Challenges and Values of Formation Testing in Tight Sand in Monterey Formation Using Modular Dynamic Tester (MDT)*

Manish K. Lal¹, Viet Hoang Tran², and Larry E. Drennan²

Abstract

A vertical appraisal well was drilled in the southern San Joaquin Valley to evaluate two intervals in the Monterey Formation. The target reservoirs have decent porosity but low matrix permeability. The well will have comingled production, if completed in both zones. The purpose of the appraisal well is to properly characterize the reservoirs and evaluate technologies that can lead to the development of tight reservoirs in the area. A secondary objective is to understand the individual zone production such that we may target a single zone for future development. The completion and producibility of these tight intervals is still in debate and quite challenging. These zones will likely need to be hydraulic frac stimulated due to very low permeability. This paper describes the challenges and values of formation testing using the Modular Dynamic Tester (MDT) run in the well. The MDT was selected to run to measure formation pressure, collect fluid samples for PVT analysis, and test the hydraulic frac closure pressure. A decision was made beforehand to run the MDT tool through drill pipe to avoid any potential drilling issues. However, this had less flexibility in moving up / down the hole and was time consuming. The tightness of the reservoir posed additional challenges to be able to collect fluid samples in a limited time frame and with conventional sample collection techniques. However, continuous onsite monitoring, on the fly changes in the sample depths in response to formation behavior, and optimization of sample chamber opening time enabled us to successfully collect one water and two oil samples. At two depths we were able to get reservoir pressure data that was more accurate than data from XPT. The sample is being currently analyzed for fluid properties which will help narrow down the uncertainties and aid in planning the stimulation of the well. This is especially important to prove and maintain the commerciality of the reservoir.

Lessons Learned:
1. MDT is a proven technique but needs special attention including on-site monitoring when evaluating tight rocks.
2. Remote monitoring may not always be real time. Decision may need to be made on the fly.

Best Practices:
1. Early engagement with Subject Matter Experts (SMEs) and vendor for job planning.
2. Ensure people in early engagement meetings are available during job execution.

**Challenges:**
1. Running tool on drill pipe, though safer, is time consuming.
2. Persons executing the job were not involved in pre-job planning.
CHALLENGES AND VALUES OF FORMATION TESTING IN TIGHT SAND IN MONTEREY FORMATION USING MODULAR DYNAMIC TESTER (MDT)

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Oxnard, CA

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Chevron
Outline and Field Location

- Monterey Formation
  - Background
  - Current Status
- MDT
  - Objectives
  - Procedure
  - Results
- Summary
  - Lessons Learned
  - Best Practices
  - Challenges
Monterey Formation Background

- Monterey shale (Opal CT & Quartz) is a silica-rich diatom deposition in the Monterey formation
- Miocene age
- Is naturally fractured, has migrated oil, and is normally pressured
- It has decent porosity but low matrix permeability
Monterey Formation
Uncertainty Management

Key decisions and uncertainties identified

All uncertainties identified and ranked

Focused on high and medium impact uncertainties

Majority of the uncertainties could be narrowed down with delineation wells

A similar delineation well UMP workshop was conducted to identify decisions and uncertainties related to delineation wells

<table>
<thead>
<tr>
<th>Key Decisions</th>
<th>Weighting</th>
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</thead>
<tbody>
<tr>
<td>Stimulation (book-ended with acid and fracing)</td>
<td>5</td>
</tr>
<tr>
<td>Well spacing</td>
<td>4</td>
</tr>
<tr>
<td>1 completion per well or commingling zones</td>
<td>3</td>
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<tr>
<td>Areal extent</td>
<td>3</td>
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<tr>
<td>Vertical vs. Horizontal wells</td>
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</tr>
<tr>
<td>Completion type (slotted liner or cased)</td>
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<tr>
<td>Well Design</td>
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<tr>
<td>Facilities Infrastructure Design</td>
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<tr>
<td>Artificial Lift Method</td>
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<tr>
<td>Development pace (rig years per year)</td>
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<tr>
<td>Build Dedicated Well testing facility or use temporary/mobile</td>
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<table>
<thead>
<tr>
<th>Degree of Uncertainty</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
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</thead>
<tbody>
<tr>
<td>Compositional changes over time</td>
<td>PVT properties</td>
<td>Performance forecast</td>
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<tr>
<td>Natural Fracture characteristics &amp; vertical communication</td>
<td>Characterize productive zones</td>
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<td>Net pay / Oil saturation distribution</td>
<td>Geomechanical properties</td>
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<td>OOIP</td>
<td>Primary drive mechanism (vertical vs horizontal)</td>
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<td>Mineralogy, clay content</td>
<td>Stratigraphic continuity</td>
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<td>Faulting</td>
<td>Compartimentalization</td>
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<tr>
<td>Structural complexity</td>
<td>Formation damage (drilling mud, LCM)</td>
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<tr>
<td>Reservoir Pressure</td>
<td>Pore pressure profile</td>
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<td></td>
</tr>
</tbody>
</table>

Low

Medium

High

Impact on Key Decisions - (Weighted)
Decision criteria for delineation drilling: Resolve Well Performance Uncertainty

Resolution path

Delineation wells
- critical data

Reservoir characterization
- Uncertainty resolution

Successful stimulation
- Frac
- Acid
- Other
- None

Optimal completion
- Cased
- Slotted liner

Best well type
- Vertical
- Horizontal

Reduce well performance uncertainty

Courtesy of Baker Hughes
Monterey Formation Delineation Wells

- Drilled delineation wells
  - Planned to stimulate and complete in 2015
  - Understand diagenetic phases, structure, stratigraphy, OOIP, COIP
  - Resolve key uncertainties

- Additional vertical and horizontal delineation wells planned

- Monterey Formation development program
Modular Dynamic Tester (MDT) Objectives

- Collect reservoir pressure
- Collect reservoir fluids for analyses using dual packer (3 ft)
  - Proper pressure measurement
  - Attempt fluid sampling in low-permeability & fractured formations
- Carry out micro-frac tests:
  - Allows quick and accurate determination of rock mechanics properties (closure stress, barriers to frac propagation, etc.)
MDT Job Challenges
Common Issues with Probe Test

- No fracture -> no flow
- Low mobility -> supercharge effect
- Big fracture -> seal leak
- Not in an oil zone

Supercharging:
- Pressure at sand face higher than undisturbed formation pressure due to mud filtrate invasion
- Mud loss in formation due to Spurt loss (insignificant), static, and dynamic invasion
MDT Job Challenges
Advantages of Dual Packer

- Flow area:
  - Single probe: 1-60 sq cm
  - Dual Packer: 6300 sq cm in 8.5” bit size

- When do we run packers?
  - When flow are of probe inadequate
  - Low perm / mobility
  - Poorly consolidated formations
  - Fractured formations

- Packer applications:
  - Sampling / down hole fluid analysis
  - Mini DST
  - Vertical Interference Testing (VIT)
  - Micro-frac stress testing
MDT – Flow-back Mode Procedure

- MDT – Flow back mode
  - Ran and tested in both single probe and dual packer mode

- Single probe measurements to verify formation pressure and get a quick look of mobility; helps to decide if we want to set the dual packer or not

- In the graph shown, formation pressure at xx82.5’ was validated as 8.2 ppg EMW

- Acquisition difficult due to low mobility, one pressurized sample and one unpressurized sample obtained in the Opal CT Phase and one water sample obtained in the Quartz Phase
MDT – Injectivity (Micro-frac) Mode Procedure

- MDT Injectivity (Micro-frac) Mode Procedure in theory: Break Down, Growth, Closure, Reopen
- A hypothetical micro-frac response chart showing fracture initiation, propagation, and closure for two cycles

Measured closure stress at interval xx55’-xx59’:
- First cycle closure not obvious
- Second cycle gave a clear closure 4479 psi
- Repeated test to confirm closure with additional 1500 cc of fluid (compared to second cycle) and obtained closure 4508 psi
Interval xx55’-xx59’: Core and Logs
Modular Dynamic Tester (MDT) Results

Formation water sample from Quartz phase

Oil samples from Opal CT

No sample taken. High gas on LFA at low pressure
Modular Dynamic Tester (MDT) Results

- Very tight reservoir
  - Difficult to produce naturally
  - Requires stimulation
- Saw some oil in LFA but not a continuous slug
  - Implies no well developed fracture network
  - Consequently very low mobility
  - 6 hours not sufficient for mud and filtrate clean up
- Pressure build up in dual packer mode was very slow – impractical
  - As such not attempted to get pressure in the dual packer mode
  - Focused on collecting fluid ID and samples
Modular Dynamic Tester (MDT) Results

- Collected rock mechanics data from multi zones
- Gathered reservoir pressure data and multiple pump outs confirmed oil in tight reservoir (mobility < 0.3)
- 2 oil and 1 water samples collected
- Dual Packer MDT (mini-DST and micro-frac modes) first run in this area
- Tough logging condition (TLC) first successful run in the valley recently
- Total 6 days of MDT job
Lessons Learned

- MDT is a proven technique but needs special attention and monitoring for ongoing jobs in tight rocks.
- Remote monitoring may not always be real time. Decision may need to be made on the fly.
  - Real time monitoring by the team was critical
  - Physical presence at well site critical for making key decisions when the plan calls for change/flexibility
- Decision making and data streaming capability required to quickly analyze wireline logs/image logs to pick suitable points for MDT run
- MDT jobs can be pretty long – need to coordinate with team members for continuous presence at the well site
Lessons Learned

• Speed clean up job:
  • Initially pump out fast and then if pressure falls, either lower the pump out rate or shut-in the pump for short build ups

• No high cable tension or stickiness observed during operation:
  • TLC may be safe but is very time consuming
  • Extra time due to running on TLC also calls for wiper trips in between

• May run MDT on wireline in future:
  • Saves time and allows us to test more points
  • Faster trouble shooting
Best Practices, Challenges Faced

• Best Practices
  • Early engagement with Subject Matter Experts (SMEs) and vendor for job planning.
  • Ensure people in early engagement meetings are available during job execution.
  • Plan for optimum time for MDT job.
  • Improved coordination and collaboration among well site personnel, SMEs, and vendor champions

• Challenges Faced
  • Running tool on drill pipe, though safer, is time consuming.
  • People executing the job were not involved in pre-job planning.
  • Different views on what is called a valid test, when to collect samples, and when to call an issue a tool failure.