Deep Trek JIP for Advancing Deep, Hard Rock Drilling Performance through Controlled, Full-scale Laboratory Drilling Experiments with Aggressive Bits and Specialized Fluids

DEA Project 162

Championed by British Petroleum

Drilling Engineering Association Meeting

22 March 2007
Deep Trek Objectives

– Phase 1: Simulate Deep Drilling & Establish Baseline Data

– Phase 2: Improve Drilling Efficiency with Improved Bits and Drilling Fluids
Equipment, and Test Materials

- Equipment

![Equipment Diagram](image1.png)

[Image 2.png]
# Basic Properties of the Rock Drilled

<table>
<thead>
<tr>
<th>Rock/Attribute</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carthage Marble</strong></td>
<td></td>
</tr>
<tr>
<td>Bulk density</td>
<td>2.65 g/cm³</td>
</tr>
<tr>
<td>Unconfined compressive strength</td>
<td>16,000 psi</td>
</tr>
<tr>
<td>Porosity</td>
<td>1.4%</td>
</tr>
<tr>
<td>Permeability</td>
<td>0.002 md</td>
</tr>
<tr>
<td><strong>Crab Orchard Sandstone</strong></td>
<td></td>
</tr>
<tr>
<td>Bulk density</td>
<td>2.47 g/cm³</td>
</tr>
<tr>
<td>Unconfined compressive strength</td>
<td>19,000 psi</td>
</tr>
<tr>
<td>Porosity</td>
<td>7.0%</td>
</tr>
<tr>
<td>Permeability</td>
<td>0.1 md</td>
</tr>
<tr>
<td><strong>Mancos Shale</strong></td>
<td></td>
</tr>
<tr>
<td>Bulk density</td>
<td>2.54 g/cm³</td>
</tr>
<tr>
<td>Unconfined compressive strength</td>
<td>9,800 psi</td>
</tr>
<tr>
<td>Porosity</td>
<td>17.9%</td>
</tr>
<tr>
<td>Permeability</td>
<td>&lt;0.001 md</td>
</tr>
</tbody>
</table>
Equipment, and Test Materials

• Rock Preparation
Drill Bits

– Phase 1
Drill Bits

– Phase 2
Drilling Fluids

- **Phase 1**
  - Water (Water)
  - 11 ppg Water Base Mud
  - Mineral Oil—Base Oil
  - 12 ppg Oil Base Mud
  - 16 ppg Oil Base Mud

- **Phase 2**
  - 11 ppg Water Base Mud
  - 16 ppg Oil Base Mud
  - 16 ppg Oil Base Mud + Lubricant
  - 16 ppg Oil Base Mud + Alternate Weighting Matl
  - 16 ppg Oil Base Mud + MicroMax
  - Cesium Formate
  - Cesium Formate + Drill Solids
Laboratory and Field Comparison

Laboratory vs Field—Tuscaloosa Trend with a 7-Blade PDC Bit

Comparison of Laboratory and Field Penetration Rates for PDC Bits

Graph showing the relationship between Rate of Penetration (ft/hr) and Weight on Bit (lbs) for different conditions.
Laboratory and Field Comparison

Laboratory vs Field—Arbuckle Play with a TCI Bit

Field and Lab Penetration Rates with TCI Bit
11 ppg Water-Base Drilling Fluid at 110 to 120 RPM

Weight on Bit, lbs

Rate of Penetration, ft/hr

- Crab Orchard
- Carthage Marble
- IADC 737 Wheeler CO, TX
- IADC 737 Grady CO, OK
- IADC 737 Custer Co, OK
Rock Strength when Confined

Effects of Confining Pressure on Rock Compressive Strength

Confining Pressure (psi)

Rock Compressive Strength (psi)

Crab Orchard Sandstone
Carthage Marble
Mancos Shale
Carthage Marble

Rate of Penetration of Various Bits in Carthage Marble with Oil and Cesium Formate Muds at 85 to 95 RPM

Graph showing the relationship between weight on bit and rate of penetration for different bit types and mud compositions.
Crab Orchard Sandstone

Rate of Penetration of Various Bits in Crab Orchard Sandstone
with Oil and Cesium Formate Muds at 85 to 95 RPM
Crab Orchard Sandstone

Rate of Penetration of Various Bits in Crab Orchard Sandstone with Oil and Cesium Formate Muds at 85 to 95 RPM

Weight on Bit, lbs

Rate of Penetration, ft/hr

M333-2, CF-16+
M233-2, OB-16
M333-2, OB-16
M333-2, OB-16+Alt
M333-1, OB-16
M333-2, OB-16+Mn
M121-1, OB-16
Objectives of DEA 162

Extend work done during Deep Trek

Extend the analysis of rock failure mechanisms

Improve the experimental design to evaluate all critical factors and determine their significance
Technical Approach

- Test Facilities and Equipment
- Rock Samples
- Drill Bits
- Drilling Fluids
Scope of Work

- Rock Sample Procurement and Preparation
- Bit Procurement
- Drilling Tests
- Data Analysis
- Cuttings Analysis
- Reporting
Deliverables and Schedule

• A kickoff and planning meeting will be held with technical representatives in Houston in January 2008
• Technical representatives will meet in Salt Lake City to finalize and approve the plans in March 2008
• Quarterly reports of progress
• Raw date, formatted data, and a thorough statistical analysis
• Final report
• Lesson’s learned meeting
Project Cost

- $100,000 per participant
- Target seven participants to start