An Overview of Heavy Oil Carbonate Reservoirs in the Middle East*

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Abstract

Global heavy oil resources in carbonate rocks have been estimated to be on the order of 1.6 trillion barrels, of which about one-third may occur in the Middle East. Owing to its vast light oil reserves, documentation in the public domain on Middle Eastern heavy oil accumulations is not complete, but enough information is available to assemble a reasonable picture of the geological setting, reservoir and oil quality issues and the status of cold and EOR production in the region.

Productive heavy oil carbonate fields can be grouped into two categories: 1) low matrix permeability, fracture dependent, and 2) matrix permeability dependent production. Fracture enhanced, low matrix permeability production is dominant and occurs in Oman, Iran, Iraq, Syria, Turkey and Egypt and includes producing fields such as Qarn Alam in Oman and Issaran and Bakr-Amer in Egypt. In Iran, several fractured carbonate fields have successfully cold tested oil qualities on the order of 10 degree API. Wafra, located in the Partitioned Neutral Zone (PNZ) of Kuwait and Saudi Arabia, is the most notable example of an accumulation that has ample matrix permeability to allow economic cold production without significant fracture enhancement. Ultimate recovery from these fields is heavily dependent on oil viscosity and the ability to lower it. EOR implemented in the region include a CO2 flood at Bati-Raman in Turkey, a full-field crestal steam injection project that is underway at Qarn Alam, and an ongoing pilot steam flood at Wafra that commenced in February 2006. These three fields, along with Issaran, where a CSS project began in 2006, constitute the bulk of carbonate heavy oil activity in the Middle East. Current carbonate heavy oil production is on the order of 100-150 TBD (0.5% of Middle East production) and will likely stay at that level until Wafra production is increased or fields with large potential, such as Ferdows in Iran, are brought onstream.
References


An Overview of Heavy and Extra Heavy Oil Carbonate Reservoirs in the Middle East

April 2010

John W. Buza
Difficult to obtain uniformly reliable data but can get “picture”
Published STOOIP of 500-971 BBO vs. 130 BBO in published fields
STOOIP estimates include all rock types but ME dominated by carbonates
- No demonstrated supergiants in inventory, Ferdows (Iran) and Wafra (PZ) possible

Production of 125-200 TBD for foreseeable future (0.5% ME)
Dominated by Wafra with small future increases in Oman & Egypt

Rock Fabric is a key element for cold production
Fractures required in low matrix perm, extra heavy oil reservoirs
Good poro-perm overcomes need for fracture network (Wafra)

Recovery factor most dependent on oil viscosity

EOR underway includes CSS, Steamflood, TAGOGD & CO₂
World Heavy Oil & Bitumen Resources

Middle East No. 4 in World
~ 80 Bm³ (500 Bbbls)

Source: Schlumberger
U.S. Geological Survey
Heavy Oil Distribution

Middle East - Heavy Oil Carbonate Reservoirs

Legend (all demonstrated cold with exception of Burgan)

- Cold
- EOR Production
- EOR Screening
- Fractured
- Non-Fractured
Middle East Heavy Oil Carbonate STOOIP

Total STOOIP = 130 BBO

Documented in Technical Literature

Billions of Barrels

<table>
<thead>
<tr>
<th>Country</th>
<th>STOOIP (BBO)</th>
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<td>Ikiztepe</td>
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<tr>
<td>Camuru</td>
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<tr>
<td>Raman</td>
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<tr>
<td>Issaran</td>
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<tr>
<td>Karatchok</td>
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<td>Zaqeh</td>
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<td>Bakr-Amer</td>
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<td>Qarn Alam</td>
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<td>Bati Raman</td>
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<td>Kuh-E Mond</td>
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<tr>
<td>Umm Gudair</td>
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<tr>
<td>Wafra</td>
<td></td>
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<tr>
<td>Ferdows</td>
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<td>Saudi Arabia</td>
<td></td>
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<tr>
<td>Others</td>
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</table>
Middle East Daily Carbonate HO Production
125-150 TBD

- Wafra, 86
- Bakr-Amer, 15
- Karatchok, 19
- Jibessa, 7
- Isarran, 6
- Raman, 5
- Bati Raman, 10
- Qarn Alam, 2

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### Age of Middle East HO Carbonate Reservoirs

<table>
<thead>
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<th>PERIOD</th>
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<td>Early</td>
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- **Aptian-Miocene**
Middle East HO Carbonate Rock Types

- Limestone: 62%
- Dolomite: 23%
- Dolo-Limestone: 15%
Outcrop Analog

- Fractures
- Low Matrix Poro-Perm Carbonate Rock
Oil-Filled Fractures vs. Cement-Filled Fractures

Oil-filled fractures

Cement-filled fractures
Middle East HO Pay Depths

 Depth, ft.

- Issaran
- Bakr-Amer
- Zaqueh
- Kuh-E Mond
- Bati Raman
- Camurlu
- Ikiztepe
- Qarn Alam
- Wafra
- Umm Gudair

Approx. Depth Limit for Steam

Overburden  HO Zone
Middle East HO Carbonates
Matrix Porosity vs. Permeability

Porosity (%) vs. Permeability (md)

- Non-Fractured
- Fractured

Locations:
- Wafra
- Umm Gudair
- Karatchok
- Jebissa
- Bati Raman
- Qarn Alam
- Issaran

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Sustainable Cold production possible

- Qarn Alam (Steam)
- Bati Raman (CO₂)
- Issaran (Steam)
- Ferdows

Middle East HO Gravity & Viscosity

Viscosity, cP

API Gravity, Deg., mid-points

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Middle East HO Water Saturation

Water Saturation (%)

Issaran, Karatchok, Jebissa, Zaqeh, Bakr-Amer, Qarn Alam, Wafra, Raman, Bati Raman

Oil-wet reservoir
Middle East HO Recovery Factor

Viscosity

- cP < 300
- cP > 300

Recovery Factor (%)

- Issaran
- Karatchok
- Jebissa
- Zaqeh
- Bakr-Amer
- Qarn Alam
- Wafra
- Raman
- Bati Raman
- ME Overall

- Steam
- CO₂

Favorable Perm

6.5%
Bati Raman Production

- BOPD

- Water Injec.

- CO₂
Issaran Field, Gulf of Suez, Egypt

Source: Rally Energy website
Issaran Field, Egypt
50 Mmbtu/hr Steamer

Source: Rally Energy website
Issaran Production

Source: Rally Energy website
Qarn Alam, Oman, TAGOGD Process
(thermally assisted gas-oil-gravity drainage)

Pilot confirmed:
• No significant dissolution of matrix or caprock
• Matrix heated adequately to liberate oil to fractures

from Penney, R.; Moosa, R.; et al, 2005
Qarn Alam Oil Production Profile

Historical  Projected

Steam

Source: Wood Mackenzie
Objectives and Scope Steam Flood Pilots

Small Scale Test (1.25 ac, 2006)

Objectives
- Generation of steam from produced water
- Injectivity of steam in carbonate reservoir over long duration

Large Scale Pilot (40 ac, 2009, 16-2.5 ac inverted 5 spots)

Objectives
- Determine Field Wide EOR expansion potential
  - Production response
  - Recovery
  - Overall efficiency
Small Scale Test

Injection Well

Observation Well
Large Scale Pilot Steamflood Project

40 Acre Well Pad
# Middle East HO Carbonate Reservoirs Production Processes and EOR Evaluations

## Production Process

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<thead>
<tr>
<th>Turkey</th>
<th>Oman</th>
<th>Egypt</th>
<th>Iran</th>
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## Thermal

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## Combustion

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## Non-Thermal

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<th>Water flooding</th>
<th>CO2 Injection</th>
<th>Chemical Injection</th>
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</table>

## Legend

- **X** Screen Result
- **X** Demonstrated
- **O** Operational Now
- **O** Tested, Suspended
Resource base estimates appear overly optimistic

- 130 BBO documented vs. 500-971 BBO estimated STOOIP
- No *demonstrated* supergiants in inventory
  - Wafra and Ferdows have supergiant potential

Production of 125-200 TBD for foreseeable future (0.5%)
- Could reach ~1MMBO if Wafra and Ferdows successful (3%)

Rock Fabric is a key element - 2 types dominate

- Fractures needed in low matrix perm, extra heavy oil reservoirs
- Good poro-perm overcomes need for fracture network (Wafra)

Viscosity is major control on ultimate recovery

Thermal and CO₂ methods successful and in use today