Chapter 4
Borehole Environment

Lecture notes for PET 370
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Schematic of rotary drilling system
Mud circulation system

• Drilling mud, mudcake, mud filtrate
  \[ R_m \quad R_{mc} \quad R_{mf} \]

• Drilling fluids generally adversely affect logging tool response. Function of:
  - tool design
  - borehole size
  - mudcake thickness
  - depth of invasion
  - mud type: oil, water or air

• Electric properties of mud differ from formation, creating a considerable resistivity contrast.
In gauge
• borehole diameter is equal to drilling bit size

Borehole reduction
• mud cake buildup, precursor to permeable formation

Borehole enlargement
• swelling and sloughing of shales
• collapse of poorly cemented porous rock
• dissolution of salts, evaporites

Logging tools typically calibrated on 8” borehole. Corrections necessary for smaller and larger borehole sizes
Profile of a borehole (Bassiouni, 1994)
Applications

• evaluate the borehole environment for logging measurements

• identification of mudcake deposition, evidence of formation permeability

• estimate hole volume to determine cement volume requirements

• determine competent formations to set packers

• provide position data for dipmeter interpretation

Methods

• acoustic
• electromagnetic
• mechanical
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Caliper Logging

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Pad-type devices
Bassiouni (1994)
Anisotropic mechanical properties of the formation.

Result:

Elliptic boreholes

Schematic of elliptical borehole showing the preferential position of a pad-type device

Most probable positions assumed by a Three-arm caliper in an elliptical borehole

Bassiouni, 1994
Comparison of various caliper devices
**Invasion** - The pressure differential between the mud in the annulus and the formation fluid pressure, forces drilling fluid into the formation.

Dewan, 1983
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Invasion

Formation damage near the wellbore

Particle invasion and bridging
Western Atlas (1992)
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Idealized invasion profile

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Flushed Zone</th>
<th>Transition zone</th>
<th>Virgin Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>resistivity</td>
<td>Rxo</td>
<td>Ri</td>
<td>Rt</td>
</tr>
<tr>
<td>porosity</td>
<td>φ</td>
<td>φ</td>
<td>φ</td>
</tr>
<tr>
<td>water saturation</td>
<td>Sxo</td>
<td>Si</td>
<td>Sw</td>
</tr>
<tr>
<td>water</td>
<td>Rmf</td>
<td>Rz</td>
<td>Rw</td>
</tr>
<tr>
<td>equations</td>
<td>Sxo = \frac{Fr \ Rmf}{Rxo}</td>
<td>Si = \frac{Fr \ Rz}{Ri}</td>
<td>Sw = \frac{Fr \ Rw}{Rt}</td>
</tr>
</tbody>
</table>
Invasion profile – water zone
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Invasion

Invasion profile – oil zone
Chapter 4, Sec. 4.1-4.4, Bassiouni, Z: Theory, Measurement, and Interpretation of Well Logs, SPE Textbook Series, Vol. 4, (1994)


Western Atlas, Introduction to Wireline Log Analysis, Houston, TX (1992), Chapter 1

Hilchie, D. Applied Openhole Log Interpretation, CSM (1978)