[PS]Discovery of Subtle Traps in Early Cretaceous Formations of Kuwait through an Integrated Study*

Shaikh Abdul Azim[1], Salah Al-Anezi[1], Mariam Al-Blayyes[1], Sarah Al-Qattan[1], and Bader Al-Saad[1]

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Abstract

Aggressive exploration and development activities of this decade have led to discovery of hydrocarbons in fault-controlled anticlines and stratigraphic pinch outs of Zubair and Ratawi Formations of Kuwait. A detailed study of the Lower Cretaceous stratigraphy and structural history followed by targeted drilling have established the complexity of fluid distribution and trapping mechanism.

The Zubair Formation consists of arenaceous clastics of high to transgressive systems tracts in an intensely faulted anticline. An integrated method of fault mapping from seismic signatures including coherency, amplitude and frequency volumes tied to well and production data from shallow reservoirs yielded three categories of faults for target identification: Significant, obvious but smaller and minor or indeterminate faults. Definition and mapping of quality of oil with respect to fault seal was used to identify locales of migrated oil and sweet spots of trapped oil. Trapping mechanisms were identified to be genetically and tectonically controlled: migration/leaking of oil from the high stand reservoirs up-structure and along fault conduits in the channel sand sections abetted by insufficient clay smearing to form local seals. In transgressive system tracts, the thinner sands have sufficient seals to prevent oil leakage. Mapping of sands from seismic attributes within an overall sequence stratigraphic framework is observed to be useful in delineating stratigraphically controlled traps. Comparative study of trapping mechanisms with dominantly oil-bearing equivalent systems of adjacent fields was used to construct the fault related oil-leaking pattern. Localized pressure differentials were used to locate fault traps and huge reserves were added in the process.

Paleogeographic reconstruction, diagenesis and structural analysis were used for locating stratigraphic traps in Ratawi Formation. In the upper clastic unit, oil trapping in sands is controlled by stratigraphy and lithology. Porous shoreface sands are oil bearing in three strata bound layers in areas of distinct paleogeography. The northern part is devoid of oil due to intense cementation and gradation of clastics to carbonates. The abnormally pressured limestone member is a ramp carbonate with intense cementation towards the base. Lesser-connected vuggy pores in upper

part contain biograded oil from early charge, which was followed by a lighter fraction.

The paper describes the challenges in exploring the subtle traps in detail.

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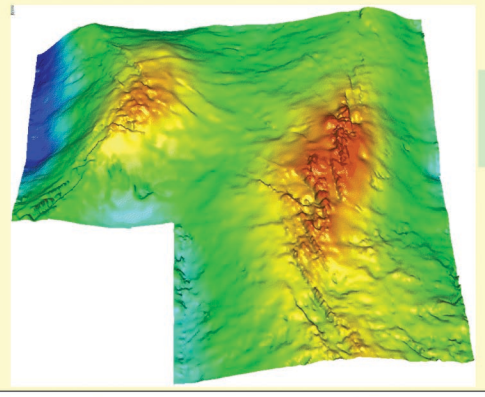
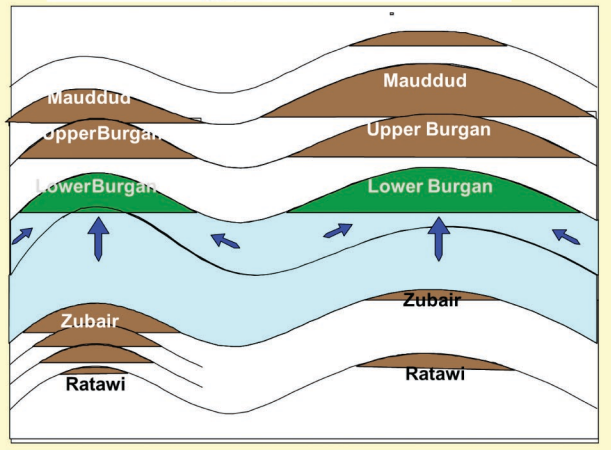
STRUCTURE



Raudhatain and Sabiriyah are the main fields in North Kuwait with Multiple reservoirs

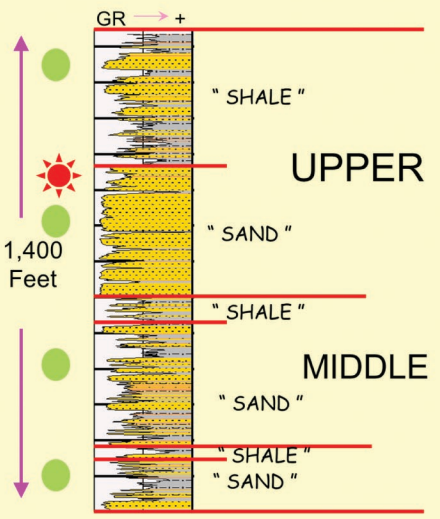
Structure Mapped from 3D Seismic
Doubly Plunging Anticlines
Highly Faulted
- Dominant Trends:
- NE-SW
- ESE-WSW

Faults Affected Palaeo fluid flow

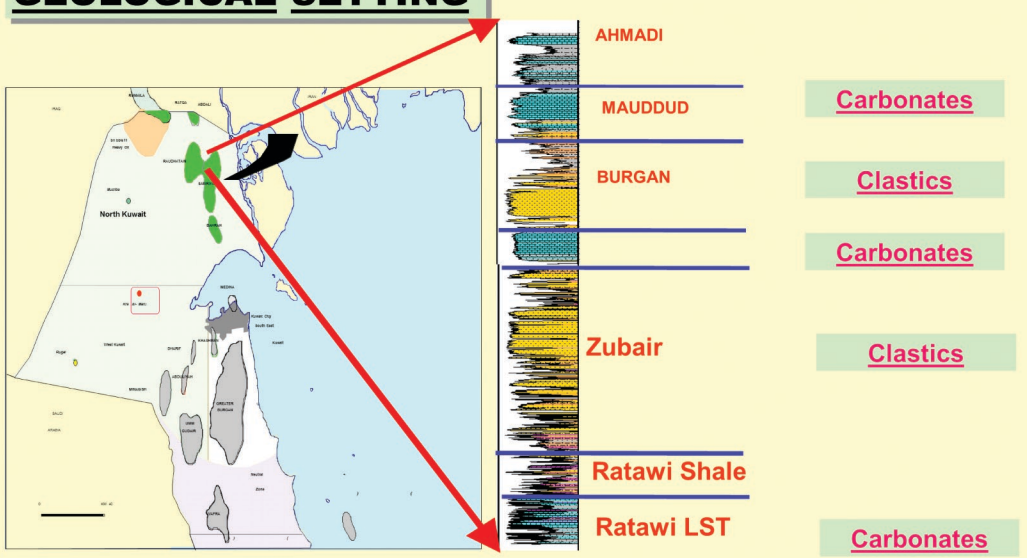


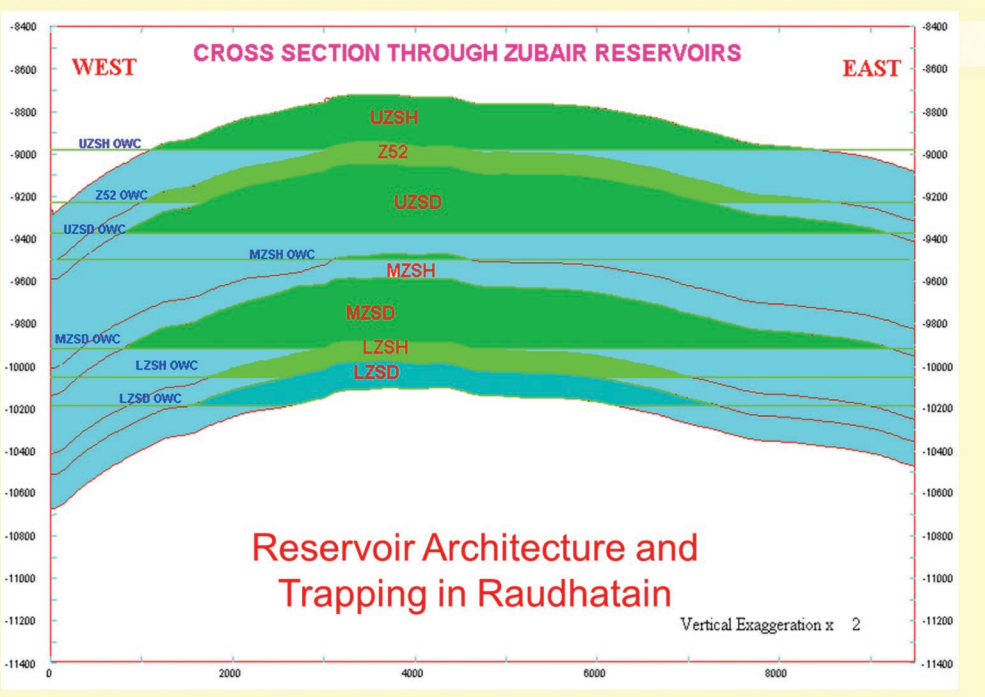
A Schematic E-W cross section across the field showing multiple pools

Main Reservoir Intervals in Zubair



GEOLOGICAL SETTING





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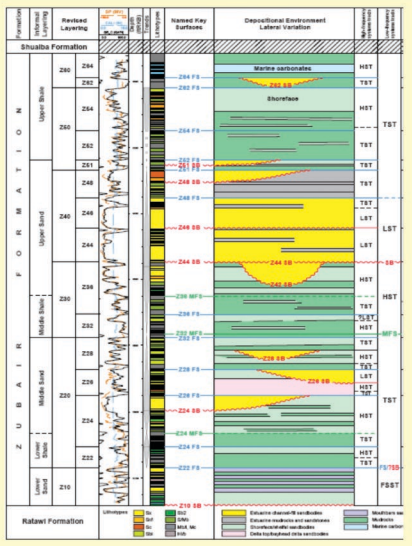
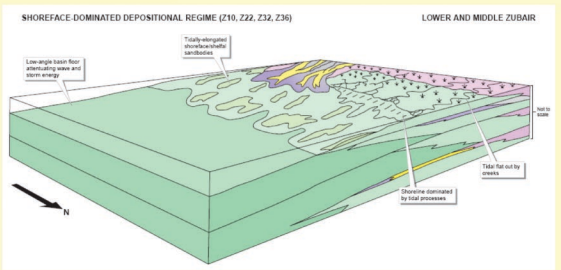
RESERVOIR CHARACTERIZATION

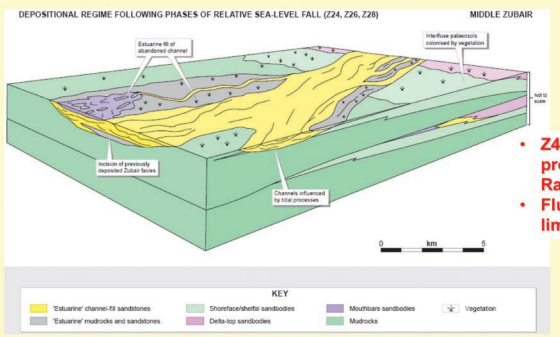
SEQUENCE STRATIGRAPHY and LATERING SCHEME

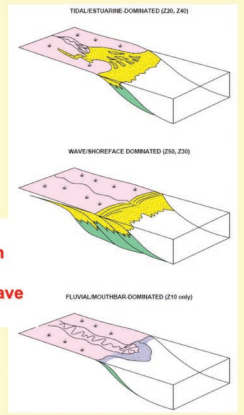


- Main Reservoir Rock in Low Stands
- One channel interval at top (Z62CH)



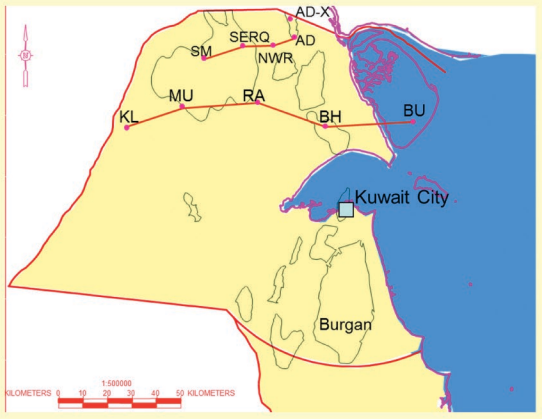
- Cap rocks are in TST
- Shoreface sands in HST are moderate quality reservoirs with greater extent



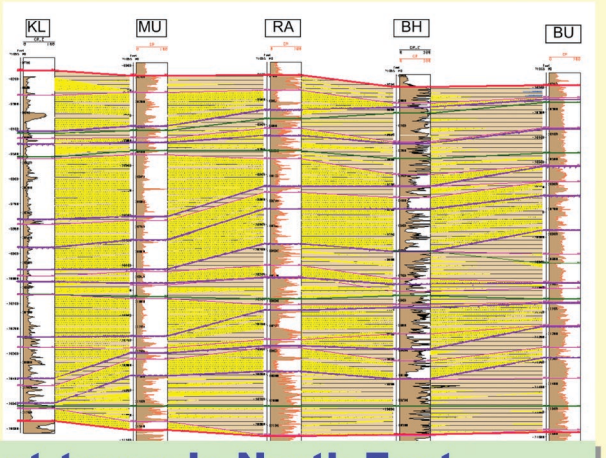


- Z40 Unit is main producing horizon in Raudhatain Field
- Fluvial Mouthbars have limited reservoirs

Regional Geology of Zubair Formation



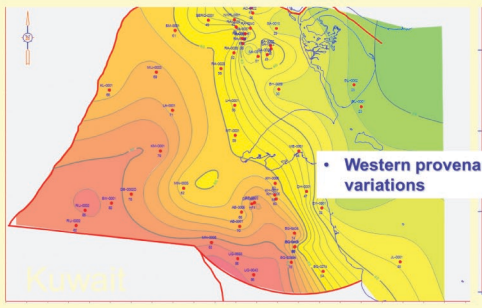
Regional correlation within the Zubair Formation along depositional dip



- Zubair Formation is highly arenaceous towards West as in KL structure
- It is mostly argilaceuos in Bubyan Structure
- A gradual change in Facies is observed

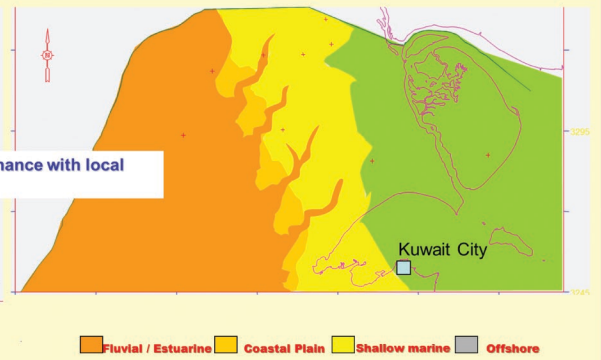
Paleo-Current towards North-East

Sand Percent Map of the Zubair Formation



- Western provenance with local variations

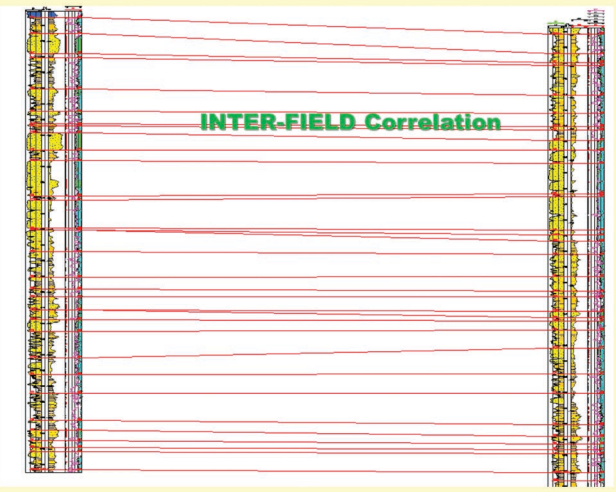
Paleogeographic Map Showing FaciesDistribution.



Reservoir Extent

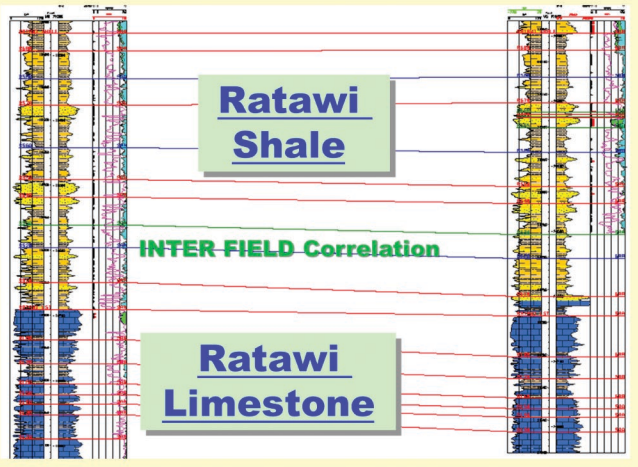
Zubair

Raudhatain — Sabiriyah



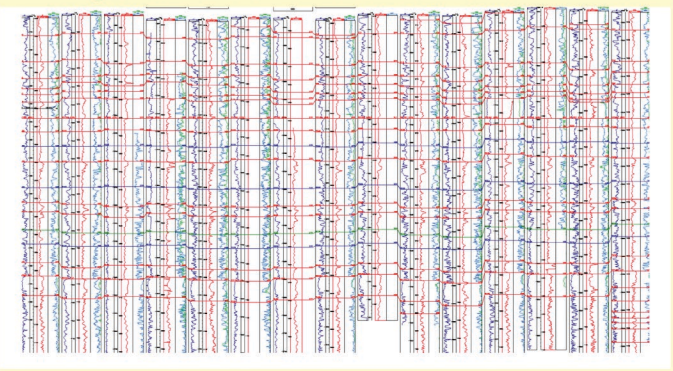
- Layers are broadly correlatable across two fields even in wells lying 20 KM apart
- Wells in Raudhatain Field are more Sand prone with higher frequency Channels
- Precise mapping of channels is possible due to high well density in Raudhatain

Ratawi Limestone and Shale



- Ratawi Layers are more continuous than Zubair across the Fields
- Thin layers up to 5 thick can be easily correlated
- Sands within Ratawi Shale are cemented and have low porosity
- Initial reservoir pressure was higher than hydrostatic Pressure: Dropped on production

Layer Correlation of Zubair/Ratawi in RA and SA wells



- ❖ Correlatable thin layers
- ❖ More Fluctuation of Sea level in Ratawi Shale
- ❖ Upper Zubair more Arenaceous
- ❖ Calcareous cement in most of the thin marine sands

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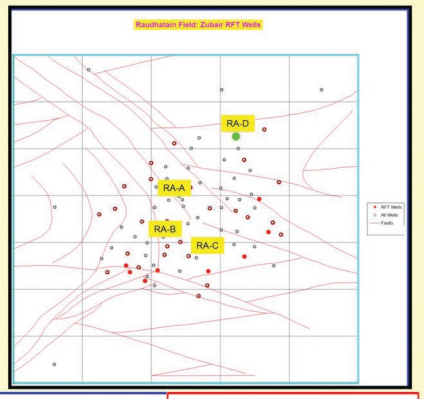
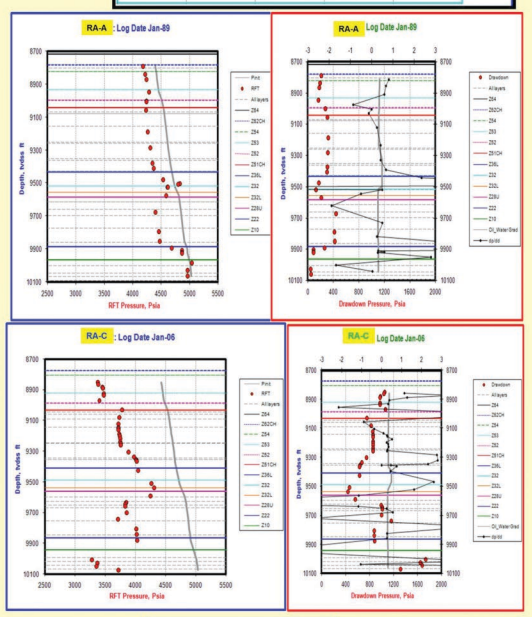
Hydrodynamic Connectivity and Trapping Mechanism

Pressure Communication

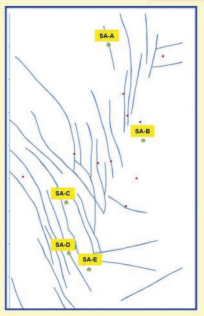
Raudhatain Field



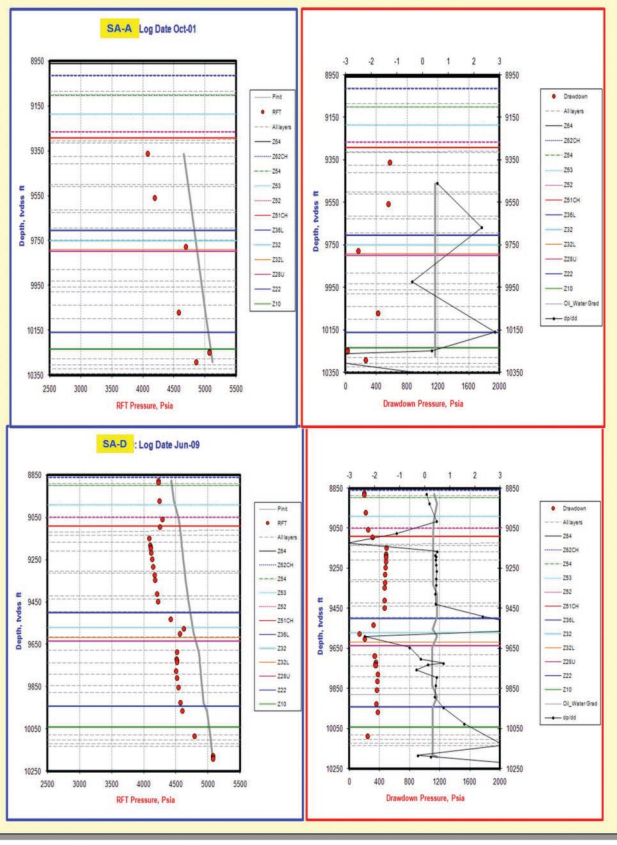
Layer wise RFT Pressures

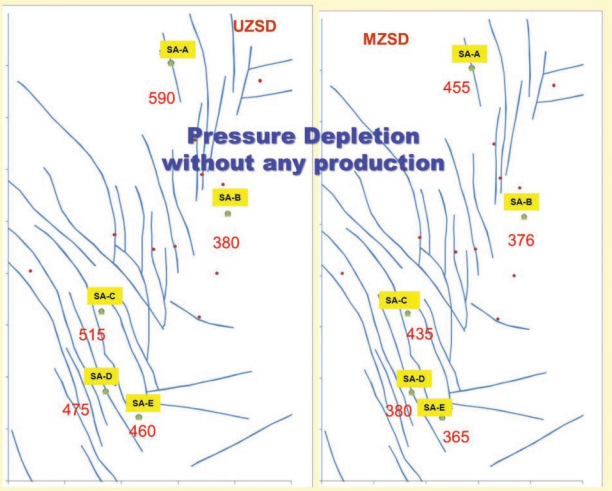


Sabiriyah Field

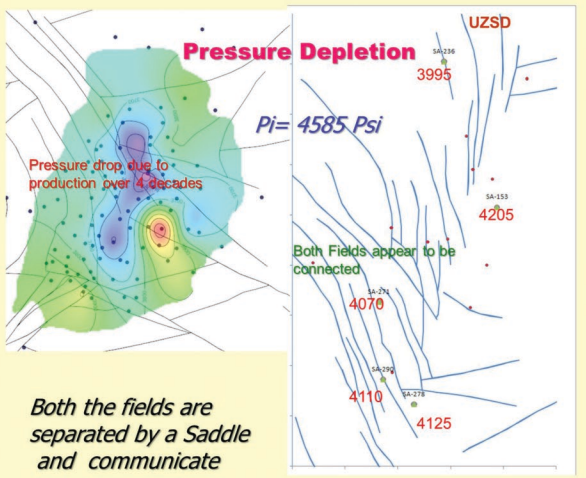


No Production from Zubair/Ratawi





Reason for Pressure Depletion :
1. Dump flooding Upper Reservoirs

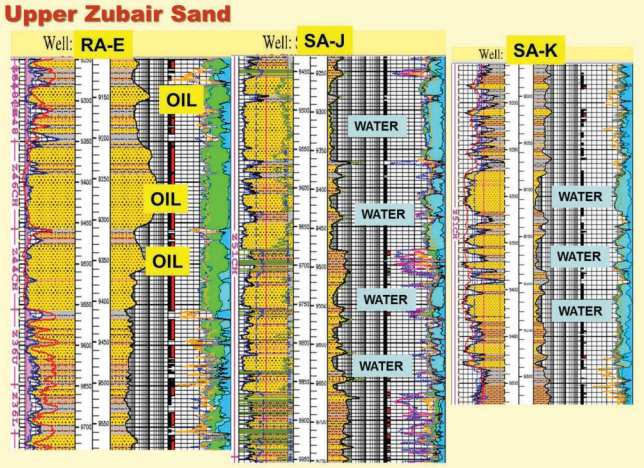


Both the fields are separated by a Saddle and communicate

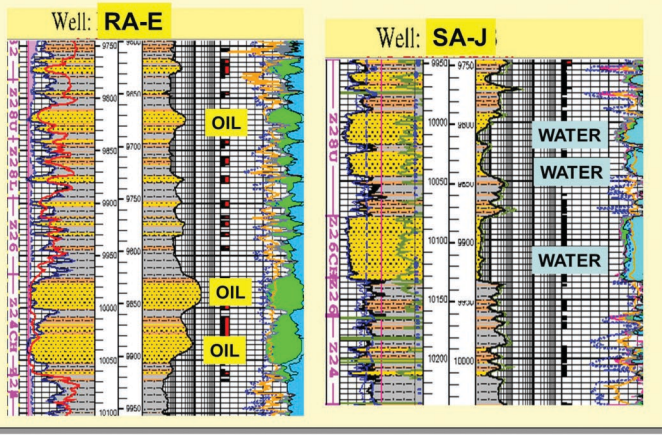
Reason for Pressure Depletion :
2. Lateral Communication with Raudhatain Zubair

FLUID DISTRIBUTION

Upper Zubair Sand



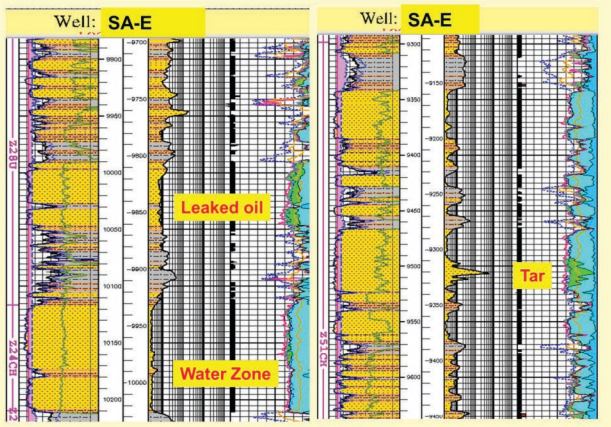
Middle Zubair Sand



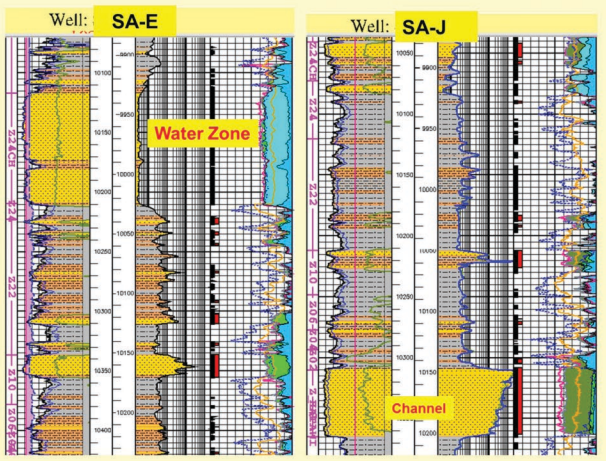
Trapping Mechanism

Water Zone and Leaked oil Zone in Middle Zubair

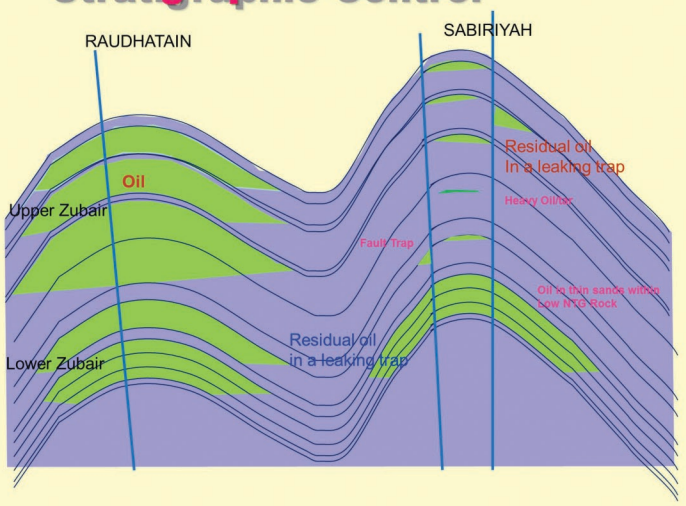
Tar /Heavy oil in Upper Zubair Sand



Thick sand bodies in LZSD: Thicker Shales above

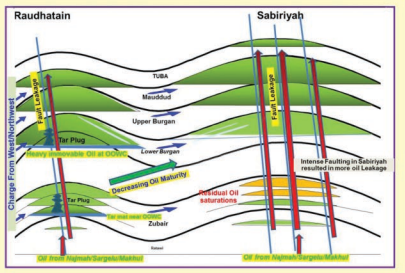


Zubair Traps: Structural and Stratigraphic Control



Distribution of Oil in Raudhatain and Sabiriyah Fields

- **Ratawi**
  - Strartigraphic traps
- **Zubair**
  - RA: Structural
  - SA: Stratigraphic in LZ, Leaked oil in MZ/UZ
- **Burgan**
  - RA: Oil till spillpoint
  - SA: Migration to south
- **Tuba**



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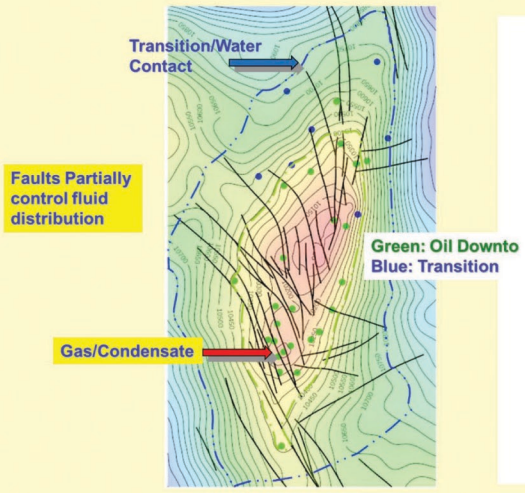
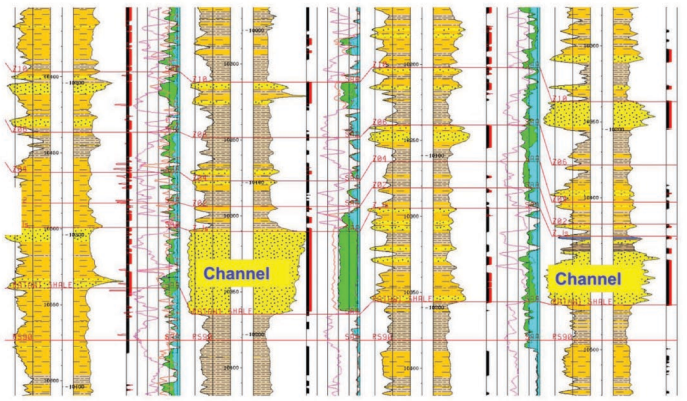
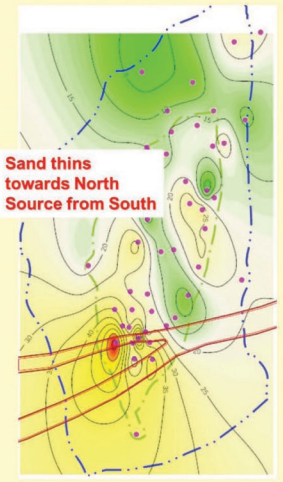
Upper Zubair Sand Stratigraphic Traps

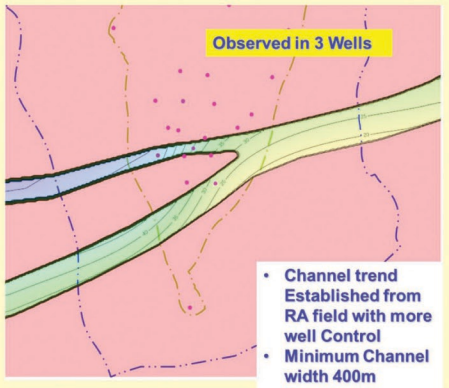


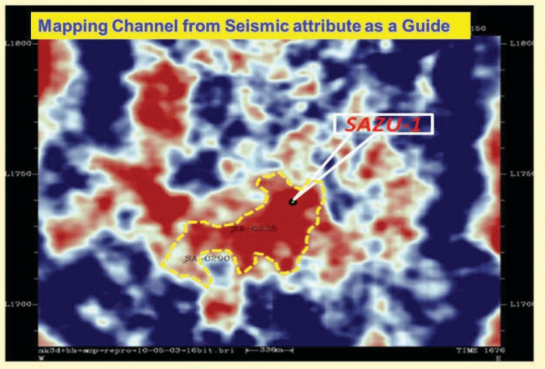


Structure on Z_Is

Facies Variation



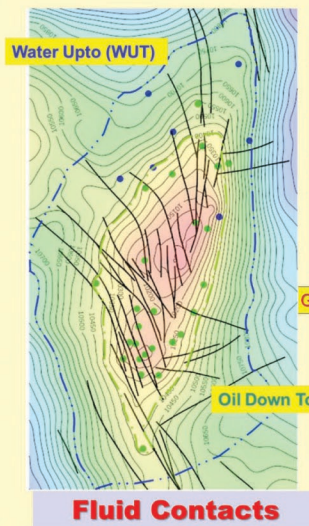


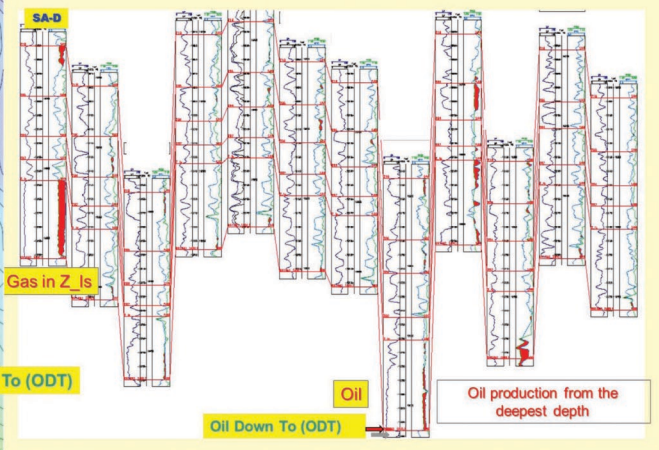


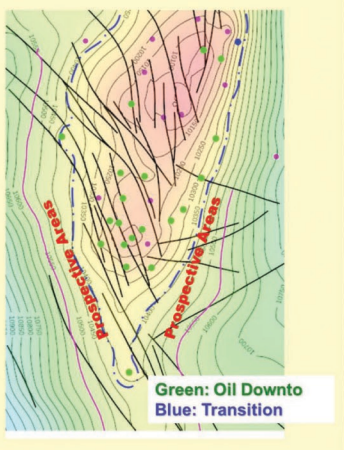
Net Sand thickness of Z_Is

Channel in Z_Is

Thickest Oil bearing Layer in Sabiriyah Zubair



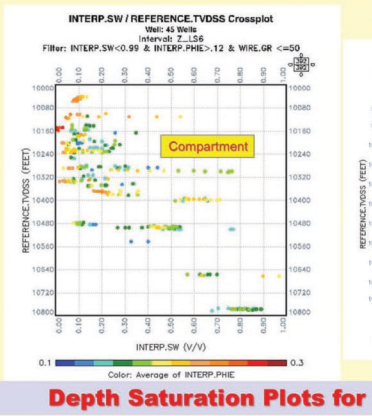


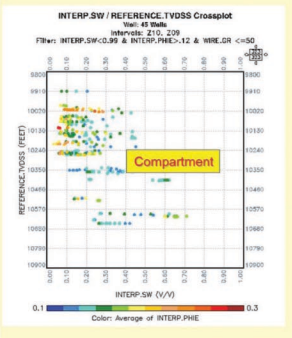


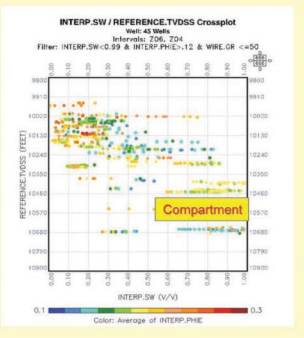
Fluid Contacts

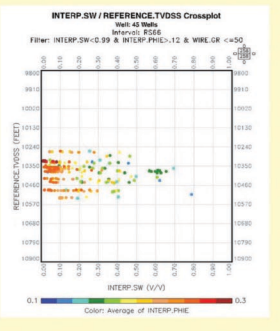
Zubair LZSD: Structural Disposition

Prospective Areas









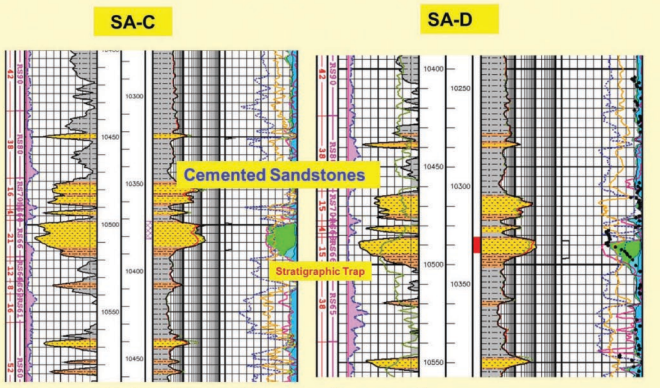
Depth Saturation Plots for Fluid Contacts

High Sw at shallower depth show leaked compartments

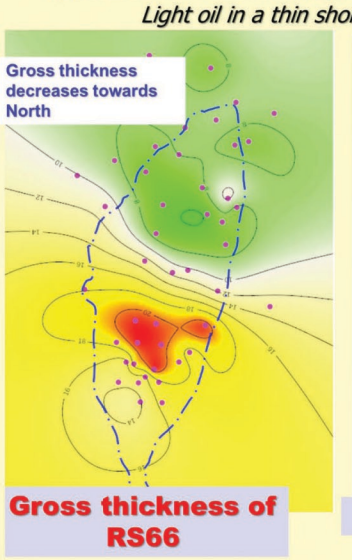
RS66: Low Sw at deepest known depth: more oil further down to south

Ratawi Shale/Limestone

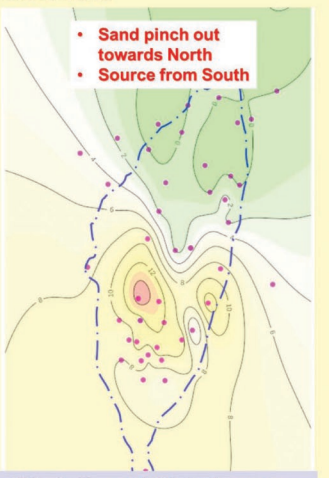
Stratigraphic trap in Ratawi Shale



Light oil in a thin shoreface sand

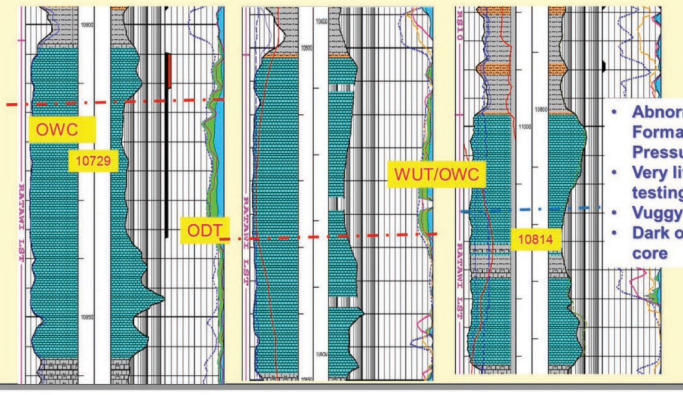


Gross thickness of RS66



Net Sand thickness

Heavy oil in Ratawi Limestone



Challenges

- Structure and faults
- Leaking faults:
  - ❖ Oil leaked from main reservoirs-UZSD, MZSD
  - ❖ Some good sands in LZSH/LZSD show oil leak
- Fault Compartmentalization
  - ❖ Different OWC in fault blocks
  - ❖ Need more well control for defining OWCs
- Facies Change: Pinchouts and increased cementation towards north
- Thin and Shaly sands:
  - ❖ Continuity/Productivity: Production so far are from good and thick sands
- Presence of Tar in adjacent Field field

Opportunity

- Thicker Channels of Z_Is towards south and other parts of field
- Commercial production from South Sabiriyah
- Deeper OWC towards South: to spill point
- Porous areas for Ratawi Shale
- Fault compartments in UZSH,UZSD,MZSD with independent oil pools adding to STOIIP