Limited experience

- Most operations in sedimentary formations
  - Relatively soft
  - Hard stringers
  - Section in one run with good progress
- Drilled basalt outside Faroe Islands
- Drilled calcareous sand in Algeria
- Drilled silica cemented sand at Morvin
- Test drilling of basalt on Iceland
Brugdan I 17 ½" basalt drilling data

<table>
<thead>
<tr>
<th>Run</th>
<th>Type</th>
<th>IADC</th>
<th>Motor</th>
<th>RPM</th>
<th>WOB (tonns)</th>
<th>ROP (m/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MX-ST31</td>
<td>115</td>
<td>12 ¾&quot; X-treem</td>
<td>120</td>
<td>30</td>
<td>1,6</td>
</tr>
<tr>
<td>2</td>
<td>M57ODCPS</td>
<td>635</td>
<td>Rotary</td>
<td>105</td>
<td>27</td>
<td>1,4</td>
</tr>
</tbody>
</table>

- 1.15 sg KCL mud
- 135 bar hydrostatic pressure at 1200 m TVD.
Algeria

• Erratic performance
• Short runs
• Bit selection based on limited experience
Morvin

- Experienced rapid bit wear and frequent tool failure
- Improvement seen over 4 well campaign
- Not good enough as roundtrip take 2 days

<table>
<thead>
<tr>
<th></th>
<th>B-3 H</th>
<th>A-1 H</th>
<th>A-4 H</th>
<th>A-2 H</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of trips/bit runs</strong>*</td>
<td>17</td>
<td>8</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td><strong>Average run length</strong></td>
<td>76 m</td>
<td>142 m</td>
<td>112 m</td>
<td>178 m</td>
</tr>
<tr>
<td><strong>Average ROP</strong></td>
<td>3.9 m/hr</td>
<td>3.4 m/hr</td>
<td>3.0 m/hr</td>
<td>3.7 m/hr</td>
</tr>
</tbody>
</table>
Bit testing Iceland
17 ½” Drilling Tests Iceland

• 17 ½” HP633 Kymera S/N 7026018:

<table>
<thead>
<tr>
<th>Depth in</th>
<th>Depth out</th>
<th>Distance</th>
<th>Hrs</th>
<th>ROP</th>
</tr>
</thead>
<tbody>
<tr>
<td>97</td>
<td>270.1</td>
<td>173.1</td>
<td>16</td>
<td>10.82</td>
</tr>
</tbody>
</table>

• Dull grading:
  • PDC 1-0-BT-C-X-0-NO-TD (1 broken cutter in very centre)
  • TCI 0-0-NO-A-E-0-NO-TD

• Almost tripling the ROP compared to offset wells despite controlling ROP to max 15 m/hr due to hole problems.
12 ¼” Drilling Test Iceland

12 ¼” KG533FX Kymera S/N 7027524:

<table>
<thead>
<tr>
<th>Depth in</th>
<th>Depth out</th>
<th>Distance</th>
<th>Hrs</th>
<th>ROP</th>
</tr>
</thead>
<tbody>
<tr>
<td>270</td>
<td>397</td>
<td>127</td>
<td>5.4</td>
<td>23.5</td>
</tr>
<tr>
<td>416</td>
<td>776</td>
<td>360</td>
<td>17.5</td>
<td>20.5</td>
</tr>
</tbody>
</table>

Dull grading:

- PDC 1-3-BT-G-X-I-NO-TD (Chipped PDC cutters on the gauge)
- TCI 1-1-WT-A-E-I-NO-TD

Drilled twice as fast with substantial lower WOB compared to offset wells and observed excellent steerability.
Conclusions, Kamyra Iceland tests

• 100% - 200% improvement in ROP.
  − ROP controlled to max 15 m/hr because of temperature problems.

• Rock types drilled: basaltic Tuff, glassy Basalt, fine medium grained Basalt, medium coarse grained Basalt, basaltic Breccia.

• Icelandic basalt are on the low side in strength.

• No signs of detrimental drilling dynamics.

• Minor wear observed.
17 ½” SDH616S – Best Estimate

• ROP
  – Brugdan I: 17 ½” TCI, 25m @ 1.6 m/hr
  – PDL test, S / H type: 580 / 780% increase
    • ROP differentiation holds true for pressurized conditions and bit size-up
    • Brugdan I: 17 ½” TCI less aggressive compared to 8 ½” TCI benchmark in PDL testing

→ Brugdan II: 9.3 m/hr in S type basalt
12 ¼” Drilling Test Houston, Results

[Graph and chart showing data for different RPMs and WOBs.]
12 ¼" vs. 17 ½" hole

• 17 ½" hole has 100% larger area than 12 ¼" hole.
• 17 ½" bit needs 100% more WOB than 12 ¼" bit to get the same WOB / area.
• 17 ½" hole has 43% larger circumference than 12 ¼" hole.
• 17 ½" radial speed are 43% higher than 12 ¼" at same RPM.
Conclusions and Need

• We can increase penetration rate by several 100 % using latest bit technology
  − From 2 m/hr to 10 m/hr ?
• Need to look at well design to reduce hole sizes through hard formation
• Drilling practice and parameters important to improve progress and run length

• Still exposed to short runs and limited ROP
• Not sufficient with operational rates of 800.000 dollar per day

• Improvement to existing technology is only giving marginal improvement.
• Need new technology
There’s never been a better time for good ideas

- Electropulse drilling
- Jet assisted drilling
- Particle impact drilling
- Hammer drilling
- Heat spallation
- Laser drilling