FLUID IDENTIFICATION IN OVERPRESSURED LOW POROSITY SHALY SANDSTONE RESERVOIRS

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OBJECTIVE

To identify reservoir fluid type based on wireline logs and incorporating all available well data such as formation pressure, mudlogs and well test results.
<table>
<thead>
<tr>
<th>INTRODUCTION</th>
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</thead>
<tbody>
<tr>
<td>• Reservoir fluid identification plays a crucial role in reservoir characterization and hydrocarbon volume estimation.</td>
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<tr>
<td>• In thick, porous and clean reservoirs, the process of fluid identification is straightforward.</td>
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<tr>
<td>• In overpressured, low porosity and shaly sandstone reservoirs, it becomes difficult to definitively identify the type of formation fluid in the reservoir of interest.</td>
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</tbody>
</table>
INTRODUCTION

• Petrophysicists and log analysts use the bulk density and neutron porosity logs in combination together with resistivity logs, to identify reservoir fluid type.

• Formation pressure gradients, obtained from wireline formation tester (WFT) tools, have greatly helped in identifying fluid types.

• In overpressured reservoirs, sometimes it is difficult to establish reliable pressure trends and gradients.
• In shaly reservoirs, the typical gas crossover effect on the density and neutron logs becomes either less pronounced or absent in some cases.

• As shaliness of the formation affects most well logs, fluid identification based on well logs alone becomes unreliable.

• An integrated approach is applied to identify fluid type in overpressured tight shaly sandstone reservoir in a field offshore Malaysia namely Well “A”, Well “B” & Well “C”
Overpressure range from 500-1200 psia
EXAMPLE FROM WELL “A”
Drilling Data
Circulation before logging = 17 hrs

WELL "A"

WELL A

SAND (1)

SAND (2)

SAND (1)

SAND (2)

Drilling Data

Circulation before logging = 17 hrs

WELL "A"

2148 2150 2175 2225 2275 2325 2375 2425

2198 2200 2248 2275 2325 2375 2425

SAND (1)

SAND (2)

1940-1955 MD
2190-2207 MD

Linear (Normal Hydrostatic Line)
Drilling Data
Mud Weight (MW) = 10.5 ppg
WELL “A” SAND (1)
WELL “A” SAND (1)

**Vp/Vs Versus DTc**

- **Vp/Vs** (Poisson's ratio) versus **DTc** (time lapse) for different rock types and fluids.

- **Anhydrite**, **Limestone**, **Dolomite**, **Salt**, and **Quartz**.

- **Unconsolidated Sediments**, **Shales**, **Salty Water**, **Fresh Water**, **Gas**, and **Oil Sand**.

- **GOR** (Gas Oil Ratio) levels: 0, 500, 1000, 1500.

- **Porosity** levels: 10%, 20%, 30%, 40%.

- Depth range: 2190-2207 MD.
WELL “A” SAND (1)

MUD GAS RATIO
- Gas Wetness Ratio
  Wh = 21 (Potential Oil)
- Gas Balance Ratio
  Bh = 8 (Heavier Oil)
- Gas Character Ratio
  Ch = 0.7

DST RESULTS
- Gas = 10.04 MMscf/day
- Condensate = 520 stb/day
- CGR = 50 stb/MMscf
- API = 47.7
## WELL “A” SAND (1) - RESULTS

<table>
<thead>
<tr>
<th>METHOD</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logs</td>
<td>Oil</td>
</tr>
<tr>
<td>Near Far Neutron</td>
<td>Oil</td>
</tr>
<tr>
<td>WFT</td>
<td>0.12 psi/ft</td>
</tr>
<tr>
<td>Vp/Vs</td>
<td>Gas</td>
</tr>
<tr>
<td>ND Crossplot</td>
<td>Gas</td>
</tr>
<tr>
<td>Carbon Number Ratio</td>
<td>Oil</td>
</tr>
<tr>
<td>Mud Gas Ratio</td>
<td>Oil</td>
</tr>
<tr>
<td>Well Test</td>
<td>Gas+Condensate</td>
</tr>
</tbody>
</table>

Interpreted fluid type: **Condensate**
WELL “A” SAND (2)

Drilling Data
Mud Weight (MW) = 12.5 ppg
WELL “A” SAND (2)

SST: Off wht, lt gy, occ lt olv gy
- lt brnsh gy, trnsp - trns, occ consl qtz gr, v f - fg, md -
sand, srt - tm, occ nd, mod -
wl srdc, non clc. pr vss por.
Weak show.

SHOW( 2425-2438m): 5-10%
aptd pale yell DF, slw stmg dull blsh wht CF, no res ring.

MD: 2418.36m, TVD: 2418.6m
INCL: 0.35, AZI: 96.16

MD: 2448.35m, TVD: 2448.0m
INCL: 0.45, AZI: 20.15
COAL: Blk, fli, sbolky - blky, wdy lek.
WELL “A” SAND (1)

Vp/Vs Versus DTc

- Anhydrite
- Limestone
- Dolomite
- Salt
- Quartz
- 2428-2435 MD

Unconsolidated Sediments
Sodium Water
Salty Water
Fresh Water
Porosity
Gas Sand
Oil Sand
Gas
GOR

GOR

Color: Maximum of DEPTH

GOR
Carbon Number Ratios

MUD GAS RATIO
• Gas Wetness Ratio
  Wh = 25 (Potential Oil)
• Gas Balance Ratio
  Bh = 6 (Heavier Oil)
• Gas Character Ratio
  Ch = 0.7

DST RESULTS
Gas = 1.35 MMscf/day
Condensate = 67.52 stb/day
CGR = 50 stb/MMscf
API = 42.6
## WELL “A” SAND (2) - RESULTS

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<tbody>
<tr>
<td>Logs</td>
<td>Oil</td>
</tr>
<tr>
<td>Near Far Neutron</td>
<td>Gas</td>
</tr>
<tr>
<td>WFT</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Vp/Vs</td>
<td>Gas</td>
</tr>
<tr>
<td>ND Crossplot</td>
<td>Gas</td>
</tr>
<tr>
<td>Carbon Number Ratio</td>
<td>Oil</td>
</tr>
<tr>
<td>Mud Gas Ratio</td>
<td>Oil</td>
</tr>
<tr>
<td>Well Test</td>
<td>Gas+Condensate</td>
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</tbody>
</table>

Interpreted fluid type: **Condensate**
EXAMPLE FROM WELL “B”
Drilling Data
Mud Weight (MW) = 10.2 ppg

Limited data available:
1. No MDT
2. No well test

Available data:
1. Logs
2. Mud gas reading
WELL "B" SAND (1)
WELL “B” SAND (1)

MUD GAS RATIO
• Gas Wetness Ratio
  Wh = 11 (Potential Gas)
• Gas Balance Ratio
  Bh = 144 (Very Dry Gas)
• Gas Character Ratio
  Ch = 0.08 (Gas)
<table>
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<tr>
<td>Logs</td>
<td>Gas</td>
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<tr>
<td>Near Far Neutron</td>
<td>Gas</td>
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<td>WFT</td>
<td>-</td>
</tr>
<tr>
<td>Vp/Vs</td>
<td>Gas</td>
</tr>
<tr>
<td>ND Crossplot</td>
<td>Gas</td>
</tr>
<tr>
<td>Carbon Number Ratio</td>
<td>Gas</td>
</tr>
<tr>
<td>Mud Gas Ratio</td>
<td>Gas</td>
</tr>
<tr>
<td>Well Test</td>
<td>-</td>
</tr>
</tbody>
</table>

Interpreted fluid type: **Gas**
EXAMPLE FROM WELL “C”
WELL “C” SAND (1)

Drilling Data
Mud Weight (MW) = 13.5 ppg
Circulation before logging = 18 hrs

WELL C

Pressure (psi)

TVDSS (m)
WELL “C” SAND (1)

SHOW (2007-2011m) : Tr - sptd 5-10%, wk, blsh wh, occ pl yel DF. Wk, milky wh, slw strmg CF. No res ring.

SHOW (2028-2031m, 2032-2035m) : Tr - sptd 5-10%, v wk - wk, pl wh, occ pl yel DF. Wk, milky wh, v slw - slw strmg CF. No res ring.
WELL “C” SAND (1)

**Carbon Number Ratios**

- **C1/C2**
- **C1/C3**
- **C1/C4**
- **C1/C5**

**Expon. (Non Productive)**

**Expon. (Oil)**

**Expon. (Gas)**

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**MUD GAS RATIO**

- **Gas Wetness Ratio**
  \( Wh = 16 \) (Potential Oil)

- **Gas Balance Ratio**
  \( Bh = 12 \) (Gas/Oil/Condensate)

- **Gas Character Ratio**
  \( Ch = 0.24 \)

**DST RESULTS**

- **Gas** = 5.47 MMscf/day
- **Oil** = 6110 stb/day
- **GOR** = 895 scf/stb
- **API** = 33.2
## WELL “C” SAND (1) - RESULTS

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<tr>
<td>WFT</td>
<td>0.24 psi/ft</td>
</tr>
<tr>
<td>Vp/Vs</td>
<td>Oil</td>
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<tr>
<td>ND Crossplot</td>
<td>Gas + Oil</td>
</tr>
<tr>
<td>Carbon Number Ratio</td>
<td>Oil</td>
</tr>
<tr>
<td>Mud Gas Ratio</td>
<td>Gas</td>
</tr>
<tr>
<td>Well Test</td>
<td>Oil</td>
</tr>
</tbody>
</table>

Interpreted fluid type: **Oil**
Drilling Data
Mud Weight (MW) = 13.6 ppg
Circulation before logging = hrs

WELL “C” SAND (2)
WELL “C” SAND (2)

Vp/Vs Versus DTc

- Anhydrite
- Limestone
- Dolomite
- Salt
- Quartz
- Water (2335-2345 MD)

Unconsolidated sediments
Saline Water
Fresh Water
Porosity
Gas
Oil Sand
Gas Sand
Unconsolidated sediments

GOR
Porosity

Color: Maximum of DEPTH

2300
2350
### WELL “C” SAND (2) - RESULTS

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<thead>
<tr>
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<tbody>
<tr>
<td>Logs</td>
<td>Water</td>
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<td>Near Far Neutron</td>
<td>Water</td>
</tr>
<tr>
<td>WFT</td>
<td>0.45 psi/ft</td>
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<tr>
<td>Vp/Vs</td>
<td>Water</td>
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</tr>
<tr>
<td>Well Test</td>
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Interpreted fluid type: **Water**
• All available data comprising mud logs, gas chromatography, gas wetness ratios, well logs, pressure and sample data used to identify the type of hydrocarbon in the reservoirs

• Interpreted fluid type confirmed by samples from wireline formation tester and well test results

• This methodology of integrating all available formation evaluation data has been implemented to successfully interpret data from subsequent wells in the nearby areas
ACKNOWLEDGEMENT

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