The Habban Field and the Fractured Basement Play in Yemen*

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Search and Discovery Article #110203 (2014)**
Posted December 15, 2014

*Adapted from oral presentation at Discovery Thinking Forum, AAPG International Conference and Exhibition, Istanbul, Turkey, September 14-17, 2014

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General Comments

Yemen in 2014

Fractured basement is one of the most important targets in the recent exploration strategy. A large proportion of Yemen’s proven oil reserves are in fractured basement reservoirs in many fields in two major sedimentary basins (Masilah and Sab’atayn).

Key Features and Findings

- The majority of basement rocks are metamorphic; they can acquire porosity through fracturing and alteration (cataclasites, breccias).
- Basement - fault/fracture system is more complex than two major fracture sets (NW-SE, NNE-SSW).
- 3D seismic is mandatory in developing a reasonable understanding of the fractured basement.
- For structural interpretation and fault characterization, CBM (all-azimuths) volume is used, as this gives the best seismic image.
- Predicted orientation of failure planes is strongly dependent on the interpreted fault pattern and not sensitive to the material properties.
• Faults and fractures in the in situ strike-slip faulting regime give a good explanation for the distinction between “open” and “closed” fractures.

**Conclusions**

• Basement plays have often been overlooked or considered to be marginally economic.
• Basement reservoirs are challenging
  - Drilling challenges
  - Development challenges
  - Production challenges
• Keys to understanding the dynamic mechanisms
  - 3D seismic
  - Fault and fracture network characterization

**Selected References**


Website

The Habban Field and the fractured basement play in Yemen

AAPG-ICE, Istanbul, September 2014
Outline

- Basement play around the world
- Some facts about the Basement play in Yemen
- Block S2 – Habban field
Outline

- Basement play around the world

Some facts about the Basement play in Yemen

Block S2 – Habban field
Basement Reservoirs around the World

- Basement rocks – definition
  “Any metamorphic or igneous rock (regardless of age) which is overlain by a sedimentary sequence”

After J. Gutmanis, T. Batchelor, L. Cotton, J. Baker and colleagues at GeoScience Limited
Hydrocarbon Production from Fractured Basement Formations v10 -2012
Basement Reservoirs around the World

Fractured Basement Characteristics - Key points

- **Naturally fractured reservoirs**
- Little to no matrix porosity and permeability
- Lithology often plays a major role in controlling reservoir quality

- **Basement charging** – different possibilities
  - Updip/lateral migration from an adjacent kitchen area into structural highs, or
  - Downward migration due to differential stresses, or
  - Long-distance lateral migration

*After J. Gutmanis, T. Batchelor, L. Cotton, J. Baker and colleagues at GeoScience Limited*
*Hydrocarbon Production from Fractured Basement Formations v10 -2012*
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After J. Gutmanis, T. Batchelor, L. Cotton, J. Baker and colleagues at GeoScience Limited
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Basement Reservoirs around the World

After J. Gutmanis, T. Batchelor, L. Cotton, J. Baker and colleagues at GeoScience Limited

Hydrocarbon Production from Fractured Basement Formations v10 -2012

Vietnam
Cuu Long Basin
85% of the production from fractured basement in 2005

After J. Gutmanis, T. Batchelor, L. Cotton, J. Baker and colleagues at GeoScience Limited

Hydrocarbon Production from Fractured Basement Formations v10 -2012
Basement Reservoirs around the World

After J. Gutmanis, T. Batchelor, L. Cotton, J. Baker and colleagues at GeoScience Limited

*Hydrocarbon Production from Fractured Basement Formations v10 -2012*
Basement Reservoirs around the World

USA
Wilmington Field
22 MMbbl produced

After J. Gutmanis, T. Batchelor, L. Cotton, J. Baker and colleagues at GeoScience Limited

*Hydrocarbon Production from Fractured Basement Formations v10 -2012*
Basement Reservoirs around the World

Yemen
50% of the country’s production

After J. Gutmanis, T. Batchelor, L. Cotton, J. Baker and colleagues at GeoScience Limited

Hydrocarbon Production from Fractured Basement Formations v10 -2012
Outline

Basement play around the world

- Some facts about the Basement play in Yemen

Block S2 – Habban field
1938
First Exploration Campaign by IPC

Yemen – Oil Discovery History
Yemen – Oil Discovery History

1938
First Exploration Campaign by IPC

1960’s – 80’s
Exploration by several foreign companies
Yemen – Oil Discovery History

1938
First Exploration Campaign by IPC

1960’s – 80’s
Exploration by several foreign companies

1984
First commercial discovery – Hunt Oil
Alif Field
Yemen – Oil Discovery History

1938
First Exploration Campaign by IPC

1940

1945

1950

1955

1960

1965

1970

1975

1980

1985

1990
Six foreign companies operating

1984
First commercial discovery – Hunt Oil Alif Field

1960’s – 80’s
Exploration by several foreign companies
Yemen – Oil Discovery History

1938
First Exploration Campaign by IPC

1940

1960’s – 80’s
Exploration by several foreign companies

1984
First commercial discovery – Hunt Oil
Alif Field

1990
Six foreign companies operating

1990 – 2004
64 PSA signed
Yemen – Oil Discovery History

1938
First Exploration Campaign by IPC

1940 - 1980
Exploration by several foreign companies

1984
First commercial discovery – Hunt Oil Alif Field

2004
Basement discovery in Block 10

1990
Six foreign companies operating

1990 - 2004
64 PSA signed
Yemen – Oil Discovery History

1938
First Exploration Campaign by IPC

1960’s – 80’s
Exploration by several foreign companies

1984
First commercial discovery – Hunt Oil Alif Field

1990
Six foreign companies operating

1990 – 2004
64 PSA signed

2004
Basement discovery in Block 10

2005
Basement discovery in Block S2
Q: What are the plans and programs for the exploration and production blocks?

(...) Follow up and evaluate the performance of reservoirs, particularly basement rocks in Hadhramawt and Shabwah. (...)

In 2009 – PEPA chairman Nasr Al-Humaidi

In Investment Magazine – June 09 2009 – Issue No. (27) Page 46
A Successful Project Heralds New Oil and Gas Discoveries and Huge Reserves...
Secret of The Oil Resources in Yemen Undiscovered Yet
In 2014 – “Yemen Today”

“The FRACTURED BASEMENT is one of the most important targets in the recent exploration strategy.” […]

“A large proportion of YEMEN proven oil reserves are in the FRACTURED BASEMENT reservoirs “[…]” in many fields in two major sedimentary basins (Masilah and Sabatayn)”.

OMV Yemen – Block S2, The Habban Field and the fractured basement play in Yemen
Yemen – Known Basement Blocks
OMV Yemen – Block S2, The Habban Field and the fractured basement play in Yemen
### Yemen – Traditional Plays

#### System

<table>
<thead>
<tr>
<th>Series/Stage</th>
<th>Formations</th>
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<tbody>
<tr>
<td>Precambrian</td>
<td>Basement</td>
</tr>
<tr>
<td>Middle-Early</td>
<td>Callovian</td>
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<tr>
<td>Jurassic</td>
<td>Oxfordian</td>
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<tr>
<td></td>
<td>Kimmeridgian</td>
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<td>Tithonian</td>
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<tr>
<td></td>
<td>Miocene</td>
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<tr>
<td></td>
<td>Pleistocene</td>
</tr>
</tbody>
</table>

#### Play Concept & Analogues

- **Camaal**
- **Heijah**
- **Hemir**
- **Tawilah**
- **Qishn**
- **Shuqra**
- **Kharir**
- **Alif, Azal, Jannah**
- **Ayad, Amal**
- **As‘ad, al Kemel, Ayad**
- **Continental Clastics**
- **Open Marine Carbonates & Deep Water Clastics**
- **Deep Water Evaporites & Fluvio-Deltaic SS**
- **Transgressive Carbonates**
- **Continental to Marine Basal Transgressive SS**

#### Sedimentation & Tectonics

- **Regional Tilting & Gravitational Sliding**
- **Red Sea Opening**
- **Gulf of Aden Opening**
- **Oman MT building**
- **Reactivation of Mesozoic Structural Elements**
- **Formation of E-W Trending Structural Elements**
- **Gravity Sliding = Gap Zones**
- **Formation of NW-SE Trending Half Grabens**
- **Break up of Gondwana**

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**Legend:**
- **QUAT.**
- **Early Cretaceous**
- **Jurassic**
- **Neogene**
- **Middle-Early Cretaceous**

**Time Periods:**
- **Pleistocene**
- **Cenomanian**
- **Albian**
- **Aptian**
- **Barrêmeian**
- **Valanginian**
- **Berriasian**
- **Tithonian**
- **Kimmeridgian**
- **Oxfordian**
- **Middle-Early Cretaceous**
- **Early Cretaceous**
- **Jurassic**
- **Neogene**
- **Oligocene**
- **Miocene**
- **Pleistocene**

**Regional Tectonics:**
- **Regional Tilting & Gravitational Sliding**
- **Red Sea Opening**
- **Gulf of Aden Opening**
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- **Reactivation of Mesozoic Structural Elements**
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OMV Yemen – Block S2, The Habban Field and the fractured basement play in Yemen
Sab’atayn Basin Evolution

- **Pre-Rift Phase (Paleozoic to Late Jurassic)**
  - **Paleozoic to Triassic**
    - Area was uplifted and eroded
  - **Early to Late Jurassic**
    - General uplift with intermittent phases of subsidence (Kuhlan & Shuqra formations were deposited)
Sab’atayn Basin Evolution

- **Pre-Rift Phase** (Paleozoic to Late Jurassic)
- **Syn-Rift Phase**: (Late Jurassic to Early Cretaceous)
  - Marked by extension, rifting and graben formation in Late Jurassic to Early Cretaceous
  - Kimmeridgian marked the peak of subsidence.
  - Central parts of the basin were filled with deep marine sediments of Lam and Meem members (Source rock)
Sab’atayn Basin Evolution

- **Pre-Rift Phase** (Paleozoic to Late Jurassic)
- **Syn-Rift Phase**: (Late Jurassic to Early Cretaceous)
- **Late Syn-Rift to Post-Rift**: (Mid- to Late Cretaceous)
  - Massive salt deposits (Sab’atayn formation) were formed in the restricted parts of the basin
  - Post-Rift - Moderate subsidence from Early to Late Cretaceous (Nayfa and Sa’ar formations were deposited in a shallow to deeper shelf in a normal marine environment)
  - Sa’ar Formation is unconformably overlain by Mid- to Upper Cretaceous predominantly clastic Tawilah Group
  - Sediment loading mobilized the salt of the Sab’atayn Fm. resulted in formation of salt diapirs/walls
Sab’atayn Basin Evolution

- **Pre-Rift Phase** (Paleozoic to Late Jurassic)
- **Syn-Rift Phase**: (Late Jurassic to Early Cretaceous)
- **Late Syn-Rift to Post-Rift**: (Mid- to Late Cretaceous)
- **2nd Rifting** : (Oligocene to Miocene)
  - Extension and rifting in the Red Sea and the Gulf of Aden occurred during the Oligocene and Miocene
Yemen – Sab’atayn Basin
The Basement Play Elements

- Basement structure
Yemen – Sab’atayn Basin
The Basement Play Elements

- Basement structure
- The source rock
Yemen – Sab’atayn Basin
The Basement Play Elements

- Basement structure
- The source rock
- The cap rock
Yemen – Sab’atayn Basin
The Basement Play Elements

- Basement structure
- The source rock
- The cap rock

![Diagram of basement structure, source rock, and cap rock in the Sab’atayn Basin]
Outline

Basement play around the world

Some facts about the Basement play in Yemen

- BlockS2 – Habban field
Overview – Block S2 in Yemen

OMV Yemen – Block S2, The Habban Field and the fractured basement play in Yemen
Overview – Production Facilities Block S2

OMV Yemen, Block S2, The Habban Field and the fractured basement play in Yemen.
Overview – 3D seismic within Block S2
Overview
Habban – Top Basement Depth Map
Main Structural Elements
**Wells Drilled Summary - 2007**

**Strategy:** Crestal development of the fractured Basement, planned on 2D seismic
Initial Observations- Basement Lithology

- Coloured Quartzite Breccia
- Greenish Amphibolite
- Granite
Initial Observations

- No “stratigraphic” correlation observed between wells in Basement, except that granite might be found deeper in some areas. Majority of basement rocks are metamorphic.
- Metamorphic rocks can acquire porosity through fracturing and alteration (cataclasites, breccias).
- 2 major fault trends, the Najd fault trend (generally NW-SE) and the Hadhramawt fault trend (generally NNE-SSW) indicate 2 major distinct tectonic phases.
Fractured Basement Characterization
Geophysics – 2D Seismic

- Reprocessing of the 2D seismic lines
  - Top Basement, barely interpretable

- 3D seismic mandatory to develop a Fractured Basement
Fractured Basement Characterization
Geophysics – 3D Seismic

- 3D seismic acquisition - **Wide azimuth seismic**
Strategy: Further crestal development of the fractured Basement. Then drilling moved to the periphery of the crestal fracture corridor, targeting large single faults. Optimum well orientation also tested. Planned on 3D PSTM
Basement Conceptual Model

Fractures corridors

Fault

Diffuse fractures

Basement

OMV Yemen – Block S2, The Habban Field and the fractured basement play in Yemen
Fractured Basement Characterization

Basement Fault/fracture system

Classification into two different fracture sets:

- NW-SE
- NNE-SSW
Wells Drilled Summary – 2010-2012

**Strategy:** Decrease in risk – development of Habban Central.
And 2 step-out appraisal wells “Higher risk”
Planned on 3D PSDM
Wells Drilled Summary – 2010-2012

Strategy: Decrease in risk – development of Habban Central.
And 2 step-out appraisal wells “Higher risk”
Planned on 3D PSDM

Mid 2011 Production and drilling suspended due to security concerns
Fractured Basement Characterization
Geophysics

- Post-stack Seismic Attributes generation for Fault/Fracture Characterization:
  - Multi-azimuth 3D Seismic data was acquired over the Habban Field. This data has been used mainly for Seismic Anisotropy Analysis.
  - For structural interpretation and fault characterization, CBM (all-azimuths) volume is used as this gives the best seismic image.
Fractured Basement Characterization
Geomechanics

Objectives: Predict subseismic fractures pattern and assess the flow response to the in-situ stresses

Key findings:
- Predicted orientation of failure planes (strongly dependent on the fault interpreted pattern and not sensitive to the material properties)
- Faults and fractures in the in situ strike-slip faulting regime give a good explanation for the distinction between “open” and “closed” fractures
Fractured Basement Characterization
Geomechanics

- Applying the strike-slip faulting regime deduced from the study to the orientation of the 2014 fault interpretation
- More complex than the two set classification
Wells Drilled Summary – 2013-2014

Fractured Basement Characterization Geophysics – Seismic Attributes

Seismic Anisotropy
Fault/fracture Density
RGB Blend
Variance
Edge Detection
Ant Tracking
Dip Azimuth
Fault/Fracture Orientation
Fault/Fracture Detection
Seismic Attributes for Fault/Fracture Characterization
Aperture
Presence
Density
Orientation
Fractured Basement Development Continues

- Typical well plan
  - Maximize reservoir contact – maximize number of faults/corridors
  - Stay close to the top Basement
Conclusions

- Basement plays have often been overlooked or considered to be marginally economic.

- Basement reservoirs are challenging
  - Drilling challenges
  - Development challenges
  - Production challenges

- Keys to understanding the dynamic mechanisms
  - 3D seismic
  - Fault and fracture network characterization
References


Ghiglione G., Abbasi I.: Tectonic discontinuities analysis using seismic and well datasets in a fractured basement reservoir - SPE 162399, SPE ADIPEC, Abu Dhabi UAE, 11-14 November 2012

Acknowledgments

The authors would like to thank:

- all the OMV experts who contributed to the Habban field discovery and understanding since 2005

- the Block S2 joint venture partners Sinopec, Yemen Oil Company (YOC) and Yemen Resources Limited for their continuous support, and

- the Yemen Petroleum Exploration & Production Authority (PEPA) as well as the Yemeni Ministry of Oil.