Then and Now…75 Years of Logging

by

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Illinois Oil and Gas Association Annual Meeting

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The Men Responsible

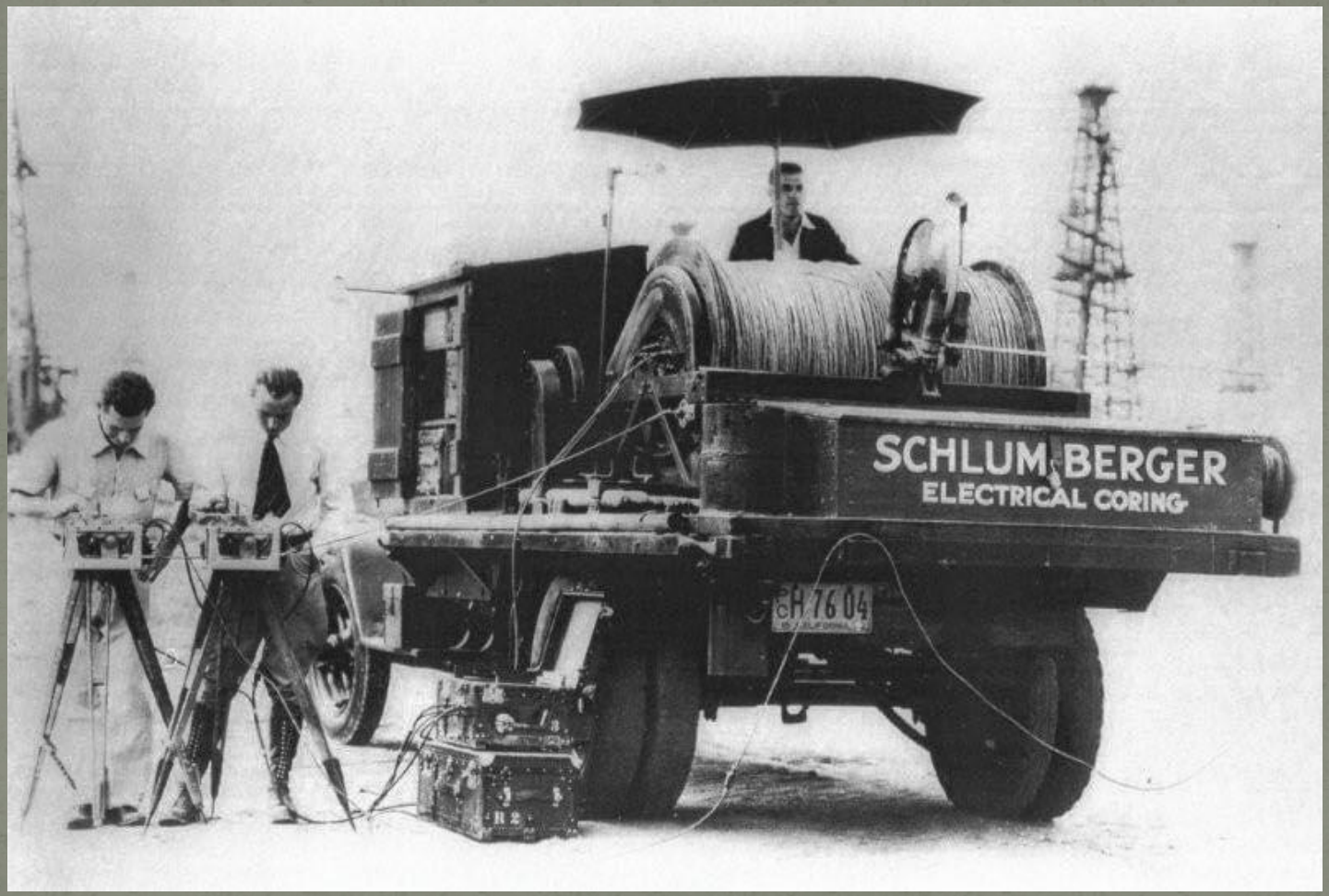
Conrad (1878 – 1936) and Marcel (1884 – 1953) Schlumberger

The Early Years

Doesn't Everyone Like Winter!

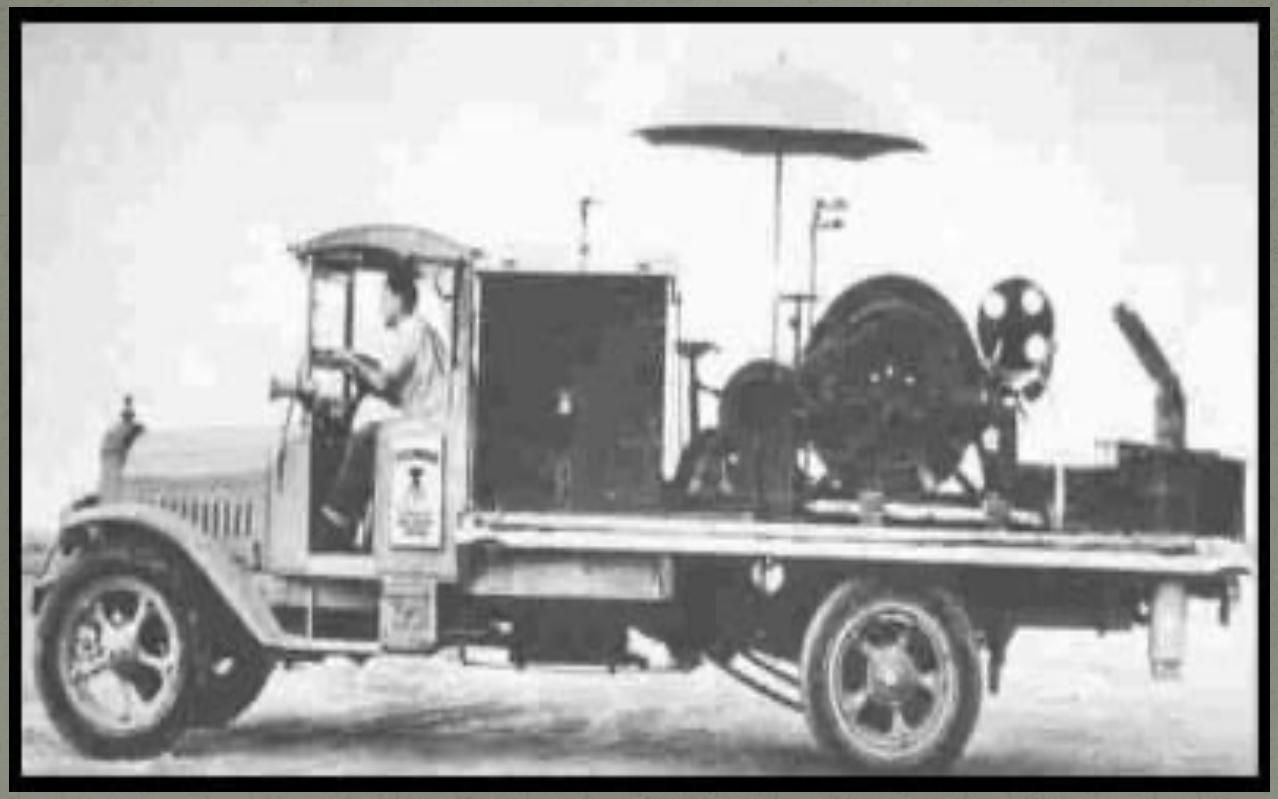
In the Beginning, 1932

I Hope It Doesn't Rain Hard



Improving, 1934

Long Time Ago



The Early Years, 1937

Better Yet

Improving, 1930's – 1950's

Long Time Ago, 1937 Cased

Wireline Logging Trucks

Many Shapes and Sizes, 1942 Model

Wireline Logging Trucks

What Do You Have in Your Trunk?

Wireline Logging Trucks

1950's – 1960's

Wireline Logging Trucks

Cased Hole Trucks, Ye Ole 'Bread' Truck

Wireline Logging Trucks

Cased Hole Truck

Wireline Logging Trucks

1970's – 1990's

Wireline Logging Trucks

Today; Light Duty

Wireline Logging Trucks

Today; Heavy Duty

The Back

Cables, Cables and More Cables

Wireline Logging Trucks

Offshore Unit

The Recorder Cab

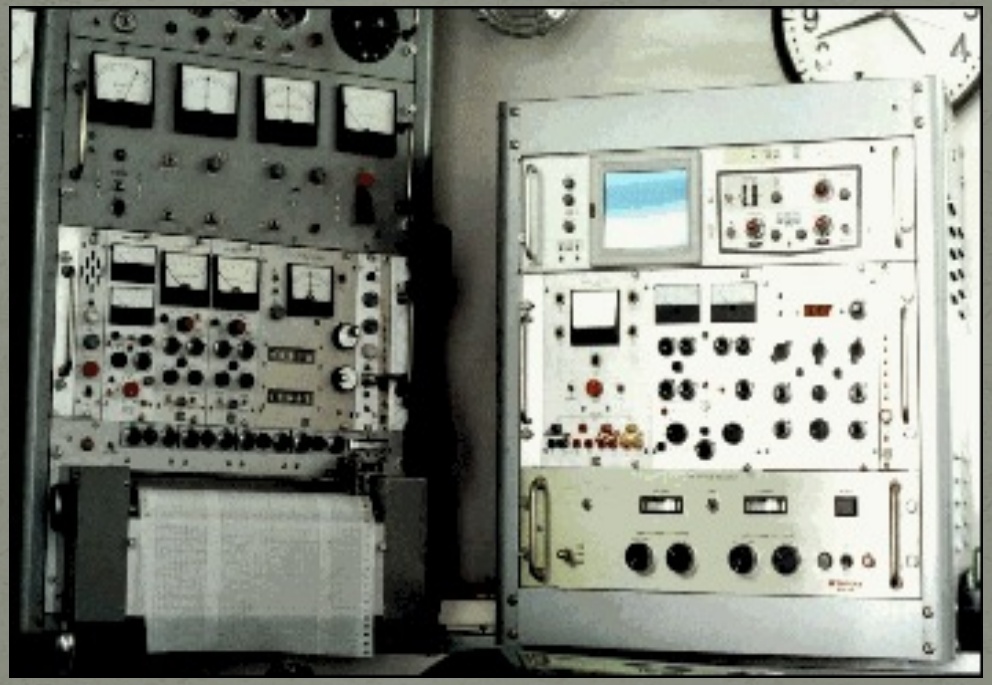
Smoking Was Mandatory

The Recorder Cab

Cased Hole

The Recorder Cab

Early Open Hole



The Recorder Cab

Tape Drive, Storing Data

The Recorder Cab

Open Hole/Cased Hole

The Recorder Cab

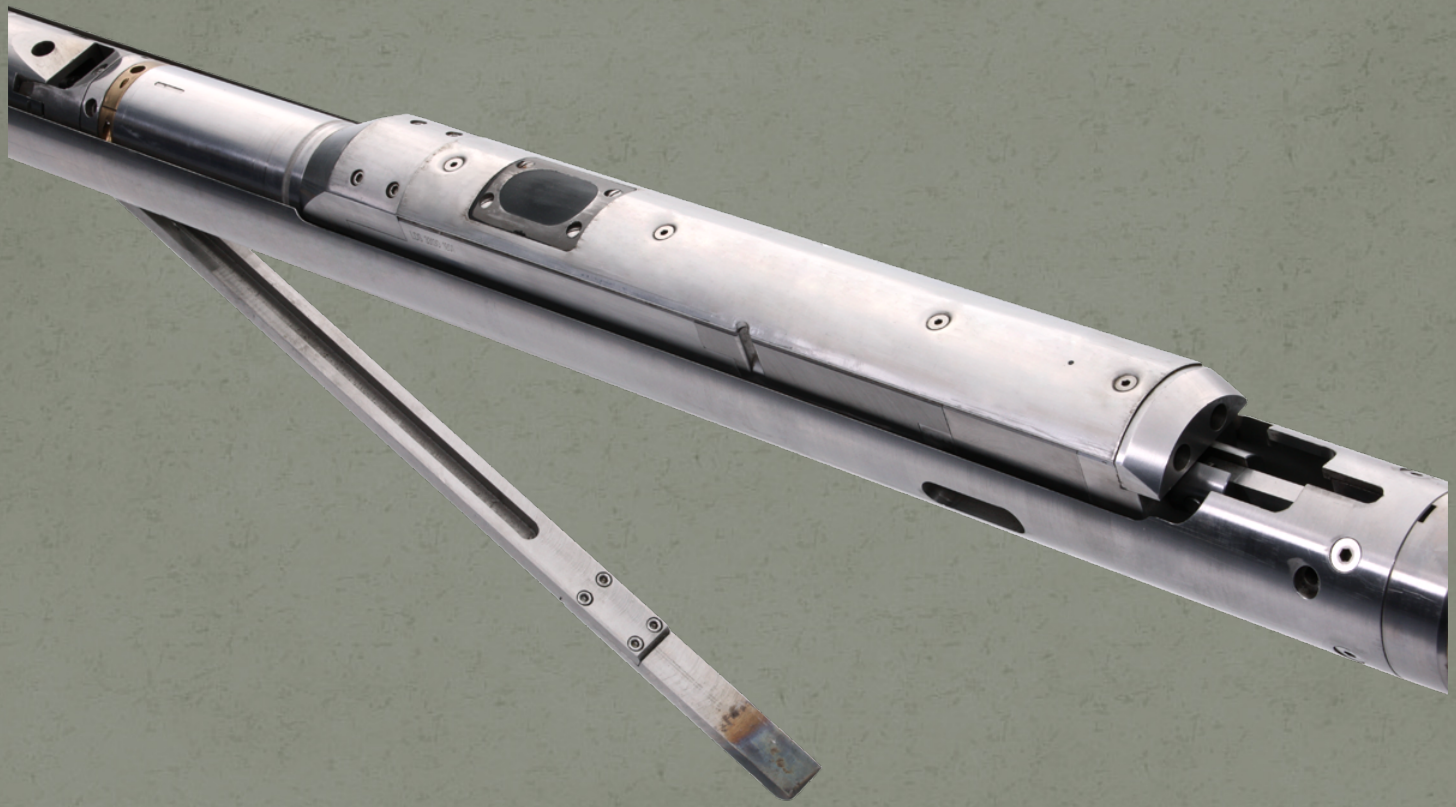
Today, All Digital

Logging Tools

The Outside; Multiple Logging Sondes

Logging Tools

Compensated Density With Pe



Logging Tools

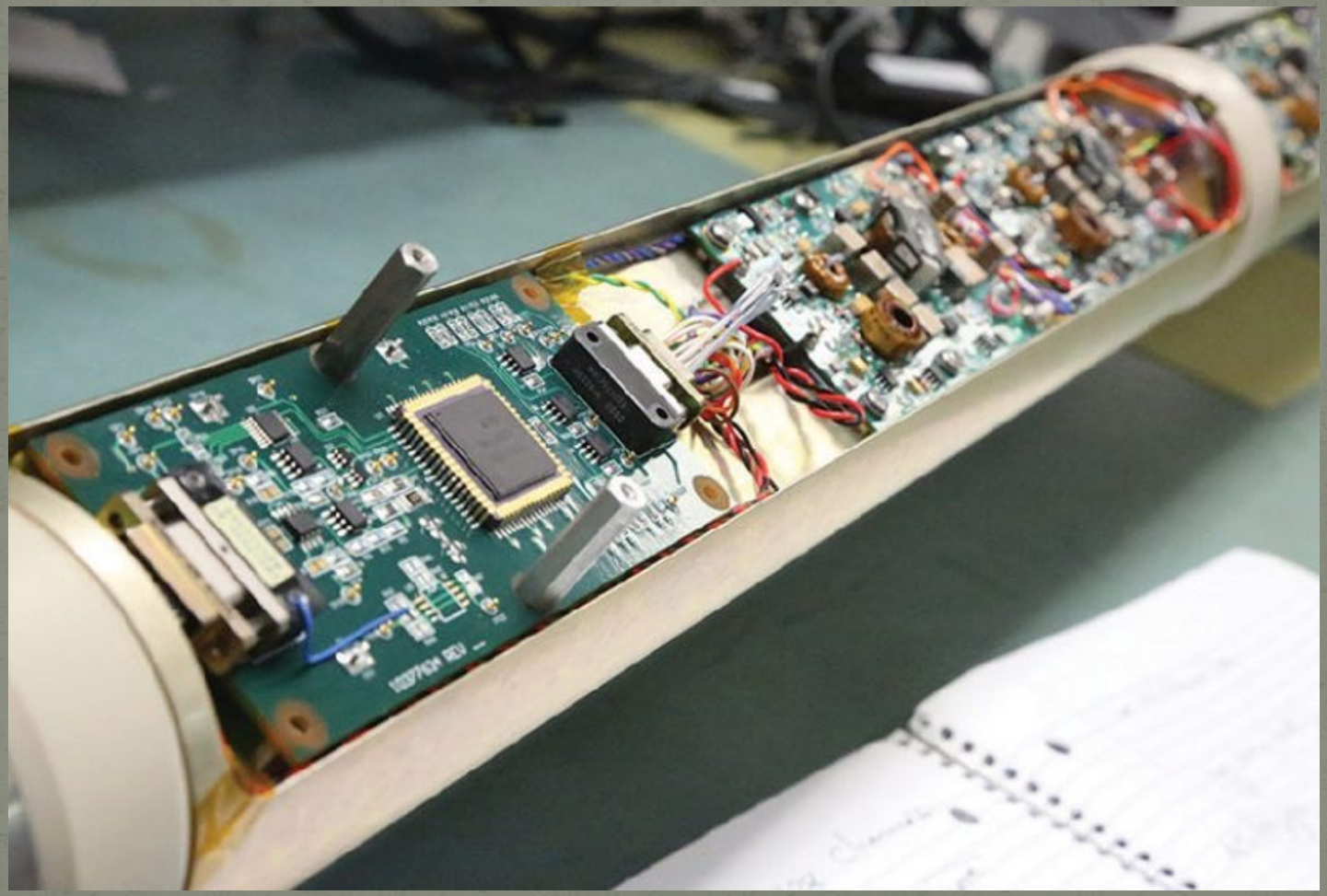
Formation Micro-Scanner

In The Olden Days

Internal Boards Had Resister and Capacitor Tubes

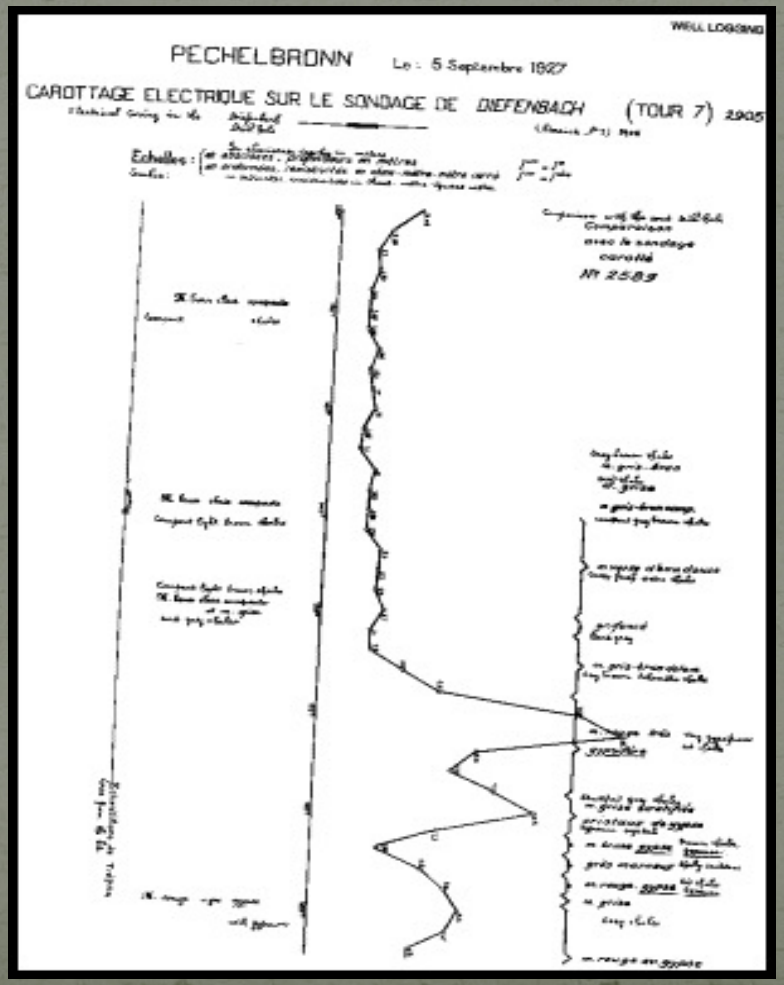
Logging Tools

Circuit Board, No More Tubes



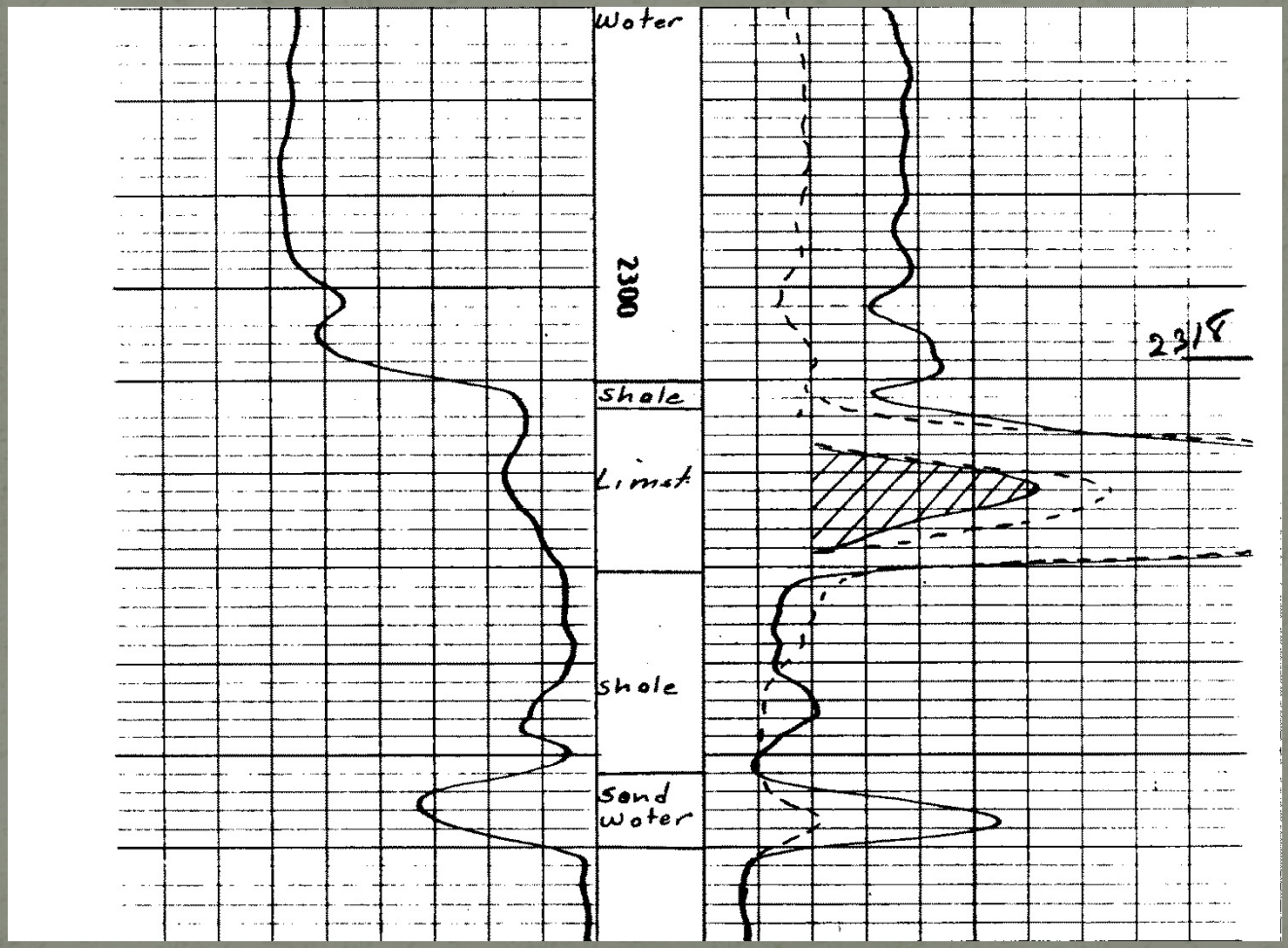
September 5, 1927 - An Industry Was Born, Recorded by Henri Doll

The First Log; Dot to Dot



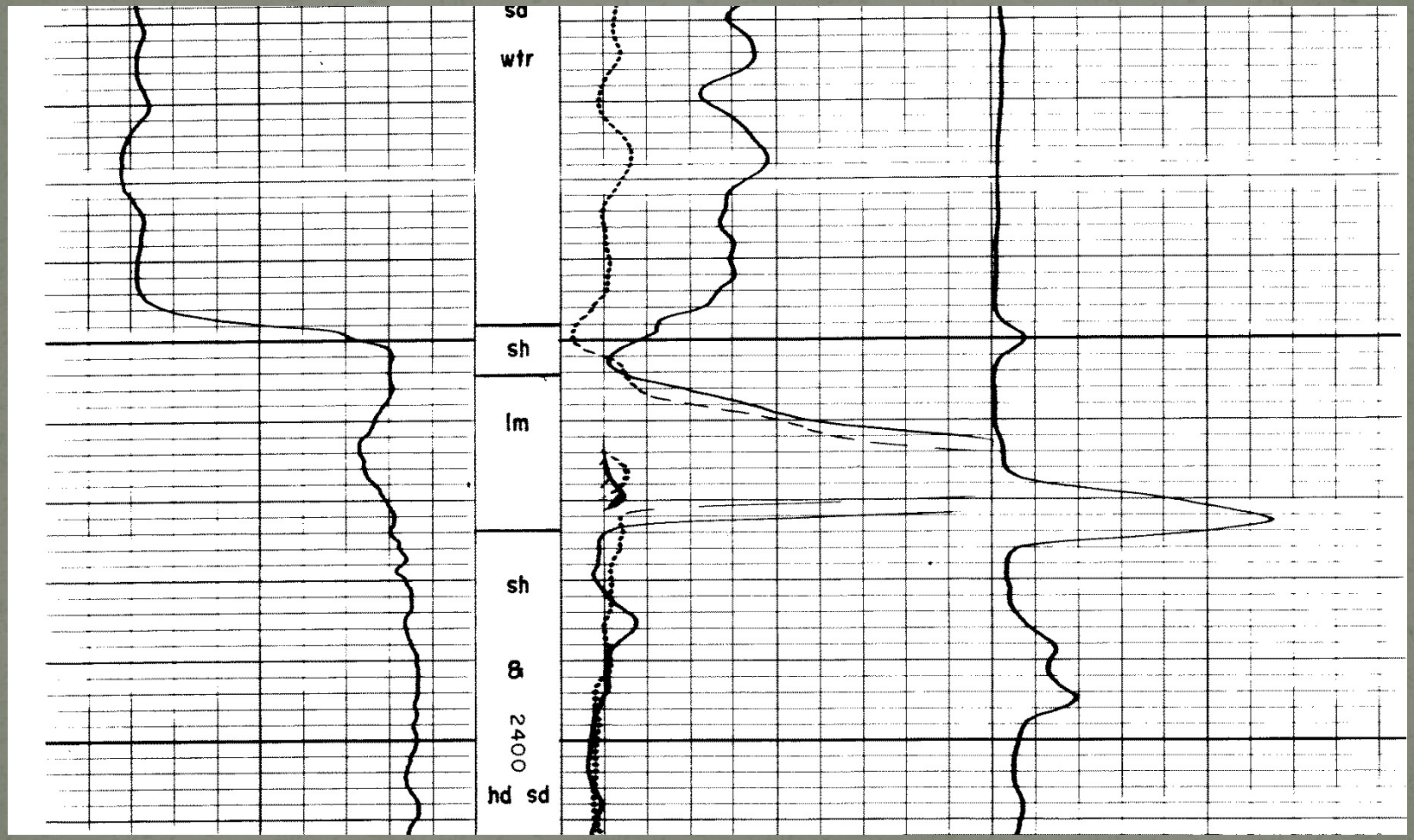
Logs

Early On; 1930's and 1940's – First Electric Logs



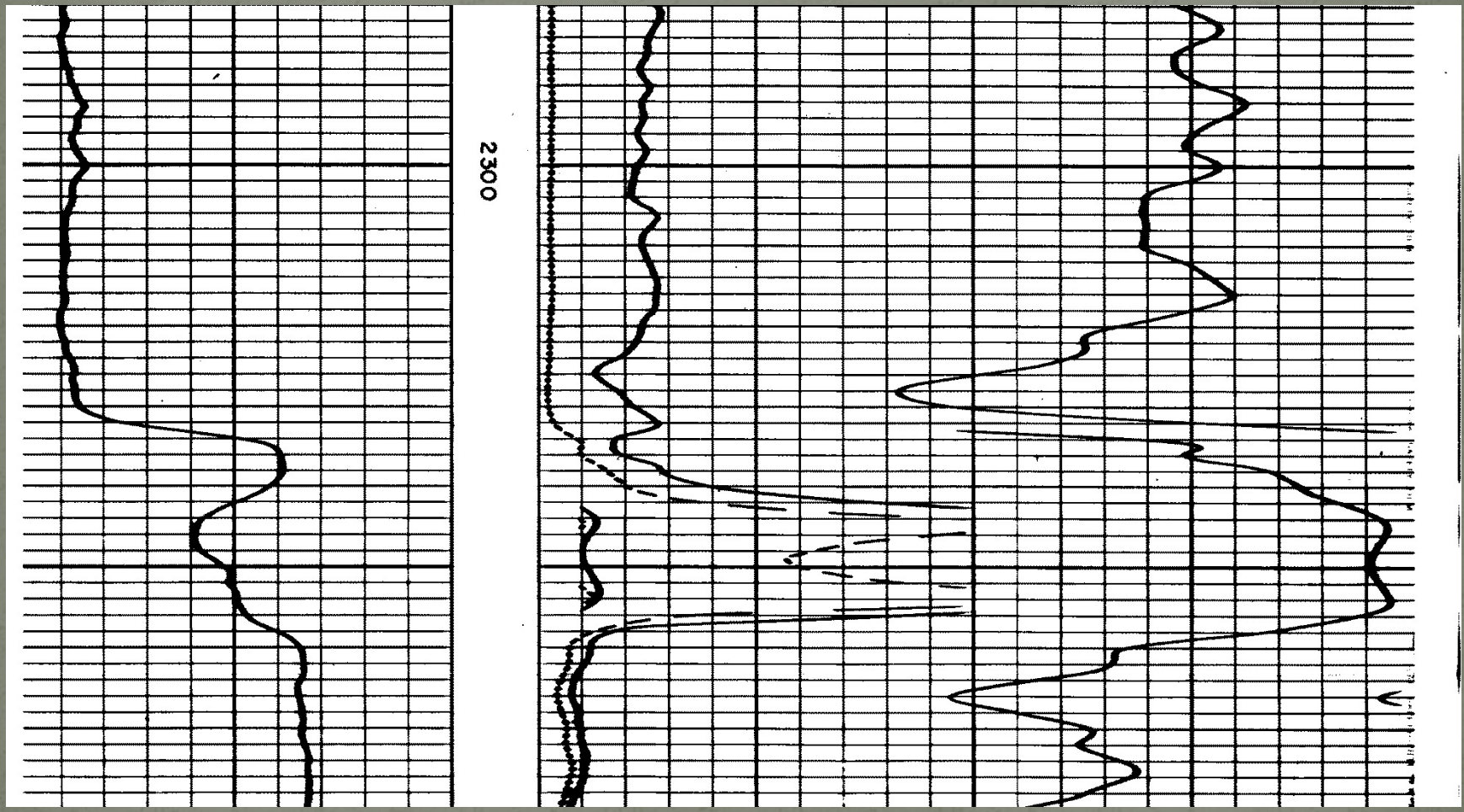
Logs

1940's through 1950's - Later Electrical Logs



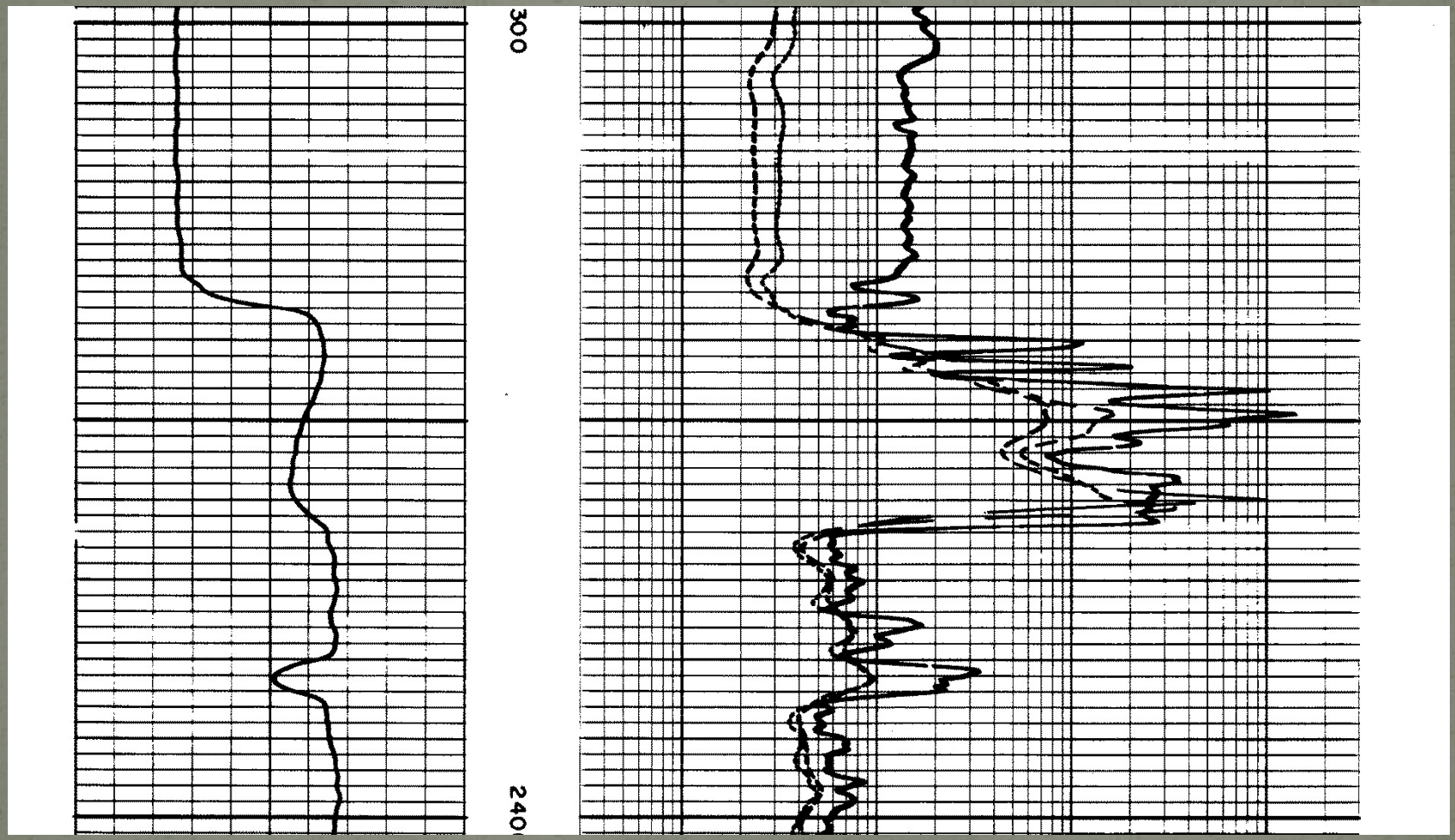
Logs

1950's - 1990's - Induction Log



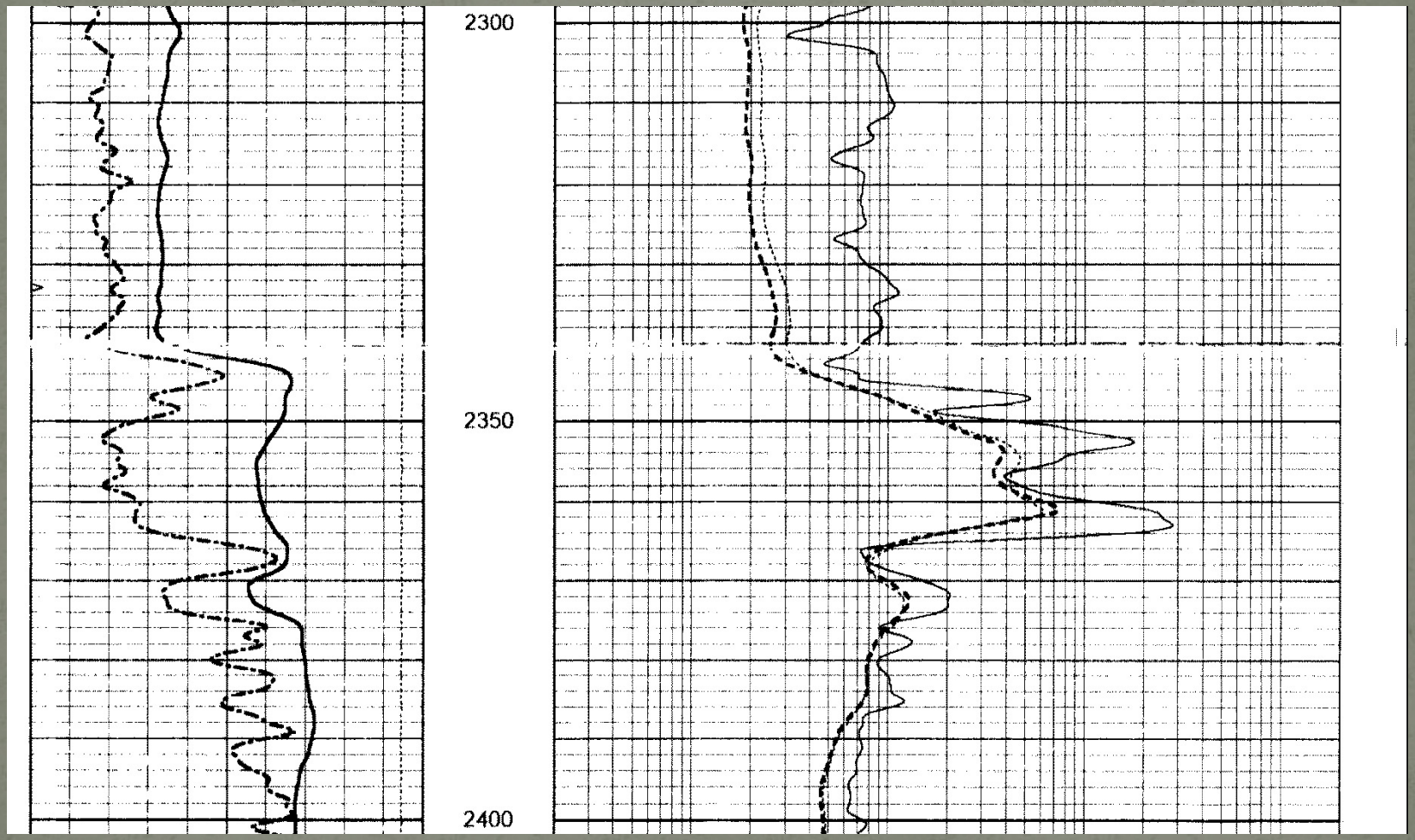
Logs

1978 to Today – Dual Induction Logs



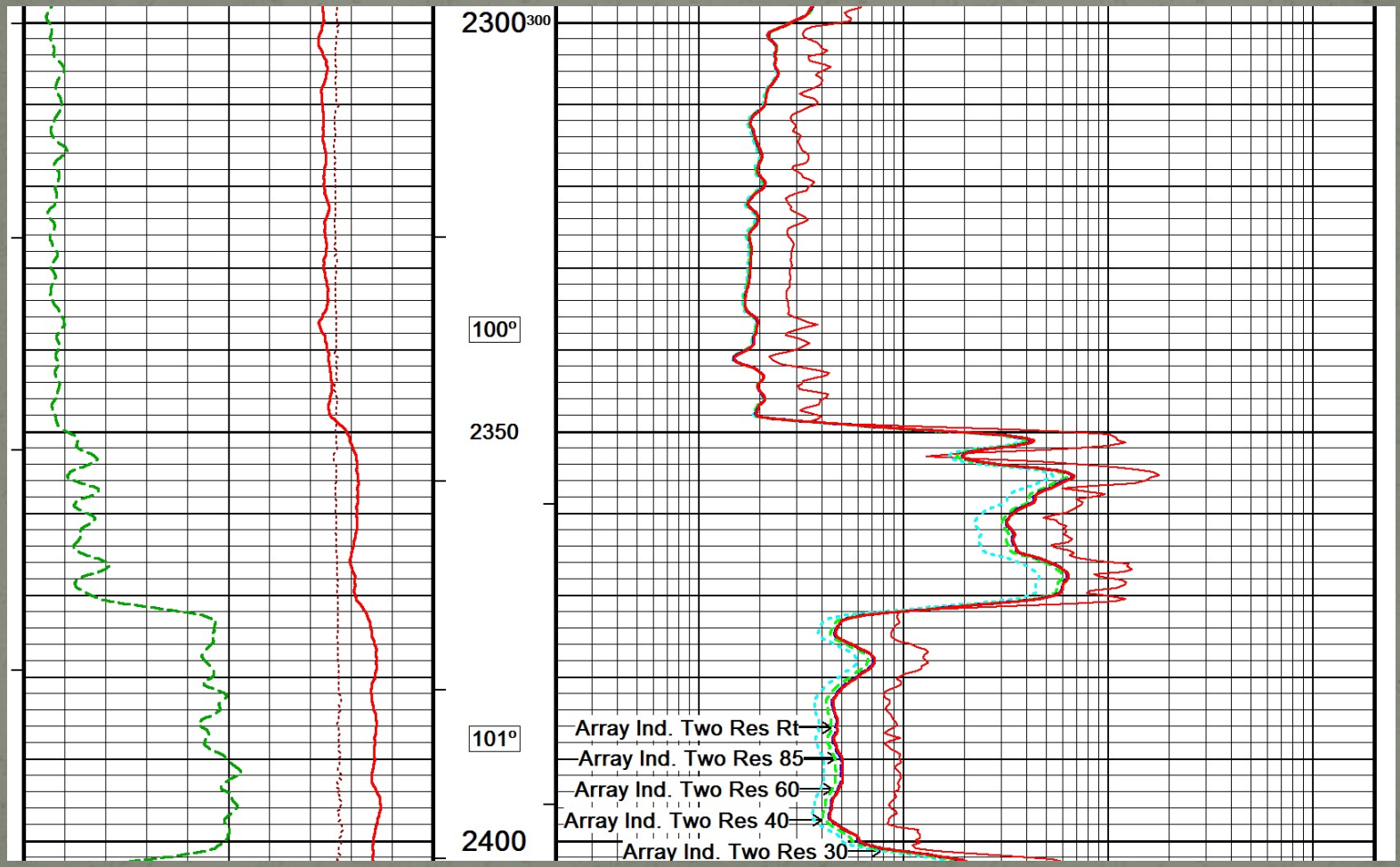
Logs

2000's to Today – Early Array Induction Logs



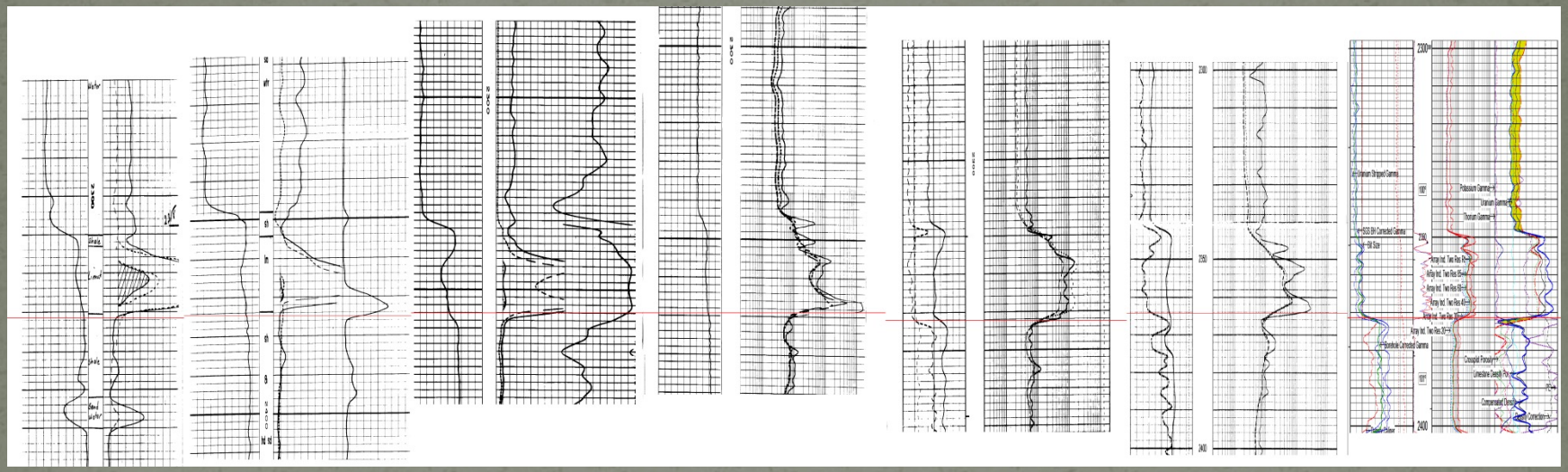
Logs

2020 – Array Induction Log



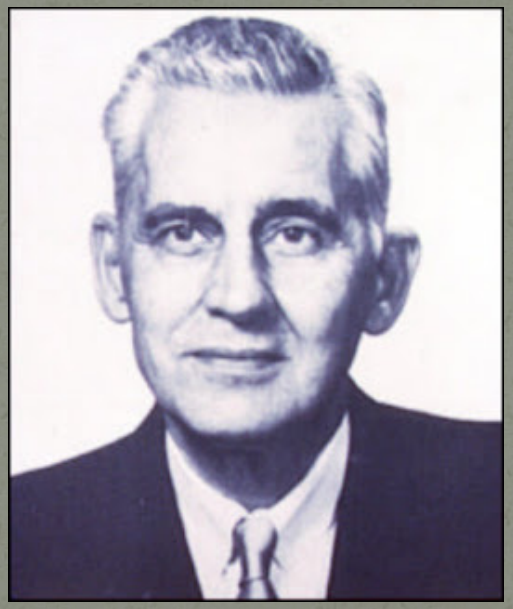
Logs

Then and Now, 1940 - 2020



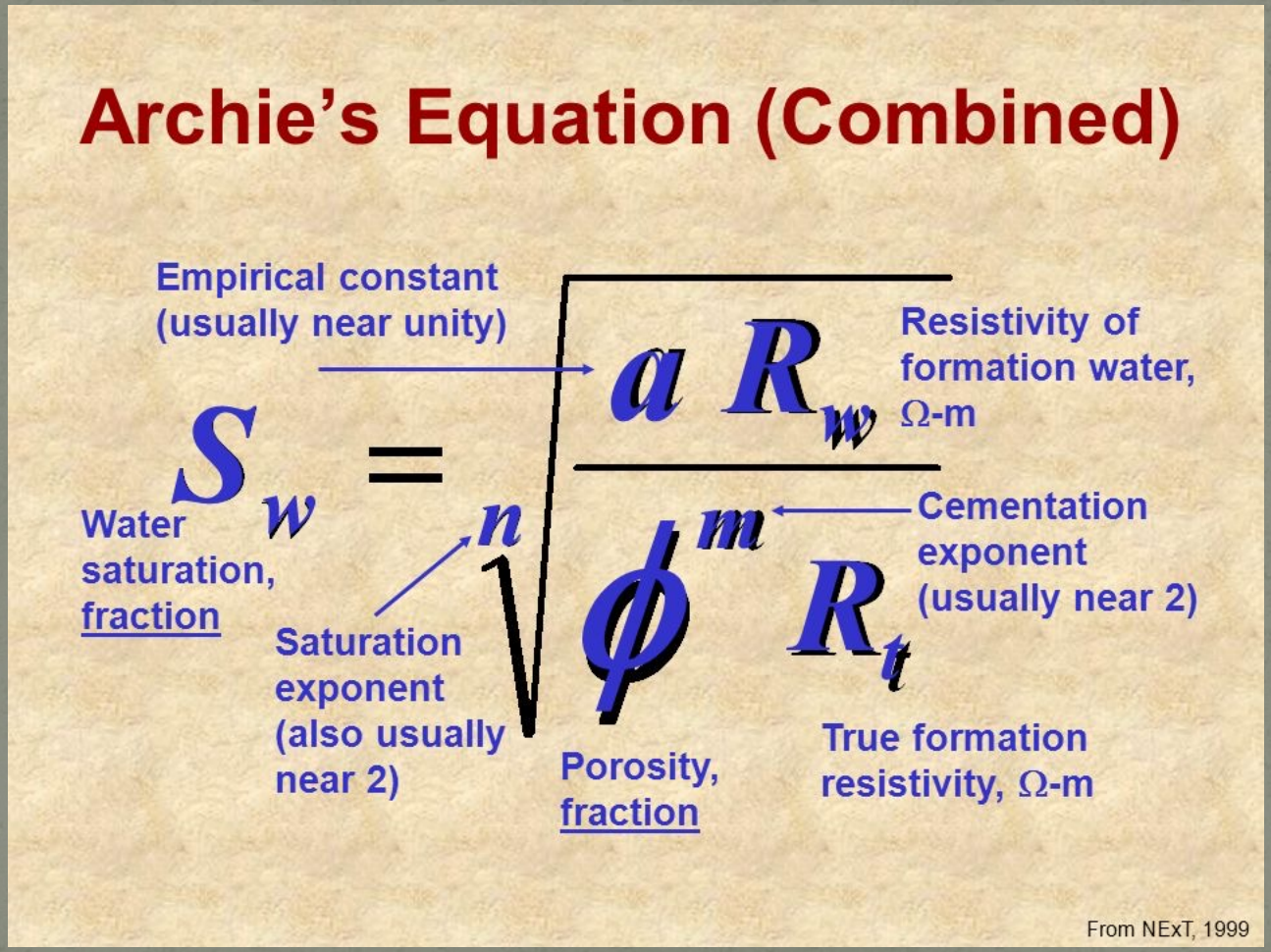
Sw, The Man Responsible

Gustavus Archie, Shell Oil (12/1901 – 1/1988)



The Archie Equation

Simple Equation Relating Formation Parameters



Logs…Why Do We Run Them

To Find Sw, Water Saturation of the Formation

TABLE 25.1 - continued

BASIC MODELS	MATHEMATICAL RELATIONSHIPS	INVESTIGATORS	REMARKS
Dispersed Clay	$\frac{1}{R_t} = \frac{V_{cl}}{R_{cl}} S_w + \frac{\phi^m}{a R_w} S_w^2$ For n = 2.0 and Humble equation: $S_w = \left(\frac{0.4 R_w}{\phi^2}\right) \left\{ \frac{-V_{cl}}{R_c} + \sqrt{\left(\frac{V_{cl}}{R_{cl}}\right)^2 + \frac{5\phi^2}{R_t \times R_w}} \right\}$	Simandoux, 1963	
Dispersed Clay	$\frac{1}{R_t} = \frac{V_{cl}^d}{R_{cl}} S_w + \frac{\phi^m}{a R_w (1 - V_{cl})} S_w^2$		Where d ranges from 1.0 to 2.0 Usually d = 2.0
Dispersed Clay	$S_w = \frac{1}{\phi_e} \left\{ \left(\frac{0.8 R_w}{R_t}\right)^{\frac{1}{n}} - \left(\frac{R_w V_{cl}}{R_{cl}}\right)^{\frac{1}{n_1}} \right\}$	Fertl et al, 1971	Variable saturation exponent for sand ($n \cong 2.0$) and clay component ($n_1 \cong 1.0$). Hence, $n \gg n_1$.
Dispersed Clay	$\frac{1}{R_t} = \frac{V_{cl}}{R_{cl}} S_w + \frac{\phi^m}{a R_w} S_w^n$	Poupon et al, 1971	Modifications of the Simandoux equation, where d = 1.0 to 2.0 for formation water salinities exceeding 50,000 ppm salinities. Too pessimistic S_w-values for $V_{cl} \geq 20$ to 25%.
	$\frac{1}{R_t} = \left\{ \frac{V_{cl}^e}{\sqrt{R_{cl}}} S_w + \frac{\phi^{0.5m}}{\sqrt{a R_w}} \right\} S_w^{0.5n}$		Where e = (1.0 − 0.5 V_{cl}). For brackish formation water environments.
Dispersed Clay	$\phi_{DL} = \phi_e + X_1 \cdot V_{cl}$ $\phi_{AC} = \phi_e + X_2 \cdot V_{cl}$ $S_w = \frac{1}{\phi_e} \left\{ \sqrt{\frac{R_w}{R_t} + \left(\frac{a V_{cl}}{2}\right)^2} - \frac{a V_{cl}}{2} \right\}$	Fertl, 1975	Where: $X_1 = \frac{\rho_{ma} - \rho_{sh}}{\rho_{ma} - \rho_{fl}}$ shale correction factor for Density response; a function of the sand matrix density (ρ_{ma}), shale density (ρ_{sh}), and fluid density (ρ_{fl}) of the mud filtrate. $X_2 = \frac{\Delta t_{sh} - \Delta t_{ma}}{\Delta t_{fl} - \Delta t_{ma}}$ shale correction factor for Acoustic response; a function of sand matrix travel time (Δt_{ma}), shale travel time (Δt_{sh}), and the fluid travel time (Δt_{fl}). $a = (X_2 - X_1)$. Area experience values for Gulf Coast a = 0.25, Rocky Mountains area a = 0.35. ϕ_e = effective reservoir porosity, corrected for gas, if necessary.
Dispersed Clay	$S_w^n = \left\{ \frac{R_t}{F \times R_w} \right\}^{-1} \left[\frac{-(1 + R_w \cdot B \cdot Q_v)}{2} + \sqrt{\left(\frac{1 + R_w \cdot B \cdot Q_v}{2}\right)^2 + \frac{R_w \times B \times Q_v}{S_w}} \right]$ $Q_v = CEC (1 - \phi) \times \rho_{ma} \times \phi^{-1}$	Waxman & Smits, 1968 Waxman & Thomas, 1974	Applicable over entire range of formation water salinities. Q_v = concentration of counter ions in formation water in contact with clays (meq/ml). Function of cation exchange capacity (meq/gm). B = equivalent conductance of clay exchange cations as function of R_w. Core-derived Q_v-values can be empirically correlated to porosity ($Q_v = 3.05 \times 10^{-4} \times \phi^{-3.49}$, Jurassic N-Sea sands), to crossplot data, and natural radioactivity (gamma ray, Spectralog).

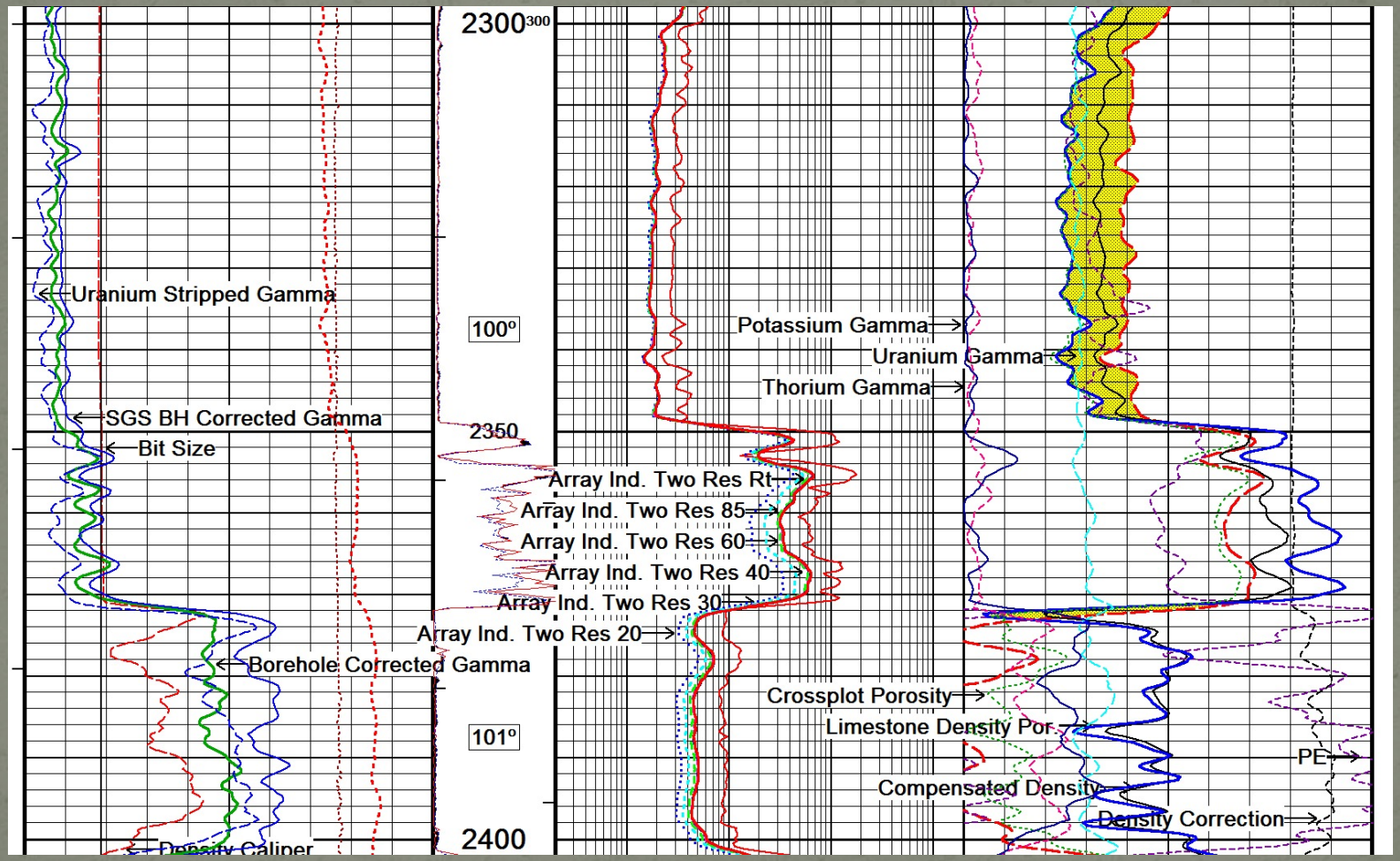
Logs…Why Do We Run Them

To Find Sw, Water Saturation of the Formation

TABLE 25.1 - continued

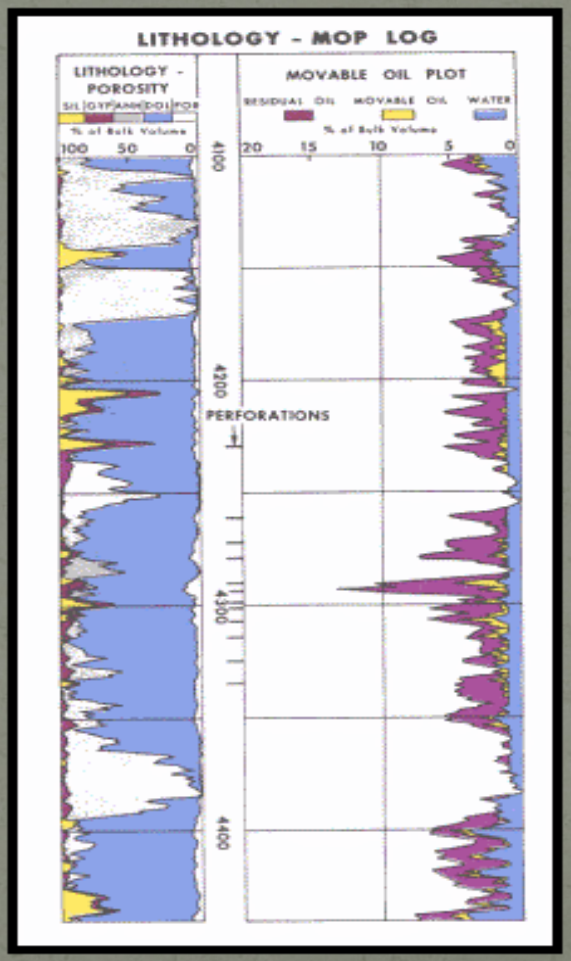
BASIC MODELS	MATHEMATICAL RELATIONSHIPS	INVESTIGATORS	REMARKS
Dispersed Clay	$R_o = F\,R_{FA} \rightarrow R_{FA} = R_o/F$ TOTAL FLUID = BOUND WATER + FREE WATER $\frac{1}{R_{FA}} = \frac{S_{WB}}{R_{WB}} + \frac{1 - S_{WB}}{R_{WF}}$	Clavier et al, 1977	Apparent fluid resistivity (R_{FA}) in clean water sand $R_{FA} = R_t\,\phi_T^2 \rightarrow R_{WF}$ In shales $R_{FA} = R_{sh}\,\phi_T^2 \rightarrow R_{WB}$ S_{WB} is function of shaliness index of reservoir rock. Technique is modification of concepts proposed by Waxman & Smits (1968) and Alger et al (1963) previously.
$(1\text{-}S_{WB})S_{WB}$ FLUID, ϕ_T	$R_o = R_{FA}\,\phi_T^{-2}$		
$\phi_T S_{WB}$	$\phi_T = 0.5\,(\phi_N + \phi_D)$		
	$R_o = \frac{R_{WF}\,R_{WB} \times \phi^{-2}}{R_{WF}\,S_{WB} + R_{WB}\,(1 - S_{WB})}$		
$Si\,O_2$ MATRIX	$S_w = \sqrt{R_o/R_t}$		
	$\phi_e = \phi_T\,(1 - S_{WB})$		
	$S_{WF} = S_W - S_{WB}$		

Logs, A Continuous Graphic Display Of Formation Parameters



Combining The Logging Data

Computer Generated Logs, Middle 1960's



Combining The Logging Data

Computer Generated Logs, 1980's, Atlas PROLOG

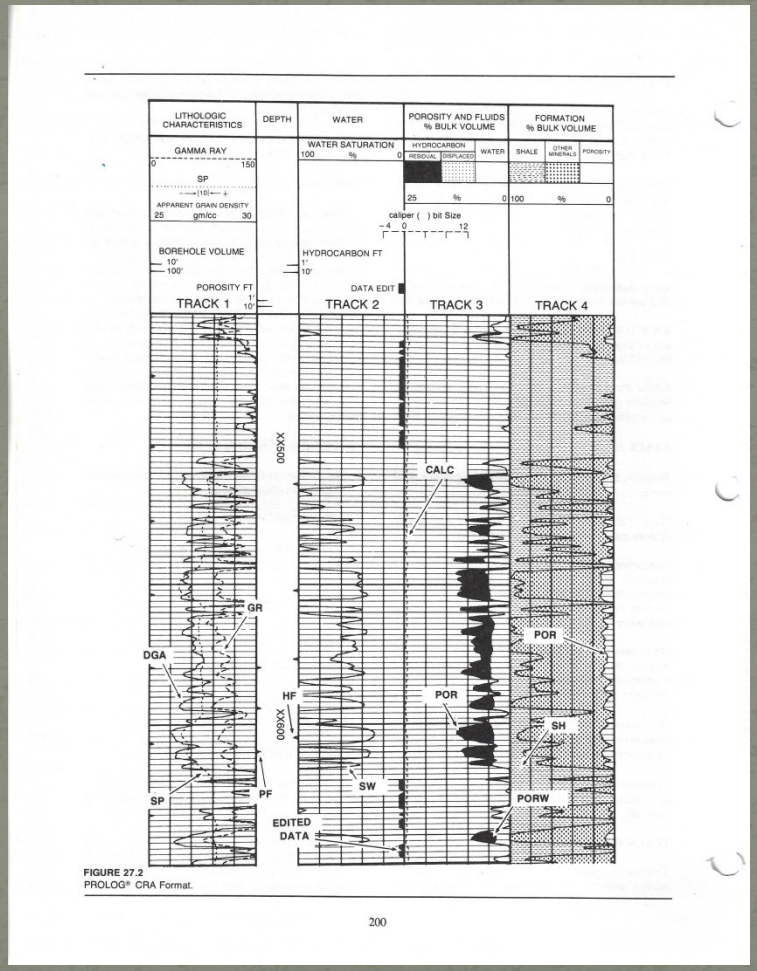
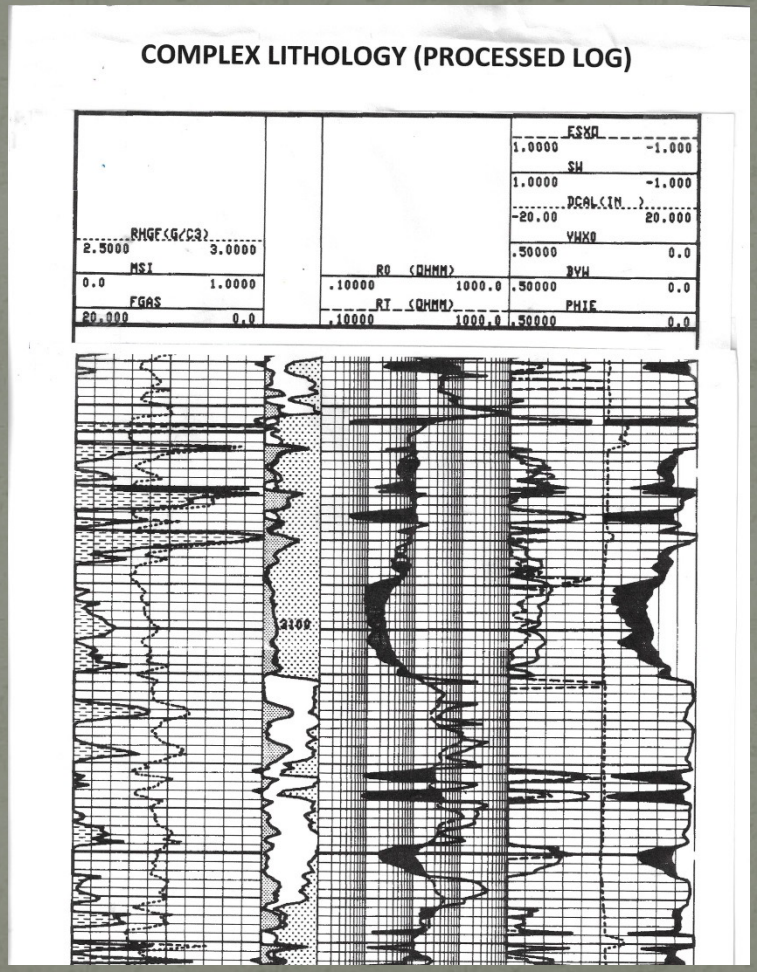


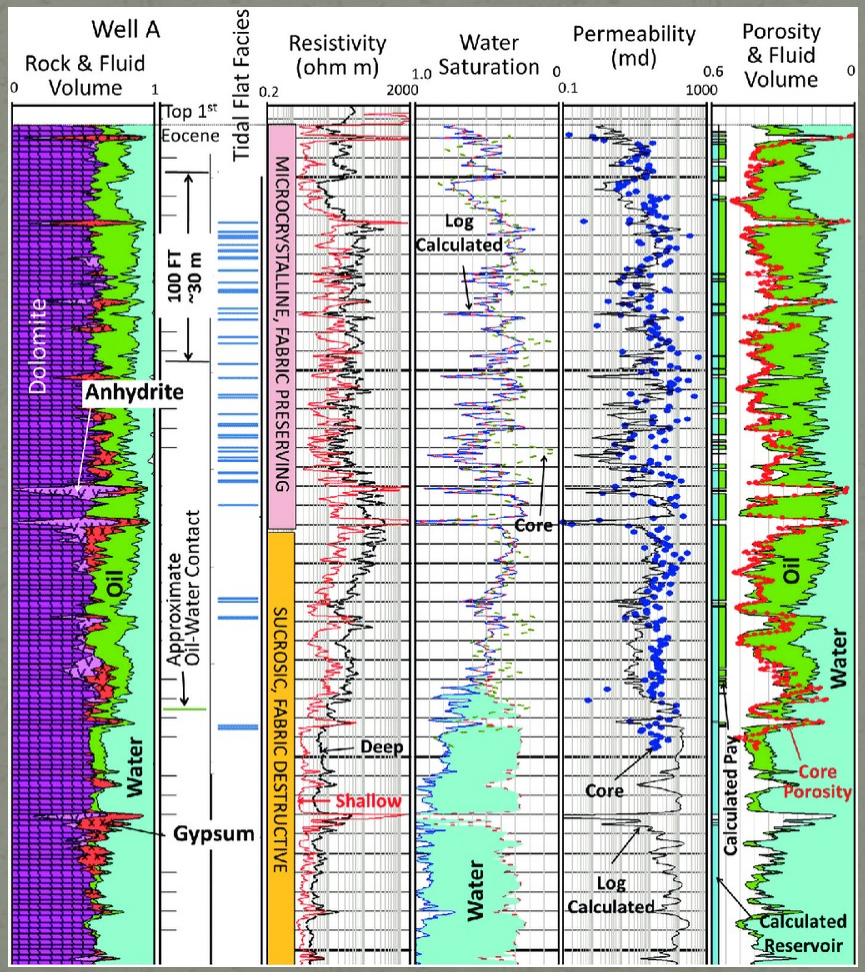
FIGURE 27.2
PROLOG® CRA Format.

Combining The Logging Data Computer Generated Logs, 1980's, SWS CYBERLOOK



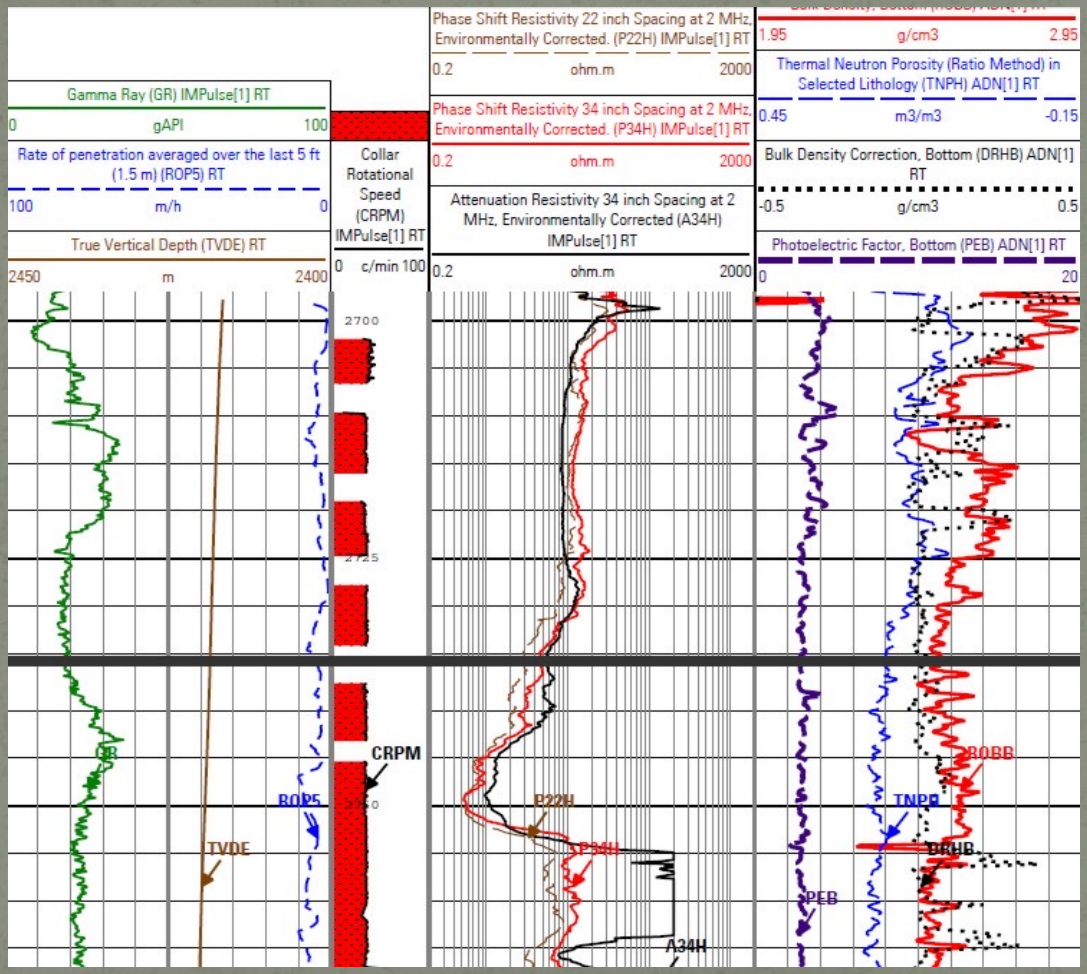
Combining The Logging Data

Today, Computer Generated Logs



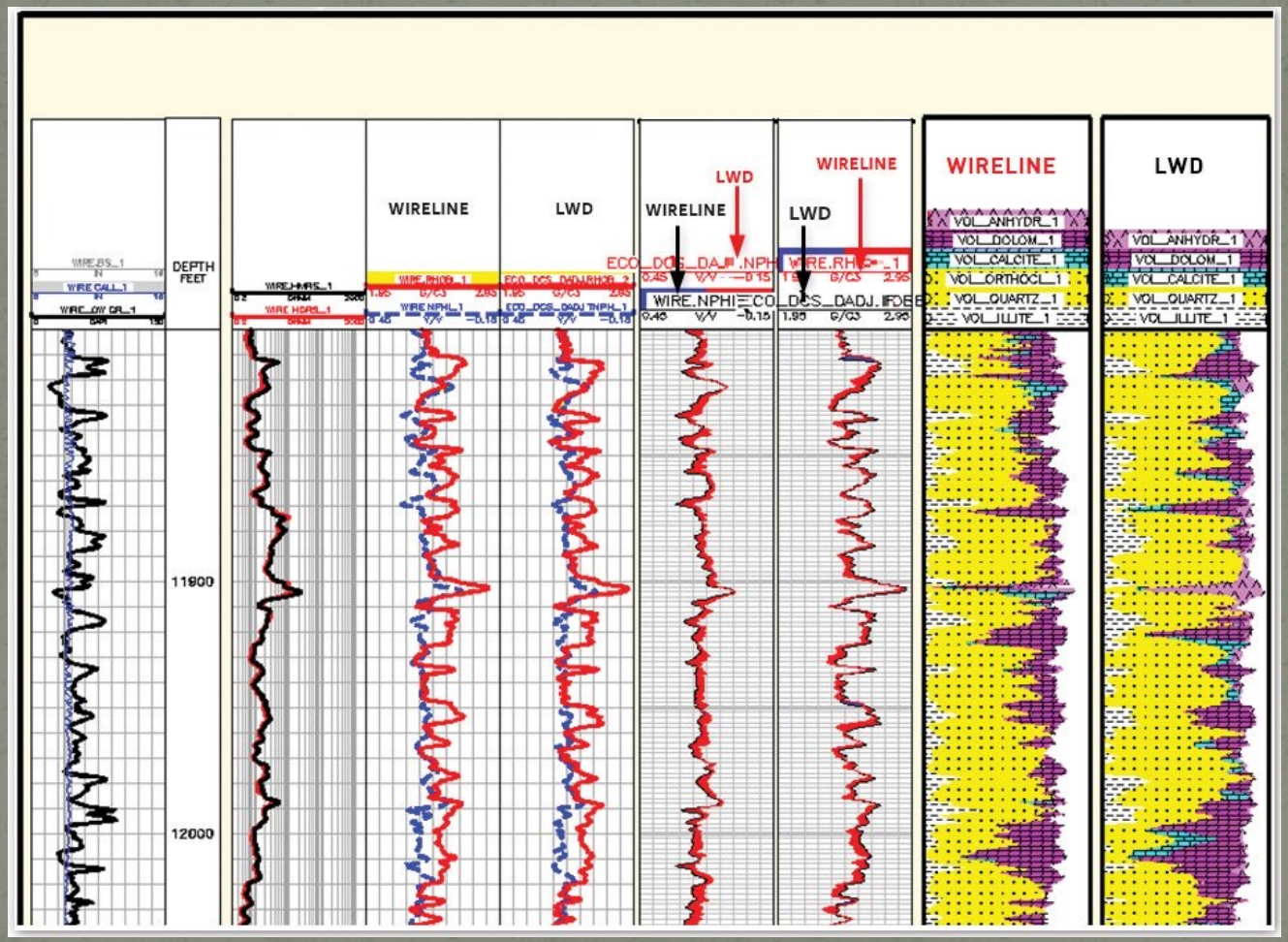
Logs While Drilling

LWD Product



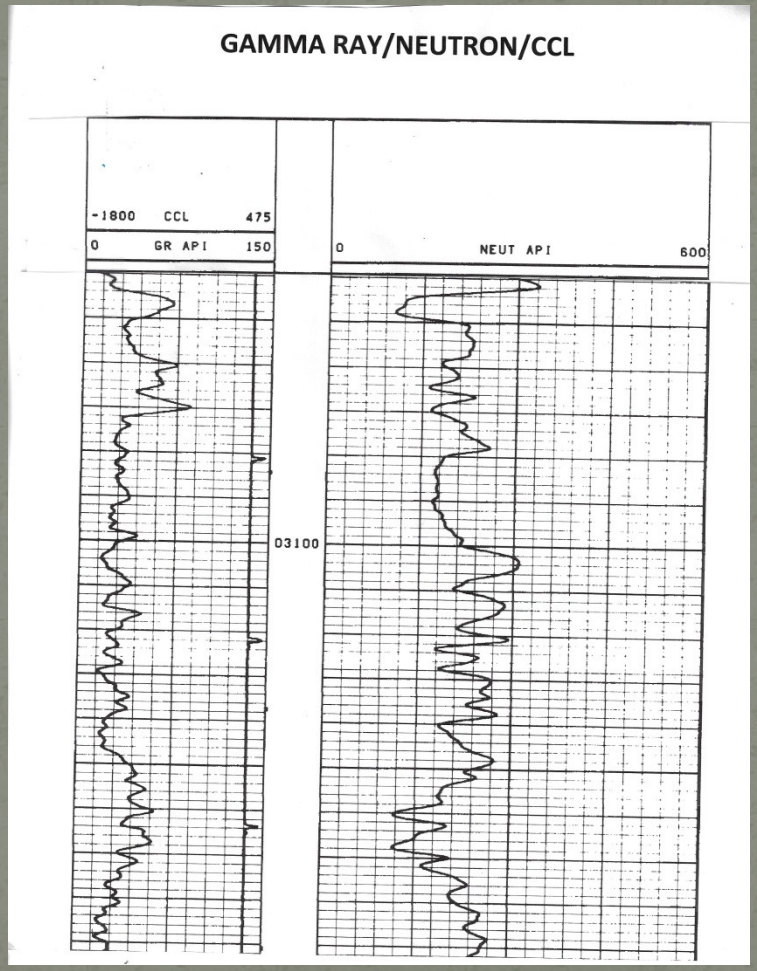
Logs While Drill

Wireline vs. LWD Data Comparison



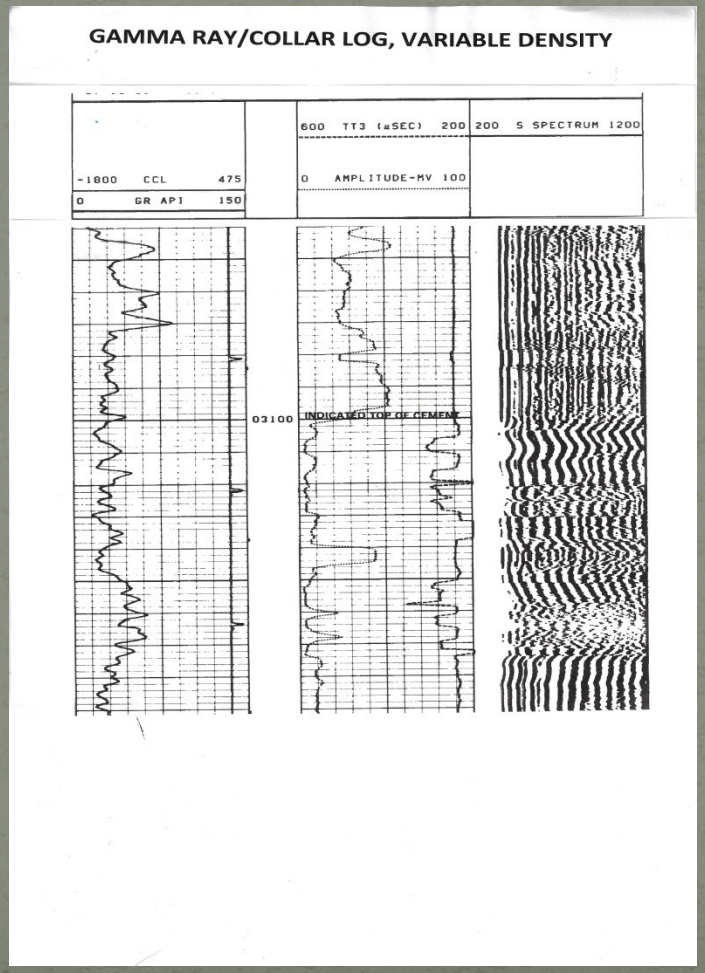
Cased Hole Logs

Cased Hole Gamma Ray – Neutron Tool



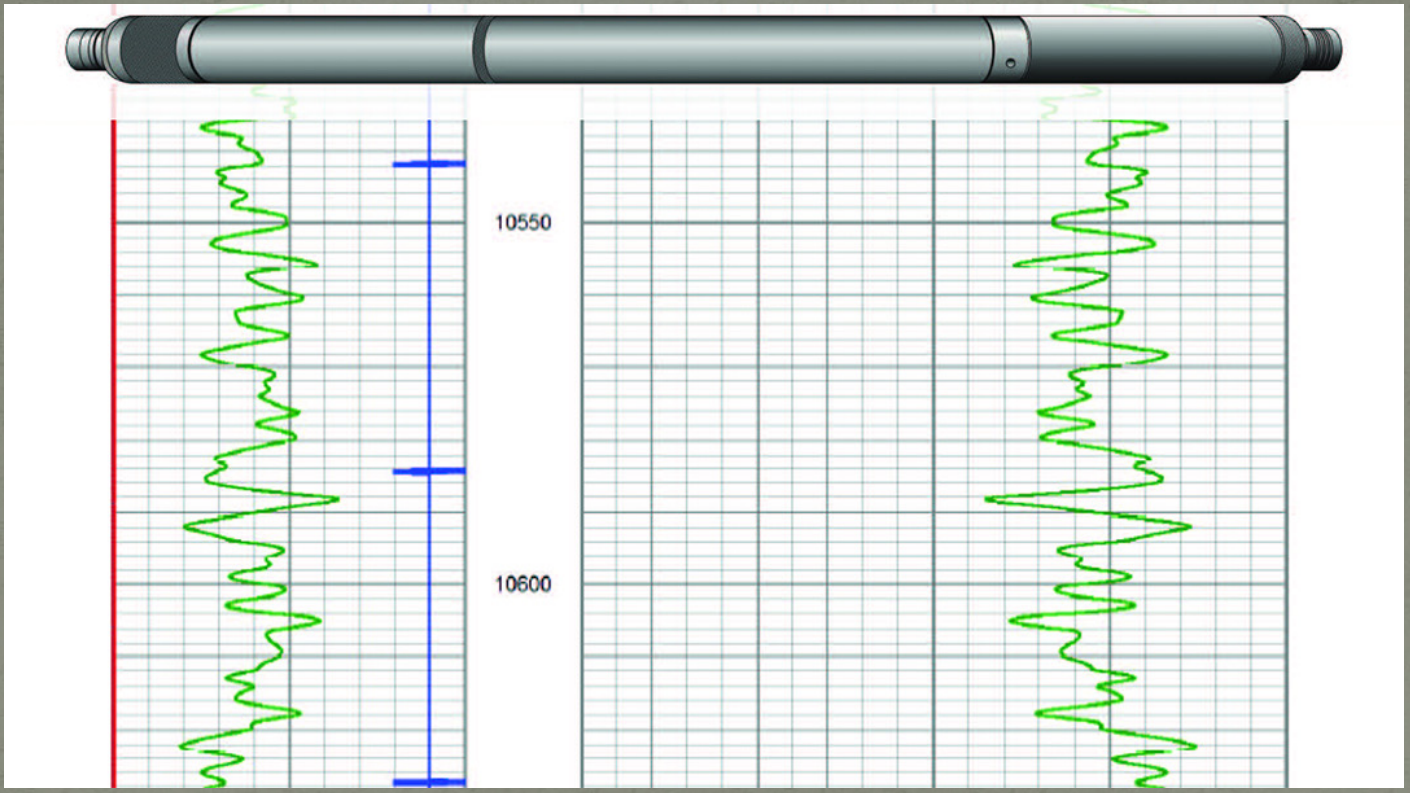
Cased Hole Logs

Cased Hole Gamma Ray - Cement Bond Log-Variable Density Log



Cased Hole Logs

Modern Cased Hole Logging Tool and Log



Completing the Well

Bullet Perforating

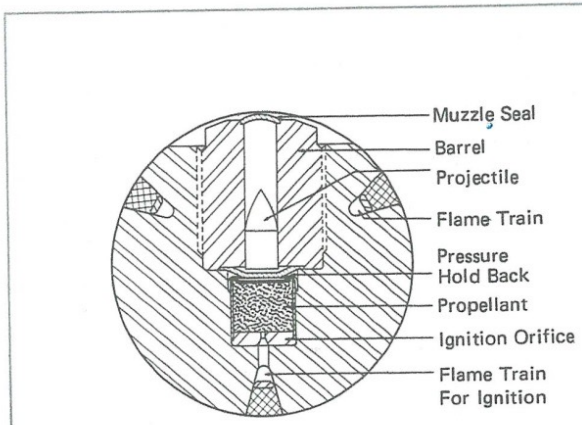
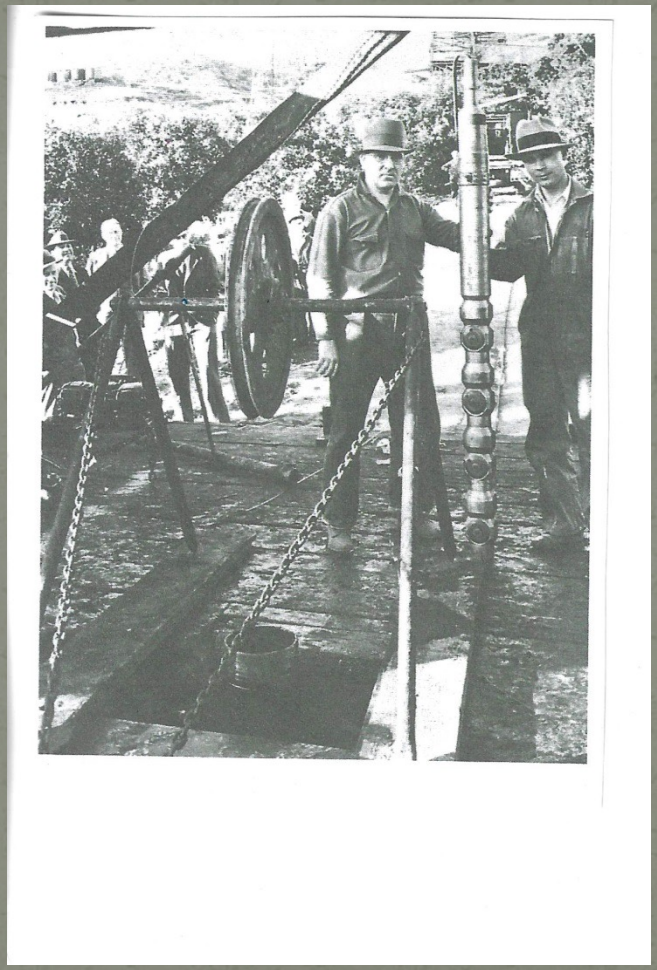


Figure 4. High Pressure Bullet Gun

Completing The Well

Bullet Perforating Guns – The First Job, Lane Wells

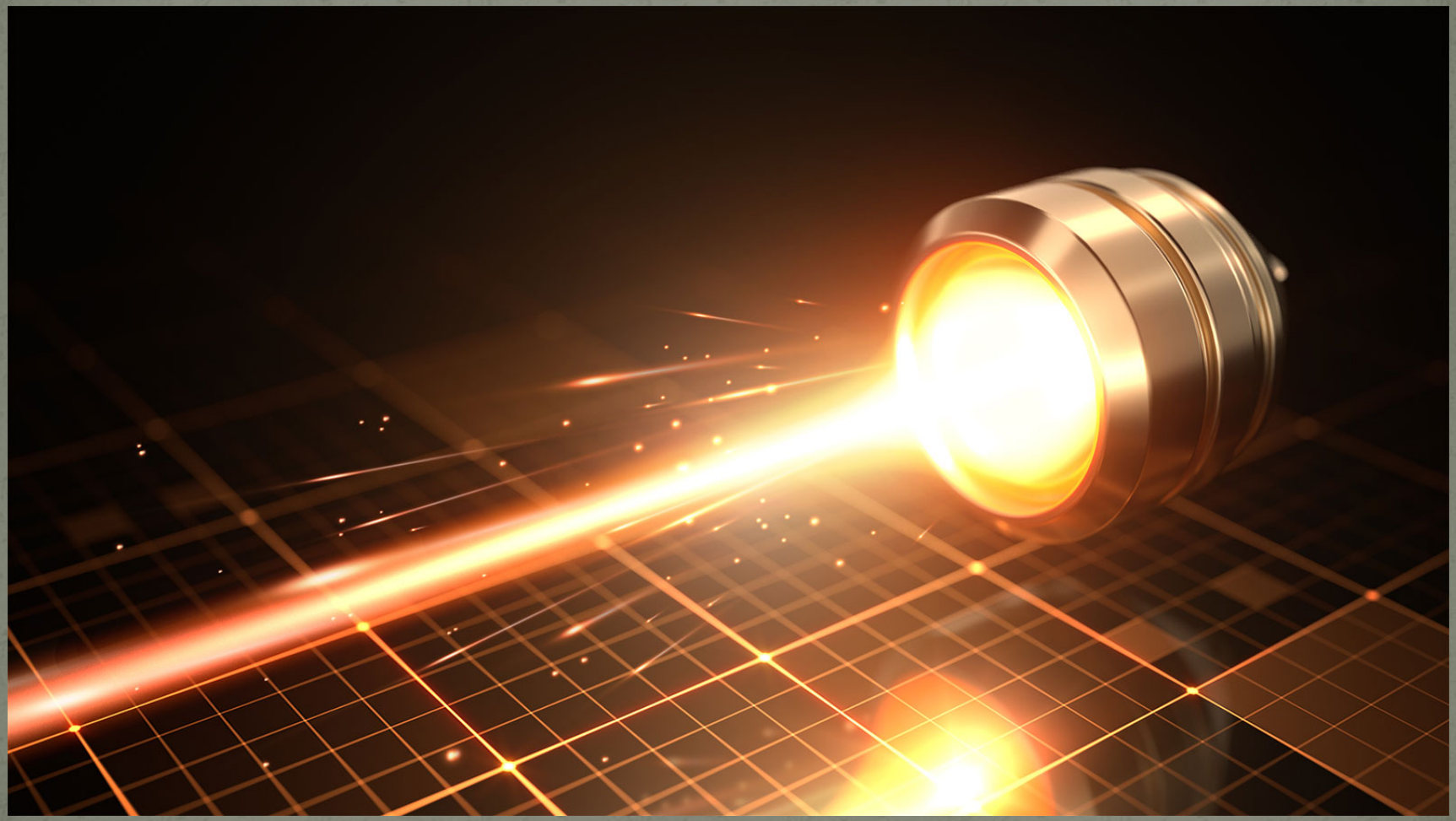


Completing The Well

Perforating Guns – Shaped Charges

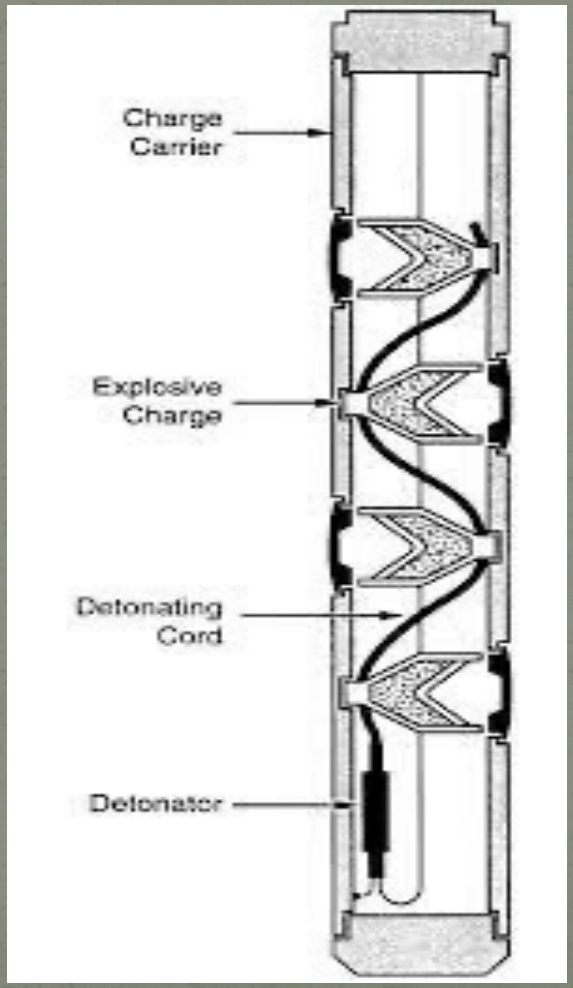
Completing The Well

Shaped Charge Firing



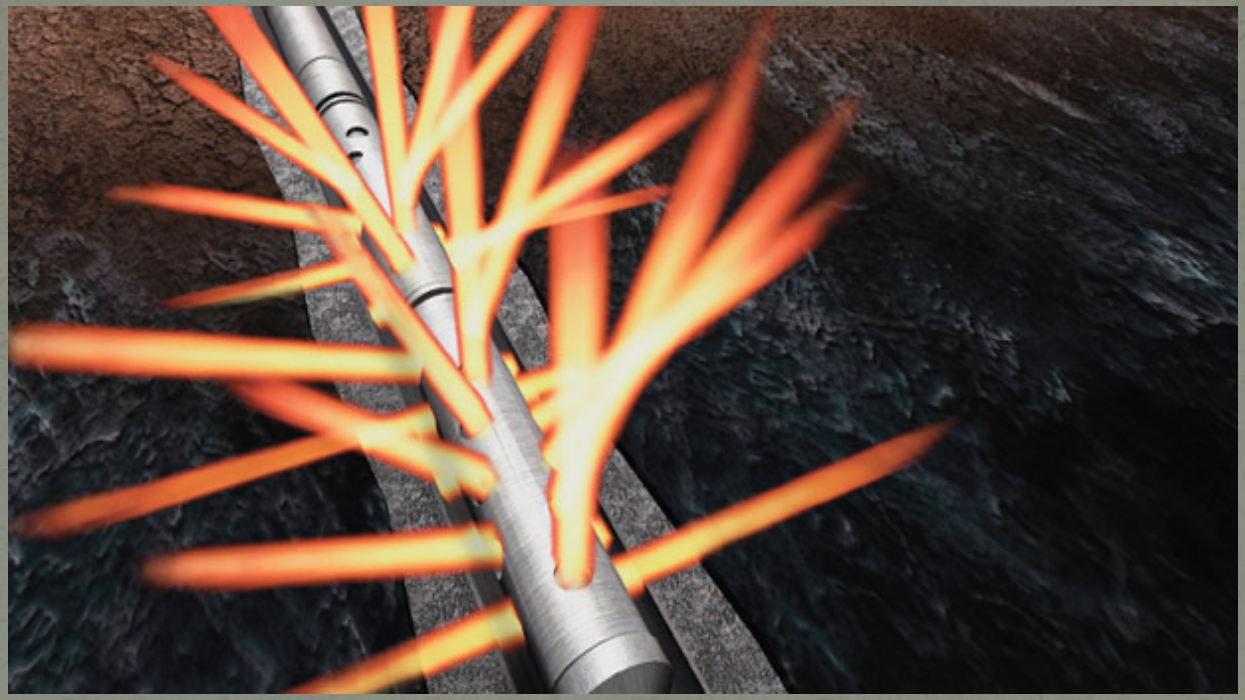
Completing The Well

Perforating Guns – Shaped Charges Secured in Gun



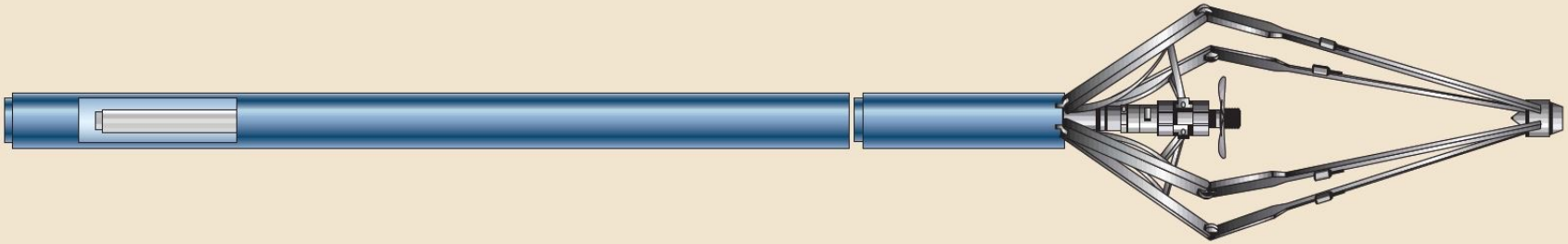
Completing The Well

Perforating Gun Firing Simulation



Cased Hole Logs

Modern Cased Hole Logging Tool



Basic Measurement Sonde

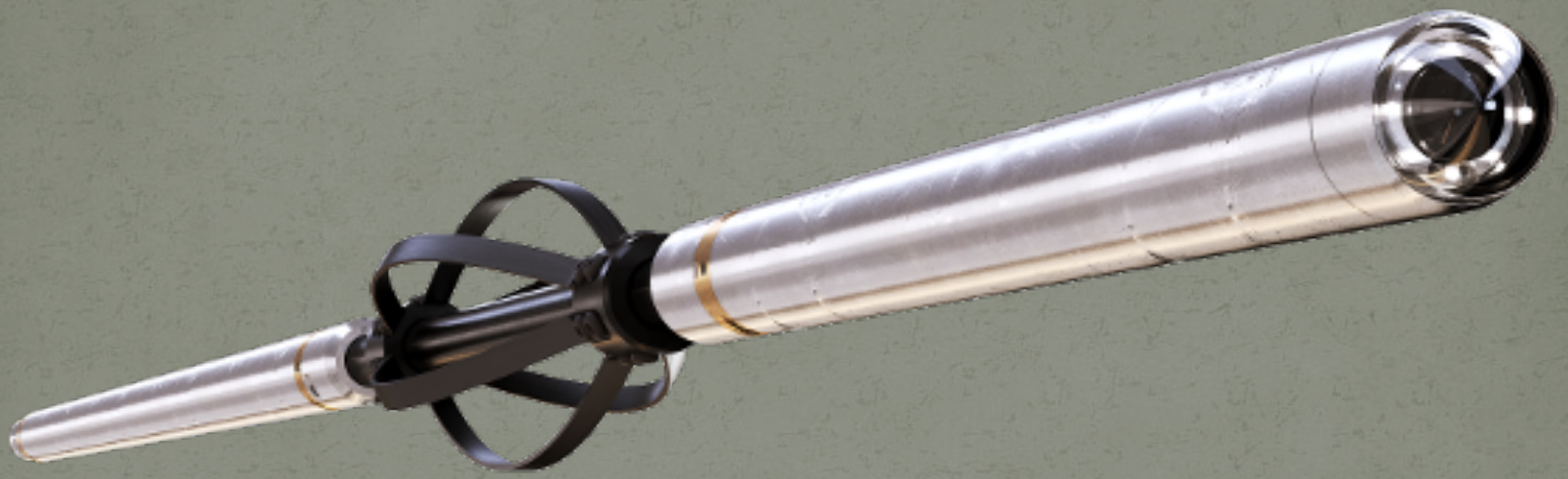
Batteries, recorder, casing collar locator and sensors to measure gamma ray, temperature and pressure

Spinner Flowmeter

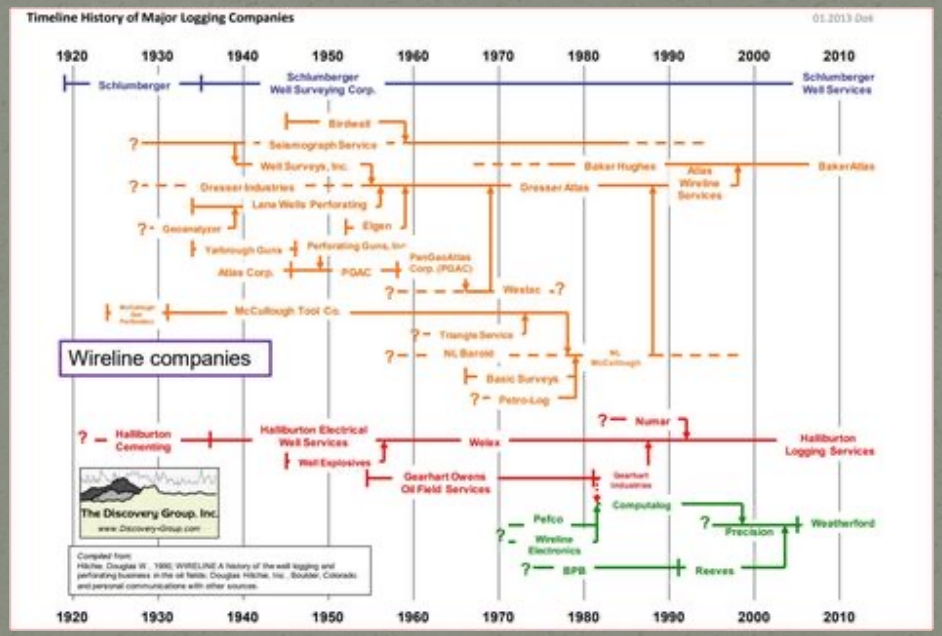
Caliper, water holdup, bubble count, relative bearing, centralizer

Cased Hole Logs

Modern Cased Hole Logging Tool- Camera



Logging Company Timeline



The Story Will Continue