

**KMS Technologies - KJT Enterprises Inc.**

**Presentation**

Strack, K. – M., Chunduru, R., Frenkel, M. A.,  
Mezzatesta, A. G., Zhang, Z.

1999

**Well Log Inversion Review: Limits &  
Possibilities**

Society of Exploration Geophysicists  
Taos NM, Summer Research

# **Well Log Inversion Review: Limits & Possibilities**

**Taos 1999**

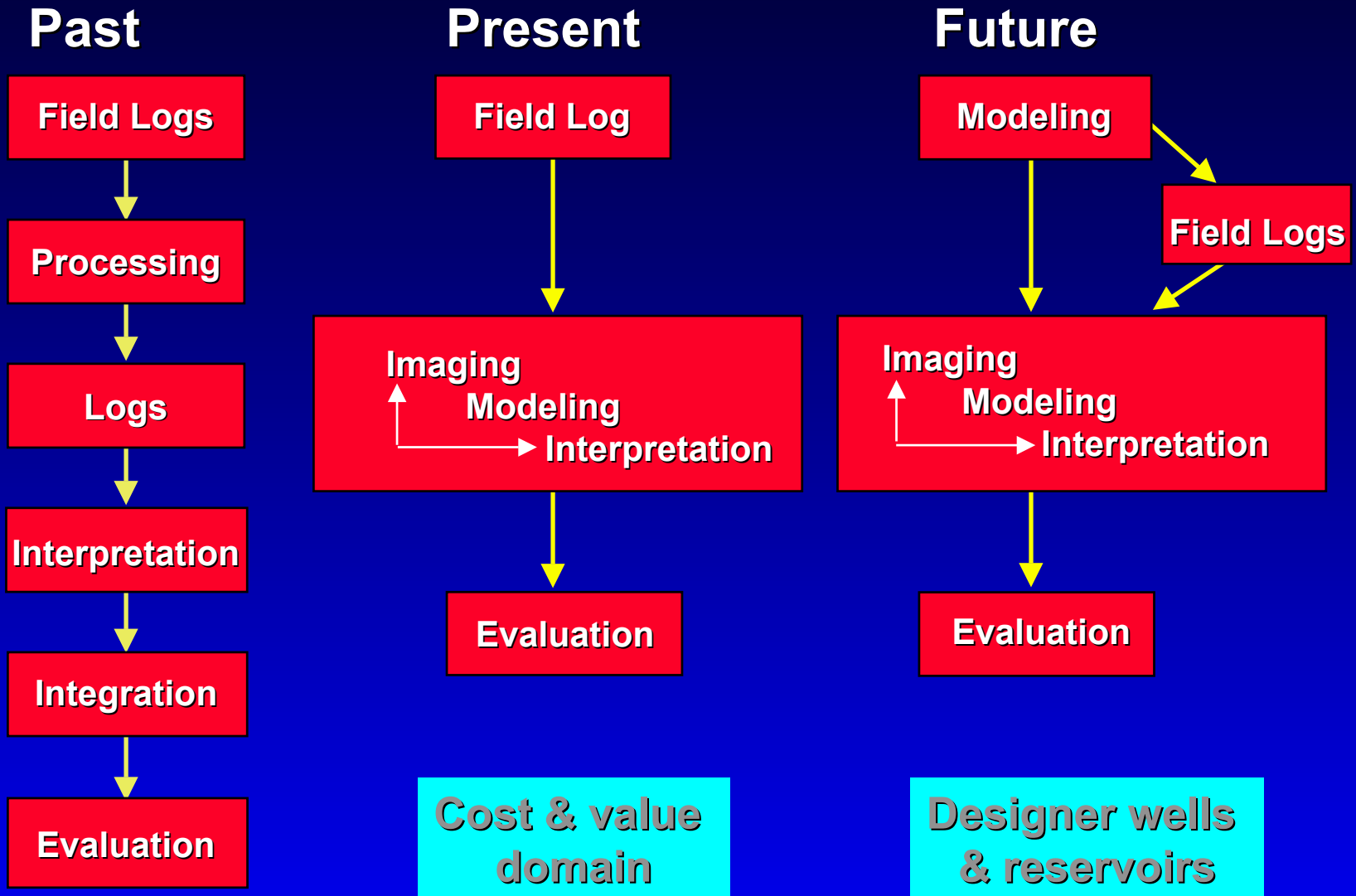
**K.-M. Strack, KMS Technologies, R. Chunduru, M.A.**

**Frenkel, A.G. Mezzatesta, Z. Zhang, Baker Atlas**

# Outline

- Objectives
- Introduction: tools and methods
- Practical implementation
- Case histories
- Conclusions

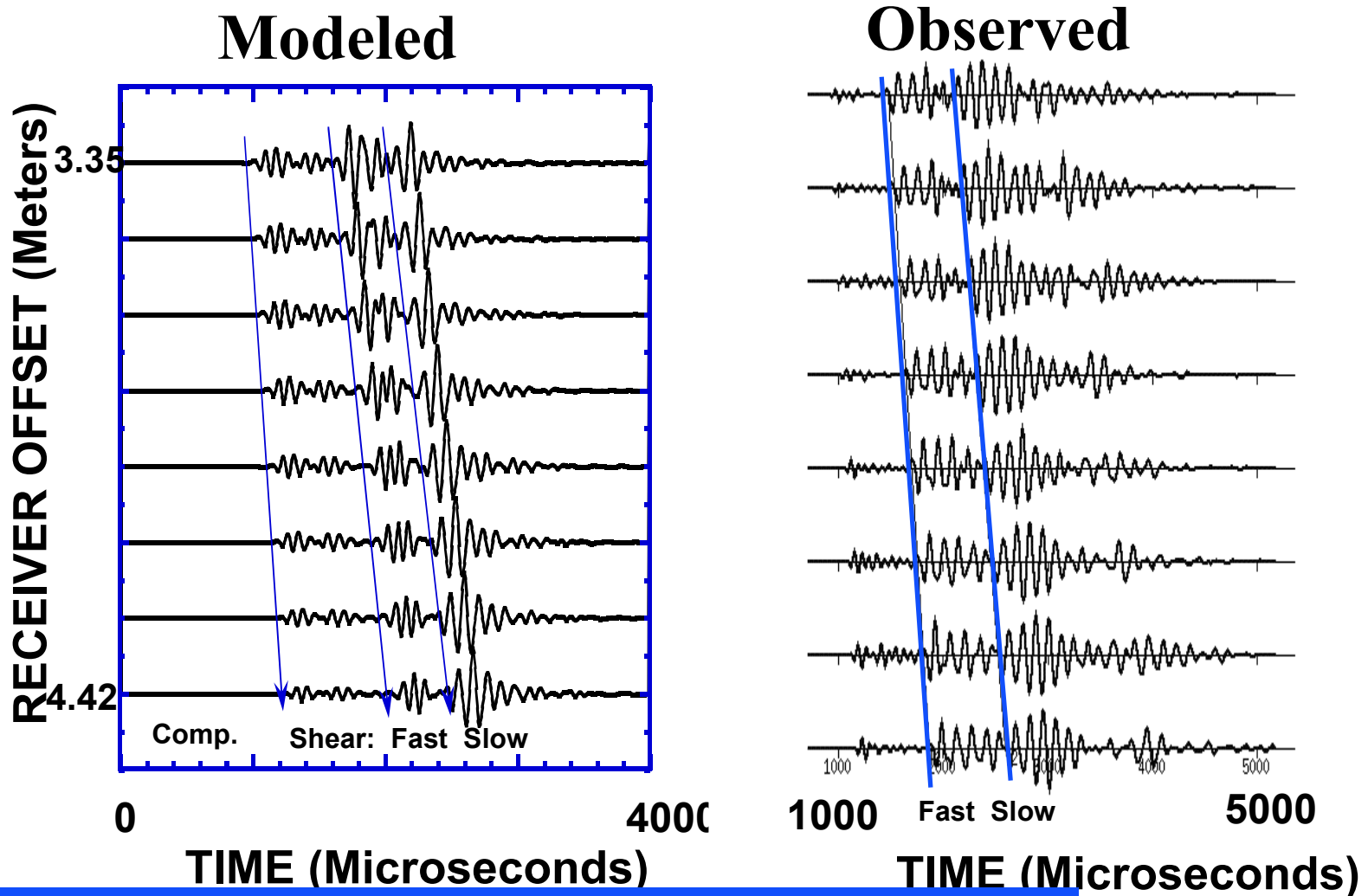
# The Paradigm Shift: log analysis



# Logging methods status

- **Nuclear:** Mote Carlo routine, parametric in early phase
- **Acoustic:** inversion in toolbox; parametric models starting, mostly non parametric
- **Electrical:** inversion in technology transfer phase
- **Borehole seismics:** well advanced, 3D almost commercial

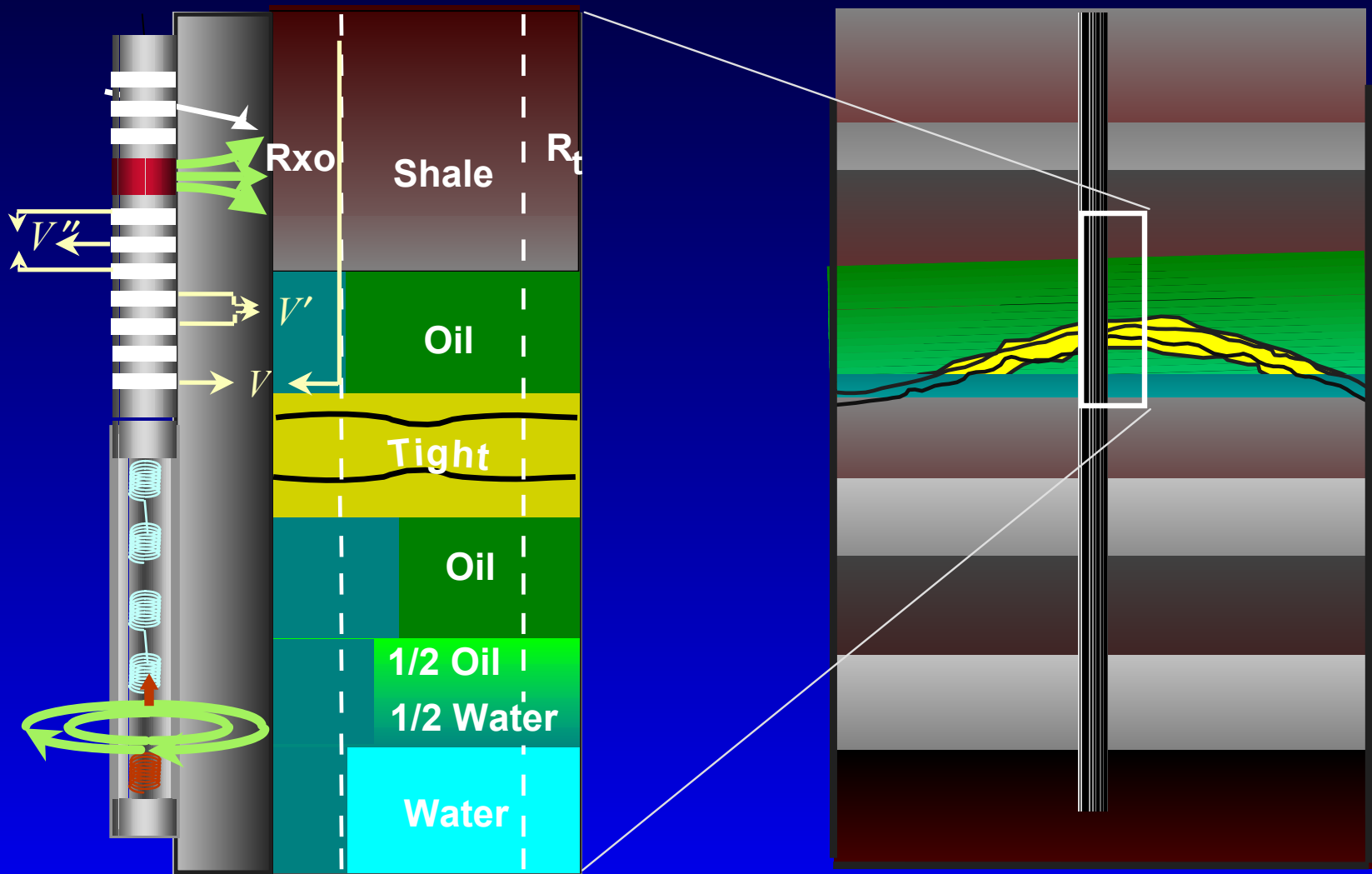
# Acoustics logs: inversion as tool



**Monopole Shear Splitting: A Stress Indication**

(after Tang 1999)

# Oil - Resistivity relationship: borehole

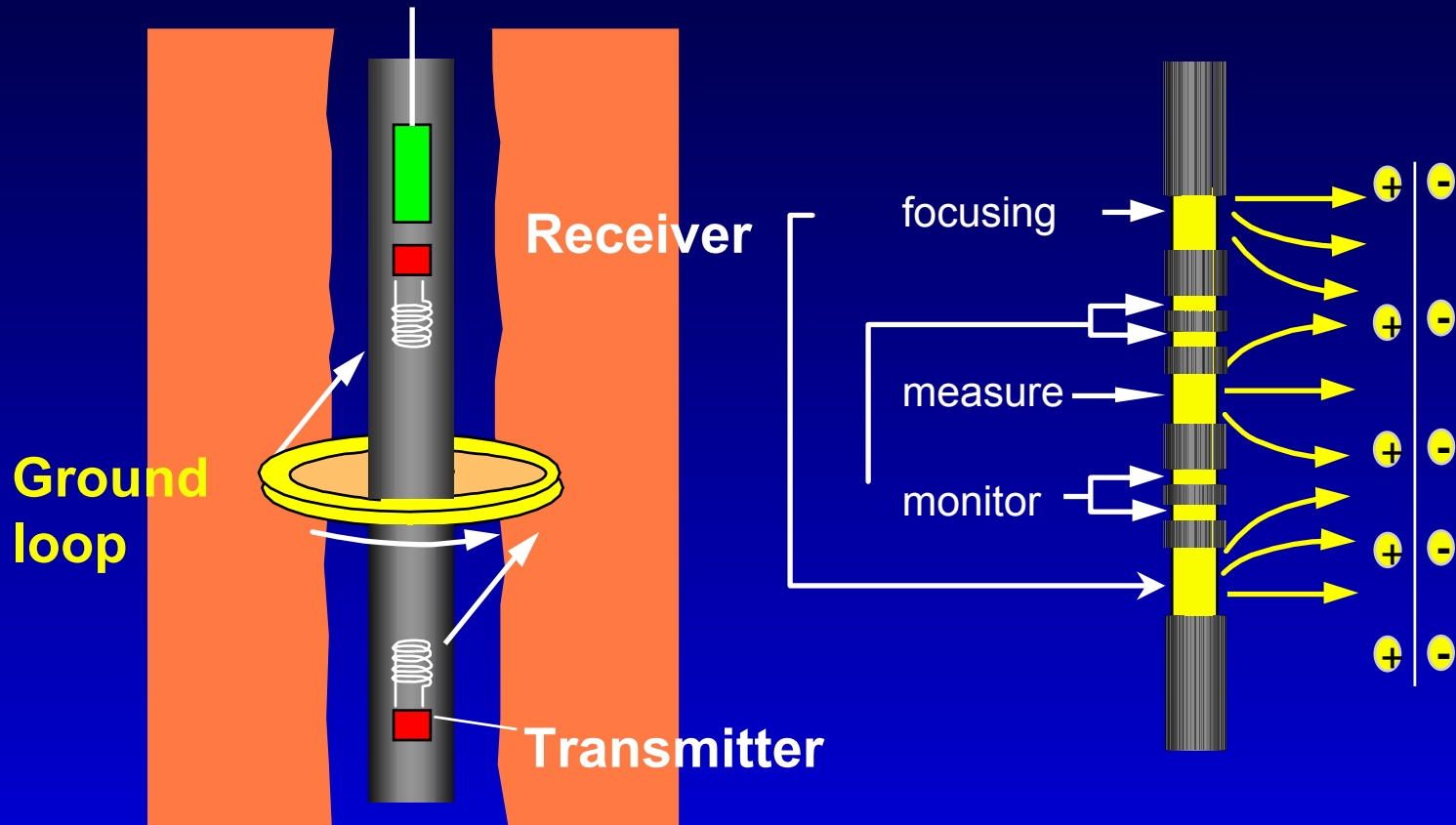


# Outline

- Objectives
- **Introduction: tools and methods**
- Inversion methodology
- Practical implementation
- Case histories
- Conclusions



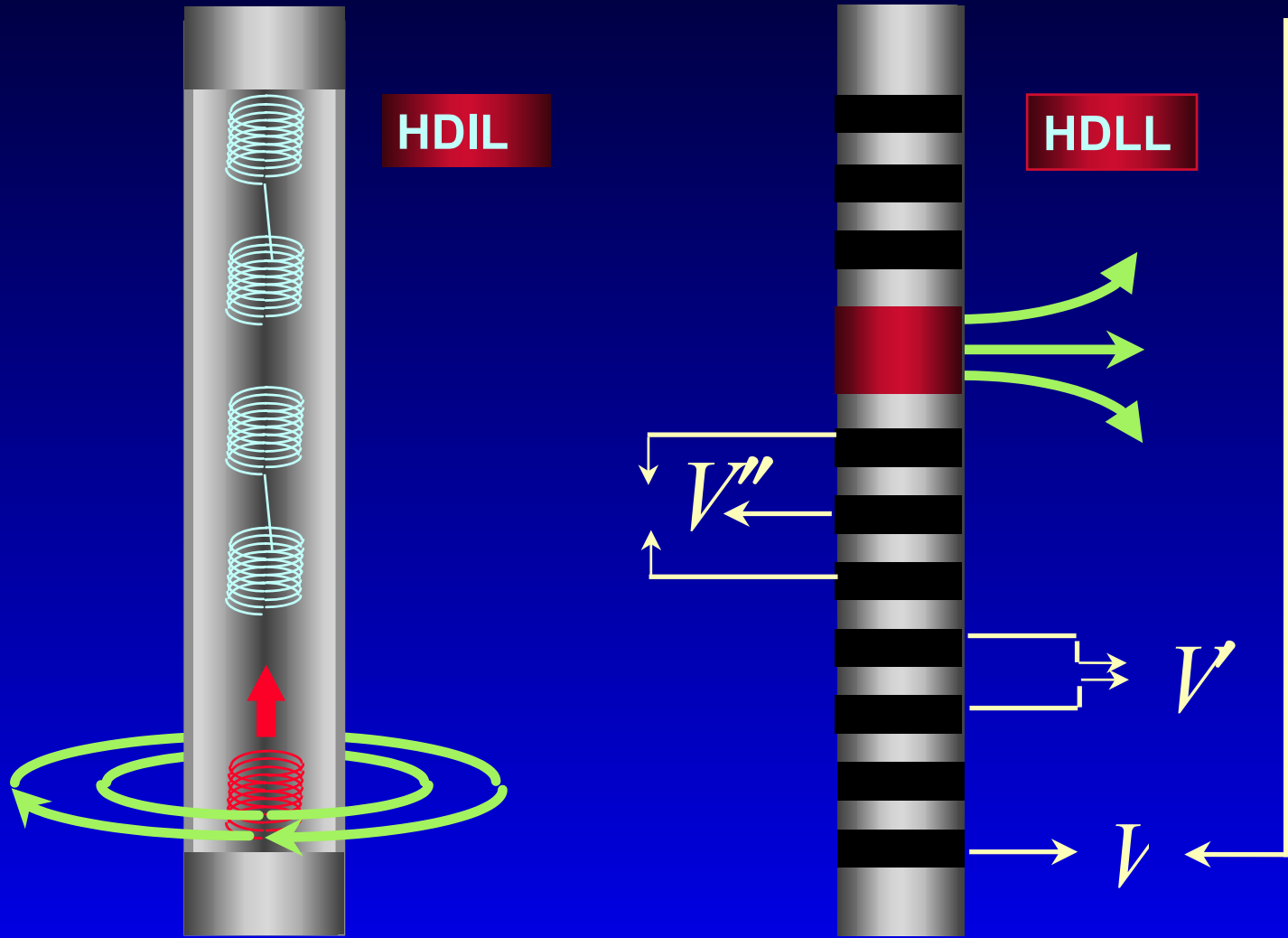
# Combination Possibilities



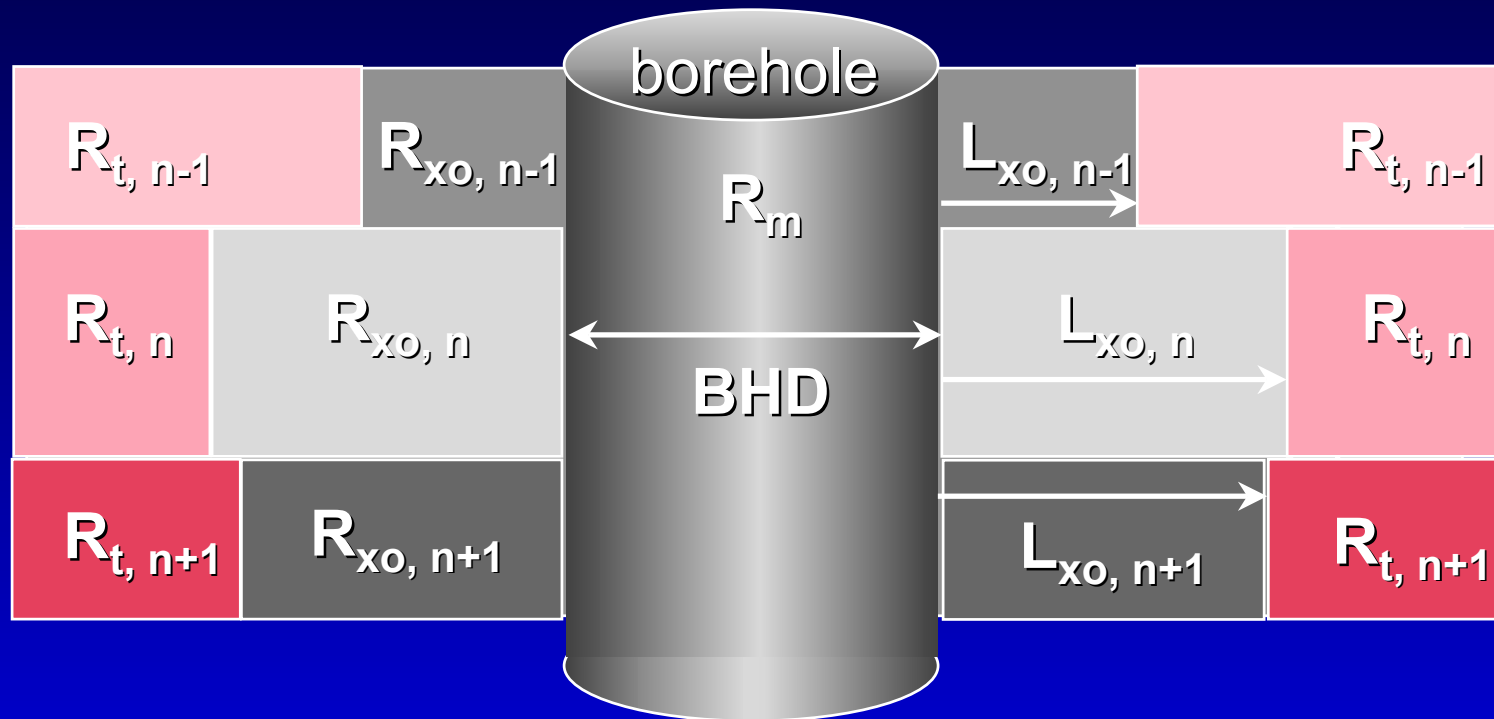
**Induction**

**Laterolog**

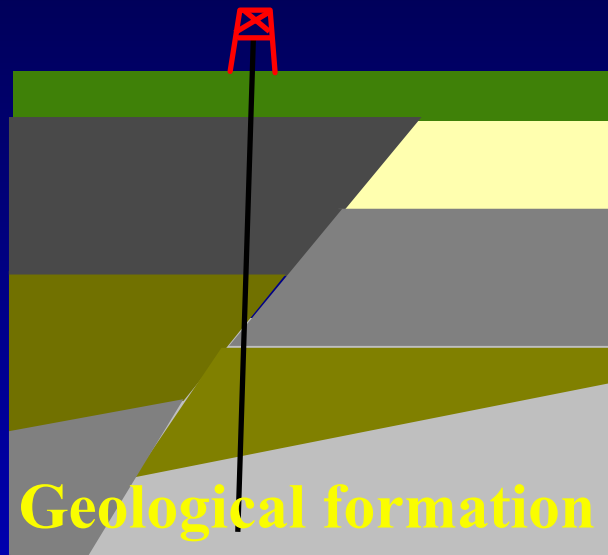
# Joint: Induction & Galvanic



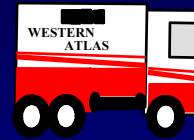
# 2-D Earth Model



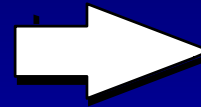
# Logging process



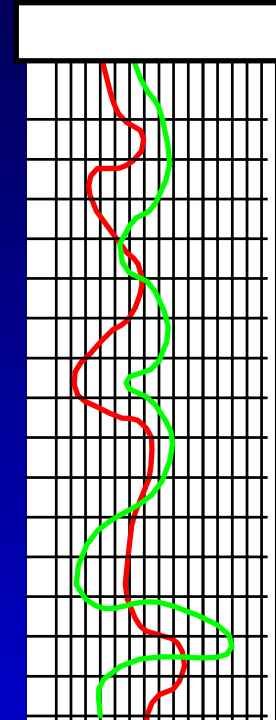
**Earth model described  
by parameters  
(resistivity distribution)**



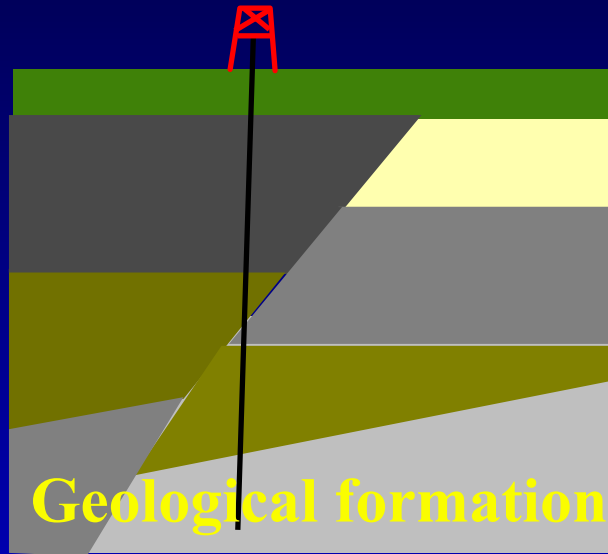
**Measurements**



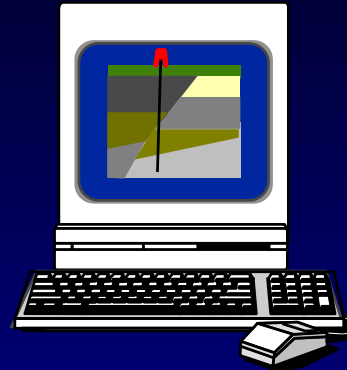
**Logs**



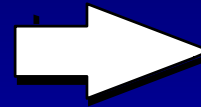
# Modeling process for logs



Earth model described  
by parameters  
(resistivity distribution)



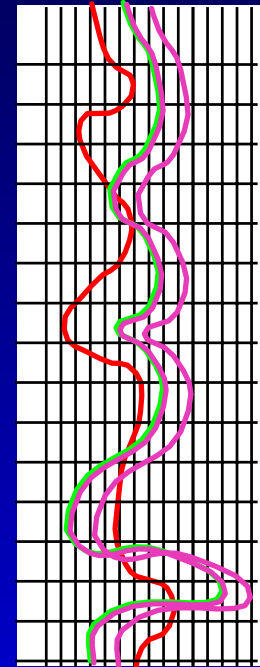
Modeling



Inversion

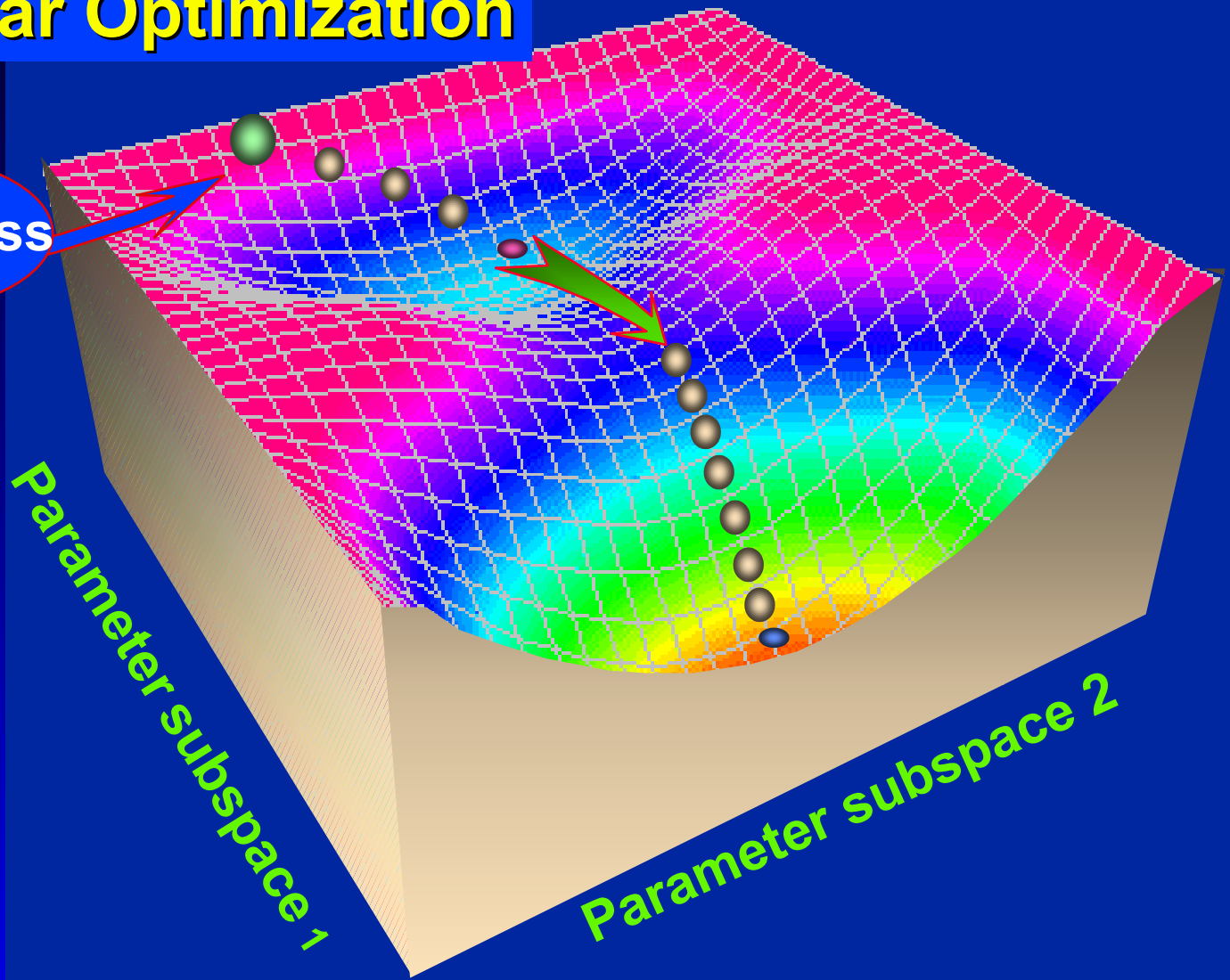


Logs



# Nonlinear Optimization

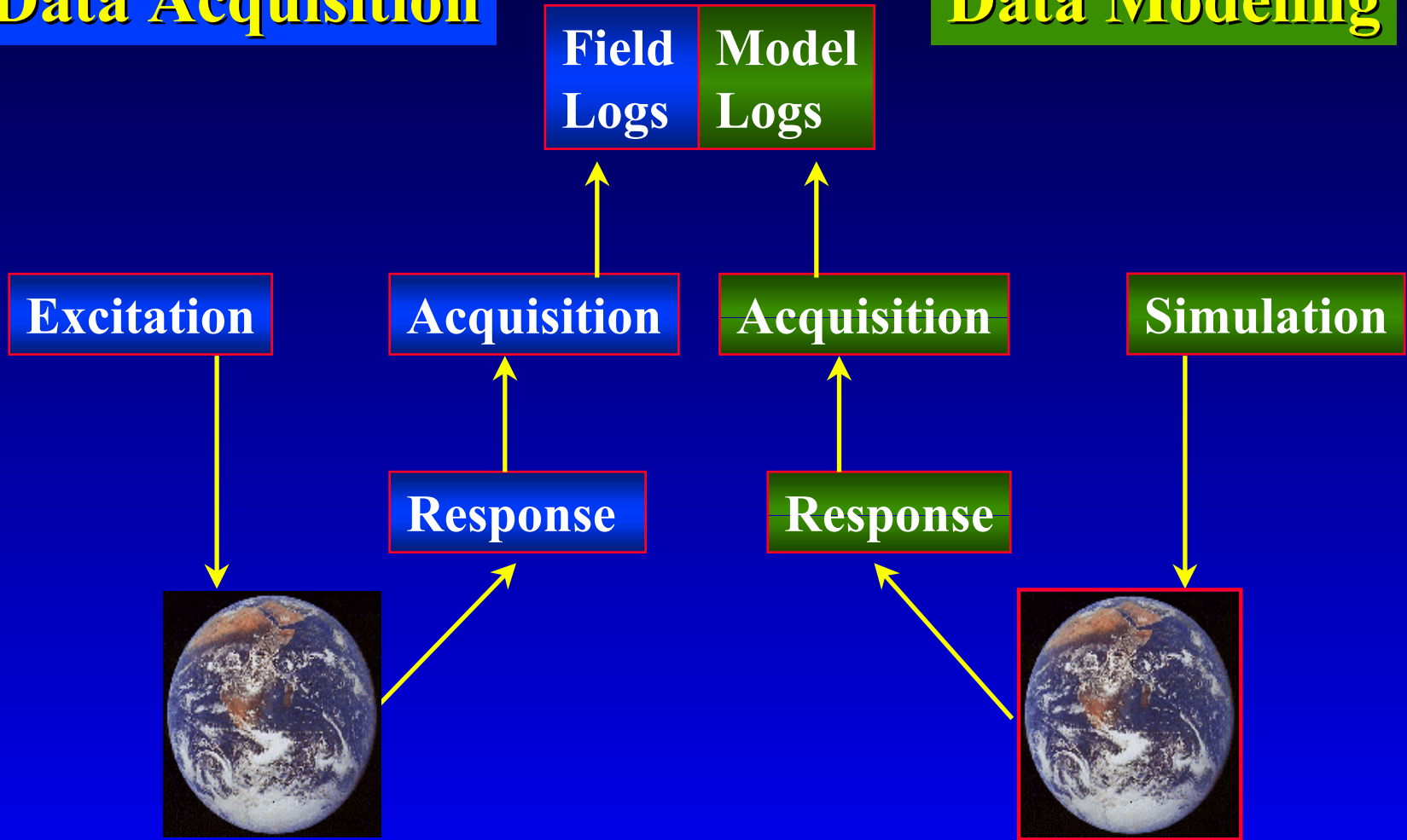
Initial Guess



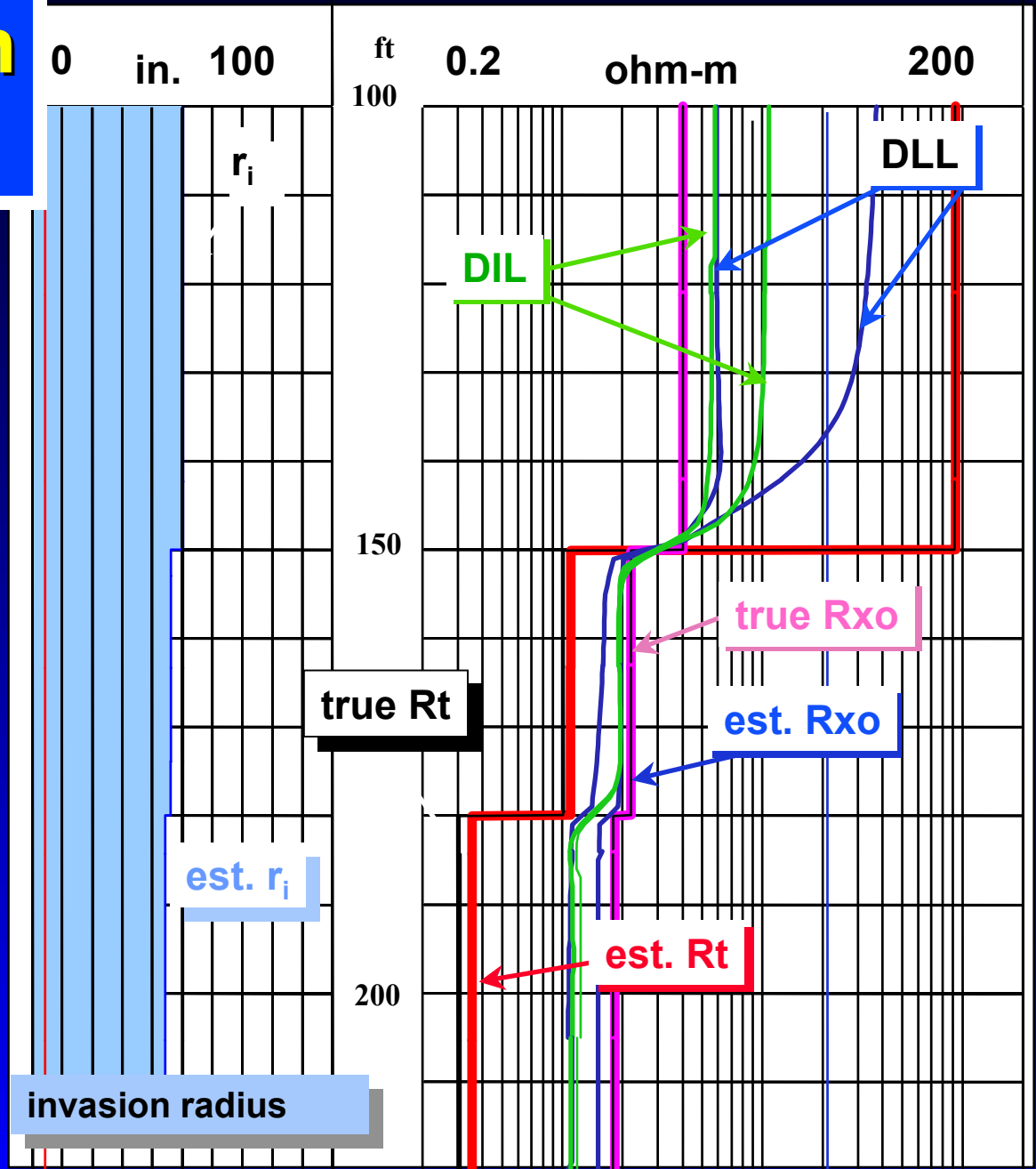
# Inversion: Process flow

**Data Acquisition**

**Data Modeling**



# 2-D Inversion Results



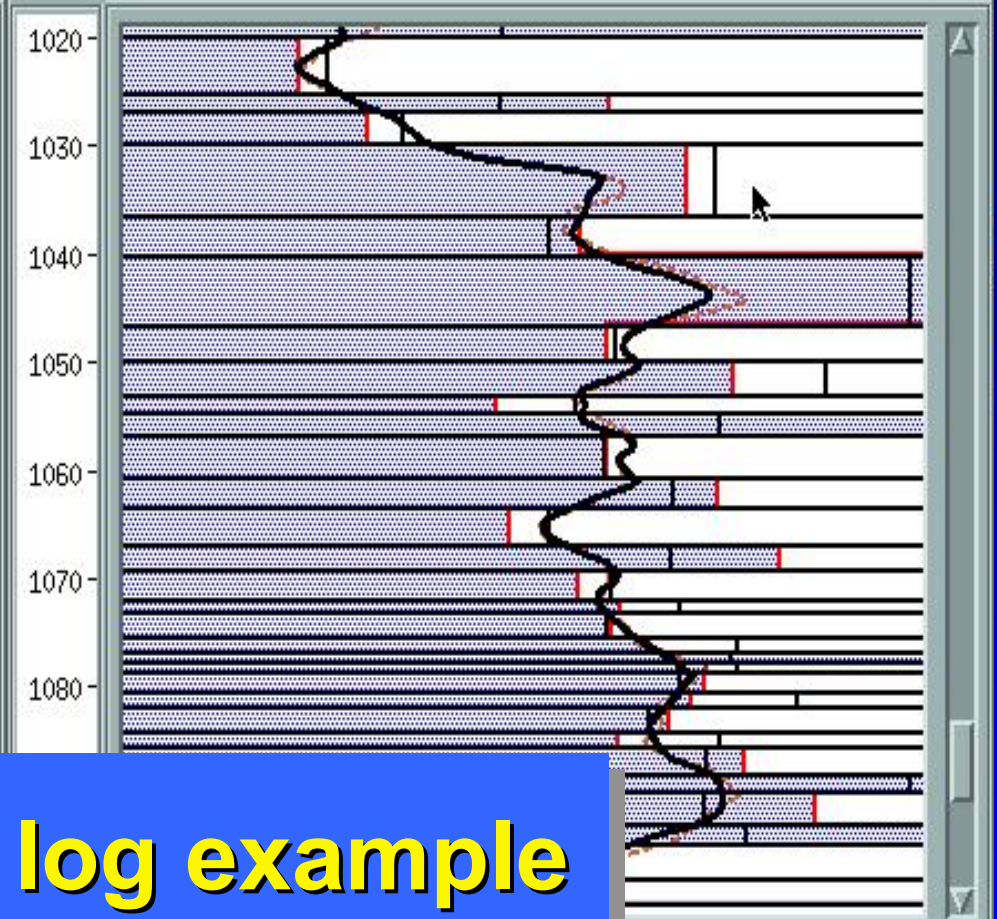
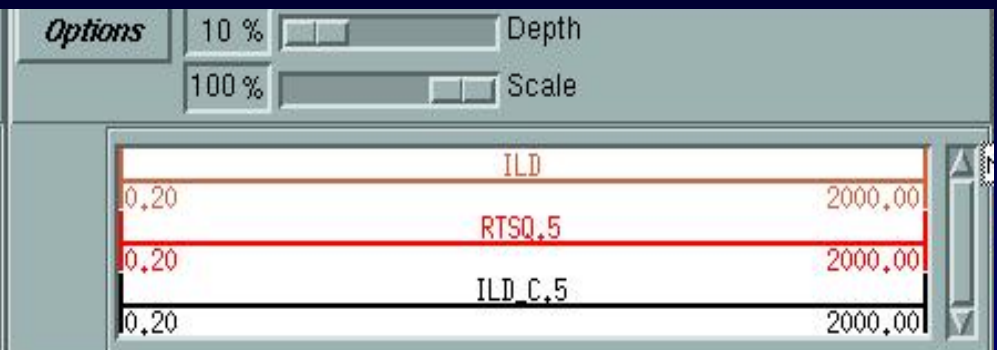
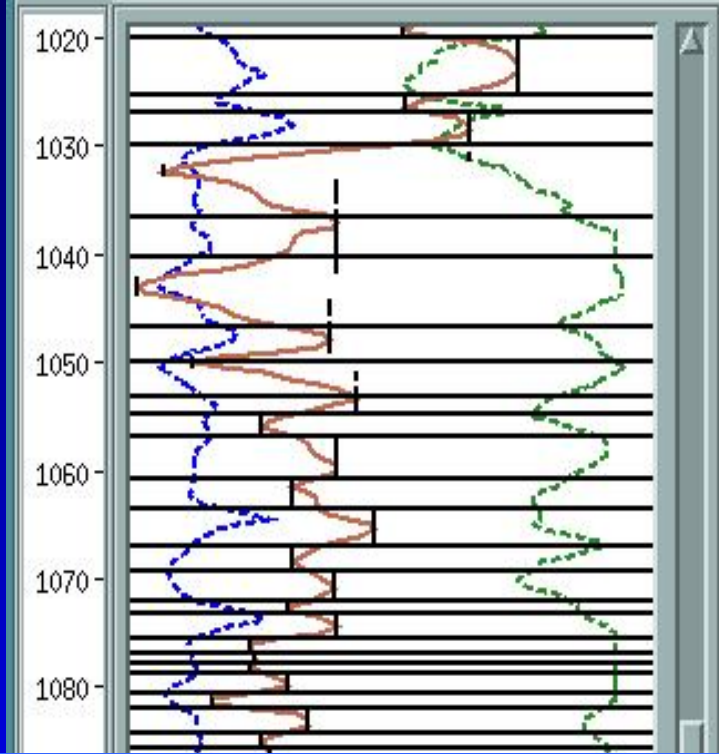
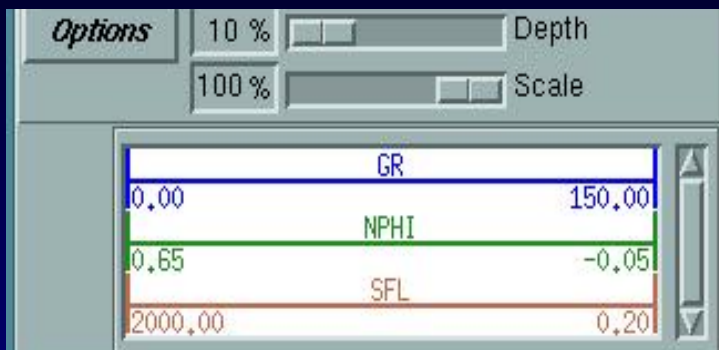
from The Log Analyst, 1994

AWS95727b-1



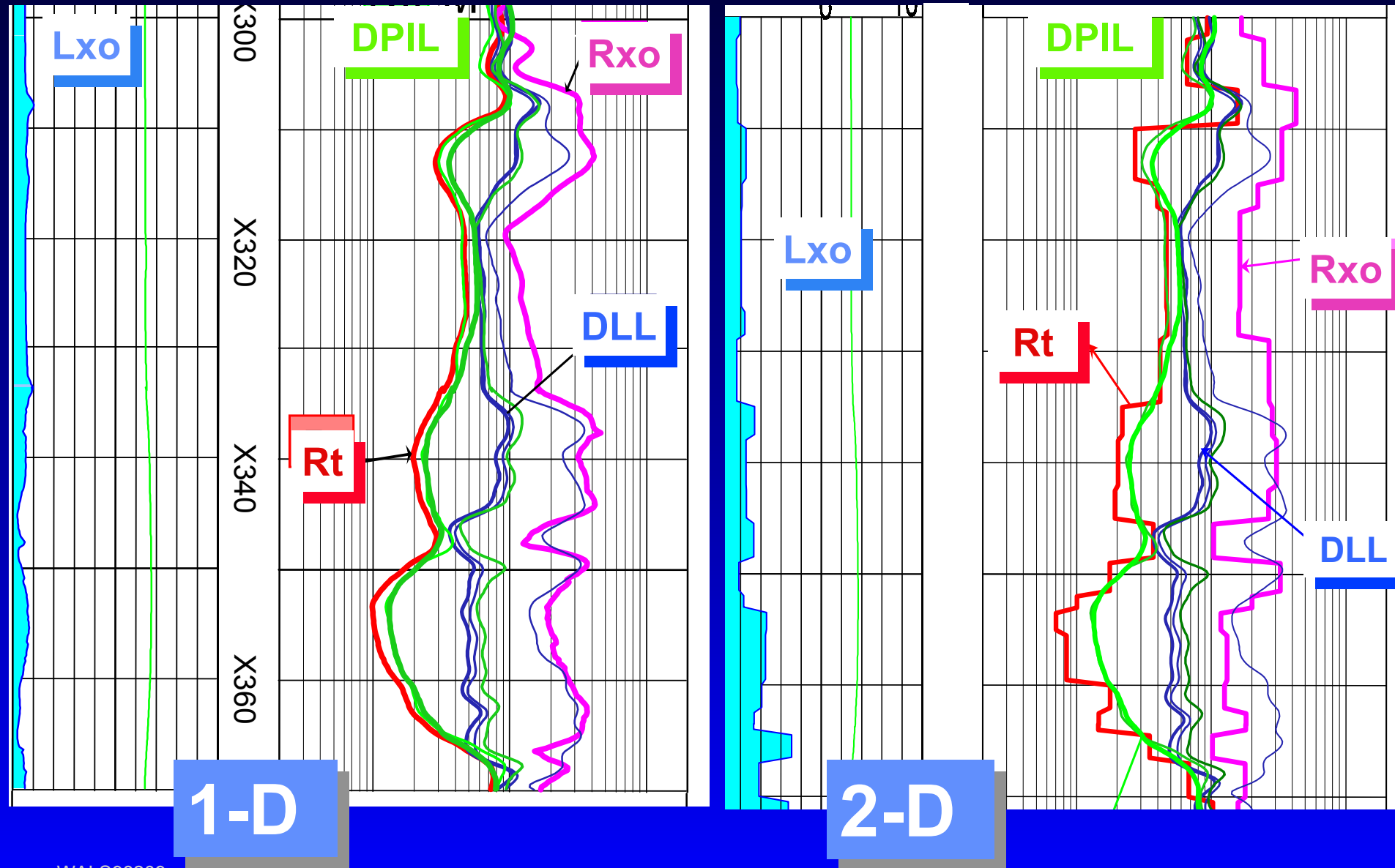
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- **Practical implementation**
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**Rtban Induction log example**

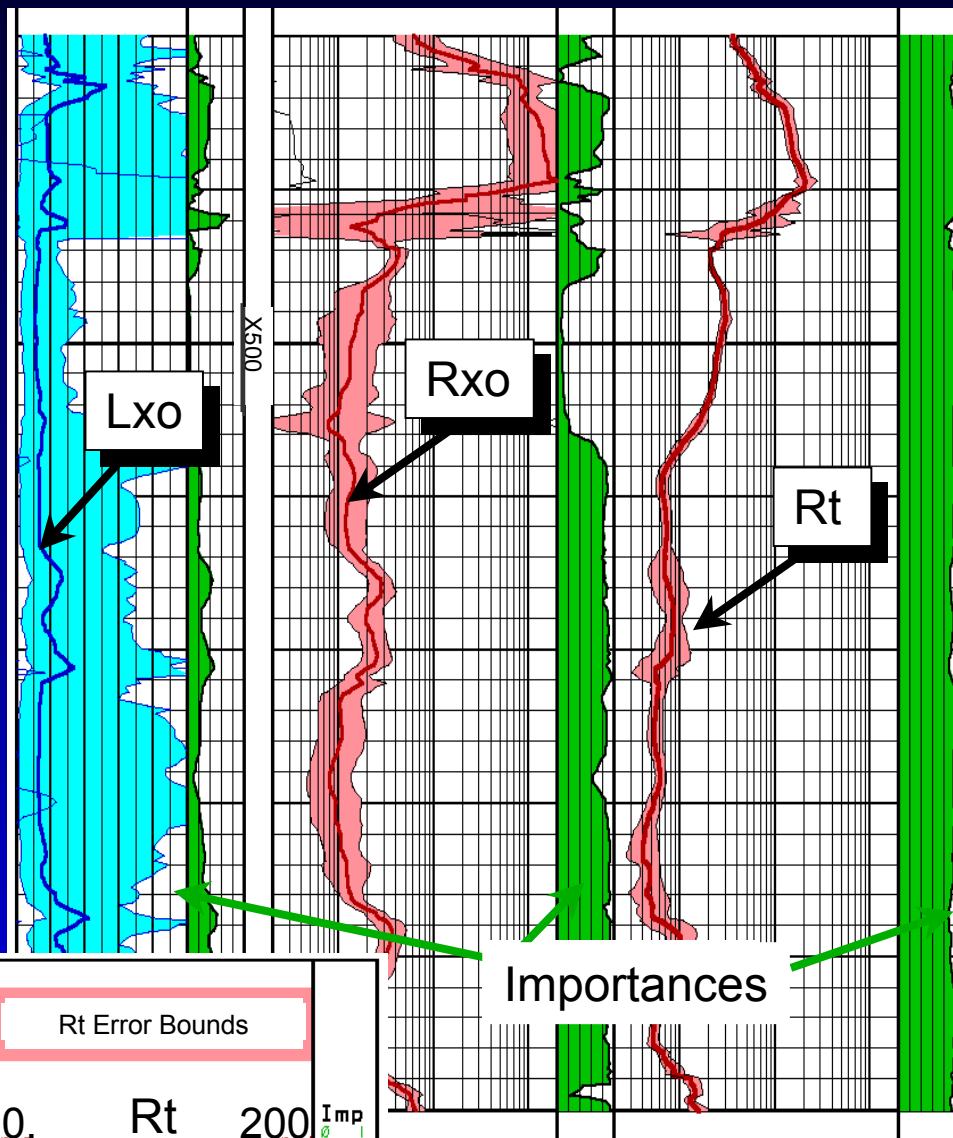
# Inversion: 1D versus 2D



# Outline

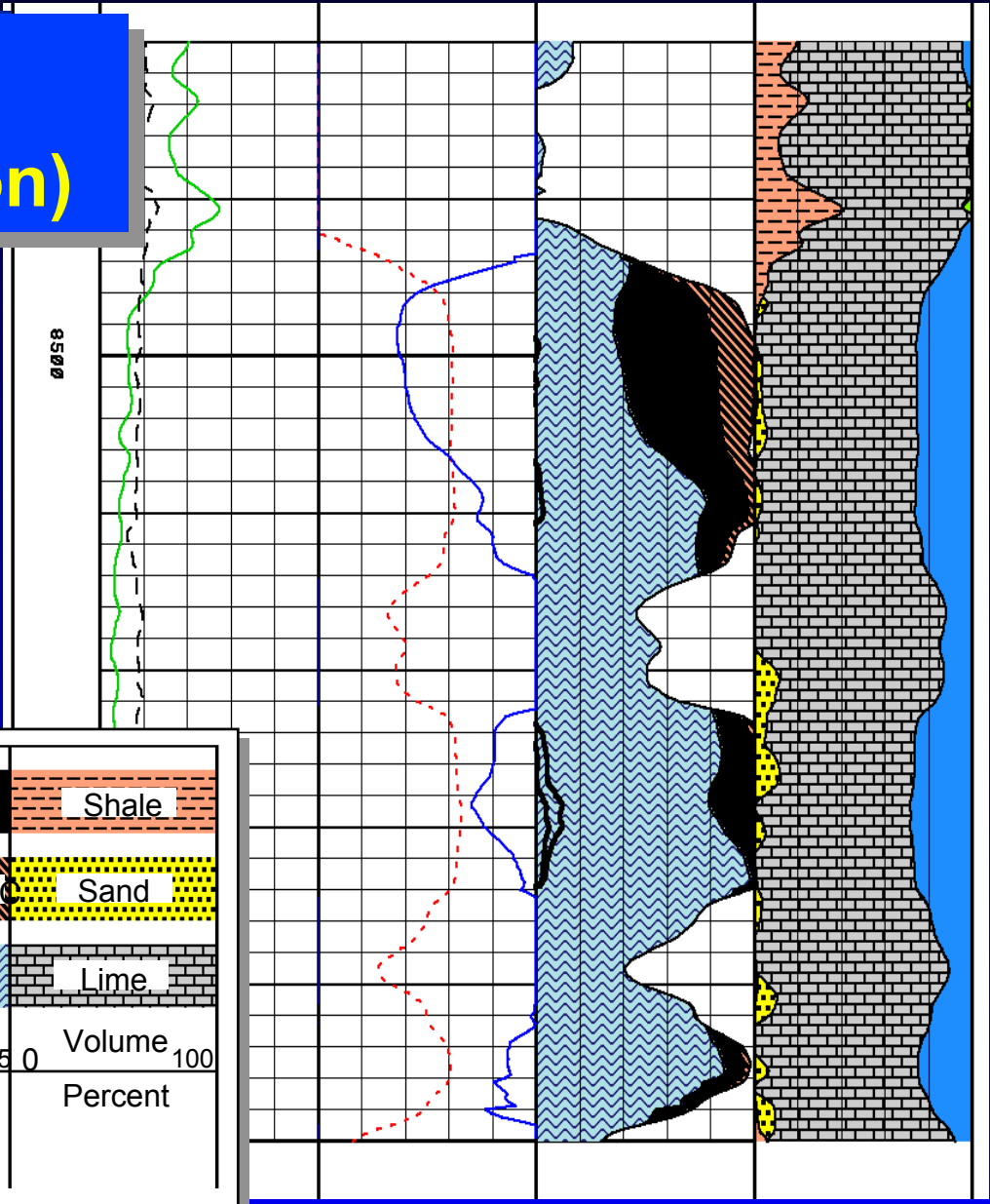
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# 1-D Statistics



# CRA

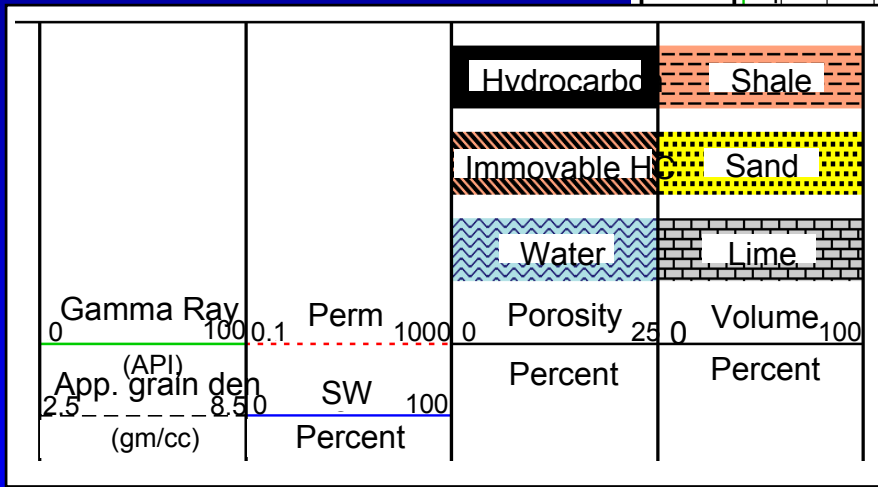
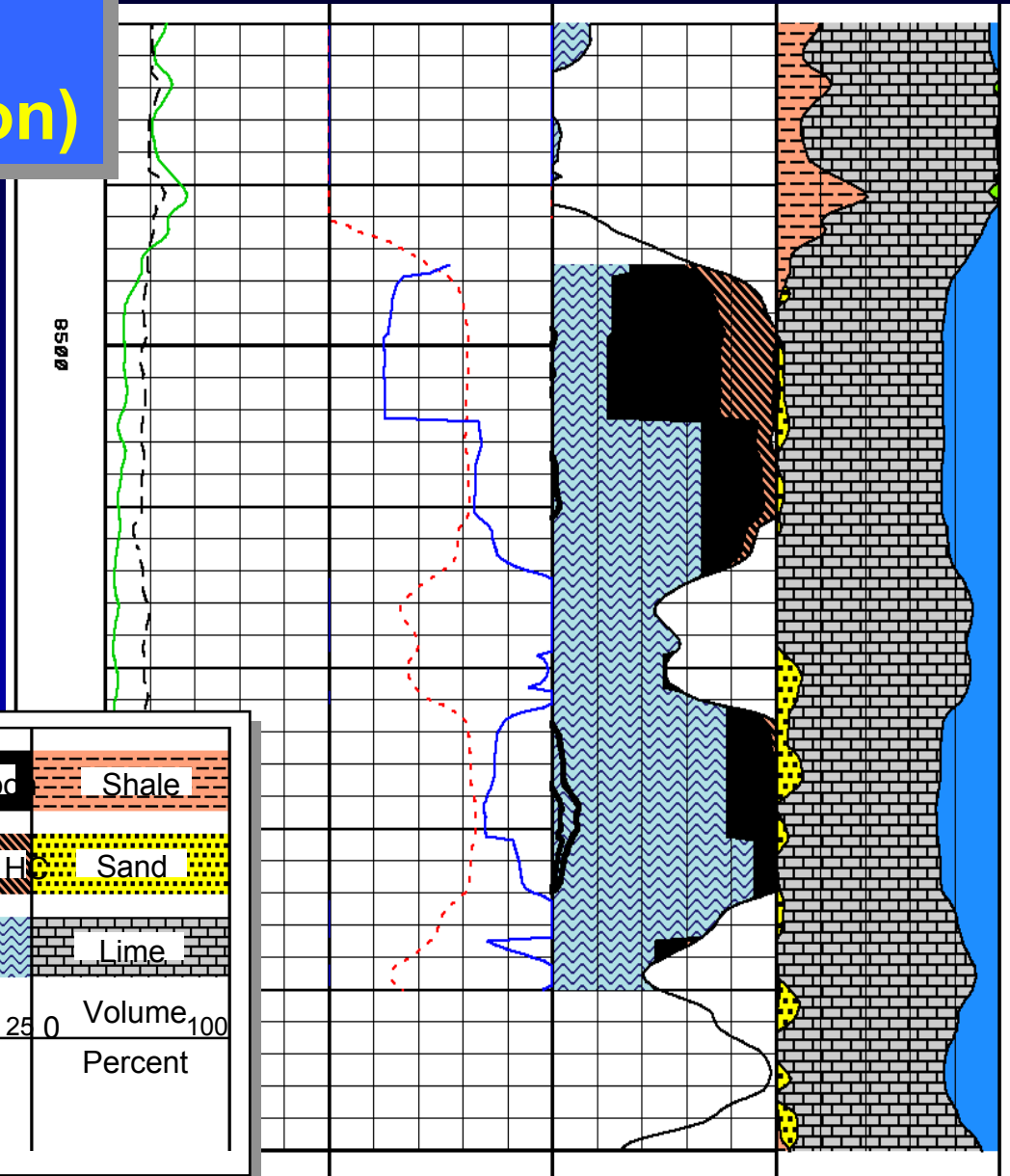
( $R_t$  from 1-D inversion)



		Hydrocarbo	Shale
		Immovable HC	Sand
		Water	Lime
Gamma Ray	Perm	Porosity	Volume
(API)	1000	0	0
App. grain den	SW	Percent	Percent
(gm/cc)	Percent		
0	0.1	25	100
2.5	100		
8.50			

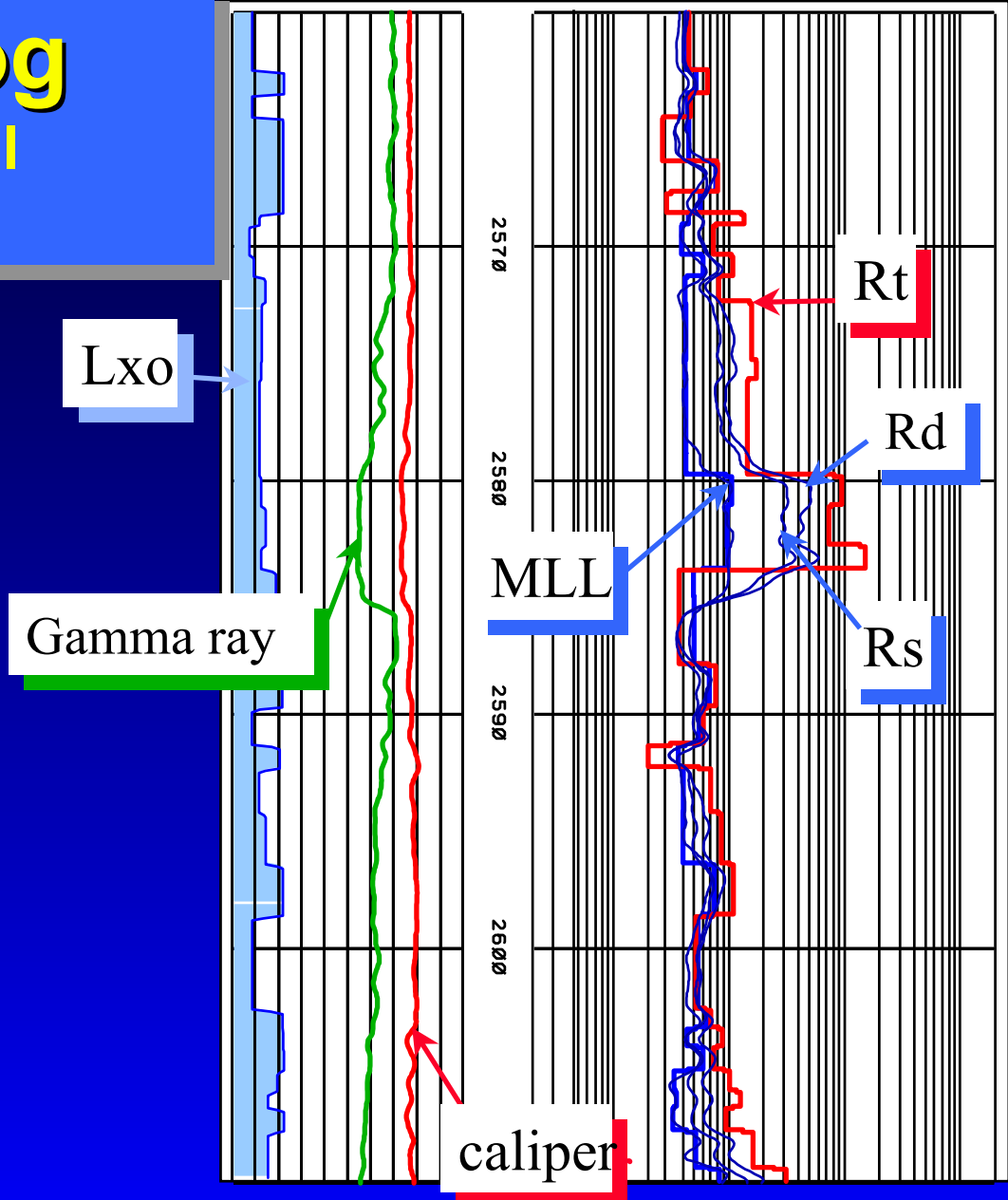
# CRA

( $R_t$  from 2-D inversion)



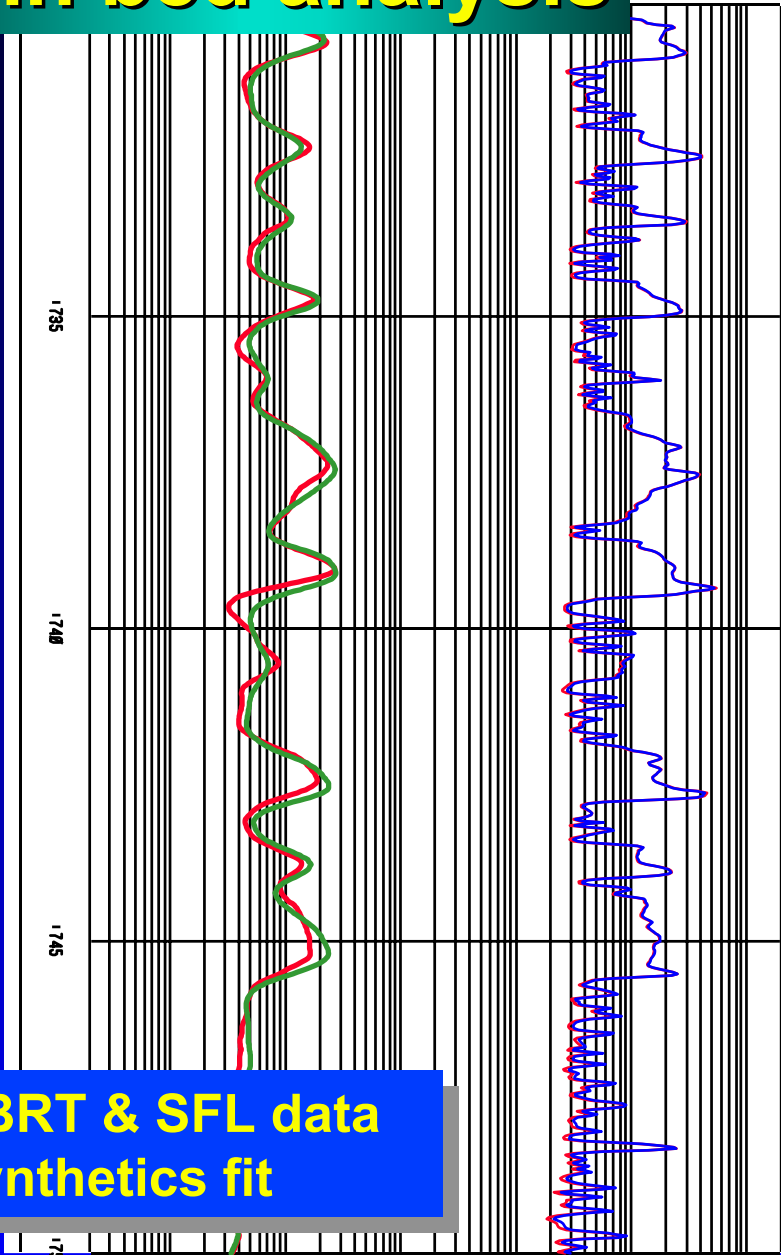
# Dual Laterolog

underestimating oil reserves



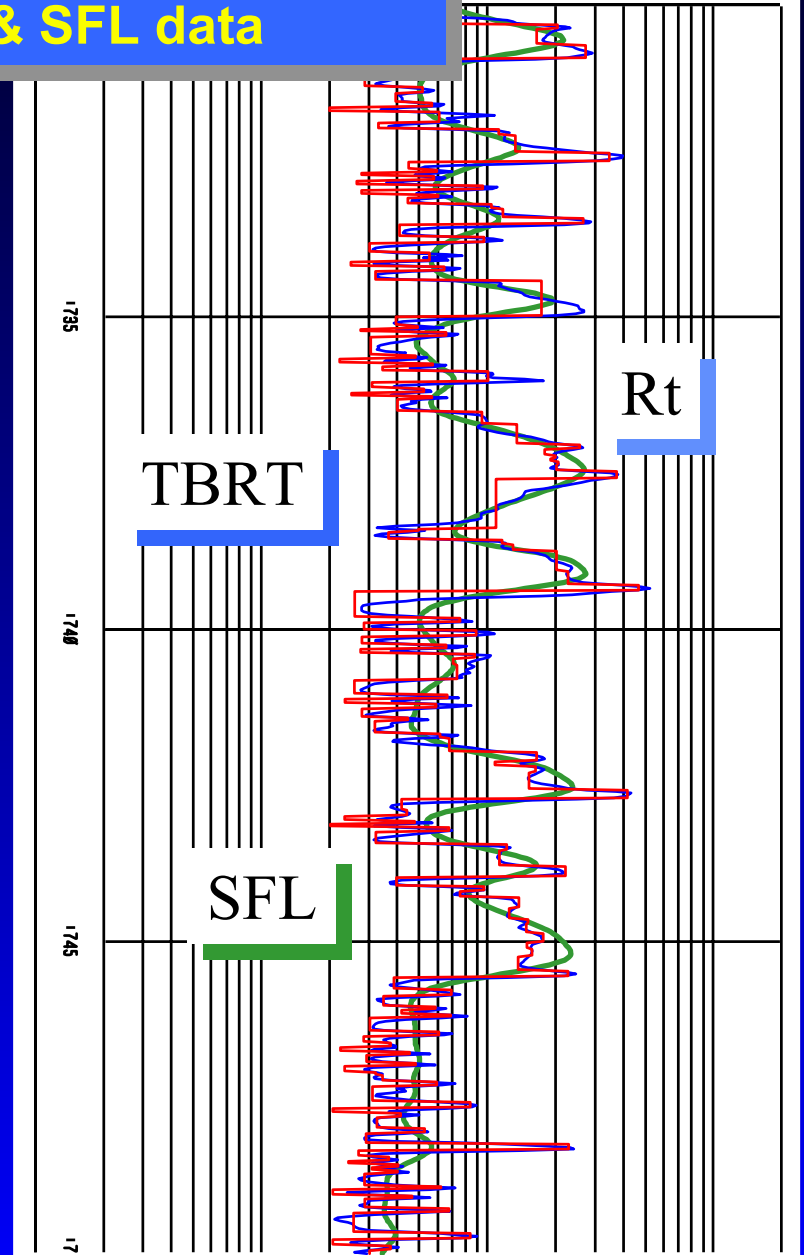


# Thin bed analysis



TBRT & SFL data  
synthetics fit

# TBRT inversion & SFL data

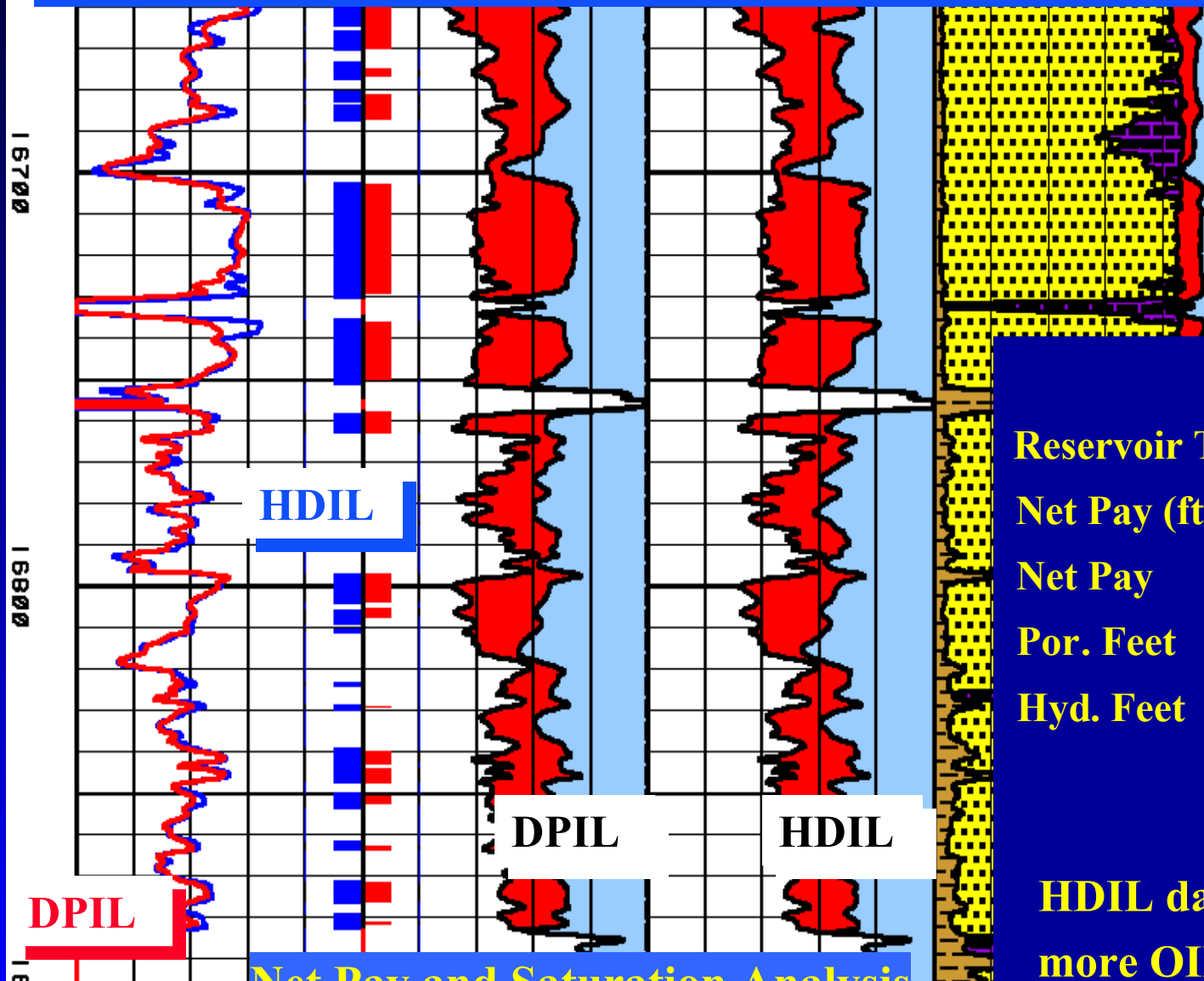


TBRT

SFL

Rt

# Step change through hardware



Reserves estimate  
DPIL vs. HDIL

	DPIL	HDIL
Reservoir Thickness:		270 ft
Net Pay (ft)	103.6	130.1
Net Pay	38.4%	48.2%
Por. Feet	15.4 ft	18.9 ft
Hyd. Feet	7.4 ft	9.2 ft

HDIL data allowed 24%  
more OIIP be booked.

Net Pay and Saturation Analysis

# Step change through software

## 2 ft VRM vs 2D Inversion

$$OIP = (A * h) * Por * (1 - Sw)$$

A = 160 acre

Assume 7,758 API Bbl/acre-foot

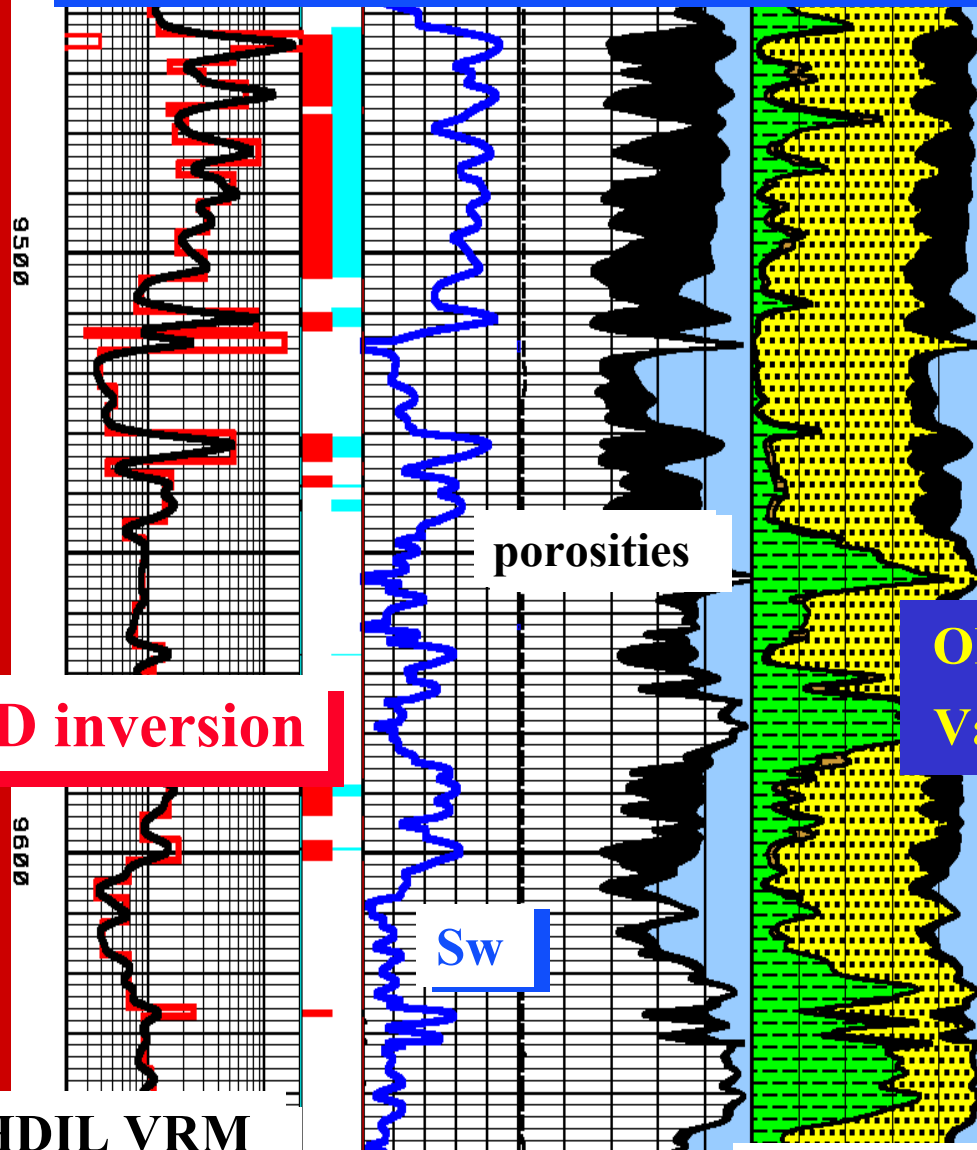
1 Bbl = \$22

OIP	14,912,427 Bbl	16,173,193 Bbl
Value	328 M\$	356 M\$

### 2 ft VRM Curves

### 2D Inversion

h	67.00 ft	74.75 ft
Por	25.8%	25.9%
(1-Sw)	69.5%	67.3%

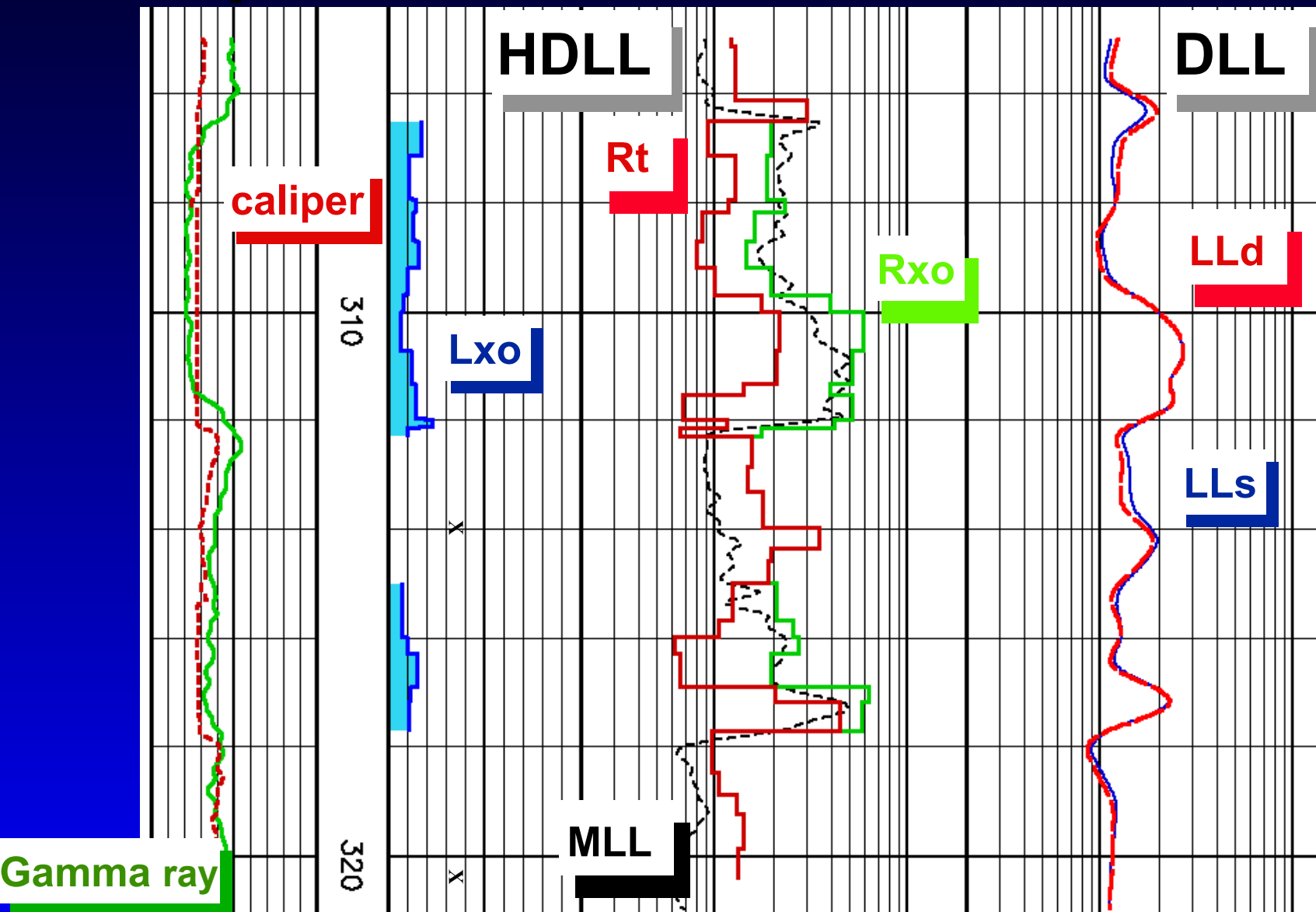


2D inversion

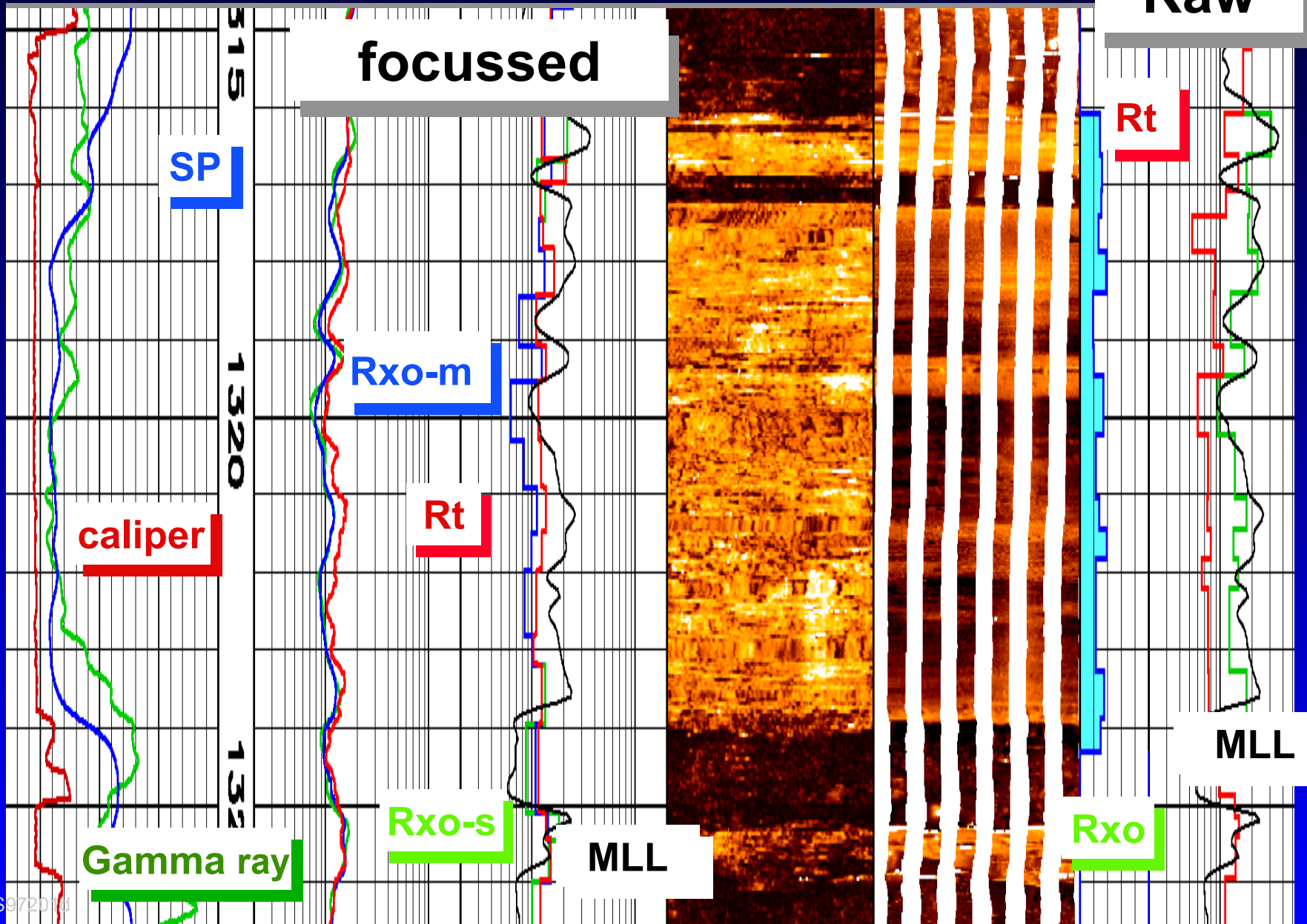
HDIL VRM

volumetrics

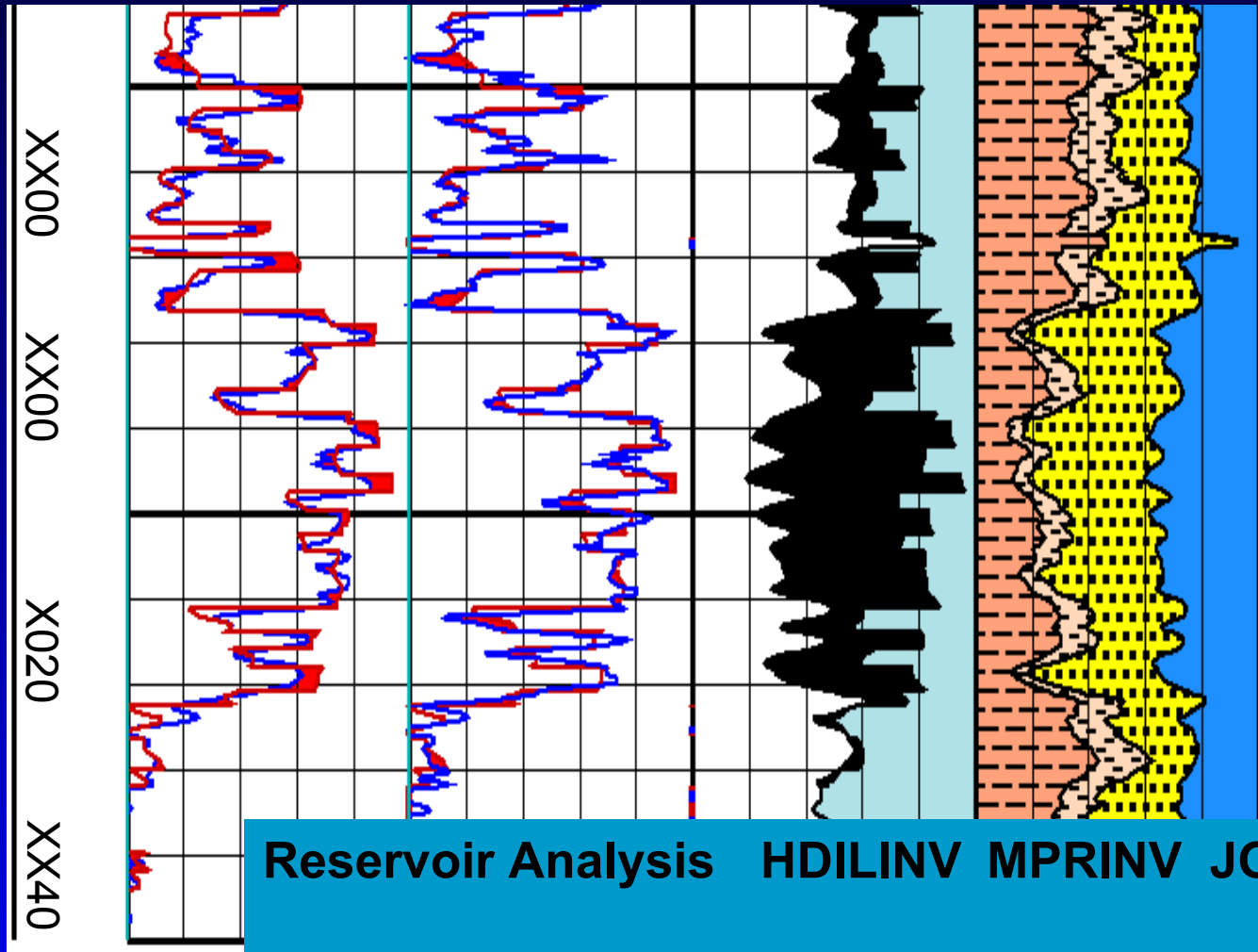
# Comparison of HDLL and MLL/DLL



# Focused & Raw Data Inversion



# Estimation of OIIP: HDIL & MPR



**Reservoir Analysis    HDILINV    MPRINV    JOINT**

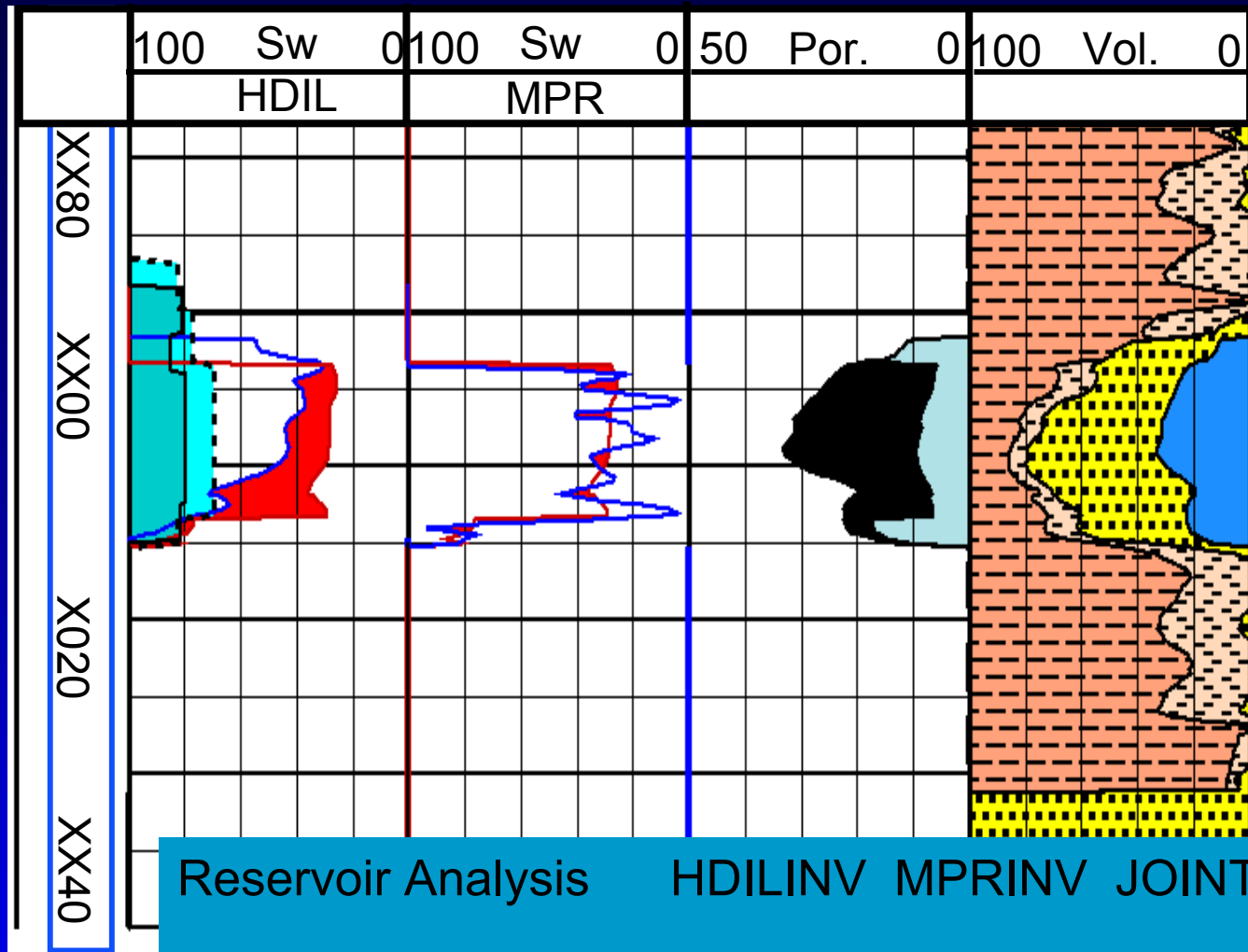
OIIP Estimates

10%

0.7%

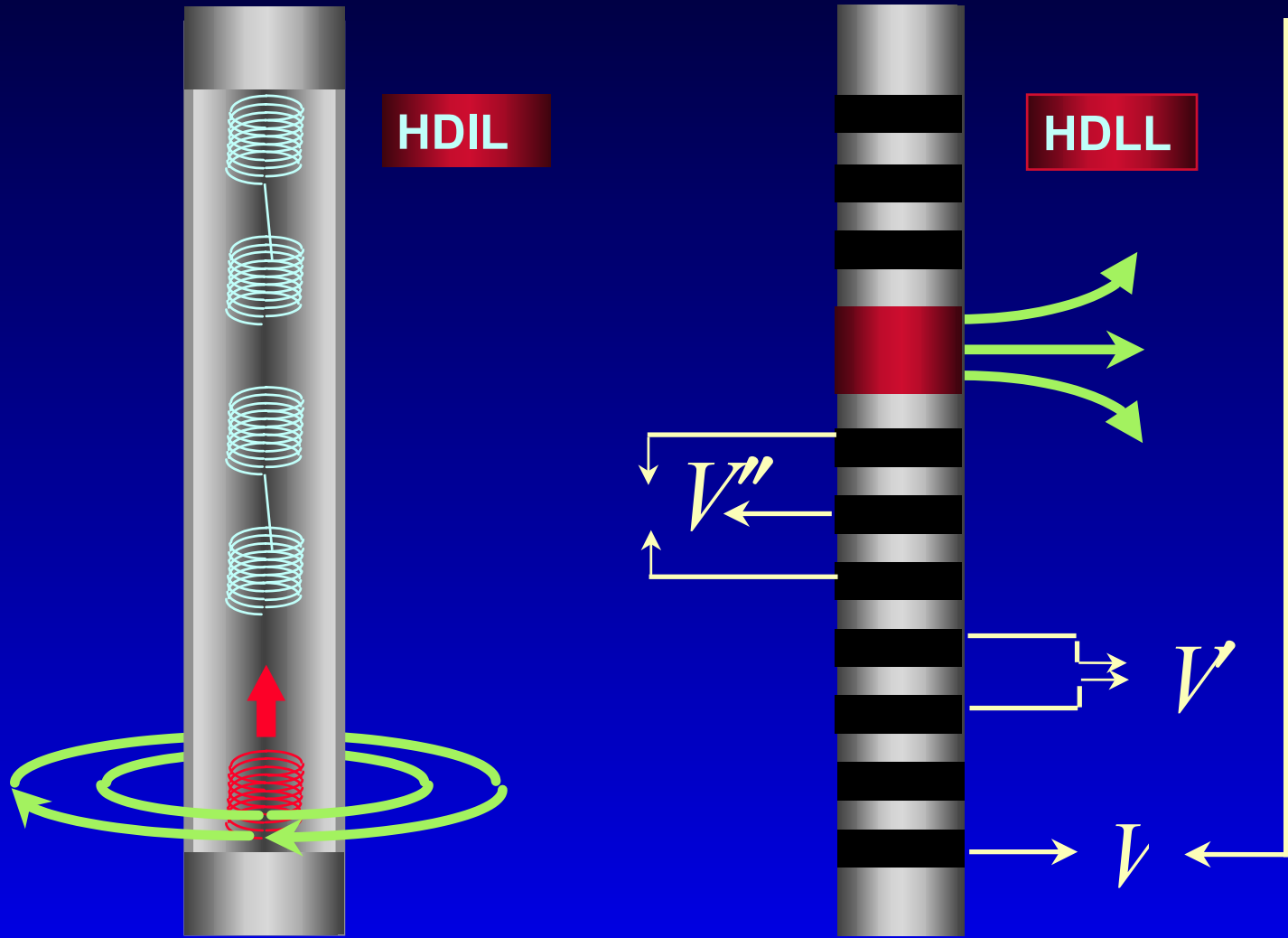
12%

# Estimation of OIIP: HDIL & MPR



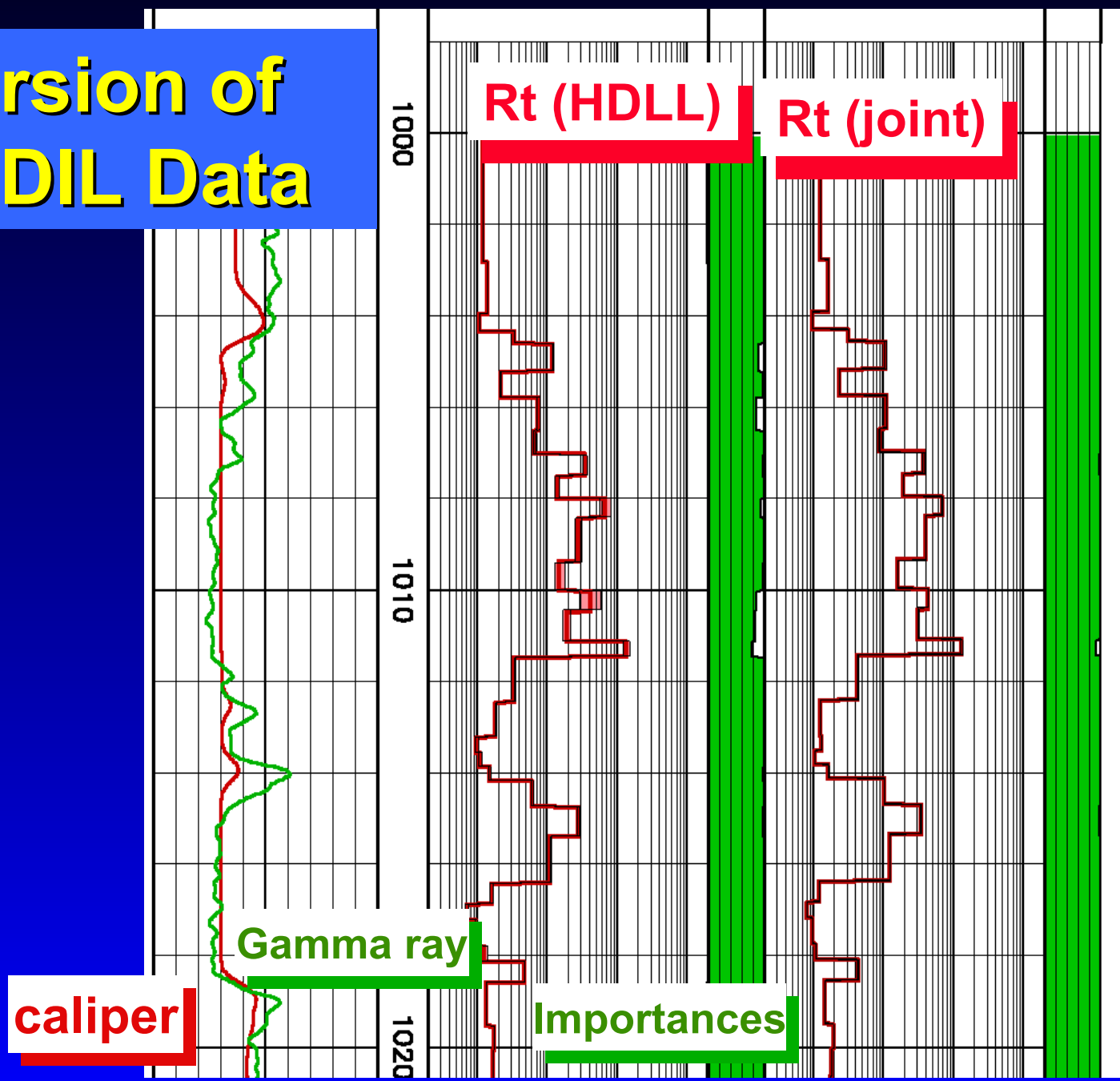
Reservoir Analysis	HDILINV	MPRINV	JOINT
OIIP Estimates	+40%	-1.3%	+43%

# Joint: Induction & Galvanic

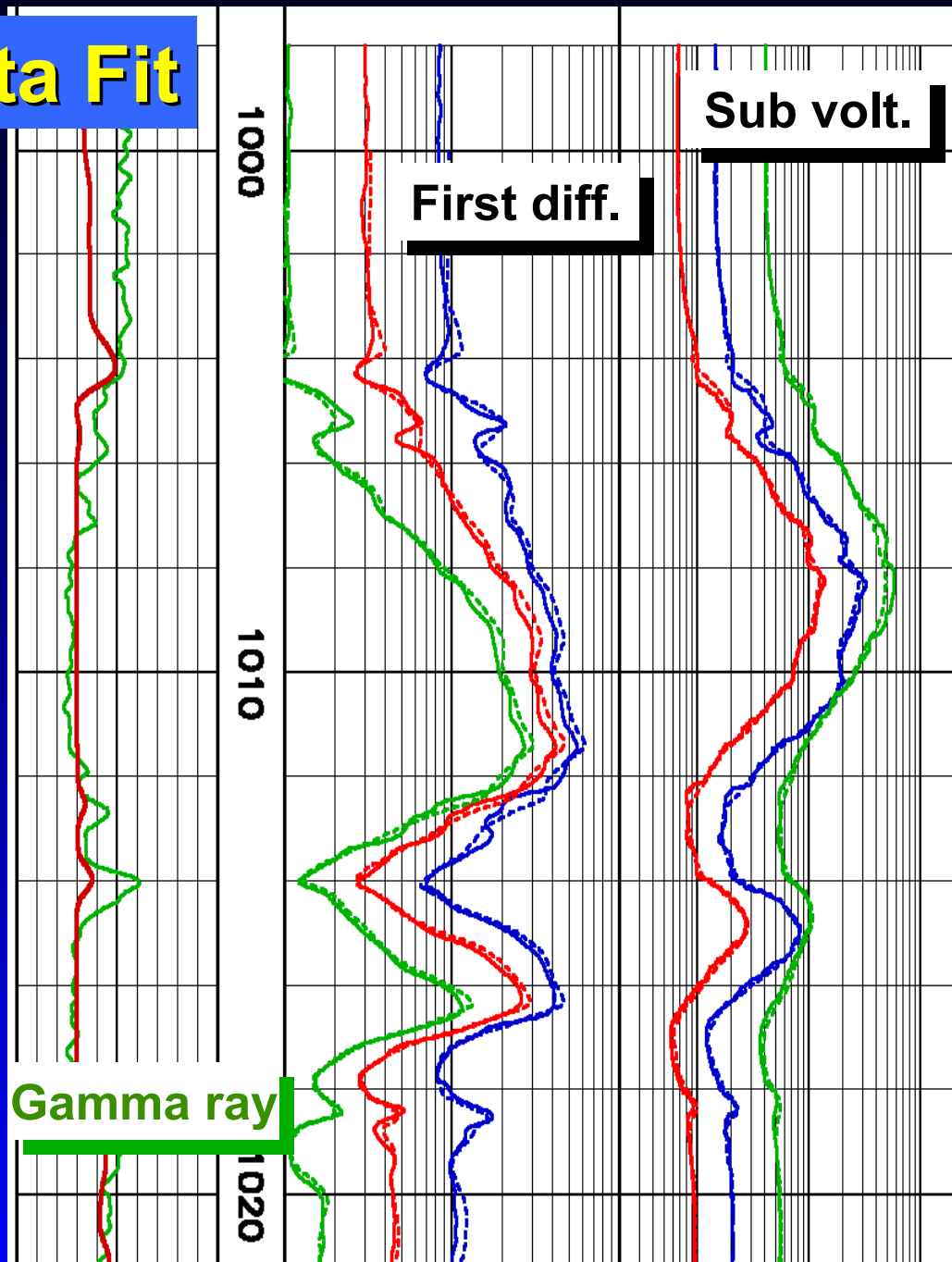




# Joint Inversion of HDLL & HDIL Data



# HDLL & HDIL Data Fit

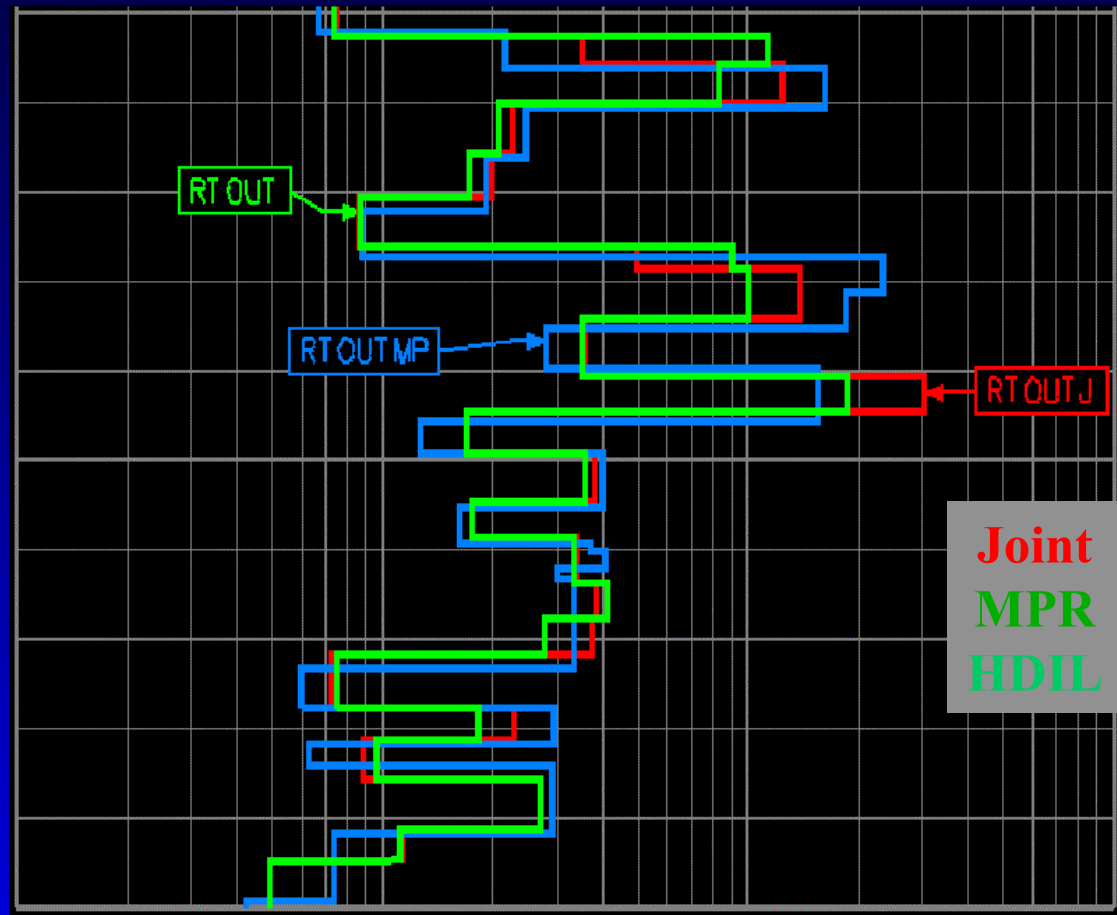


WALS97201a

**caliper**

# Formation Resistivity - LWD & Wireline

- Ability to enhance both LWD & Wireline resistivity data
- More resistive zones translate into more OIP



Joint inversion of MPR & HDIL data

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# Log inversion benefits:

- Better delineated oil bearing zones
- More accurate formation parameters
- Risk analysis parameters
- New ways for data integration & upscaling
- **BUT:** Sensitivities, Uncertainties???

# Closing the loop

**Inversion**

**Statistics / Analysis**

*Inversion expert*

*Geophysicist*

**Presentation  
Ground truth**

**Evaluate  
analysis**

*Petrophysicist*

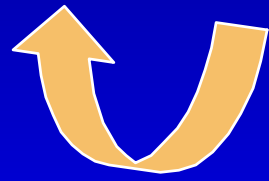
**YES/NO**

*value* \$

**Integration  
Geology**

*Geologist*

*value* \$



# Acknowledgements

**D. Beard, R. Busch, M. Eckard, G. Itskovitch, V. Koelman,  
A. Fabris, T. Fischburn, J. McDougall, M. B, Rabonovich,  
L.A. Tabarovsky, T. Tamarchenko, R. Truman**

**and others**

**data from:**

**ADCO, Agip, Chevron, PDO, Shell, Texaco**

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