Abstract

The Late Valanginian unconformity, with a hiatus of about four million years in southern Kuwait, separates the Zubair Formation from the underlying Ratawi Shale Formation. Both of these formations are dominantly siliciclastic and overlie a thick (1975-2300 feet in thickness) Early Cretaceous carbonate succession. This shift in sedimentation is attributed to the uplift and erosion in the hinterland westward in the Arabian Shield. The Zubair Formation consists of 1150-1450 feet thick sequence of interbedded sandstone, siltstone, and mudstone. A sandbody of variable thickness (0-60 feet), which is locally hydrocarbon bearing, is encountered at its base in a few geographically scattered wells. Log signatures, by comparing to the cores over similar zones, indicate them as channelized bodies which are associated with the Late Valanginian sequence boundary. Regional analyses suggest the development of northeasterly drainage during this time which eroded and incised into the exposed surface developing into incised valleys. Reservoir sandstone facies were deposited during the early phases of the channel development. These sandstone facies are overlain variably by the fine grained facies made up of interbedded sandstone, siltstone, and mudstone which could act as vertical seal for fluid migration. These fine grained facies either relate to channel abandonment and/or were deposited in estuarine and marginal marine environments as a result of the following transgression. No entrapment is expected where (1) this upper seal is not an effective barrier to fluid flow and (2) where there is no trap development. In addition to the presence of four way closure and sealing faults, one of the effective trapping mechanisms is where sealing facies impinge against a paleohigh to provide lateral as well as top seal.

With this understanding, the play is based on finding the (1) possible paleoflow pathways and once found (2) mapping of the channels by using seismic inversion and attribute analysis. By assuming the flow to follow paleolow areas, the paleodrainage pathways could be figured out from the paleotopography which existed at the time of the earliest Zubair deposition. Consequently, potentially prospective exploration areas can be determined by using these along with other favorable play elements.
References

Where to find the reservoir?

Late Valanginian

Unconformity associated play in Kuwait

Saifullah K. Tanoli, Mohammed Dawwas Al-Ajmi, Heyam Al-Ammar, and Nikhil Banik

Exploration Group, Kuwait Oil Company
Outline

• Stratigraphy
• The Play and the concept
• Case Studies
• Conclusions
Chronostratigraphic section of the early to mid-Cretaceous across the Arabian Gulf Area (from Sharland et al., 2001) showing three 2nd order transgressive-regressive cycles within megasequence AP8. The Valanginian Ratawi Shale Formation is part of the basal 2nd order cycle and is highlighted by the blue box.

Stratigraphic section of the part Early Cretaceous in Kuwait.

<table>
<thead>
<tr>
<th>Age</th>
<th>STAGE</th>
<th>GROUP</th>
<th>FORMATION</th>
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<tbody>
<tr>
<td>137.0</td>
<td>VALANGINIAN</td>
<td>THAMAMA</td>
<td>Ratawi Shale</td>
</tr>
<tr>
<td>127.0</td>
<td>HAUTERIVIAN</td>
<td>THAMAMA</td>
<td>Ratawi Limestone</td>
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<tr>
<td>121.0</td>
<td>APTIAN</td>
<td>WASIA</td>
<td>Shuaiba</td>
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<tr>
<td>112.2</td>
<td>ALBIAN</td>
<td>WASIA</td>
<td>Burgan</td>
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</tbody>
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**AGE**

- **VALANGINIAN**
  - 137.0 Ma
- **HAUTERIVIAN**
  - 127.0 Ma
- **APTIAN**
  - 121.0 Ma
- **ALBIAN**
  - 112.2 Ma

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**FORMATION**

- **Ratawi Shale**
- **Ratawi Limestone**
- **Shuaiba**
- **Burgan**
Zubair Formation

BG-A

Upper Zubair

Middle Zubair

Lower Zubair

BG-B

Upper-Lower Zubair

Basal-Lower Zubair
Kuwait Map showing location of Cross Line.
Regional correlation within the Zubair Formation along depositional dip.
Concept

• Northeastward drainage development during Valanginian unconformity time.

• Trace the paleoflow pathways to find reservoir sandbodies.

• Locally imply other geological and geophysical understanding.
Ratawi Shale paleotopography during Zubair Deposition

Warm color - High Area

Yellow - Medium

Blue: Low area
Burgan Dome
Basal Zubair Core in BG-B

Environments

- Foreshore, shallow marine
- Intertidal
- Estuarine
- Marsh
- Restricted estuarine, lacustrine, or swamp

Core Analysis

- LZ25 SKT
- LZ30 SKT
- LZ35 SKT
- LZ40 SKT
- LZ50 SKT
- RATAWI SHALE SKT

- White fine grained sandstone
- Dark grey siltstone, carbonaceous shale and sand lenses, ripple lamination
- Dark grey siltstone and carbonaceous shale
- Black and dark grey siltstone and carbonaceous shale
- Seal
- Sandstone: Medium to coarse-grained, massive to horizontally laminated, friable, oil stained, very good porosity
- TST
- 40+ft hydrocarbon column in the core
- Lowstand
- Sandstone: Medium-grained, grey brown oil staining, friable, very good porosity
- Stacked channel fills
Burrowed muddy carbonaceous sandstone.

Fining Upward sequence

Sandstone.
The Zubair Play in the Burgan Area
Seismic Amplitude Map with Proposed Well Locations
BG-C  Base Zubair-Top Ratawi Shale Core

**Description**

- Sandstone: Light grey, medium grained, friable.
- White-light grey, medium grained, friable, sugary textured sandstone with scarce ripple lamination
- Lignite
- Dark grey shale
- Brown oil stained medium-grained sandstone
- Grey, medium-grained, fairly friable, herringbone cross-bedding
- Hummocky laminated sandstone
- Grey, medium-coarse-grained, granular sandstone, cross laminated.
- Dark olive green shale with rippled sand drapes
- Dark olive grey shale, very carbonaceous, thinly laminated
- Light greenish grey, very fine-grained, bioturbated sandstone with nodular appearance
- Olive green shale, dense, with bioturbated fine-grained sandstone layers

**Environments**

- **Coastal Plain**
  - Marsh
  - Estuarine muds
- **Transitional**
  - Tidal channel
  - Storm-tide influence
- **Marine**
  - Transgressive sands
  - Unconformable surface
  - Marine Subtidal (Offshore)

**Zubair Formation**

- Ratawi Shale
- ?HST
- TST
- SB
BG-C Zubair Formation

Bi-directional cross stratified sandstone Facies

Cross bedded sandstone & shale Facies

Granular sandstone Facies
Palaeotopographic Map
Burgan Dome

Kuwait Oil Company
Post: Ratawi Shale Structure Map
R& J Grid
SCALE: DRAWN Saif Tanoli DATE 5-AUG-2010

BG-ABG-B
BG-C
BG-F
BG-E
BG-D
BG-A

Burgan Dome
Updip basal facies pinchout
Upside Lower Zubair large scale
Stratigraphic pinch out play

Dry wells

BG-C
BG-D
BG-B
BG-A
BG-F
The Zubair Play in the Burgan Area

BG-C

Area of Non-deposition

Burgan High

Ratawi Shale

Incised Valley Fill Sand

Cap Shale
The Zubair Play in the Burgan Area

Future testing of the Lower Zubair Play

Fluvial Foreshore-Shoreface
Fluvial to Estuarine
Area of Non-Deposition

Kuwait Oil Company
Sabriyah Area

• About 56 feet thick sand at base Zubair in one well.

• None of the other existing wells have more than 20 feet of sand at the base of the formation.

• Struggle is on to trace the sandbody.
Conventional OH logs Analyses
Results with MDT data

SA-A
Ratawi Shale
Zubair

UNIT C

CONDENSATE SAMPLE @ 1021
Well SA-A: Close up of Base Zubair

Channel or Tidal sand ridge
Low AI (yellow-Red) indicates high porosity.
Area: Sabriyah
Ratawi Shale paleotopography during Zubair Deposition

Red: High ground
White: Low ground
Lower Zubair section in Sabriyia Field.
Bahra Area

• Up to 50 feet thick sand at base Zubair.

• No universal homogenous distribution of the basal Zubair sandbody.

• Pay only in a well within the closure.
Conclusions

• Base Zubair reservoir distribution is at least partly related to the drainage development during Valanginian time.

• Variable mechanisms for hydrocarbon entrapment in the base Zubair sandstones.

• In case of Burgan, updip impingement of the overlying lower coastal plain muddier facies.

• In case of Sabriyah, normal structural closure and in Bahra 4 way closure + compartmentalization due to faulting.

• Local reservoir distribution help with seismic attributes.

• Regionally the play is being conceptually pursued.
During a field trip in Oman; Dr. Oliver Weidlich in action.