DRILLING AND COMPLETION PRACTICES IN THE BOOCH SANDSTONE

OR

HOW TO MAKE MONEY DRILLING THE BOOCH

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OBJECTIVES

1. Characterize the Booch sandstone from the Operator’s perspective

2. Drilling options: oil or gas target, air or mud drilling

3. Completion variables, especially fracture stimulation, and effects on production

4. Individual case studies of Booch oil and gas wells showing variability in reservoir and completion methods, and

5. Production optimization for the Booch sandstone.
Booch sandstone may be characterized as:

1. Poor quality reservoir:
   - Low porosity: effective porosity = 10% density
   - Poor permeability
   - Laminated or thin, interbedded sandstone and shale beds
   - Fine grained, poorly sorted, dirty, quartz arenite reservoir rock
Booch sandstone may be characterized as:

2. Low pressure:
   - Much of the gas-bearing portion of the Arkoma Basin is sub-normally pressured
   - Observed surface pressure 600 psig max, usually 450-500 psig
   - Oil-prone areas seem to have higher pressure gradients observed at the surface
   - Observed surface pressure 900+ psig max
   - Calculated hydrostatic pressure at 3,000 ft should equal approximately 1,370 psig
Booch sandstone may be characterized as:

3. Reservoir areal extent is usually limited:

- Mapped net sand patterns often 10 ft thick or less, with channel/bar width only one-quarter to one-half mile wide

- Many areas on Arkoma shelf and basin are heavily drilled, resulting in large areas of very limited opportunity for additional development
Northwest Scipio Field
Net Porosity Isopach
Middle Booach Sand

29 identified productive wells: Based on the mapped sand pattern, yields effective drainage density of about 40 acres per well

BOOCH ONLY
9 old wells = 3.9 BCF EUR
+ 21 new wells = 3.1 BCF EUR
29 wells total: 7.0 BCF EUR
Booch sandstone may be characterized as:

4. Sometimes difficult log analysis:

- Clay or shale content adversely affects water saturation equations
- Many Booch reservoirs produce oil with anomalously low Rt values
- Microlog is ineffective in many mud-drilled areas due to low permeability and probable skin damage while drilling
- Microlog does not work in air-drilled holes.
Booch sandstone may be characterized as:

5. **Variable reservoir drive mechanisms:**
   - Both gas and oil traps exhibit a full range of reservoir drive mechanisms, from depletion drive to strong water drive.
   - True water drive reservoirs probably are the least common.

6. **Trapping mechanisms variable:**
   - Pure stratigraphic
   - Pure structural
   - Combination traps most prevalent.
BOOCH DRILLING AND COMPLETION PRACTICES

DRILLING OPTIONS

VERTICAL WELL
  - Mud Drilling (Oil Objective)
  - Air Drilling (Gas Objective)

HORIZONTAL WELL
  - Not discussed here
Figure 6. Regional isopach map of the Booch interval. This gross interval corresponds to the stratigraphic section from the top of PS-0 (McAlester coal marker) to the base of PS-6 (top of Hartshorne Formation). Hachures indicate isopach “thicks.”
Conventional Mud Drilling
ADVANTAGES OF MUD DRILLING

1. Provides total control in difficult drilling environments:
   - Hole stability
   - Deviation
   - Well control problems
   - Lost circulation control

2. Depth or borehole angle not a limiting factor

3. Full range of logging tools available for formation analysis

4. “Status quo”
DISADVANTAGES OF MUD DRILLING

1. Cost: Current rig contracts are on day rates, not footage, and range from about $10,000 per day up.

2. Slow compared to air drilling: Comparable 3,000 ft hole will take 3+ days with 24 hour, 4 man crew.

3. Larger location needed: 1.25+ acres or more.

4. Cost of mud program, drill bits, haul off fluids, etc.

5. Environmental impact of mud system: potential spills, pit liners, closed systems required in some areas; haul off and disposal of drilling fluids.

6. Slow rig up and rig down time: 12 hours minimum, usually have 15 loads or more.
Air Drilling: “Dusting” or “Misting”
ADVANTAGES OF AIR DRILLING

1. Very Fast: Can drill wells up to about 2,600 ft in 2 days, or 3,200+ ft in 3 days, daylight only, including surface pipe. Newer style rigs use 24 hour crews, can drill typical well in 24 to 36 hours.

2. Rig up and rig down time is 3 to 4 hours maximum.

3. Economical: Current rate for shallow wells is about $12.00 per foot. Rates include hammers, bits, drilling materials.

4. Small rig uses one 2 or 3 man crew; larger rig 4 man crew in shifts.

5. Can drill large numbers of wells in a relatively short time.

6. Provides constant real-time formation analysis with sample cuttings instantaneously to surface; gas flows are easily detected.

7. Small location area (100 ft x 150 ft), able to drill in tight locales.

8. Blow pits not regulated by OCC (no pit liners required).
DISADVANTAGES OF AIR DRILLING

1. Small rigs limited to shallow depths (3,300+ ft or less).

2. Potential hole deviation problems (specifically excluded from measurement in drilling contracts).

3. Hole stability questionable in problem shale areas: sloughing or heaving shales can collapse around drill string and cause drill pipe to get stuck.

4. Difficulty in dealing with shallow water flows: cannot keep hole unloaded, slows ROP significantly, must haul off saltwater.

5. Slow trip time: small rigs are truck mounted 25 ft or 30 ft derricks, only able to trip one joint of drill pipe at a time, and have no place to stand up pipe. Pipe must be laid down one joint at a time, which is labor intensive.

6. Small rigs unable to economically run production casing (R-1 only).
Natural Gas Objective:
Generally choose air drilling due to low cost, shallow depth, small location, ease of move in and move out, and instant formation content analysis. Gas-prone areas coincidentally are located updip of the Calvin Formation outcrop.

Oil Objective:
Generally choose mud drilling since oil prone areas are generally located in areas west or downdip of the Calvin Formation outcrop at the surface. The Calvin contains a higher percentage of thick shallow water sands that air drilling techniques are unable to economically handle.
Air vs Mud Drilling
Geologic Boundary

Calvin Outcrop
Mud Drill

Senora Outcrop
Air Drill

Geologic Map of Oklahoma, c. 1954
Booch Completion Practices: Acidizing

Objective: Pump reactive fluid (acid) into perforations in order to dissolve cement and mud materials that may inhibit fluid or gas flow into the wellbore.

- Drilling muds are designed to coat the borehole wall to prevent fluid loss while drilling through the formation.
- These coatings must later be removed or bypassed in order for fluids or gas to flow from formation to wellbore.
- Cement may invade the formation while cementing casing; need to ensure the pathway from perforations to wellbore is open and clear of debris.

Acidizing removes these deposits and/or debris and may also induce flow channels from the formation to the wellbore.
Booch Completion Practices: Acidizing

Booch sandstone generally does NOT contain calcareous cement, so pumping acid deep into the formation is unnecessary.

Common acid treatments for Booch sands varies from 250 to 750 gallons of 7½ % to 15% HCl, with additives designed to clean up or dissolve mud chemicals and to inhibit reaction with clay minerals in the formation.
Acidizing

Fluid flowback after an acid job: Normal procedure is to swab back the acid treatment.

Typically will recover 60% to 100% of fluid introduced into the formation by swabbing.

During the acid job, ISIP and pump rate vs breakdown pressure are indicative of permeability, and used to help design the follow-up fracture stimulation treatment.

Spearhead acid jobs not recommended due to need to determine permeability prior to designing frac job
FRACTURE STIMULATION

Goal: the goal of Fracture Stimulation in low permeability rocks is to induce an artificial fracture to serve as a flow channel from deep in the formation to the wellbore.

Most common Booch fracture stimulation treatments:

- Natural gas wells: Nitrogen or CO2 foam fracs
- Oil wells: slick water or gelled water fracs
FRACTURE STIMULATION

• Induced fracture will follow path of least resistance (anisotropy)

• Induced fracture is held open with a propping agent, such as various sieve sizes of quartz sand or other materials

• Effective fracture stimulation results in increased flow of hydrocarbons to the wellbore, hence higher initial flow rates and better economics (quicker payout).

• Induced fractures range from long narrow cracks to (hopefully) shorter, wider fractures held open by proppants.

• Fractures propagate both vertically and horizontally away from wellbore, dependent on frac type and pump rate and pump pressure
FRACTURE STIMULATION TECHNIQUES

Water and Gelled Water Fracs: Generally used in oil productive reservoirs

Gelled water has higher viscosity than plain or ‘slick’ water, thus creating a greater fracture width and length than water alone.

Gelled fracs (crosslinked gels) carry greater volumes of proppant, pumping in various stages, to hold induced fractures open during and after flowback.

‘Crosslinked gel’ simply means chemically linking molecules together to create a more viscous fluid.
FRACTURE STIMULATION TECHNIQUES

In the average Booch oil reservoir, experience has found that gelled water fracs, utilizing about 800 bbls of crosslinked gelled water with 30,000 to 40,000 lbs of 30/40 mesh sand is effective.

The well is generally placed on pump to aid flowback, starting with propane and converting to casinghead gas within a few days.

Well typically produces all water for a few days, recovering 10 – 30% of load before showing oil at the bleeder valve.

Pump rates and flowback governed by size of pumping unit.
In low pressure natural gas wells, fracture treatments using **foam** and **gas** result in better reservoir stimulation than water or gelled water alone!
STIMULATION TECHNIQUES: FOAM FRACTURING

Primarily used for natural gas wells

Characteristics of foams and foam fracturing:

• Foams are gas-in-liquid dispersions similar to an emulsion
• Liquid used can be water, acid, alcohol, or oil
• Foaming agent usually Nitrogen or Carbon Dioxide
Quality: Volume percentage of gas in foam is termed “Quality” or “Q”

- Most fracturing foams are in range of 65 to 85 Q
- Foam qualities less than 54Q do not enhance flowback of liquids
- Foam qualities greater than about 92Q become a mist, and are not viscous enough to fracture
- Experience dictates foam qualities between 65Q and 75Q are best for Booch and Hartshorne gas-bearing sandstones in the Arkoma region.
STIMULATION TECHNIQUES: FOAM FRACTURING

Nitrogen versus Carbon Dioxide

• Both arrive at location as refrigerated liquids, then pumped downhole as gas through heat exchanger

• CO2 much more expensive than N2, much harder to locate and schedule for delivery to wellsite

• CO2 is more volatile than N2, requires greater care in handling while pumping than does N2

• CO2 is corrosive to equipment, N2 is inert

• Pipelines will not accept volumes of CO2 > 2% into system, whereas N2 limits are higher (3% +/-)

Nitrogen is gas of choice for most producers
STIMULATION TECHNIQUES

Nitrogen Foam stimulation treatment advantages:

- Improved proppant placement in reservoir
- Rapid cleanup of treatment fluids, usually eliminating need for swabbing after treatment
- Less formation damage resulting from treatment fluid

Nitrogen Foam is the preferred fracturing fluid for shallow, low pressure reservoirs, such as the Booch and Hartshorne sandstones in the Mid-Continent and Arkoma Basin area.
Nitrogen gas entrained in foam is released as the bubbles in the foam degrade, and the gas flows to point of least resistance (wellbore) carrying liquid to the surface.

Fluid loss of foam into formation (leak-off) increases rapidly where permeability is more than 5 md or natural fractures are present.

Foam becomes ineffective at permeability more than 20+ md.

Nitrogen gas does not flow to wellbore but is lost in formation, therefore becomes ineffective.

In spite of leak-off prevention, experience shows only 50 – 60+% of treatment fluid is ever recovered from the Booch formation after N2 foam fracture stimulation treatments.
STIMULATION TECHNIQUES: FOAM FRACTURING

Poor flowback procedures can ruin a nitrogen foam frac job!

- Because foams can support proppant, poor flowback procedures can cause a foam to pull proppant out of the induced fracture and create flowback to surface, if flowback initiated before foam breaks.

- Fracture must be allowed to close around proppant before flowback starts.

- Too short of shut-in time allows proppant to flow back to surface.

- Too long a shut-in time allows flowback energy created by dispersed gas (N2 or CO2) to dissipate into the formation instead of flowing back to the surface.

- Experience indicates a shut-in time of 2 to 3 hours is optimal.
## BOOCH CASE HISTORIES

<table>
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<tr>
<th></th>
<th>Name</th>
<th>Location</th>
<th>Fluids</th>
<th>Foam</th>
<th>Frac Type</th>
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<tr>
<td>1.</td>
<td>Theel</td>
<td>14-7N-12E</td>
<td>Mud</td>
<td>Gas</td>
<td>Natural (?)</td>
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<td>Stipe</td>
<td>28-7N-12E</td>
<td>Air</td>
<td>Gas</td>
<td>CO2 foam frac</td>
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<td>21-7N-12E</td>
<td>Mud</td>
<td>Gas</td>
<td>N2 foam frac</td>
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<td>36-8N-8E</td>
<td>Mud</td>
<td>Oil</td>
<td>Gelled Water</td>
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<td>5.</td>
<td>Merriman</td>
<td>4-5N-9E</td>
<td>Mud</td>
<td>Oil</td>
<td>Gelled Water</td>
</tr>
</tbody>
</table>
Otha Grimes  1-14 Theel
C SE 14-7N-12E
Pittsburg County

Spud 12/21/67, no info released
Produced 453 MMCF prior to abandonment in 1996
Natural Completion (?)

Mud Drilled Hole
No other logs available
Theel 1-14 14-7N-12E

Natural Completion (?)

First month avg prod:
170 MCFD

Start of mechanical problems and/or offset drainage

Possible pipeline problems 1980 - 1985

Well inactive by mechanical failure in 1996
Northwest Scipio Field
Net Porosity Isopach
Middle Booch Sand

29 identified productive wells: Based on the mapped sand pattern, yields effective drainage density of about 40 acres per well

BOOCH ONLY
9 old wells = 3.9 BCF EUR
+ 21 new wells = 3.1 BCF EUR
29 wells total: 7.0 BCF EUR
Laminated, shaley, but porous and permeable sand

Completion Procedure
Perf 2,346 – 2,358, No Show
Acidize 1,700 gals 7½% HCl
24 hr flow: 150 MCFD

Frac Stimulation
CO2 Frac: 480 bbl gel wtr + 30% CO2 + 33,000# sand

Avg prod rate for full month: 590 MCFD + 0 W
EUR 854 MMCF, BTU 1040

Air Drilled Hole
Slight gas show while drilling
(Muddled up for logs)

10 ft > 18% xplot
Rt 12, Rw 0.035
Sw = 30%
TPX 1-21 Falcon Club
21-7N-12E

Middle Booch

Lower Booch
**TPX 1-21 Falcon Club**

**SW/4 21-7N-12E**

**Pittsburg County**

- **Completion Procedure**
  - Perf 2,382 – 2,396 OA
  - Flow 10 – 12 MCFD
  - Acidize 500 gal 7½ % HCl + 10% Methanol
  - 24 hr Flow: 116 MCFD

- **Frac Stimulation**
  - 70Q N2 Foam Frac:
    - 185 BW + 285,000 SCF
    - N2+ 30,000# 16/30 Sand
  - SITP 450 psig, SICP 450 psig
  - Avg prod rate for full month: 315 MCFD + 0 W
  - EUR: 364 MMCF

- **Middle Booch Sand**

- **Mud Drilled Hole**

- **Laminated, shaley sand**

- **11 ft >13% xplot**

- **Rt 24, Rw 0.035, Sw = 29%**
Flint 2-36 Lakeside 36-8N-8E Hughes County

Perf 2,824 – 2,828 ft
Acid: Not Reported
Frac: Gelled Water + Sand
IPP: 30 BO + SSG + 10 BW

Mud Drilled

19% porosity, Rt 2.7, Rw .035, Sw = 60%

Cum Prod 8/84 – 4/07: 33,375 BO
Prime 1-4 Merriman  
Section 4-5N-9E  
Hughes County  
(DIL not available)

Perf Upper Booch 2770 – 2788 OA

10’ net density porosity ≥10%  
No crossplot porosity

Acidize 1000 gals 7½ % HCL

Frac 33,600 gals water + 38,600 lbs sand

IPF 65 BOPD, ¾” ck, FTP 50 psig, gravity 34 deg

DOFS: August 1981
Air vs Mud Drilling

Geologic Boundary

Calvin Outcrop
Mud Drill

Senora Outcrop
Air Drill

Geologic Map of Oklahoma, c. 1954
PRODUCTION OPTIMIZATION FOR THE BOOCH SANDSTONE
Production Optimization for the Booch Sandstone: Gas Wells

Ensure well is as near water-free at time of initial gas sales as possible:

- Swab back acid until dry (no water).
- Flowback frac job to atmosphere (no back pressure) until well is dry after a foam-assisted fracture stimulation treatment.
- Keep spacing between wells reasonable: gas wells drain 120 to 160 acres!
GAS WELL PRODUCTION OPTIMIZATION

SURFACE FACILITIES

Small plastic water tank
Soap launcher
Small gas/liquid separator
Kimray pop-off safety valve
Check meter (if utilized)
Meter run and meter house
Simple wellhead connections with soap launcher

Surface facilities for a typical low pressure, 30 - 80 MCFD Booch gas well
GAS WELL PRODUCTION OPTIMIZATION

Low Pressure Wells Love Low Pressure Gathering Systems!
PRODUCTION OPTIMIZATION FOR BOOCH GAS WELLS

Low Pressure Wells Love Low Pressure Gathering Systems!

Gathering system suction should be as low as possible, with line pressure at the wellhead ideally less than 25 psig. Flow Tubing Pressure often 25 psig or less.

Very low line pressure at the wellhead generally means suction pressure on vacuum or near zero at the inlet valve to the compressor.

Pittsburg Gathering, LLC compression station in 12-7N-12E for the NW Scipio gas field. Sold to Chesapeake in 2004.
Screw compressor in 34-7N-12E connecting the Wild Turkey low-pressure gas gathering system to Markwest pipeline (32 Booch, Hartshorne sand, and CBM wells)
Correct spring and orifice plate size will allow more accurate measurements.
Use 8 day charts instead of 31 day
Get more accurate measurement
Production Optimization for the Booch Sandstone: Oil Wells

Reservoir: Evaluation parameters can be tricky

Acid: Swab back acid until well dries up
  - Spearhead acid not recommended

Gelled Water Frac: Do not begin flowback until after gel breaks down
  Since there is little or no leakoff into formation, can wait days or weeks before flowback begins with no ill effects
PRODUCTION OPTIMIZATION FOR OIL WELLS IN THE BOOCH SANDSTONE

Drainage: Typical Booch oil well will drain between 20 and 40 acres in most areas.

Secondary Recovery in Booch Sand: Analyzed waterfloods show approx 60% additional production after primary recovery.
200 bbl SW tank (fiberglass)

4 x 20 Heater treater

202 bbl stock tanks (2)

Containment dikes

Pumping Unit

Typical Booch oil well tank battery installation
Summary and Conclusions

1. The Booch is not a user-friendly sand. Low permeability, clay/shale content, limited areal extent and low pressure are limiting factors.

2. Due to near-surface geology, air drilling is often used when targeting gas in the Booch, and mud is used when targeting oil.

3. Formation evaluation requires a knowledge of local trapping conditions, including variable production parameters and reservoir drive mechanisms.

4. Nitrogen foam fracture stimulation is the most widely accepted method of reservoir enhancement in gas wells.
Summary and Conclusions

5. Gelled water fracs are most common for Booch oil wells.
6. High initial decline rates are common, tapering off to very low decline, long-lived reserves.
7. Low cost surface facilities are adequate; measuring and collection equipment must be tailored to low pressure, low volume wells.
8. Low pressure wells love low pressure gathering systems.

When prospected, drilled and completed properly, the Booch can be a substantial asset for the producer and is a valuable part of an eastern Oklahoma oil and gas portfolio.