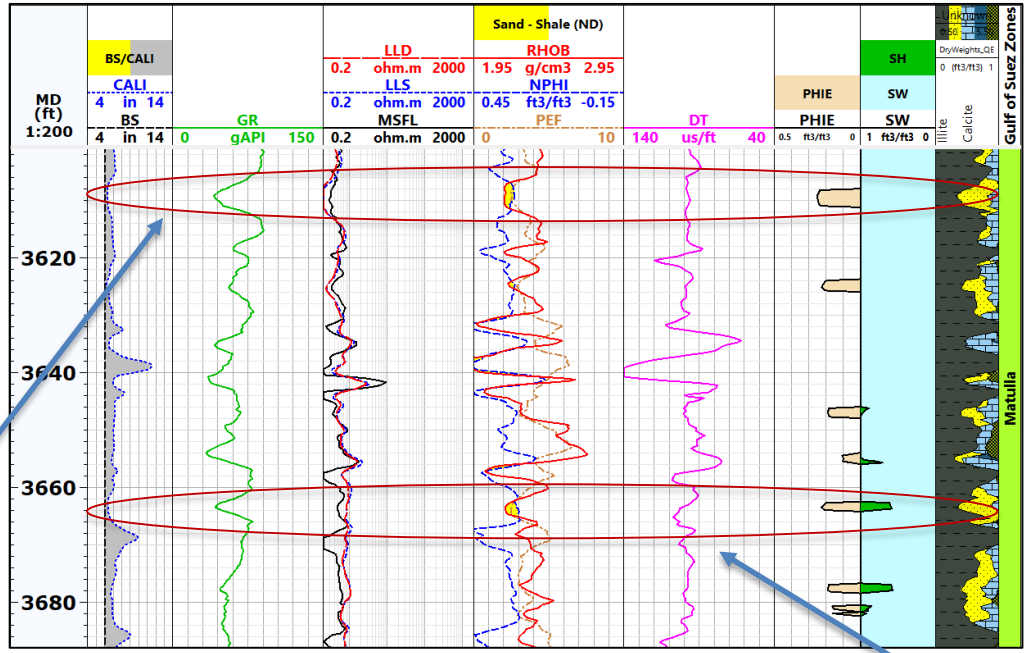
Images show that the framework grains are mainly quartz [Qz], with subordinate glaucony [Gl]. K-feldspar [KF], granitic rock fragments [GRF].

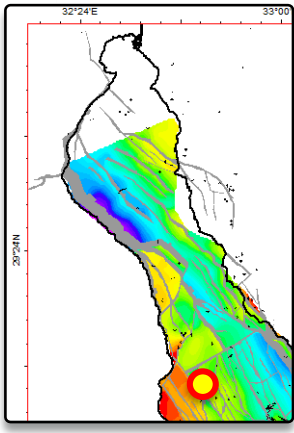
Well-1 (LRP-Matulla Fm)

- The well was drilled on 1996.
- Only oil shows in Matulla fm while drilling.
- Two RFT fluid sample were recovered in Matulla fm.

- SS: wh, cls, off wh, rnd-sbrnd, v. fn-fn grnd, w srtd, **glauc i/p**, w/ argl. cmt, occ sli calc cmt, **w/tr of spotty dead oil**.

- RFT sample (3610') recovered **water and gas.**





- RFT sample (3664') recovered only **oil and gas.**
- The maximum resistivity **0.8 ohmm**

Well-2 (LRP-Kareem Fm)

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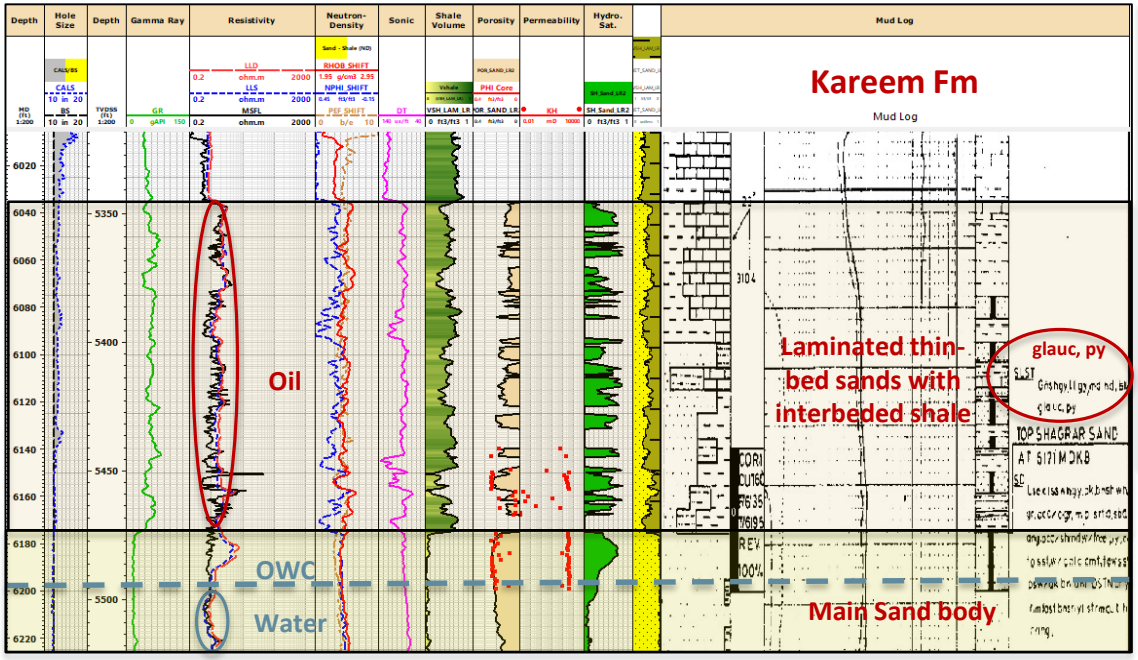
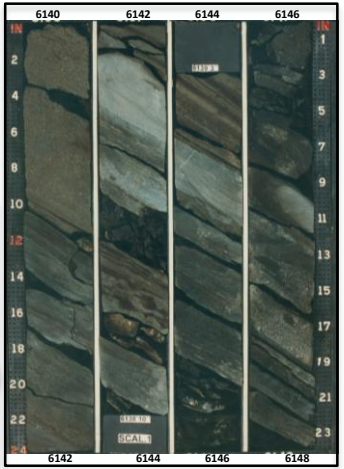
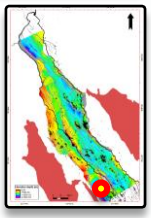




- The well was drilled on 1996 to target the sand of Kareem fm.
- The well penetrated only 15’ as oil bearing in the main sand body and penetrated the O.W.O.C.
- A conventional core was cut, covered the top part of the main sand body and the lower part of low resistive and thin laminated sand.
- The well completed as water injector



6143’-6143’ 4’’
Highly bioturbated interlaminated to interbdded brownish grey oil stained sandstone.

6152’ 2’-6152’ 8’’
Sandstone, brownish grey, non-calcareous massive highly oil stained

6161’6’’-6161’ 10’’
Sandstone, tannish grey, with selectine thinly lanted to massive oil staining highly at upper part and non at lower.

Well-2 (LRP-Kareem Fm)

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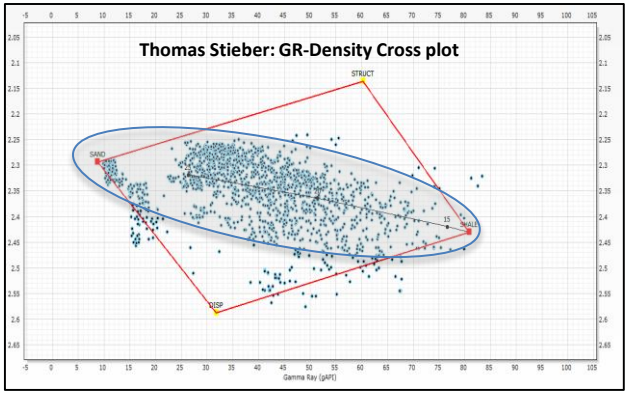
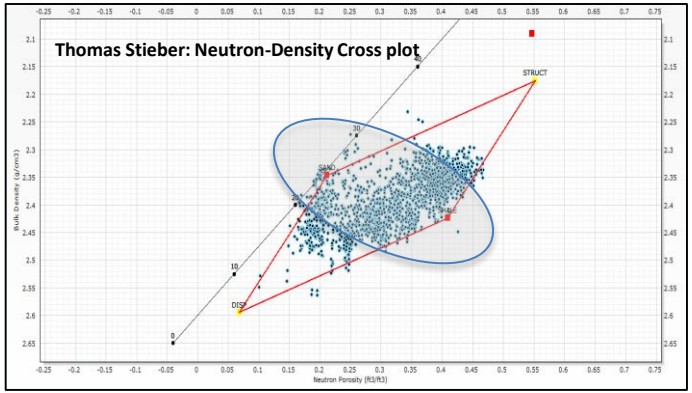
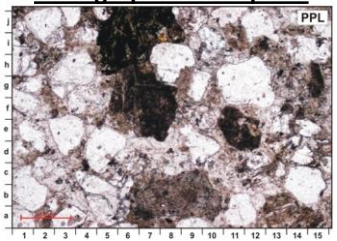
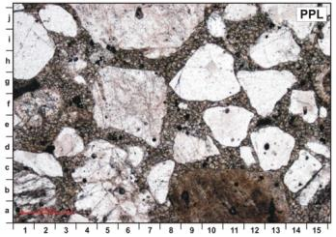




Petrographic Description



Sample Type: Core @ 6150'
Quartz (h-12), feldspar (1-13) and lithic fragments (b-9) set in a carbonate cement (g-10).



Sample Type: Core @ 6158'4''
Quartz grains (h-10), fresh feldspars (b-1) and altered feldspar grains (b-19) associated with foram tests (f-2) and set in carbonate microspar (e-9(.

Core Data

- Avg. PHI 16%
- Permeability range from 0.01-409 mD
- Grain Density, 2.67 gm/cc

Petrophysical Evaluation

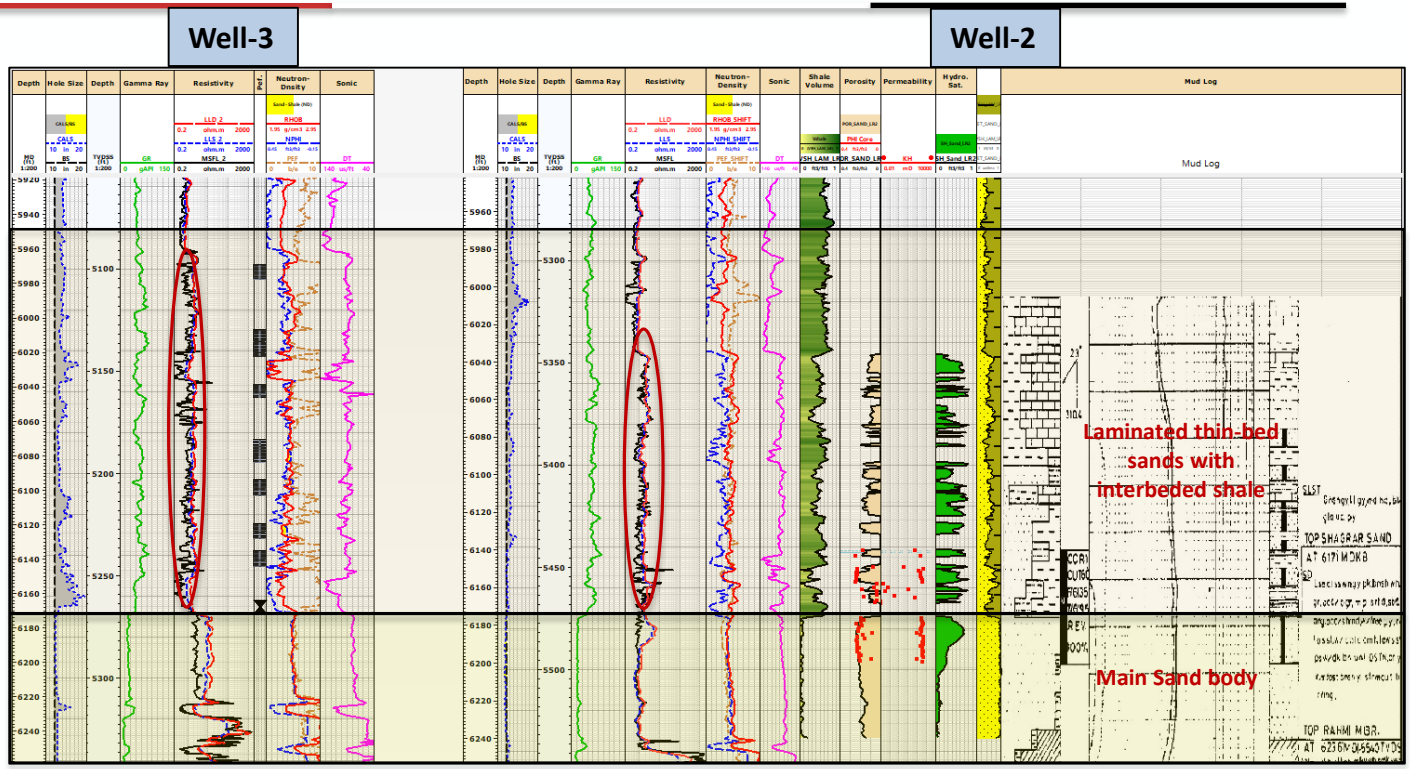
- Net Sand: 70'
- Avg. PHI 14.5%
- Avg. SW: 55 %

Core Description

@ 6142', SS: Whsh, C-v F gr, v hd, Subang-Subrrd, p std, w cmtd, calc, py.
@6143' , SS: Lt gy, M-v F gr, fri, Subang-Subrrd, mod std, mod cmtd, calc, glauc.
@6147', SS: Dk gy, v C-M gr, mod hd, Subang-Subrrd, mod std, mod cmtd, calc, py patches

What is the impact of these low resistive zones on production?

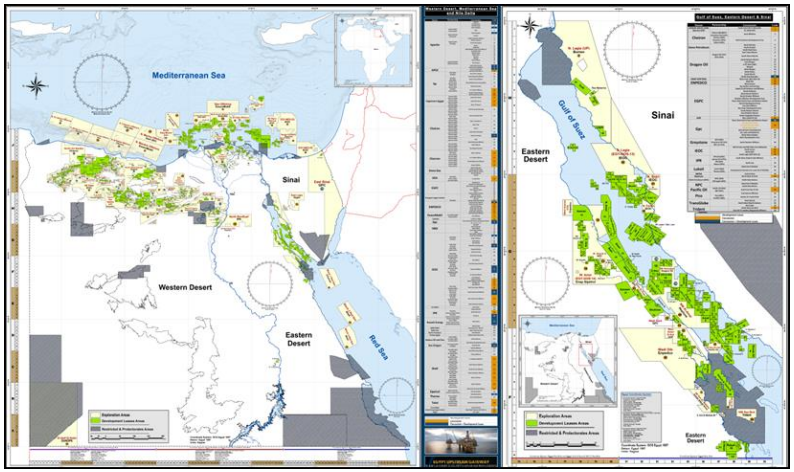
Well-2 (LRP-Kareem Fm)



- On 2012, 75' of low resistive zones were perforated in Well-3 after the main sand body was watered out.
- The initial production for these low resistive zones was 300 BOPD with nil W.C.
- The well produced 540,000 MSTB as a cumulative production from low resistive zones.

Summary

- Maximizing the reserves and production requires new Ideas.
- Being restricted to classical exploration concepts may result in losing high reserves.
- Unlocking the hydrocarbon potentiality for unconventional reservoir is a challenge.
- Hydrocarbon potentialities of Brown limestone and AR/F still unestimated.
- Bore-hole image is mandatory for the evaluation of Brown Limestone and AR/F.
- Petrophysical evaluation should be integrated with Core, XRD and NMR due to the presence of the organic matter.



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