



भारतीय प्रौद्योगिकी
संस्थान
(भारतीय खनि विद्यापीठ)
धनबाद

IIT
ISM

**INDIAN INSTITUTE
OF TECHNOLOGY**
(INDIAN SCHOOL OF MINES)
DHANBAD

GPC510 - Well logging

Semester - Winter 2024; Lecture-3

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TEACHING OUTLINE

Week 1/2

Tutorial 1 – Introduction, teaching overview, and assessment

Tutorial 2 – Well log definition, history, log format, types, units

Tutorial 3 – Borehole effects, environmental impacts

AGENDA

- Tool geometry
- Borehole effects
- Speed of the logging tool
- Environments

DIGITAL LOG FORMAT - LAS

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~Version Information
VERS.                2.0: CWLS log ASCII Standard Version 2.00
WRAP.                NO: One line per depth step

~Well Information Block
#MNEM.UNIT          Value                Information
#-----
STRT.M              2211.0192             :START
STOP.M              3529.1268             :STOP
STEP.M              0.1524                :STEP
NULL.               -999.25                :NULL VALUE
COMP.               Woodside Energy LTD       :Company
WELL.               Pluto-3ST1          :Well Name
FLD.                Pluto                :Field
LOC.                WA-350-P            :Field Location
PROV.               Atwood Eagle         :Province
CNTY.               Australia           :County or Rig name
STATE.              :State
CTRY.               Australia           :Country
DATE.              :Log Date
SRVC.               Schlumberger         :Service company
UWI.                W002813                :Unique Well ID
API.                :API Number
NATI.               Australia           :Nation
STAT.               Western Australia       :State
FL1.                X = 307 534.2 mE         :Field Loc. 1 / Northing
FL2.                Y = 7 797 210.8 mN       :Field Loc. 2 / Easting
LATI.               019 54' 43.000" S      DMS      :Latitude
LONG.               115 09' 40.820" E      DMS      :Longitude
PD.                LAT                :Perm. Datum
EPD.M               0.0                :Elevation Perm. Datum
EDF.M               22.4                :Elevation DF (wrt EPD)
EGL.M               -584.59998         :Elevation GL (wrt EPD)
ELZ.M               22.4                :Elev. Log Zero (wrt EPD)
APD.M               22.4                :Above Perm. Datum
LMF.                RT                :Log measured from
MP.                RT                :Drill measured from
OS1.                FMI-HNGS-MSIP         :Other Services Ln 1
OS2.                MDT-CMR          :Other Services Ln 2
OS3.                FMI-MSIP          :Other Services Ln 3
OS4.                VSI / MDT-FMI       :Other Services Ln 4
OS5.                MSCT / CST         :Other Services Ln 5
TD.M                3530                :TD Date

~Curve Information
#MNEM .UNIT          API CODE Curve Description
#-----
DEPT .M              00 001 00 00:  0 Depth
DF .N                00 000 00 00:  1 Uncalibrated Downhole Force {F13.4}
DSO8 .IN             00 000 00 00:  2 HRDD HiRes Density Standoff {F13.4}
EHGR .GAPI           00 000 00 00:  3 HiRes Gamma-Ray {F13.4}
HCAL .IN             70 280 00 01:  4 HRCC Cal. Caliper {F13.4}
HDRA .G/C3           45 356 01 01:  5 HRDD Density Correction {F13.4}
HPRA .               00 000 00 00:  6 HRDD Photoelectric Factor Correction {F13.4}
HTNP .V/V           00 000 00 00:  7 HiRes Thermal Neutron Porosity {F13.4}
NPHI .V/V           42 890 01 01:  8 Thermal Neutron Porosity (Ratio Method) {F13.4}
PEF8 .               00 000 00 00:  9 HRDD High Resolution Formation Photoelectric Factor {F13.4}

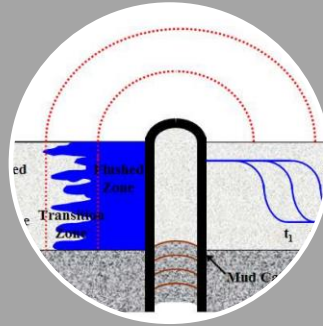
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- ~V - contains the version and wrap mode information
- ~W - contains the well identification information
- ~C - contains log curve information
- ~P - contains well parameters and constants
- ~O - contains additional information such as comments
- ~A - contains the log data

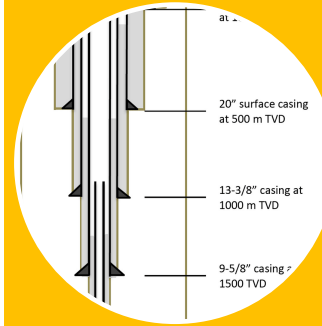
BOREHOLE EFFECTS



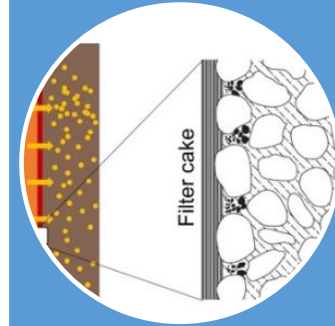
Drilling
Mud



Invasion



Casing
&
Cement



Fluid
mobility

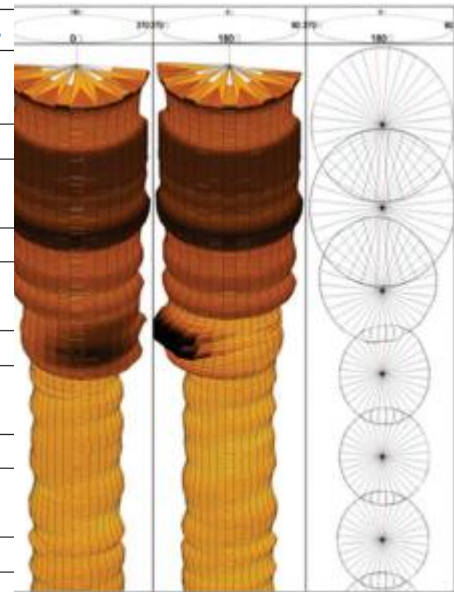


DRILLING MUD

- Influence of the drilling mud on log response depends upon:
 - A: Diameter of the wellbore

Borehole Size Specifications for Large-Hole Tool Kits

	Borehole Size—Min.	Borehole Size—Max.
Resistivity		
Platform Express* AIT* Array Induction Imager Tool (AIT-H)	9½ in. [24.13 cm]	20 in. [50.80 cm]
Powered Caliper Device (PCD-B)	7 in. [17.78 cm]	25 in. [63.50 cm]
Neutron porosity		
Platform Express Highly Integrated Gamma Ray Neutron Sonde (HGNS)	15 in. [38.10 cm]	22 in. [55.88 cm]
Compensated Neutron Tool (CNT-H)	14 in. [25.56 cm]	22 in. [55.88 cm]
Density		
Litho-Density* tool (LDT-D)	14 in. [25.56 cm]	30 in. [76.20 cm]
Platform Express High-Resolution Mechanical Sonde (HRMS)	16 in. [40.64 cm]	28 in. [71.12 cm]
Sonic		
Digital Sonic Logging Tool (DSLIT)	14 in. [35.56 cm]	30 in. [76.20 cm]
DSI* Dipole Shear Sonic Imager	14 in. [35.56 cm]	20 in. [50.80 cm]
Sampling		
MDT tool with MRLH-AA	7½ in. [19.05 cm]	19 in. [48.26 cm]
MSCT with shoe extender	5½ in. [13.97 cm]	19 in. [48.26 cm]
Seismic		
CSI Combinable Seismic Imager	7 in. [17.78 cm]	22 in. [55.88 cm]

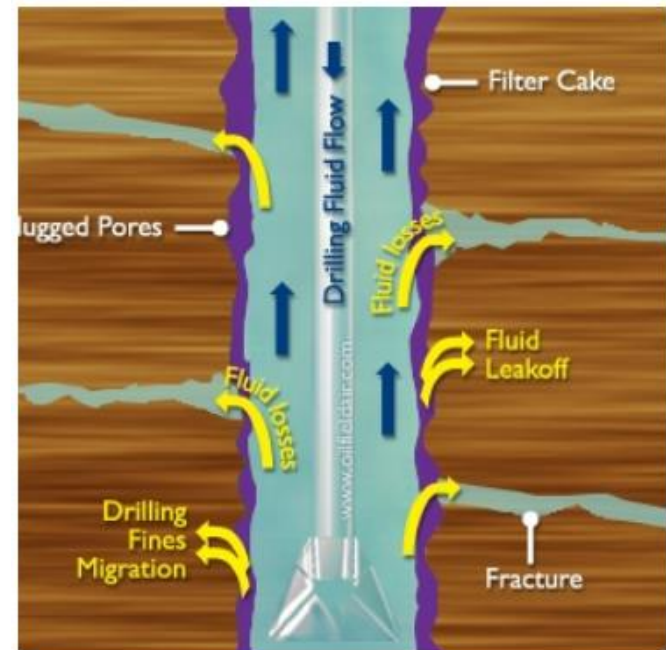
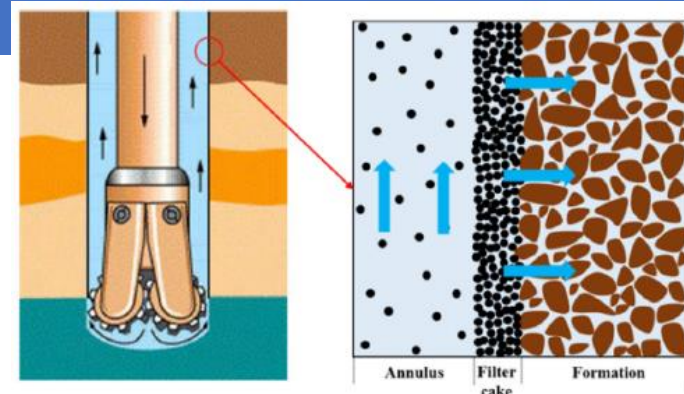


DRILLING MUD

- B: Type of mud and density
- Two categories of mud:
 1. Water-based
 2. Oil-based
- For oil-based mud - acoustic signal propagation is poor and non conduct of electric current
- Water-based mud with added salinity affects electric property measurements and hydrogen index
- Mud density influences absorption of gamma rays

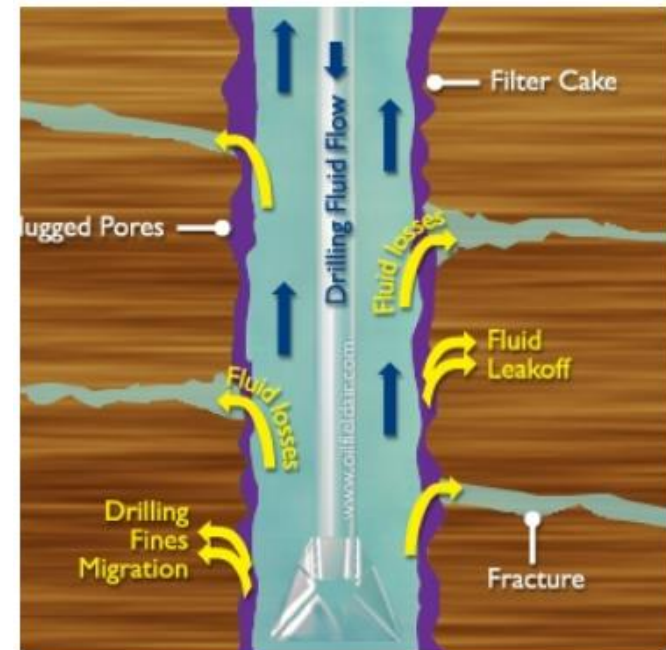
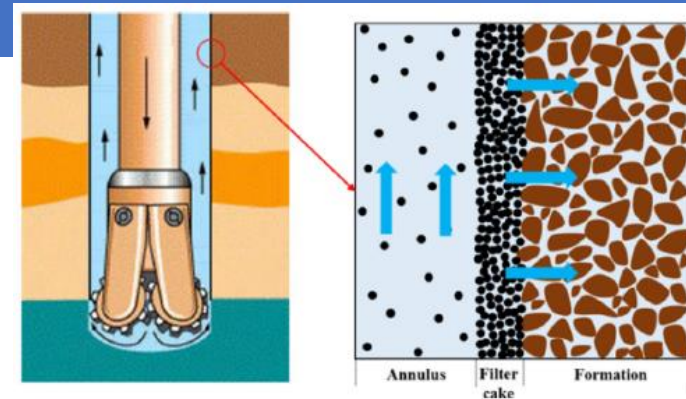
INVASION

- Main functions of the drilling mud are:
 1. Cooling down of drill bit
 2. Avoid borehole collapse
 3. Prevent blow-out
 4. Allow flow of cuttings to the surface
- Mud density depends upon formation pressure to make a safer drilling scenario [ranges from 1 to 2.4 g/cm³]



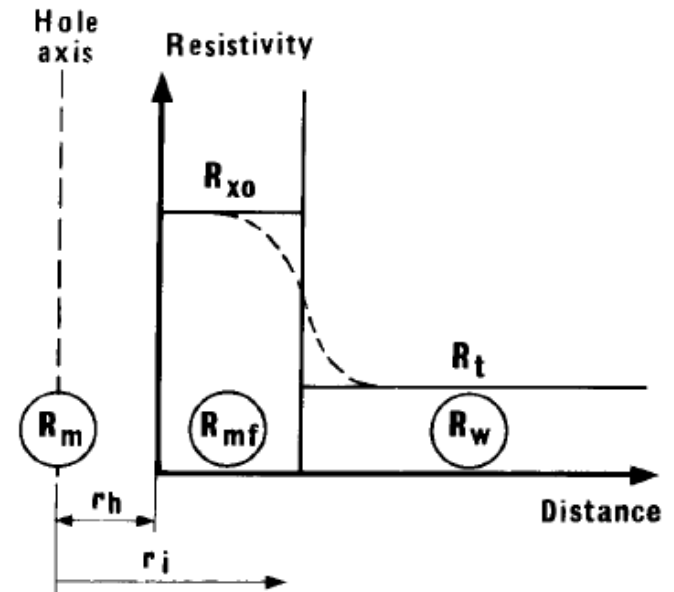
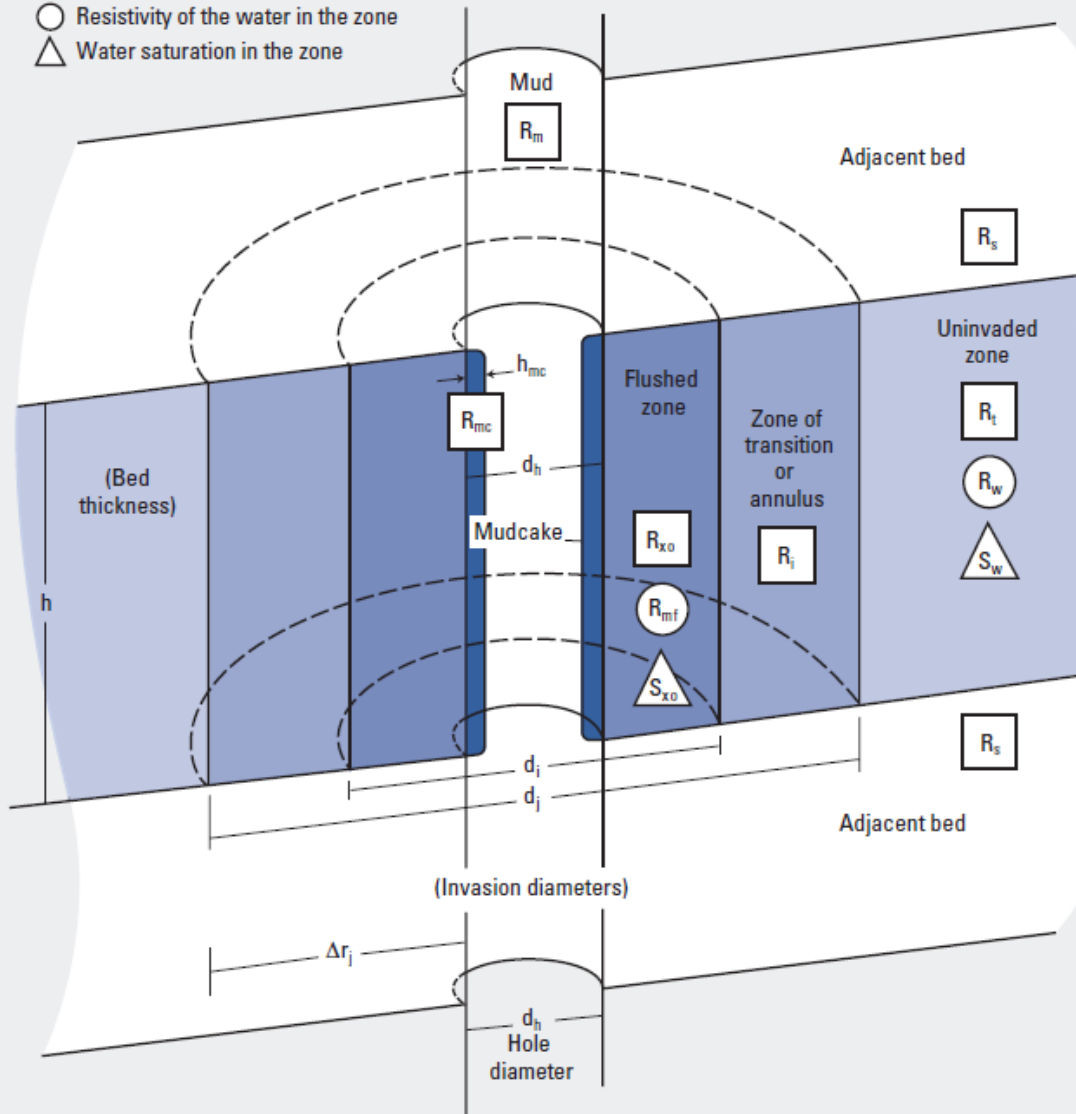
INVASION

- Mud is kept slightly higher than formation pressure, which causes mud to infiltrate porous and permeable beds
- Solid particles in the mud are slightly larger than pores, therefore only liquid content can invade
- Mud cake will form during drilling wherever mud filtrate infiltrates. Therefore with time an impermeable membrane form which prevents further invasion
- Mud-filtrate displaces some of the interacting formation fluids.
- Following factors define the depth of invasion (i) porosity (ii) permeability (iii) water loss factor of mud (iv) pressure difference



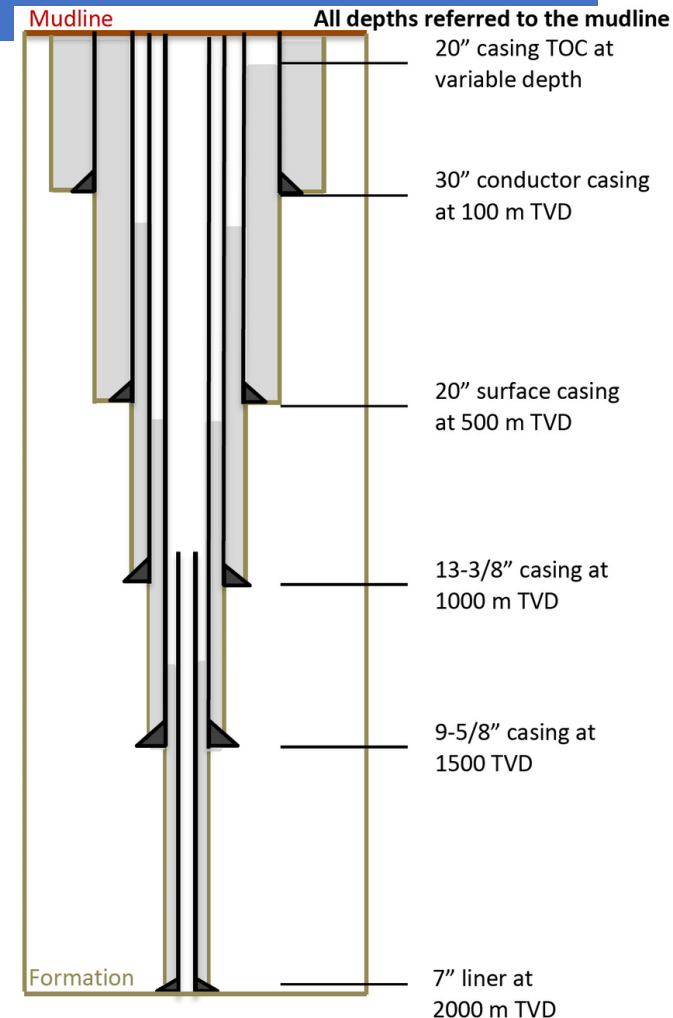
INVASION

- Resistivity of the zone
- Resistivity of the water in the zone
- △ Water saturation in the zone



CASING & CEMENT

- Casing followed by cementing is required for a safer well bore design.
- Design of casing is the beyond the scope of this unit
- Casing and cement prevent certain logging measurements (resistivity)
- Nuclear measurement can be done



FLUID MOBILITY

- Saturation - ratio of pore volume occupied by fluid to the total pore volume
- Invasion can be used as an indicator of mobility of the reservoir fluids
- We need to derive saturations from invaded S_{x0} and virgin zones S_w
- $POI = \phi (S_{x0} - S_w)$, producible oil index (POI) can be act as an indictor of recoverable hydrocarbon
- Recoverability factor is defined as $f = \frac{(S_{x0} - S_w)}{(1 - S_w)}$

S_w = water saturation

LOGGING SPEED

- The speed of the logging tools are not same
- Natural and radio-active phenomena are random in nature, therefore necessary to accumulate count data over a period of time and compute the average to obtain a representative reading.
- Sufficient period of time to obtain a reading is required. It referred as “Time constant” (TC)
- Other factors such as uniformity of cable tension and risk of damage of pad type equipment are also considered

Recommended maximum logging speeds.

Survey	Maximum logging speed		
	(ft/min)	(m/min)	
SP	100	30	
Induction	100	30	
Laterolog	50	15	
Microlaterolog	35	10	
Neutron	} TC = 2 sec TC = 3 sec TC = 4 sec	30	9
GR		20	6
Density		15	4.5
TDT			
Sonic		70	20
Amplitude		35	10

Example of a logging setup

WORKING ENVIRONMENTS

- Subsurface pressure (~ 10 MPa/km) and temperature (~ 25 - 30 °C /km) normally increase with depth
- Logging companies provide operating conditions of the tools. Beyond that scenario, it is not recommended to run any of those logs

Example of a particular tool's environment specification

Environmental specifications

Max. vibration, g_n [m/s ²]	20 [200] (G_{rms} random, 5 to 1,000 Hz)
Max. shock, g_n [m/s ²]	500 [5,000]
Max. temperature, degF [degC]	302 [150], 350 [175] ^{§§}
Max. working pressure, psi [MPa]	25,000 [172]
Mud sand content, %	1

END OF LECTURE

data collection



H_2 - CH_4 blend
Underground
Storage Reservoir



Geochemistry
analysis



DNA analysis



Subsurface
simulation
experiments

Thank you

Acid formation (H^+ , H_2S)