Penilaian Formasi Lanjutan

Porosity Logs

Density Logs

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Agenda

1. Porosity Logs
2. The Compensated Density Tool
3. Porosity Derivation From The Density Log
4. The Litho-Density Log
5. Lithology Interpretation with rhob-Pe Curves

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Porosity Logs

Basic Log Interpretation Equation:

$$S_w = c\sqrt{\frac{Rw / Rt}{\phi}}$$

N = 7,758 bbl/acre-ft × ϕ (1 - S_w) × *h* (ft) × *A* (acres)

where *h* = reservoir thickness (ft),
A = drainage area (acres),
ϕ = porosity (%),
and S_h = (1 – Sw) = pore space portion filled with hydrocarbon (%).

G = 43,560 cubic ft/acre-ft × ϕ (1 - S_w) × *h* (ft) × *A* (acres)

where *h* = reservoir thickness (ft),
A = drainage area (acres),
ϕ = porosity (%),
and S_h = (1 – Sw) = pore space portion filled with hydrocarbon (%).

3 Porosity-measuring tools:

1. Density
2. Neutron
3. Sonic

Porosity Logs

Density-Neutron combination has become the primary source of porosity information, reasons are:

- Porosity can be determined without precise knowledge of rock matrix
- There is no need for the compaction correction required with Sonic porosity
- Overlay of Density-Neutron curves is an excellent gas indicator
- Transition from one type of rock matrix to another can often be distinguished
- Shale effect are more evident and can be accounted for more precisely

Sonic Log is becoming a backup porosity tool, where:

- Hole is very irregular
- Secondary porosity is important
- Heavy mineral such as pyrite adversely affect the Density
- When a synthetic seismogram will be generated (from Sonic and Density Logs) for depth calibration of seismic section

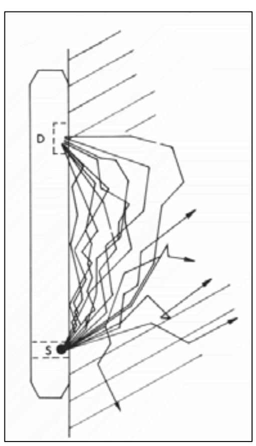
Porosity tools, less sensitive to borehole and mud-cake effects than uncompensated:

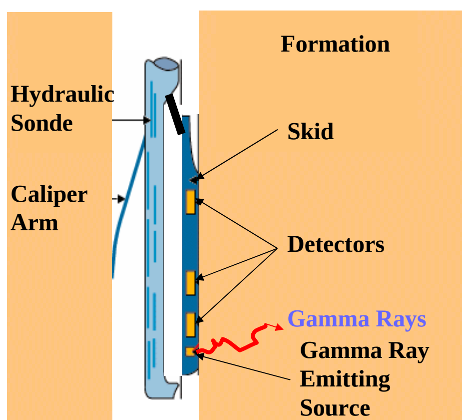
1. Compensated Density
2. Compensated Neutron
3. Compensated Sonic

The Compensated Density Tool

1. Density Log
2. Compensated Density Tool

Density Log





Density devices employ a chemical source of gamma radiation (Cs-137; $T_{1/2}$ = 30.2 yr; Eg = 663 keV) and two gamma ray detectors to determine the formation bulk density.

Common names FDC, LDT, ZDEN, or RHOB

Compensated Density Tool

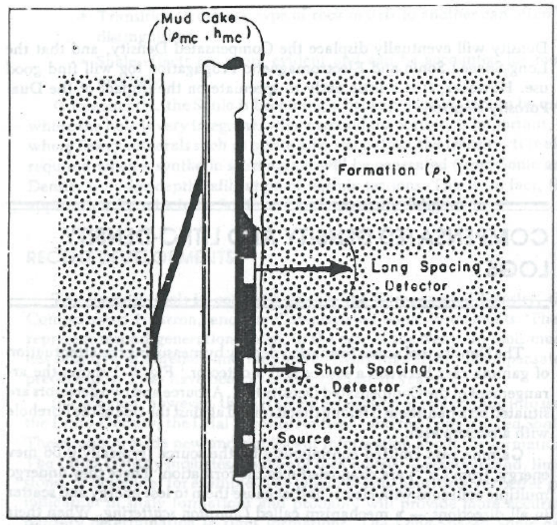


Fig. 5-1 Source-detector configuration of the Compensated Density tool (courtesy Schlumberger, © SPE-AIME)

Deviation of Density and Density Correction

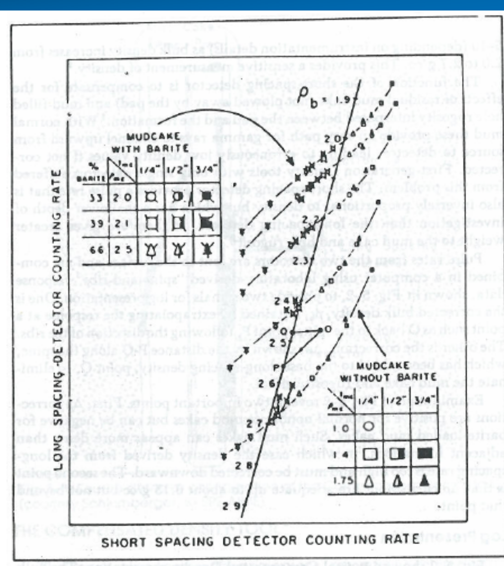


Fig. 5-2 De:.ation of density and density correction from short and long-spacing detector rates (courtesy Schlumberger)

Compensated Density Recording

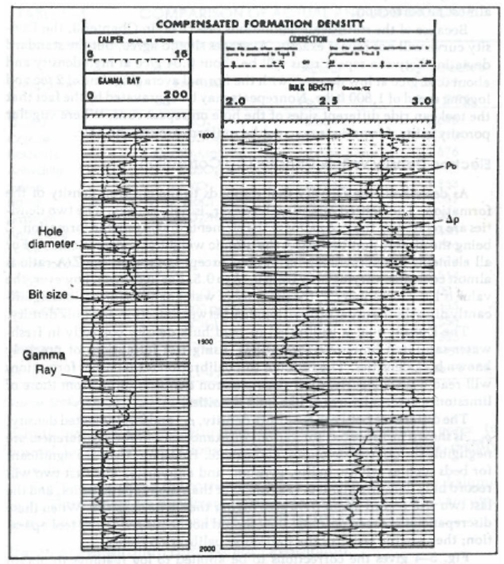
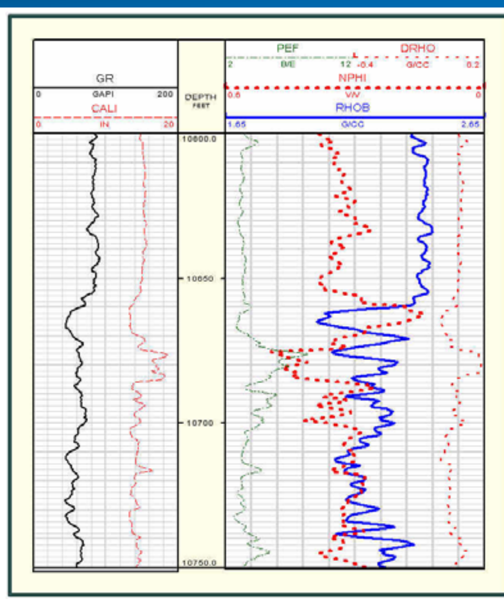


Fig. 5-3 Example of a Compensated Density recording (courtesy Schlumberger)

Example Log RHOB, Pe, & DRHO



Comparison of Actual and Log-Indicated Densities

TABLE 5-1 COMPARISON OF ACTUAL AND LOG-INDICATED DENSITIES

Compound	Formula	Actual Density, ρ_b, g/cc	Log-Indicated Density, ρ_{log}, g/cc
Quartz	SiO_2	2.654	2.648
Calcite	$CaCO_3$	2.710	2.710
Dolomite	$CaCO_3MgCO_3$	2.870	2.876
Anhydrite	$CaSO_4$	2.960	2.977
Sylvite	KCl	1.984	1.863
Halite	NaCl	2.165	2.032
Gypsum	$CaSO_4 2H_2O$	2.320	2.351
Anthracite coal		1.400	1.355
		1.800	1.796
Bituminous coal		1.200	1.173
		1.500	1.514
Fresh water	H_2O	1.000	1.00
Salt water	200,000 ppm	1.146	1.135
Oil	$n(CH_2)$	0.850	0.850
Methane	CH_4	ρ_{meth}	$1.335\ \rho_{meth} - 0.188$
Gas	$C_{1.1}H_{4.2}$	ρ_g	$1.325\ \rho_g - 0.188$

Source: Schlumberger *Log Interpretation/Principles*

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Corrections to Obtain True Bulk Density

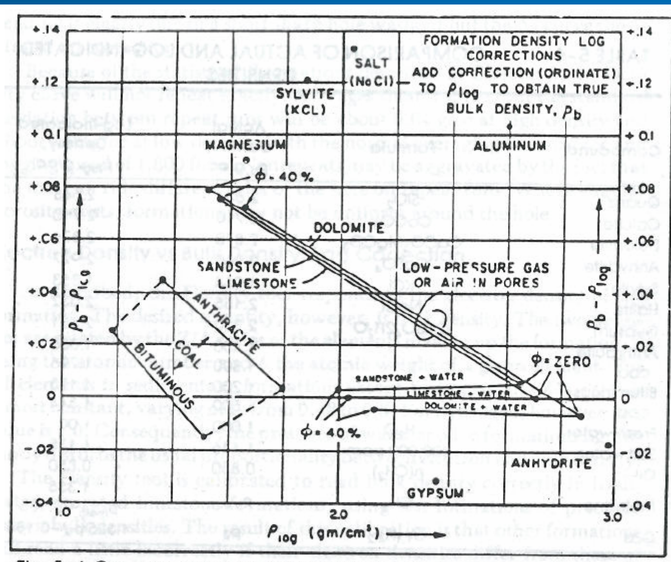

Fig. 5-4 Corrections to obtain true bulk density from log density (courtesy *Geophysics*, reprinted by Schlumberger)

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Determination of Porosity

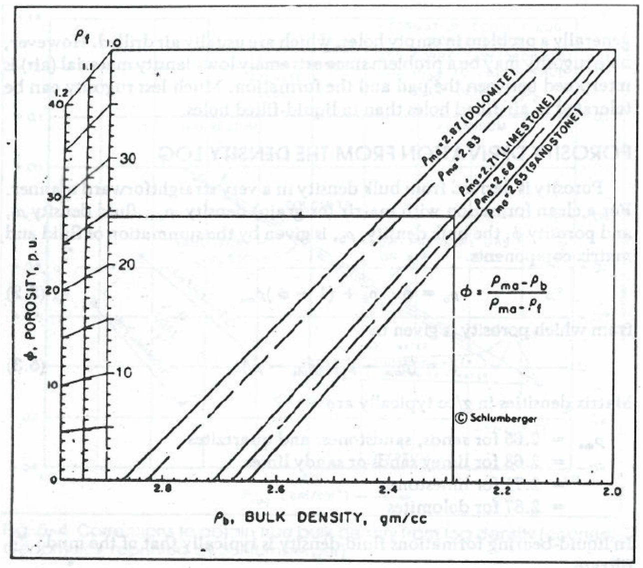

Fig. 5–5 Determination of porosity from bulk density (courtesy Schlumberger)

Estimation of Gas Density

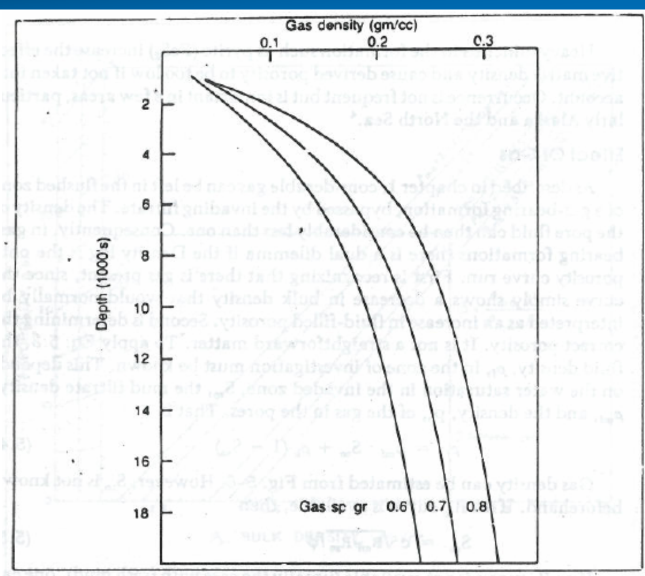

Fig. 5–6 Estimation of gas density (from *Applied Openhole Log Interpretation*, courtesy D.W. Hilchie)

Detection Windows for the Litho-Density Tool

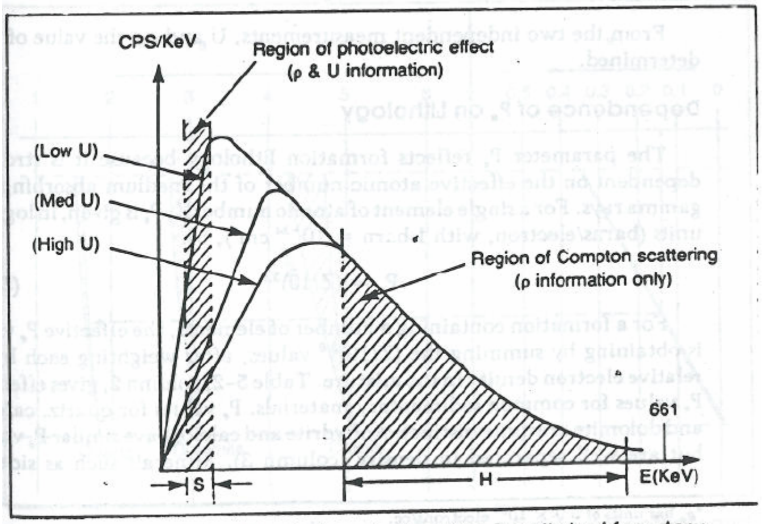

Fig. 5-7 Detection windows for the Litho-Density tool (courtesy Schlumberger and SPWLA)

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Photoelectric Absorption

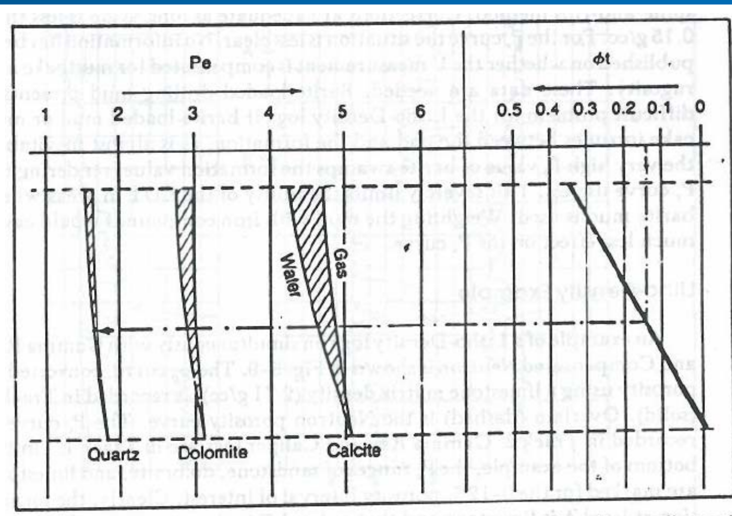

Fig. 5-8 Photoelectric absorption coefficient as a function of porosity and fluid type (courtesy Schlumberger and SPWLA)

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Values of Photoelectric Absorption Coefficient

TABLE 5-2 VALUES OF PHOTOELECTRIC ABSORPTION COEFFICIENT PER ELECTRON, P_e, AND PER CC, U, FOR VARIOUS SUBSTANCES

	P_e	Sp. gr.	ρ_{log}	U
Quartz	1.81	2.65	2.64	4.78
Calcite	5.08	2.71	2.71	13.8
Dolomite	3.14	2.87	2.88	9.00
Anhydrite	5.05	2.96	2.98	14.9
Halite	4.65	2.17	2.04	9.68
Siderite	14.7	3.94	3.89	55.9
Pyrite	17.0	5.00	4.99	82.1
Barite	267	4.48	4.09	1065
Water (fresh)	0.358	1.00	1.00	0.398
Water (100K ppm NaCl)	0.734	1.06	1.05	0.850
Water (200K ppm NaCl)	1.12	1.12	1.11	1.36
Oil ($n(CH_2)$)	0.119	ρ oil	1.22 ρ oil-0.188	0.136 ρ oil
Gas (CH_4)	0.095	ρ gas	1.33 ρ gas-0.188	0.119 ρ gas

Litho-Density Tool

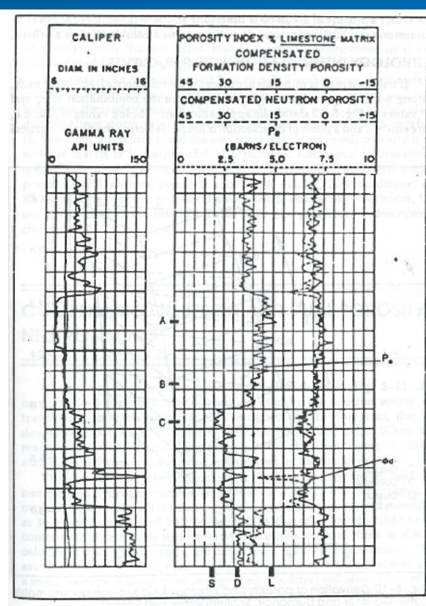

Fig. 5-9 Example of a Litho-Density log (courtesy Schlumberger)

Derivation of Porosity and Lithology

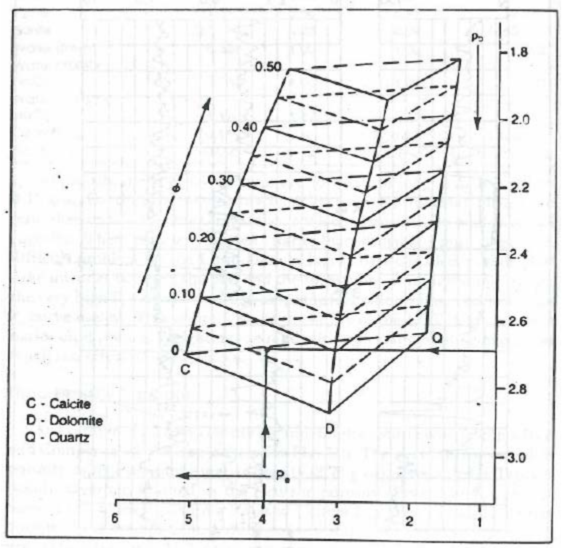

Fig. 5-10 Derivation of porosity and lithology for a two-component matrix (after Gardner and Dumanoir, Schlumberger and SPWLA)

Resources

- Course Materials: http://www.geocities.com/ridwanwd/PFL/
- The Society of Petrophysicists and Well Log Analysts: http://www.spwla.org
- Society of Petroleum Engineers: www.spe.org
  Formation Evaluation: http://www.spe.org/spe/jsp/basic/0,,1104_1714_1003934,00.html
- Schlumberger Interpretation Chart: www.slb.com or http://content.slb.com/Hub/Docs/connect/reference/Chartbook/

Question and Answer