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 upstructure 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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Aggressive exploration and development activities of this decade have led to discovery of hydrocarbons in fault controlled anticlines and stratigraphic pinchouts 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.

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Paleogeographic reconstruction, diagenesis and structural analysis were used for locating stratigraphic traps in Ratawi Formation. In 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. 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 heavier/biograded oil from early charge which was followed a lighter fraction later.
**RESERVOIR CHARACTERIZATION**

**SEQUENCE STRATIGRAPHY and LATERING SCHEME**

- **Main Reservoir Rock in Low Stands**
- **One channel interval at top (Z62CH)**
- **Cap rocks are in TSB**
- **Shoreface sands in HST are moderate quality reservoirs with greater extent**

**Regional Geology of Zubair Formation**

- **Z60 Unit is main producing horizon in Raudhatain Field**
- **Fluvial Mouthbars have limited reservoirs**

**Paleo-Current towards North-East**

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

**Reservoir Extent**

- **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**
Hydrodynamic Connectivity and Trapping Mechanism

Pressure Communication

Raudhatain Field

Reason for Pressure Depletion:
1. Dump flooding Upper Reservoirs

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 - Stratigraphic traps
- Zubair - RA: Structural
- SA: Stratigraphic in LZ, Leaked oil in MZ/UZ
- Burgan - RA: Oil till spillpoint
- SA: Migration to SOUTH
Discovery of Subtle Traps in Early Cretaceous Formations of Kuwait through an Integrated Study

Shaikh Abdul Azim, Salah Al-Anezi, Mariam Al-Blayyes, Sarah Al-Qattan and Bader Al-Saad
Kuwait Oil Company

**Upper Zubair Sand Stratigraphic Traps**

- **Structure on Z_Is**
  - Channel trend: Established from RA field with more well control
  - Minimum Channel width 400m

- **Facies Variation**
  - Thickest Oil bearing Layer in Sabiriyah Zubair

- **Net Sand thickness of Z_Is**
  - Observed in 3 Wells

- **Observations**
  - Channel trend
  - Faults Partially control fluid distribution

**Ratawi Shale/Limestone**

- **Stratigraphic trap in Ratawi Shale**
  - Light oil in a thin shoreface sand

- **Gross thickness of RS66**

- **Net Sand thickness**

**Channel in Z_Is**

- **Heavy oil in Ratawi Limestone**
  - Abnormal Formation Pressure
  - Very little influx on testing
  - Vuggy Limestone
  - Dark oil stains in core

**Fluid Contacts**

- **Zubair LZSD: Structural Disposition**

**Prospective Areas**

**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

**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 STOIP

**Depth Saturation Plots for Fluid Contacts**

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

- **High Sw at shallower depth show leaked compartments**