

KMS Technologies - KJT Enterprises Inc.

Presentation

Strack, K. – M.

1999

**Advances in Electrical Logging Tools for
Reservoir Characterization**

European Association of Geoscientists & Engineers
Conference & Technical Exhibition, Helsinki,
Finland

Advances in Electrical Logging Tools for Reservoir Characterization

EAGE 99

K.-M. Strack

KMS Technologies

& Baker Hughes - Baker Atlas



Outline

- The challenge to the industry
- Introduction: tools and methods
- Case histories
- Conclusions

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DeepLook: Vision

Breakthrough

Now

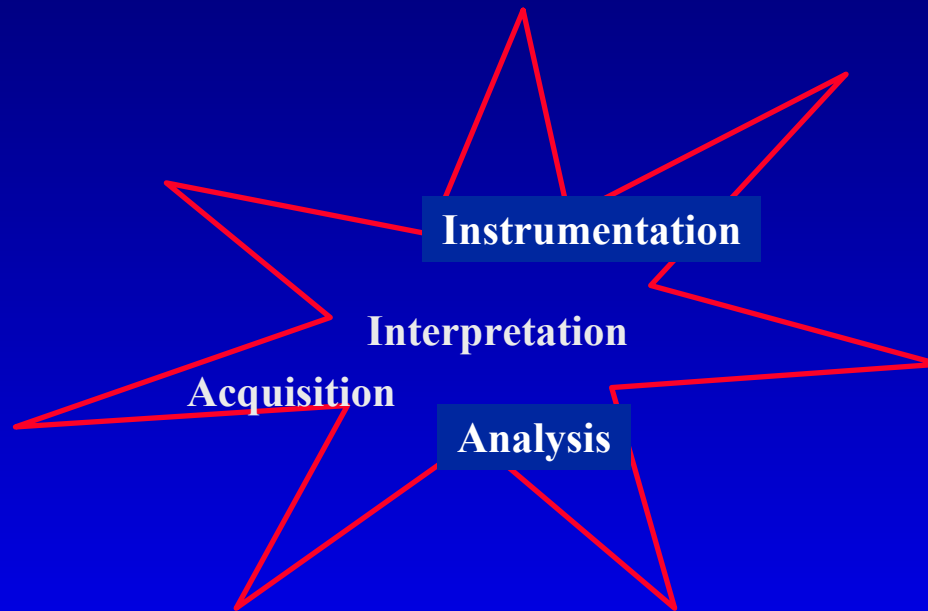
Vision
2000



Bypassed production
Mis-positioned wells
Low well productivity

Expensive testing
Reserves uncertainty
Aquifer drive ??

<35%



70%+ recovery

Optimal well
targeting

Right facilities

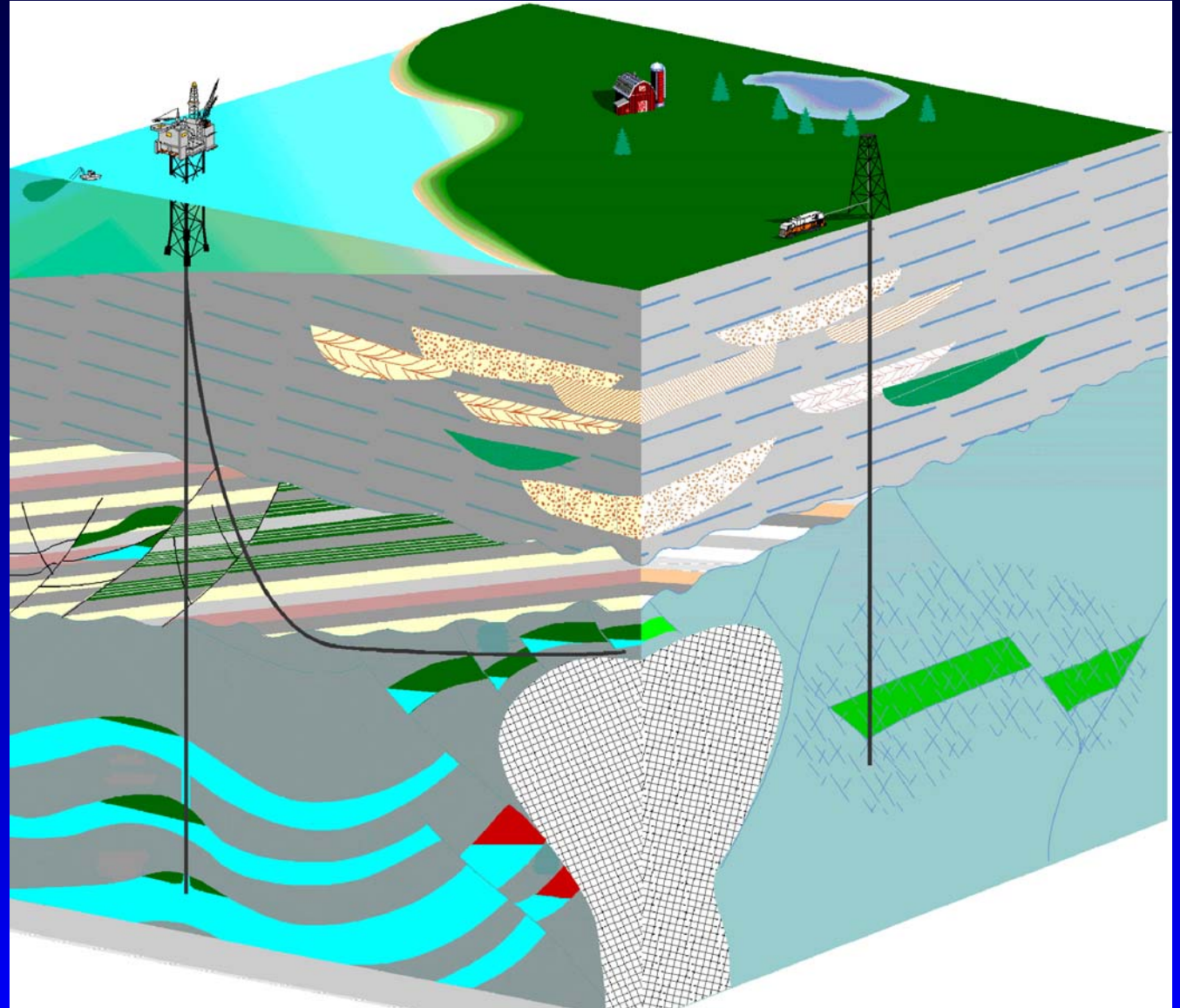
Minimum water
production

70%

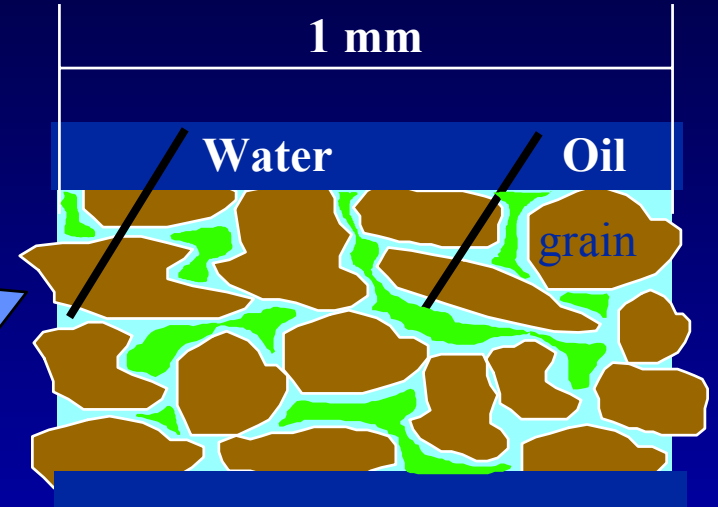
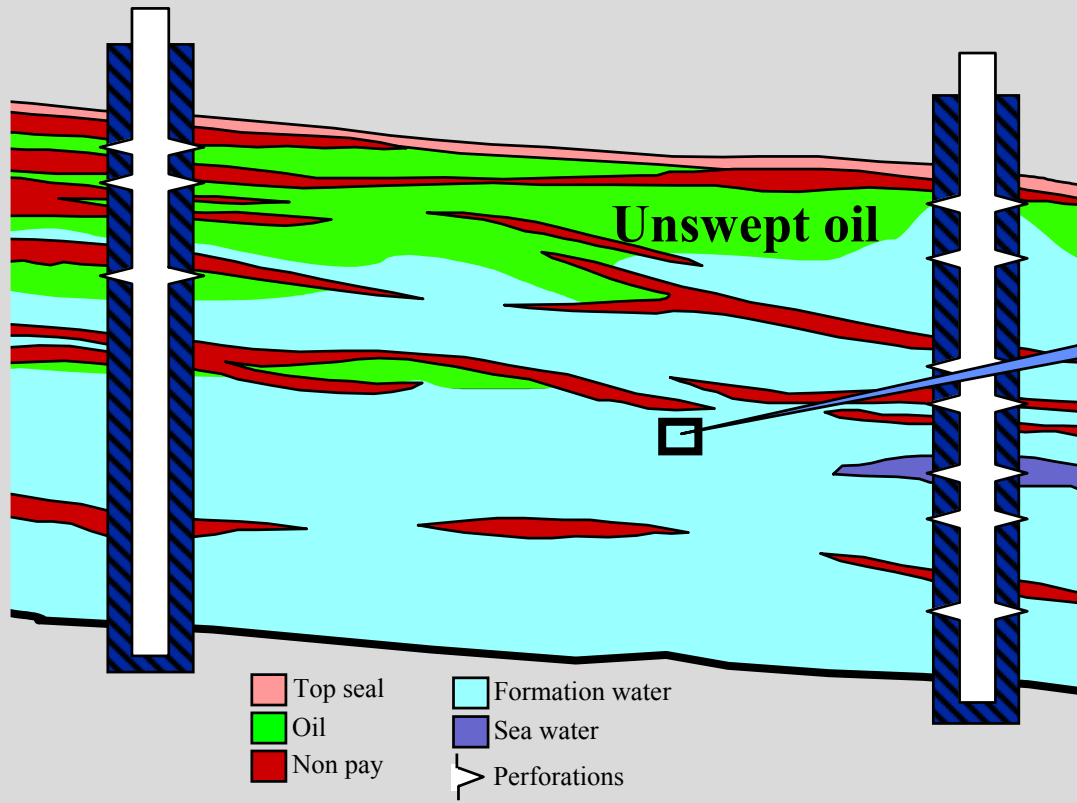
Pilot Projects

The Paradigm Shift: information value

**Integration
information
in the
3 D volume**

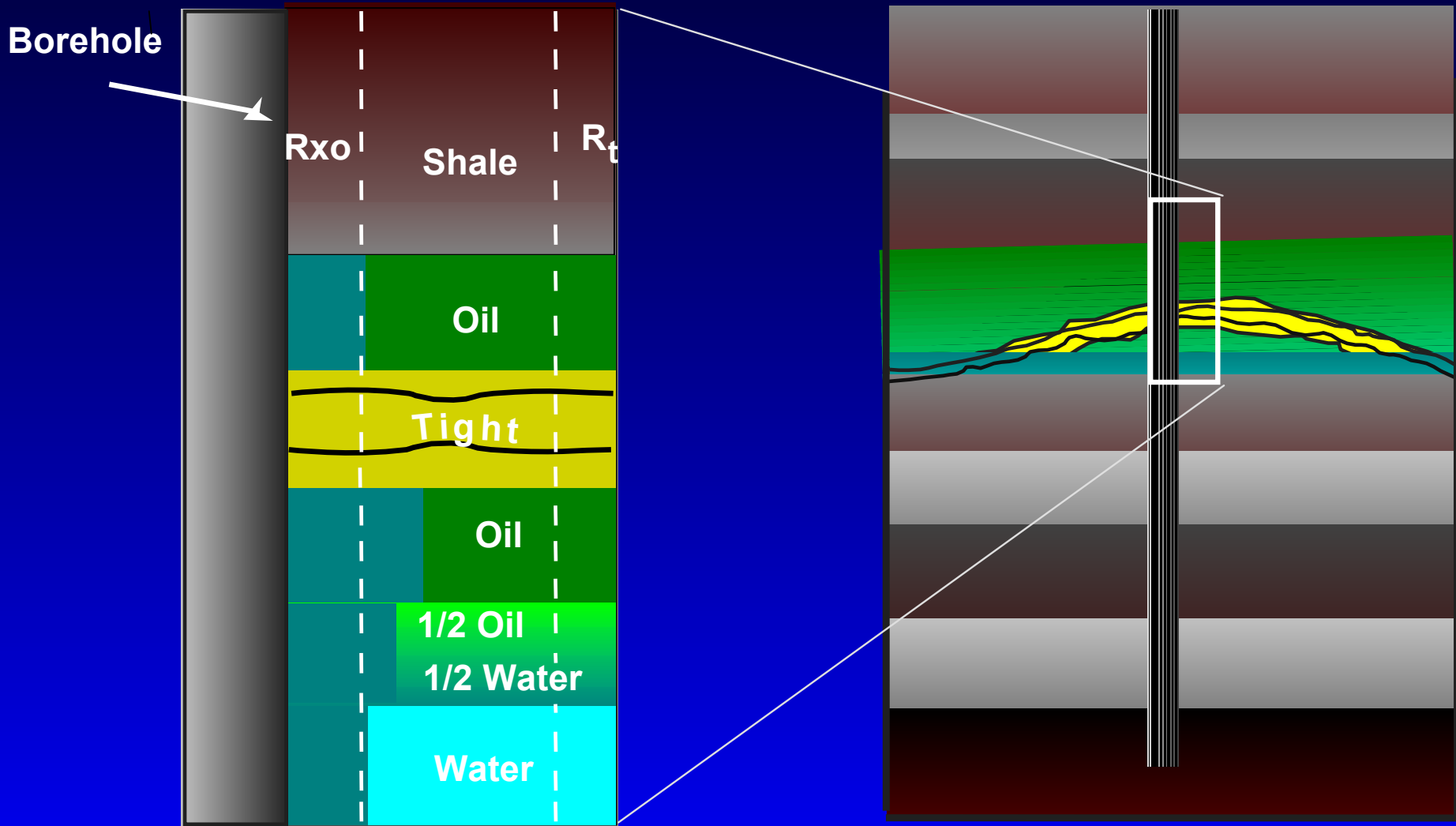


Scope of the Challenge



Oil is trapped by surface tension and structure.

Oil - Resistivity relationship



Formation Evaluation Trends

- **Reservoir/production: Drainage**
 - Measurements: Stress & structure (fractures, interwell geology), Horizontal well (guidance, assessment), Through-casing (existing reservoirs)
 - Modeling & Inversion (logs and integration) **UNCERTAINTIES**
- **Deep investigation techniques: The Next Generation**
 - Cross-well techniques...selective cases
 - Single well/ cross-well seismic
 - Single well EM
 - Borehole gravity **JOINT technology gives answer**

Shopping list:

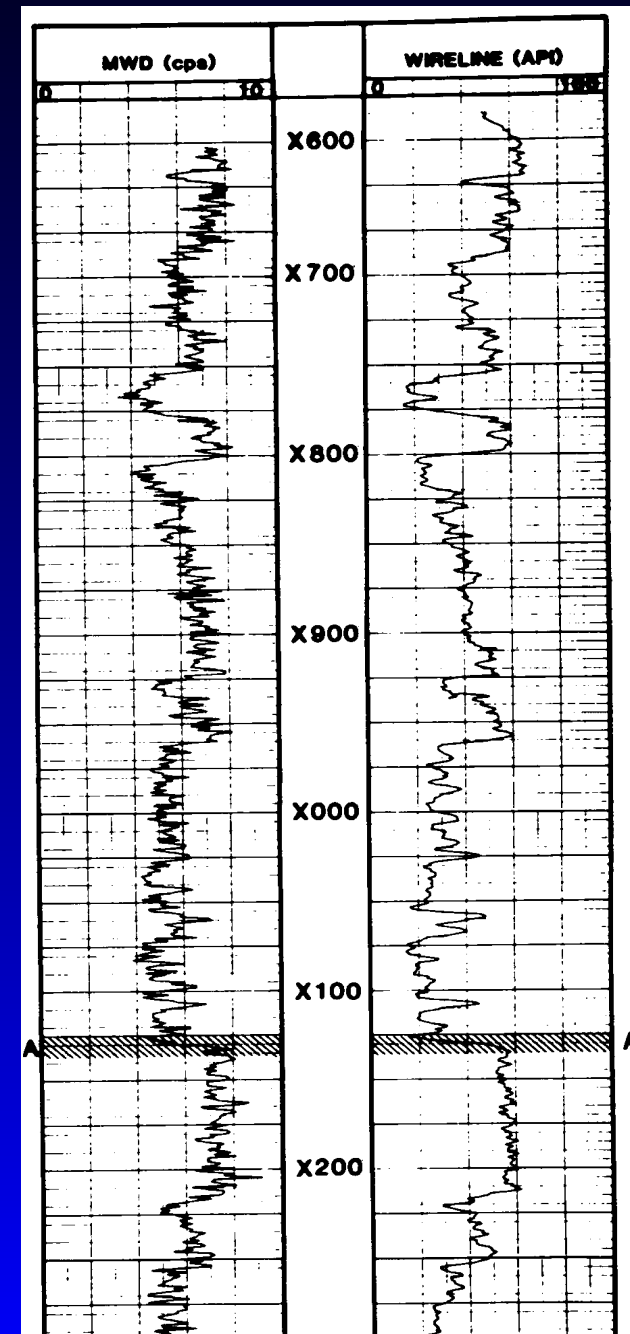
- **Optimum use of MWD & wireline**
 - **MWD: routine and steering**
 - **wireline: imaging and deep**
- **Advanced logs:**
 - **faster well-site decisions,**
 - **higher resolution**
 - **deeper investigation**
- **Permanent sensors**

Outline

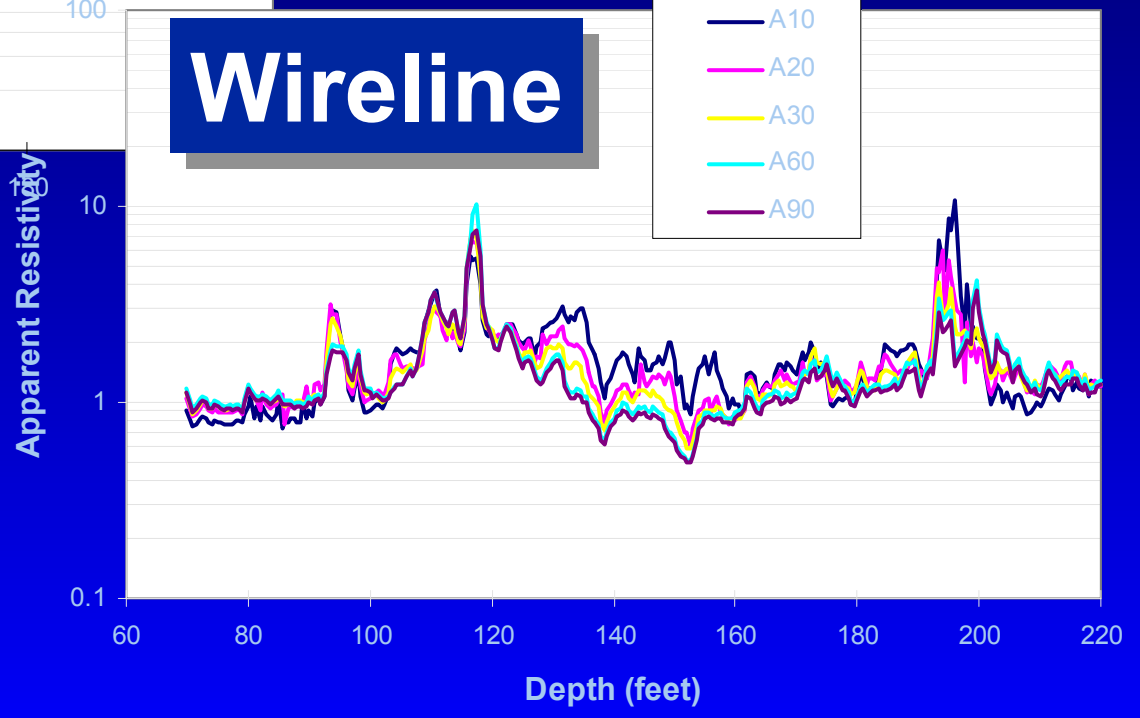
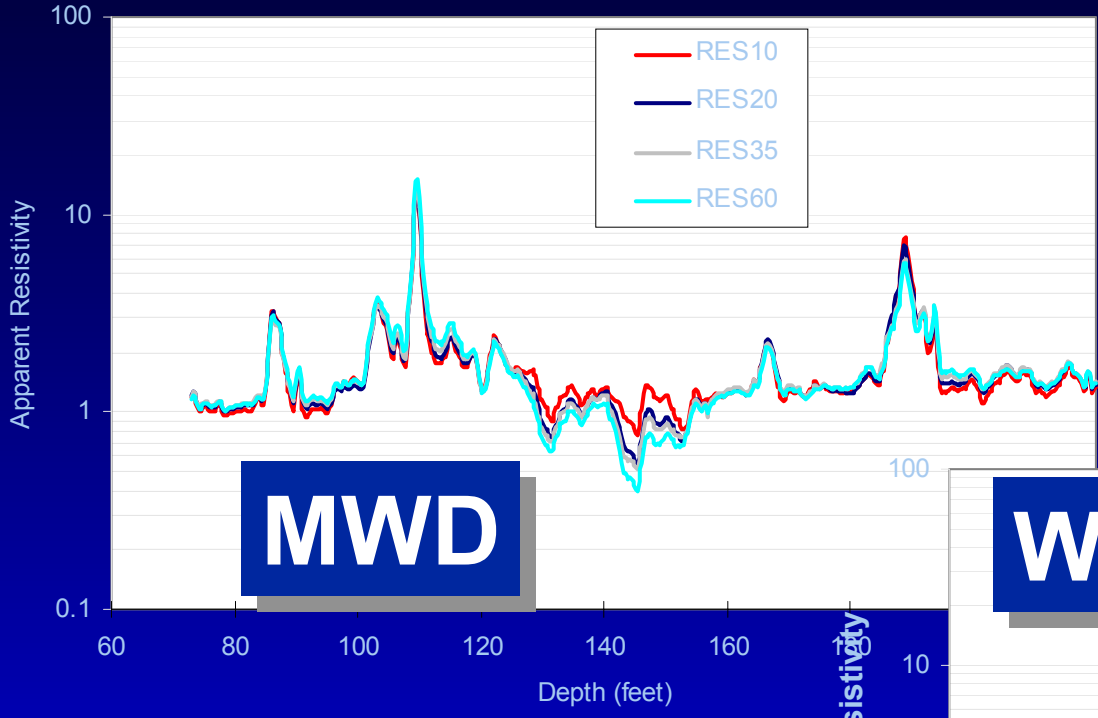
- The challenge to the industry
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LWD and wireline methods definitions:

- **MWD/LWD - measurement/logging while drilling**
 - sensor is part of the drill string; hostile sensor environment; basic sensors exist; making fast progress, data transmission via mud pulse (few 10 Hz) & memory packages
- **Wireline - sensor attached to armored long cable**
 - delicate instruments with real time surface acquisition; formation samplers to high data rate imaging tools (video).

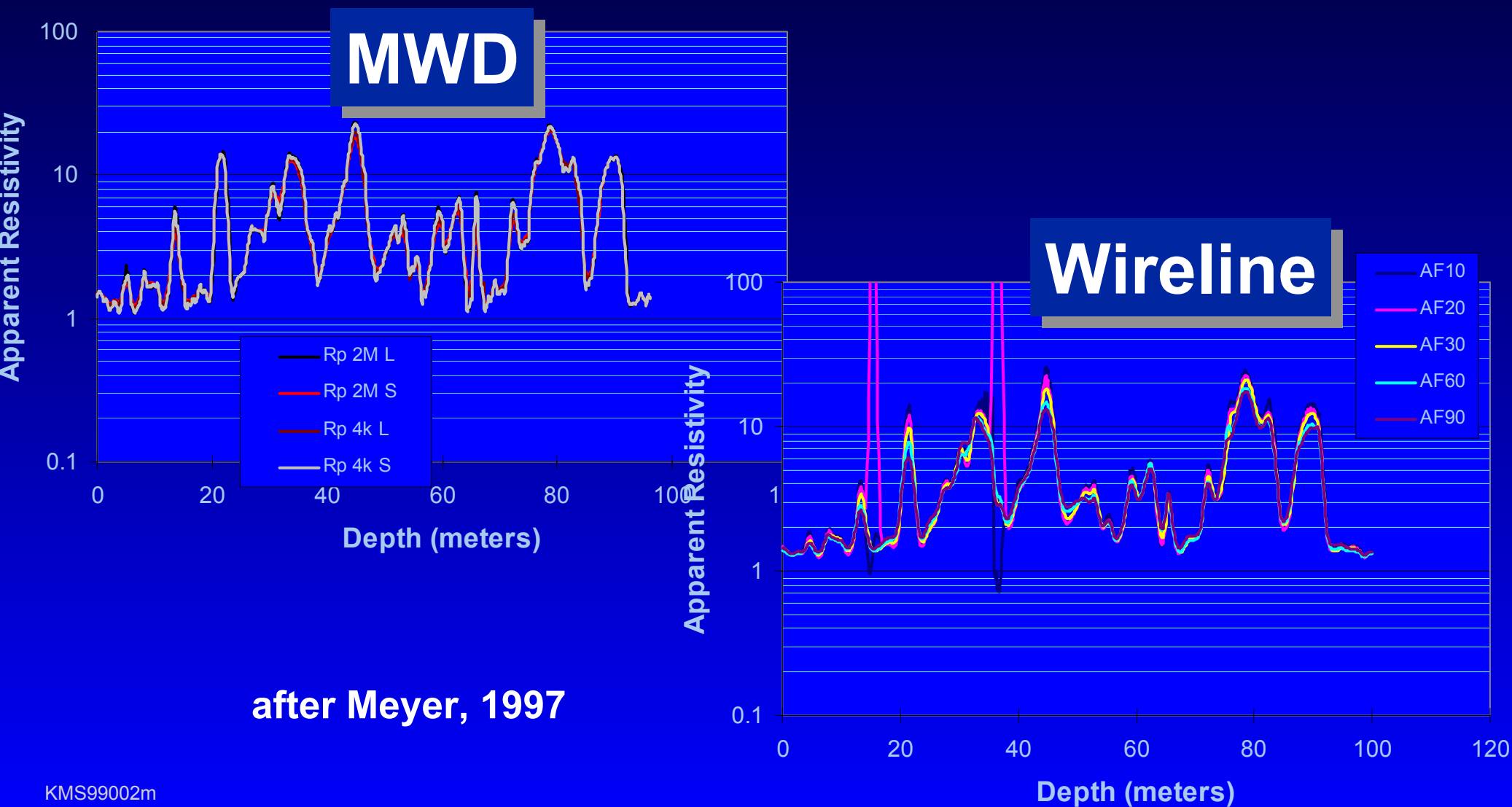


MWD and wireline induction logs GOM

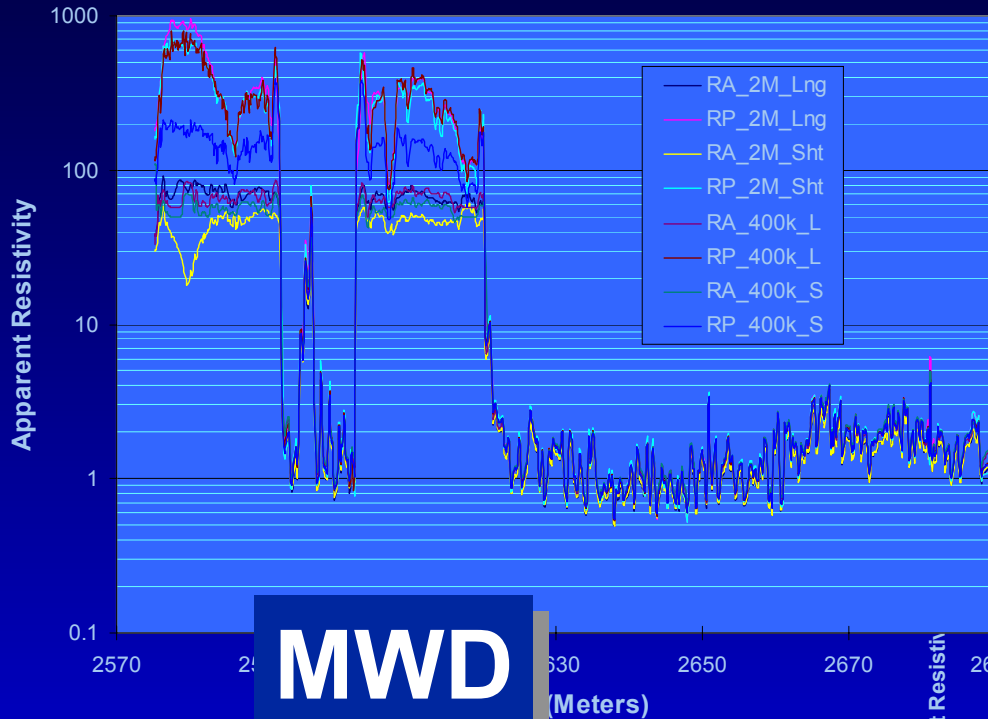


after Meyer, 1997

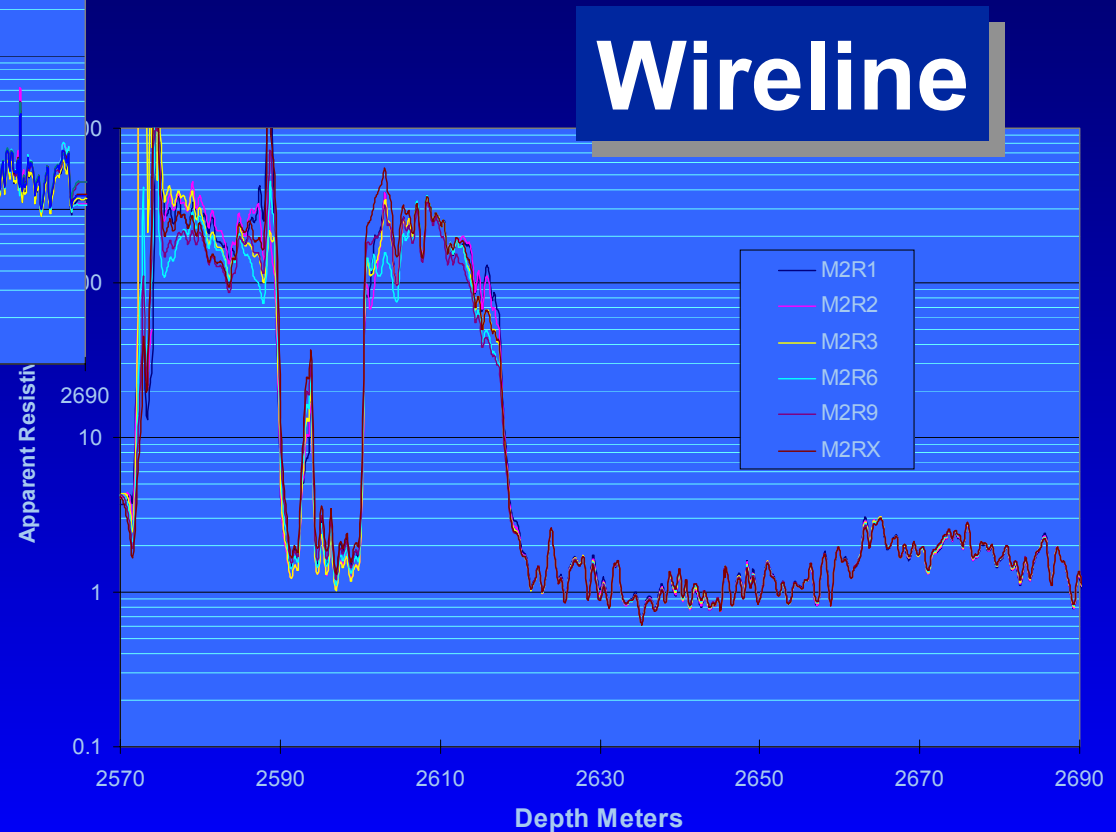
MWD and wireline induction logs North Sea



MWD and wireline induction logs North Sea

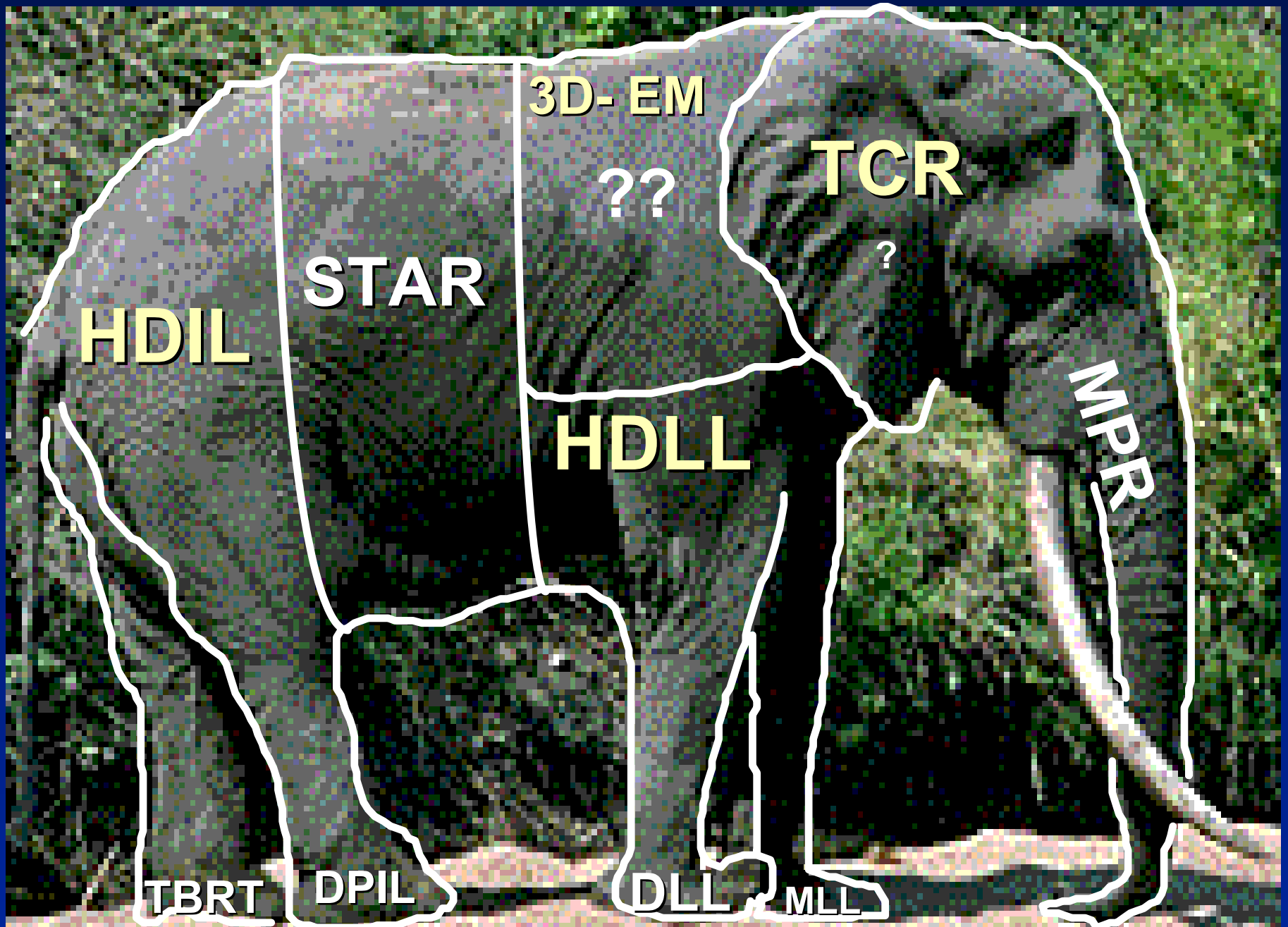


after Meyer, 1997

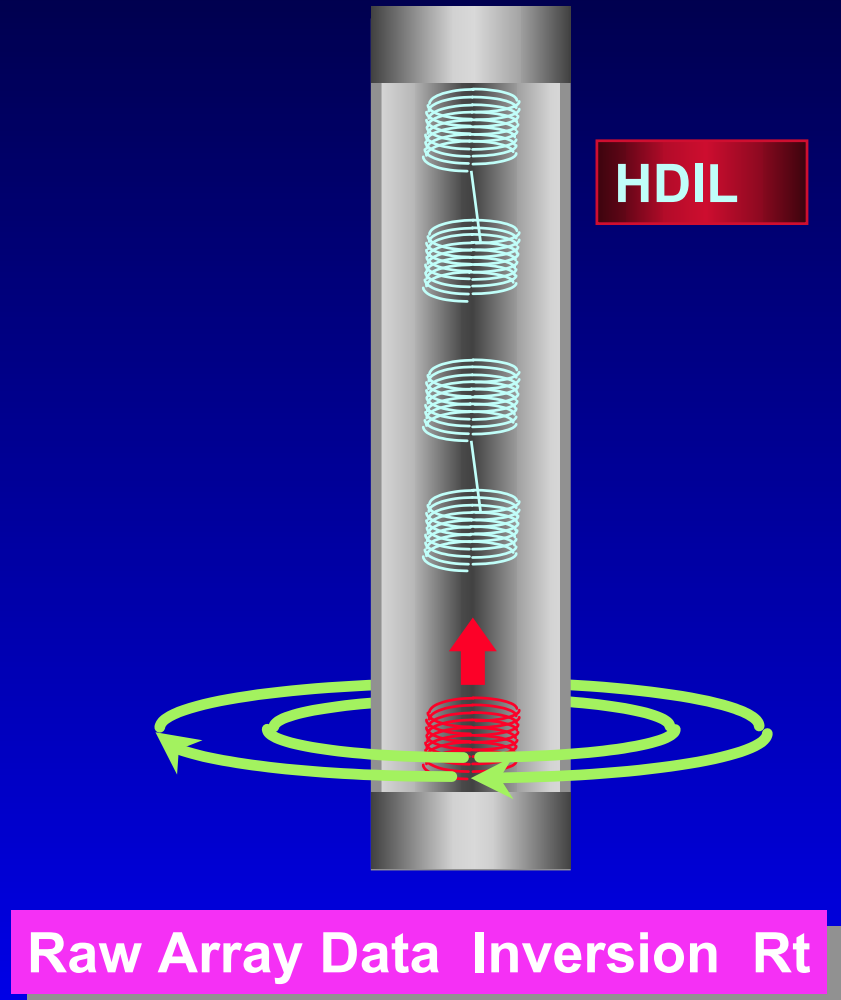
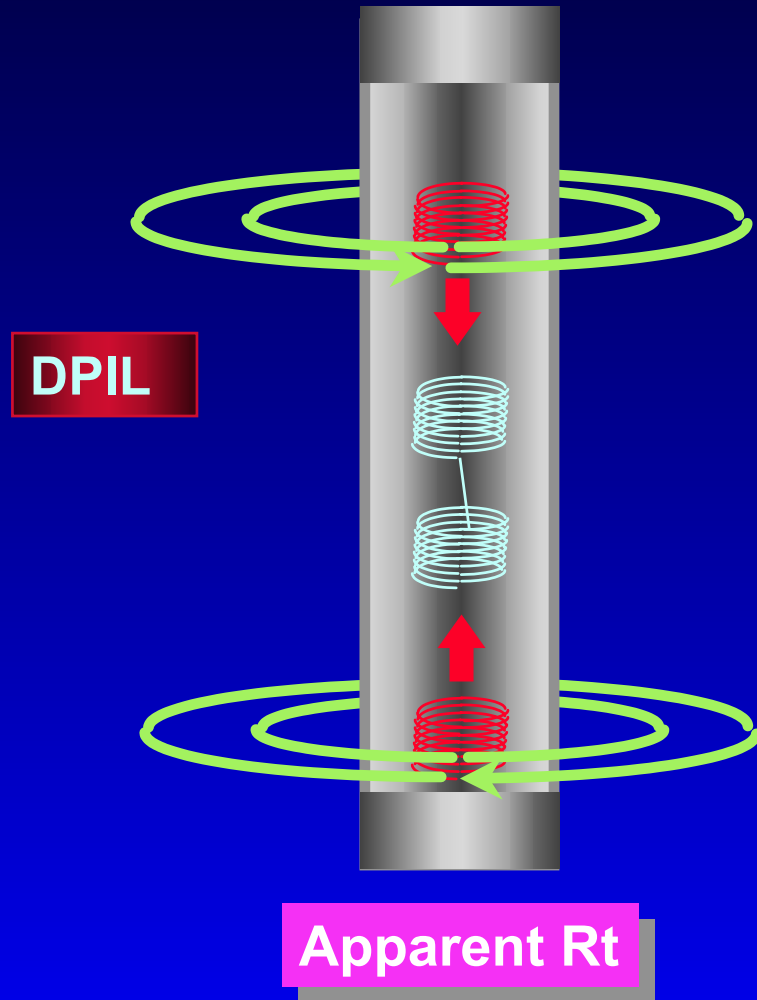


Tools & Methods:

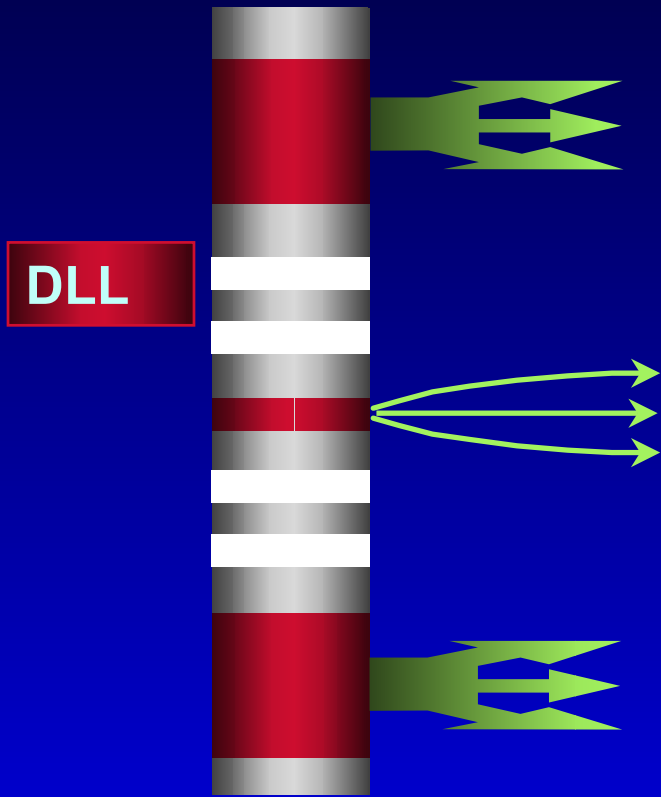
- **Resistivity logging status**
- **Meters versus acquisition systems**
- **Hardware: analog versus 24 bit**
- **Interpretation: chart versus inversion**
- **3D modeling**



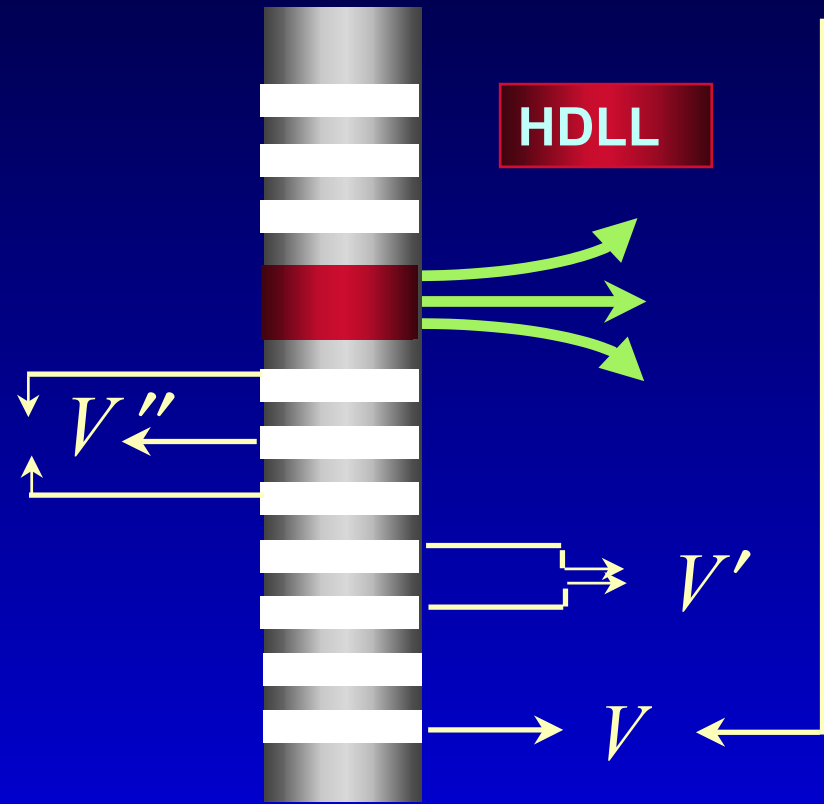
Meters vs acquisition systems: Induction



Meters vs acquisition systems: Galvanic



Apparent R_t

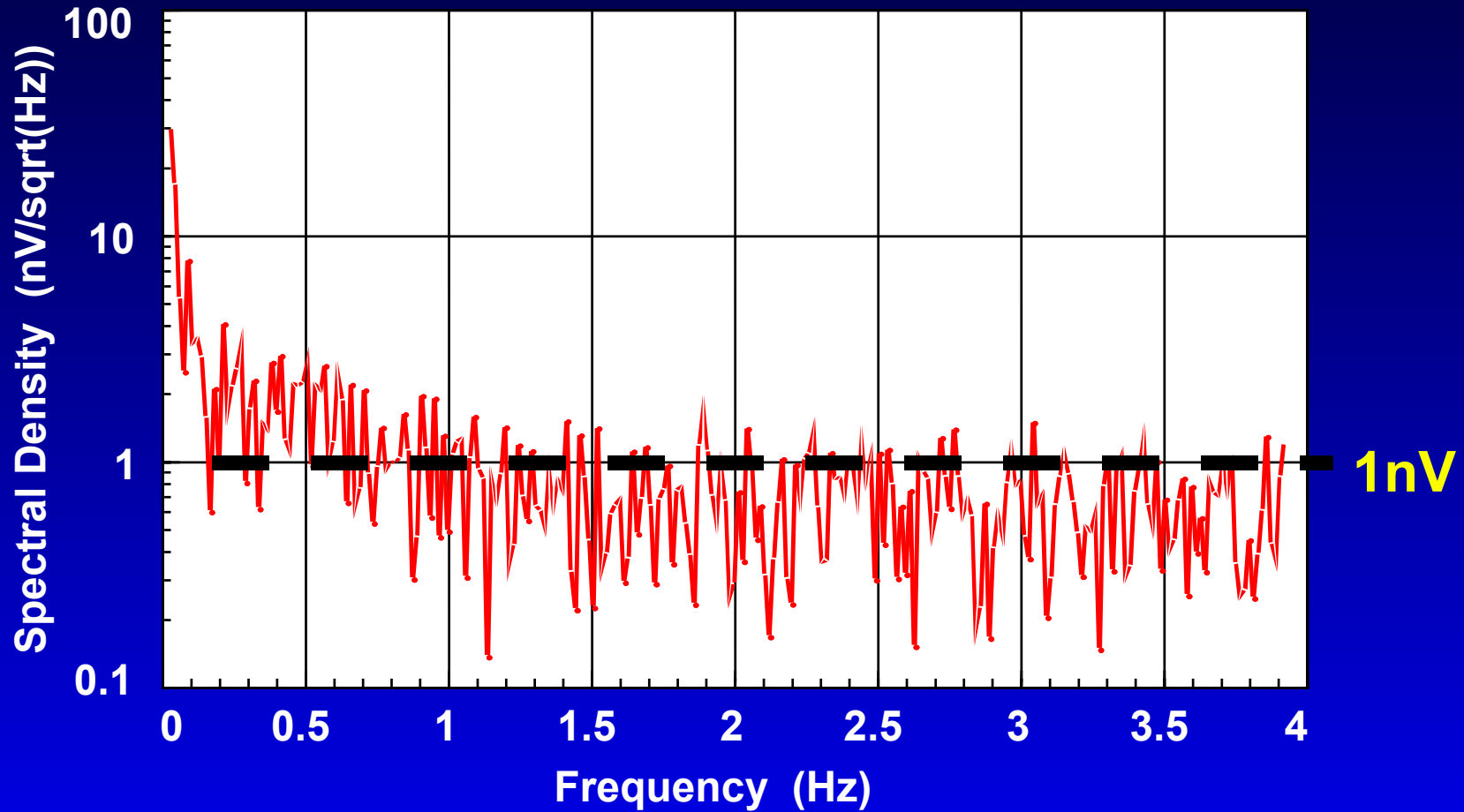


Raw Array Data Inversion R_t

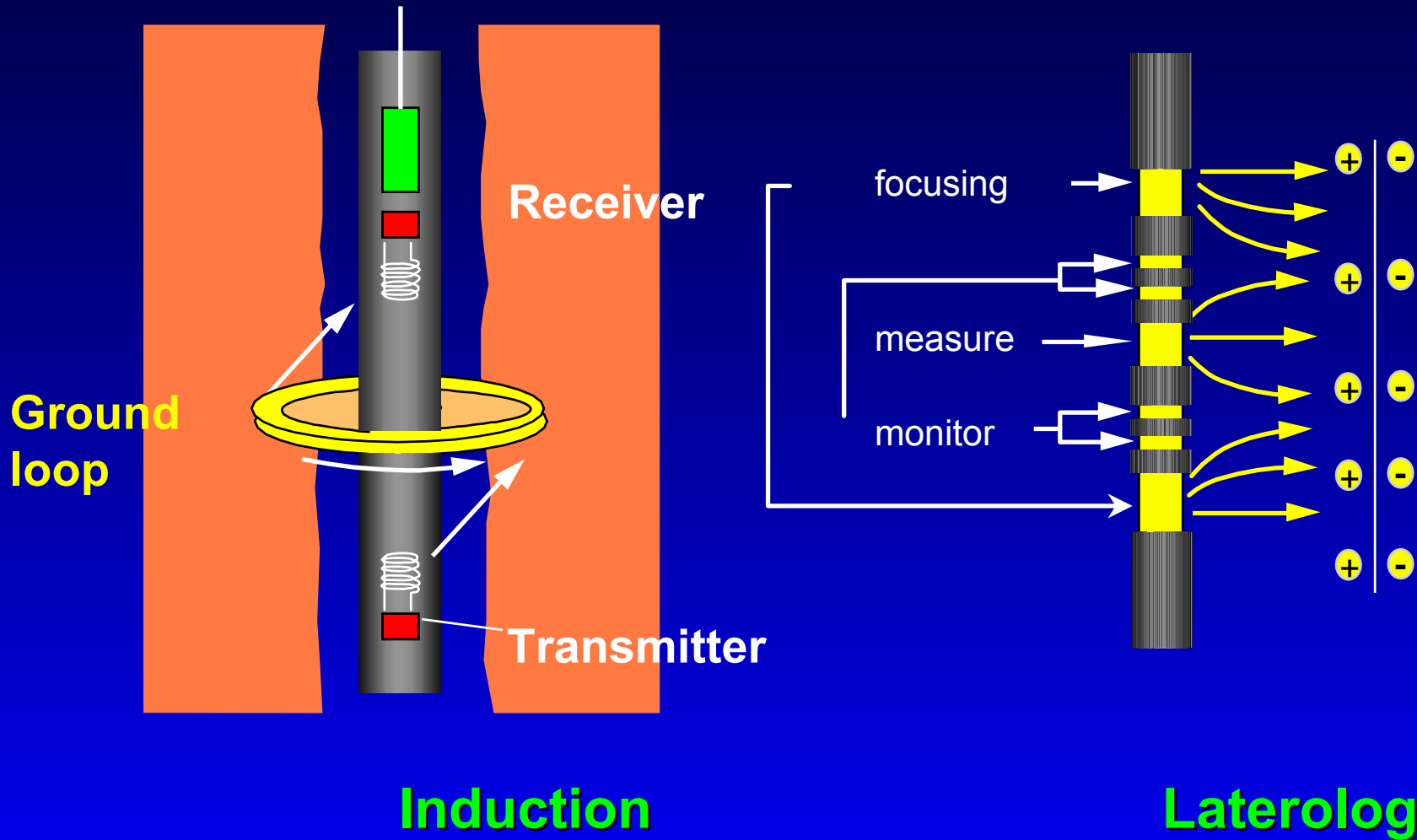
Hardware: Analog versus 24 bit

- OLD
 - analog detectors to surface
 - balanced (formation sensitive)
 - 12 bit
 - temperature sensitive
- NEW
 - digital signal processing at sensor
 - high instantaneous dynamic range
 - 24 bits sigma delta
 - high temperature
 - array measurements

Input amplifier noise



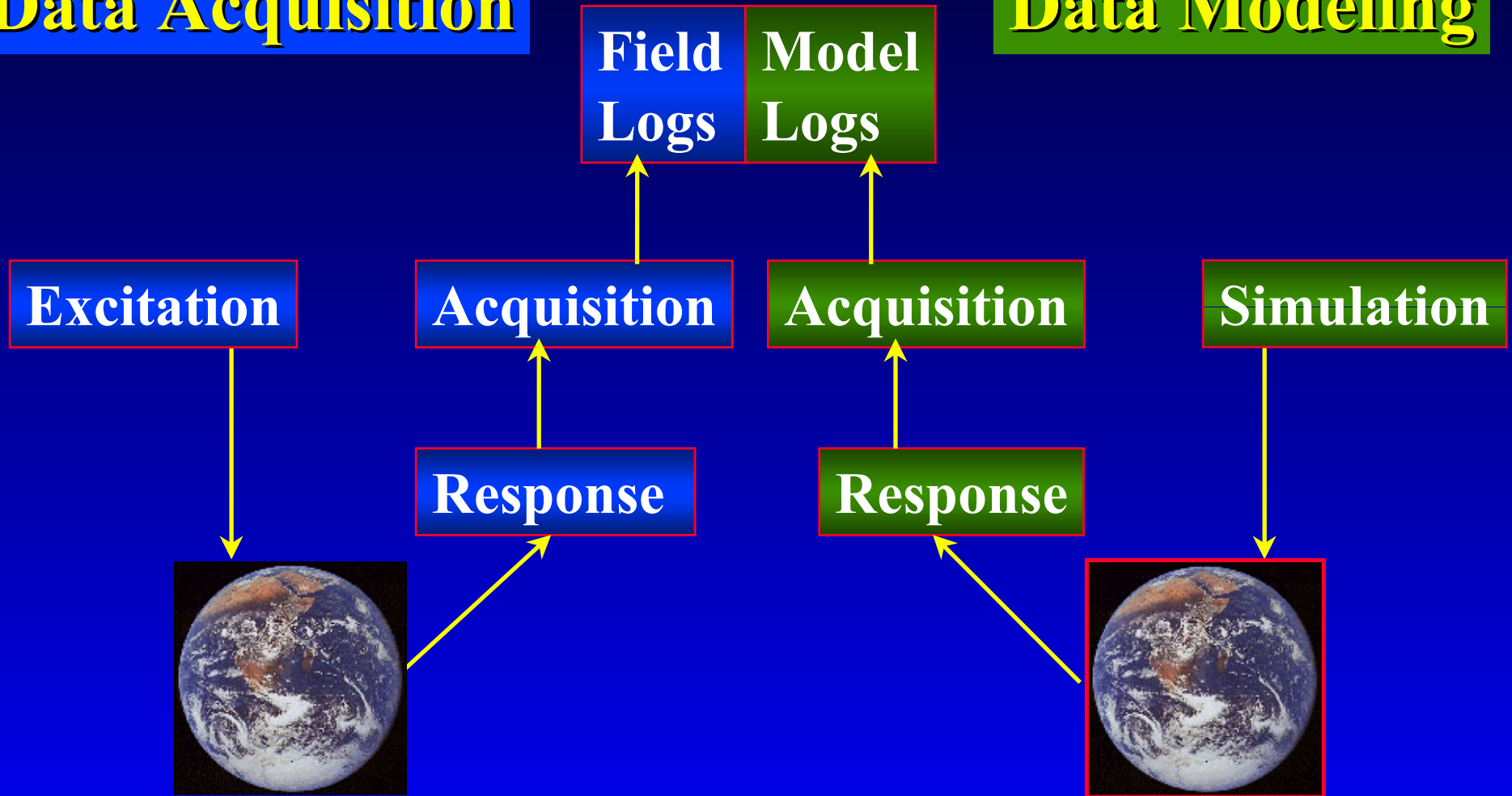
Geoinversion: Log integration & upscaling



Inversion: Process flow

Data Acquisition

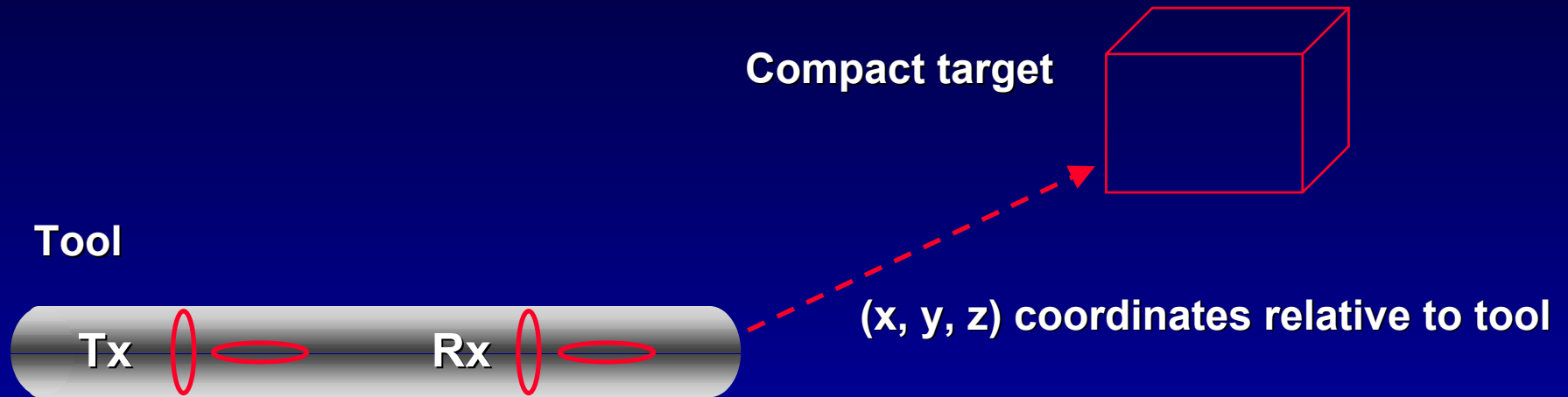
Data Modeling



3D Modeling

- OLD
 - algorithms not widely available
 - Run time too long
 - mainly vertical wells
- NEW
 - algorithms more available
 - Super/parallel computer on desktop
 - mostly horizontal wells

Directional Sensitivity



Can pinpoint location of compact target in uniform host, plus sign and magnitude of conductivity contrast

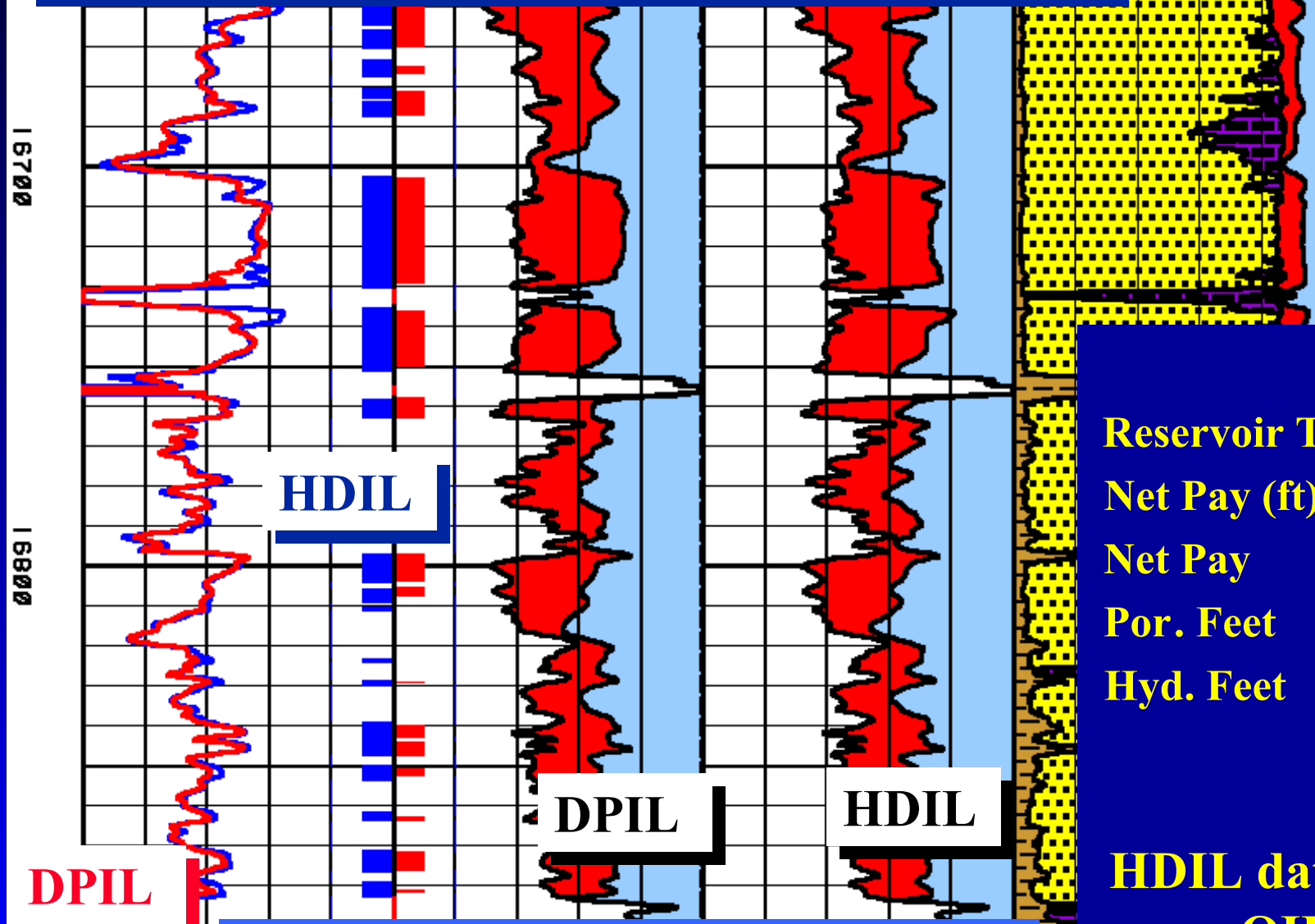
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Case histories

- **Array tool advantage**
- **1D versus 2D**
- **Upscaling**
- **3D example**
- **Multi-component - the future**

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

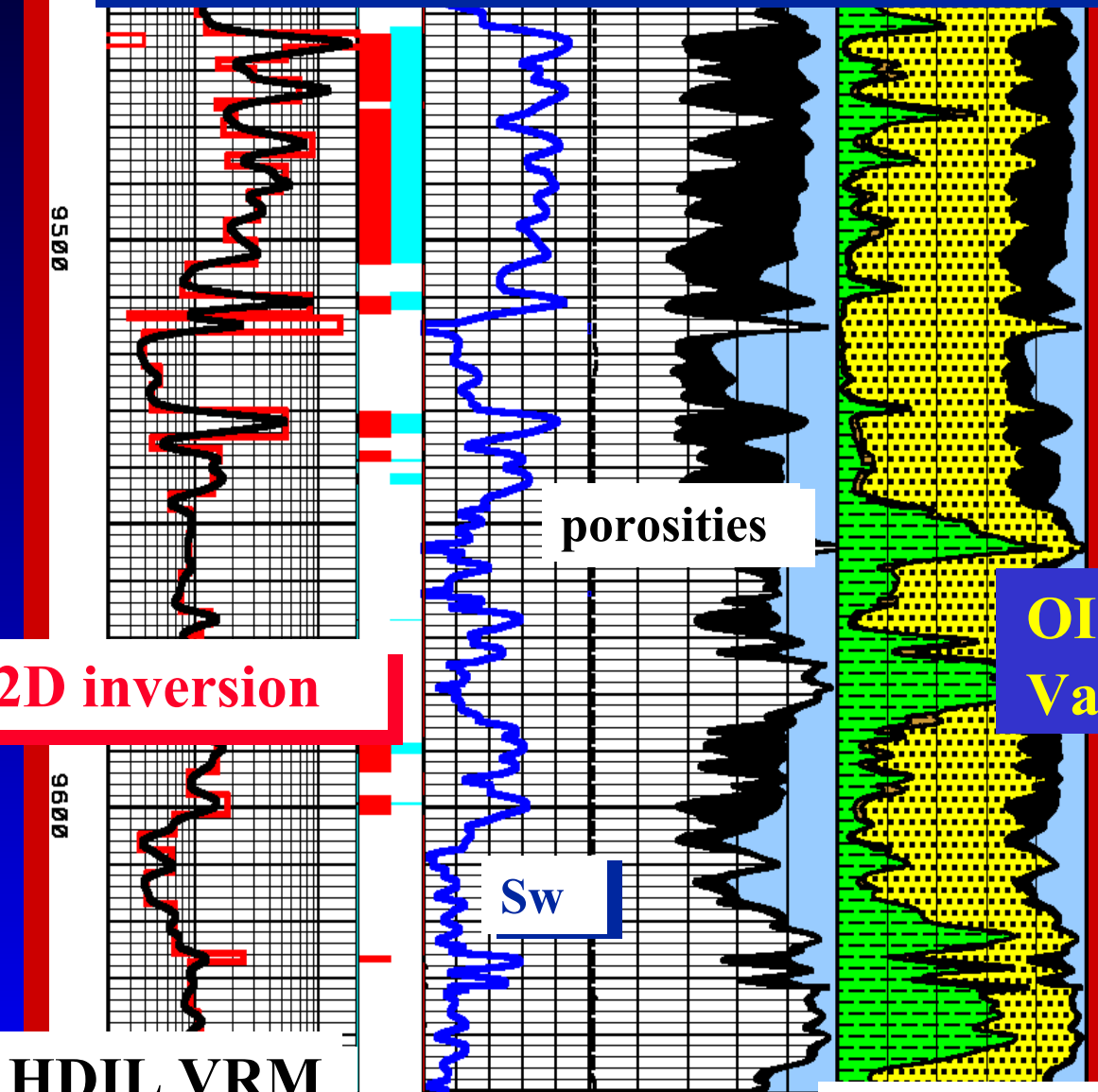
HDIL data allowed 24% more OIIP be booked.

Net Pay and Saturation Analysis

DPIL

WALS98209g

Step change through software



2D inversion

HDIL VRM

porosities

Sw

volumetrics

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%

HDLL vs DLL

Gamma ray

caliper

SP

Improved vertical Resolution

305

310

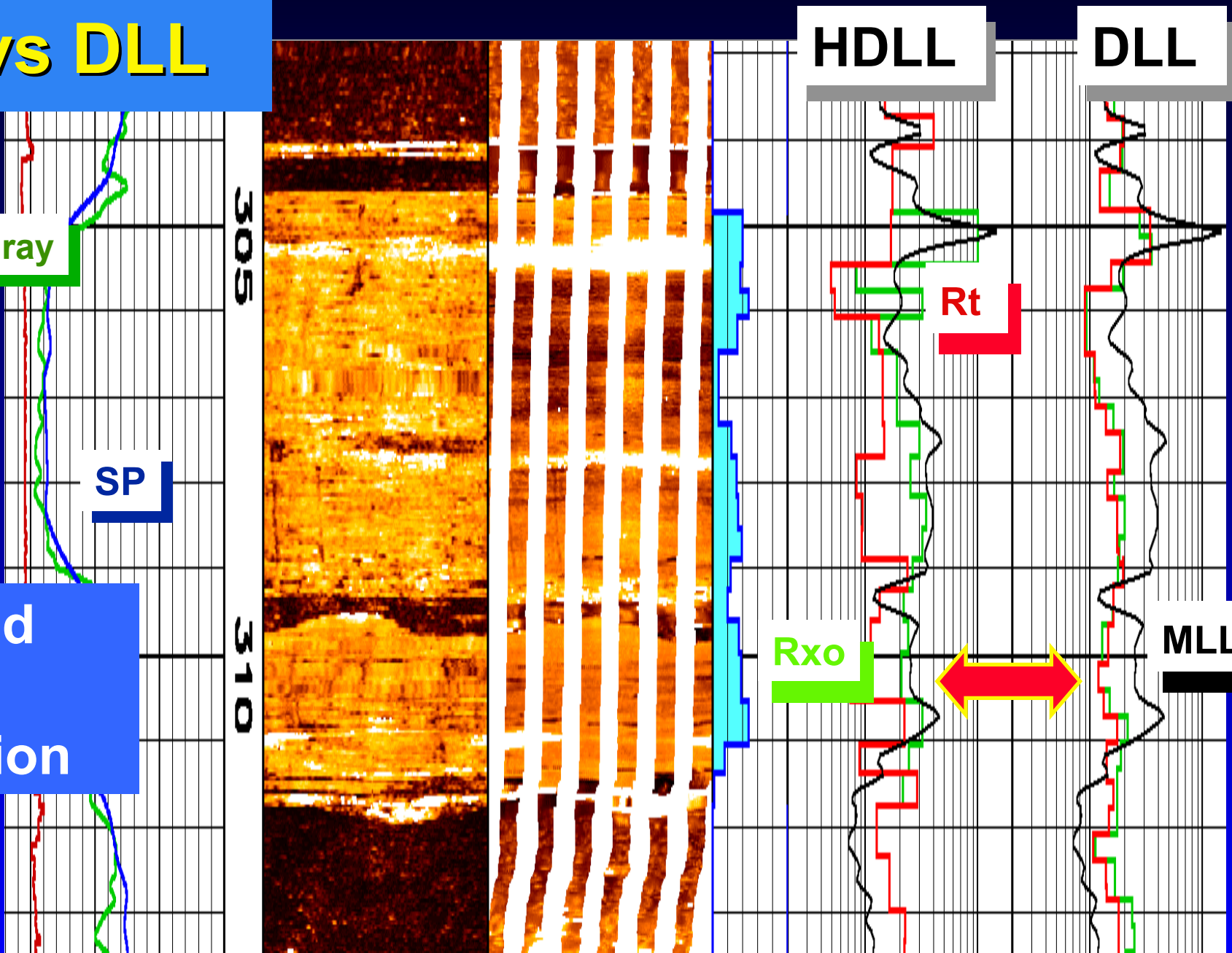
HDLL

DLL

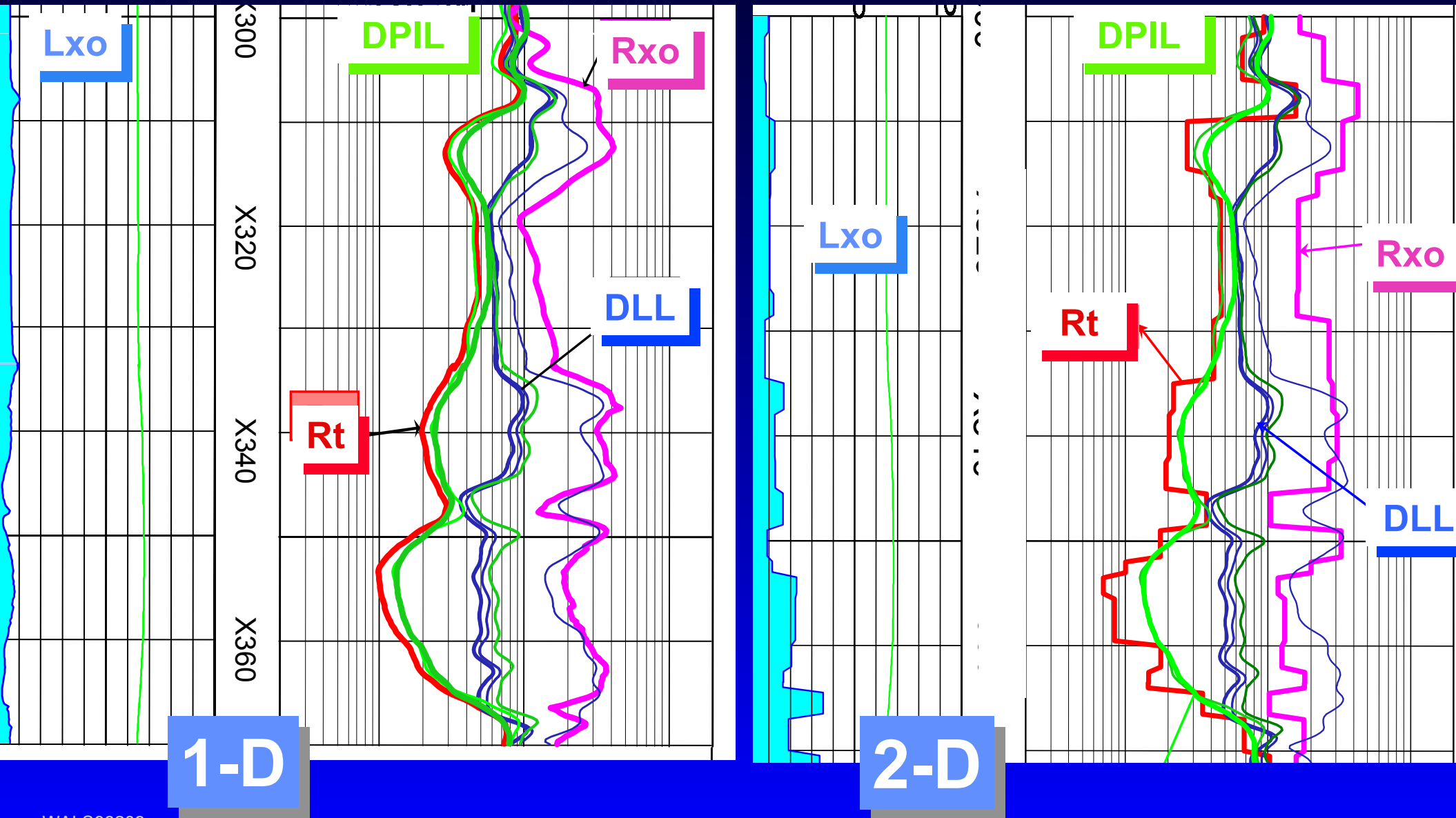
Rt

Rxo

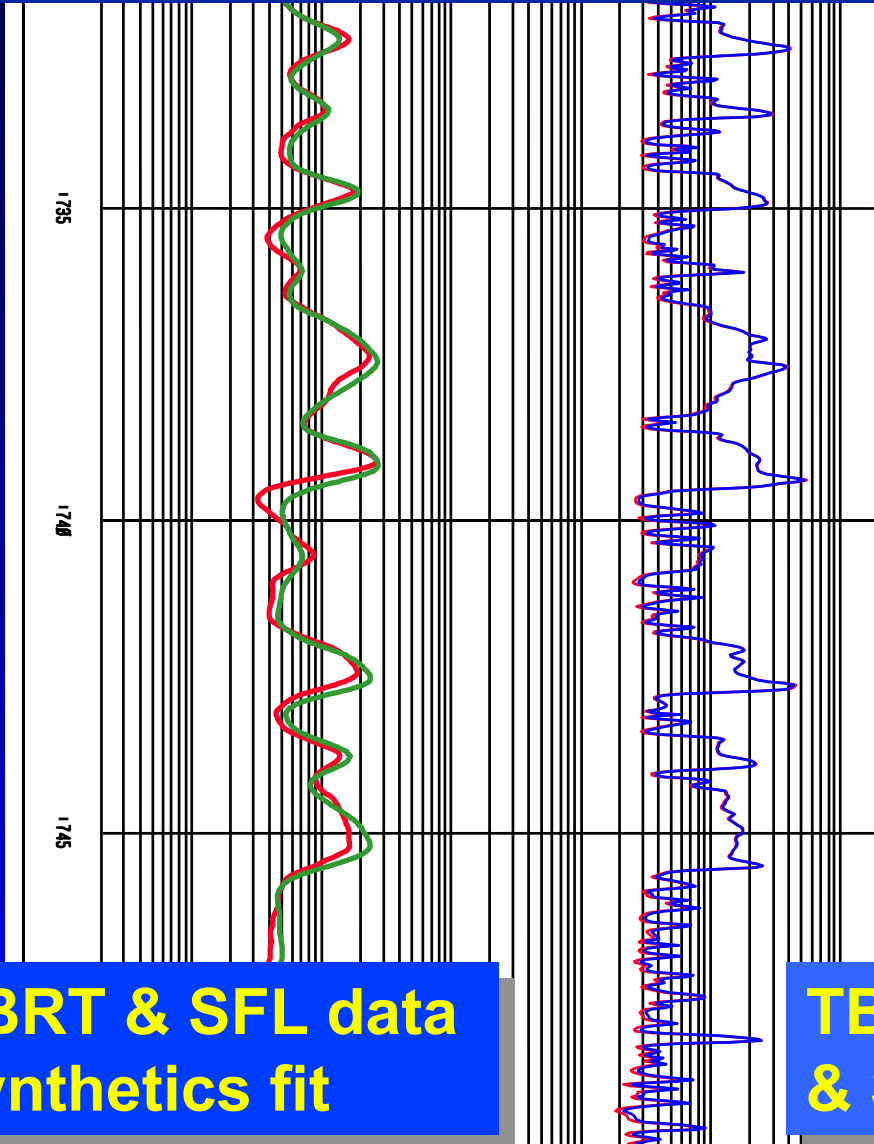
MLL



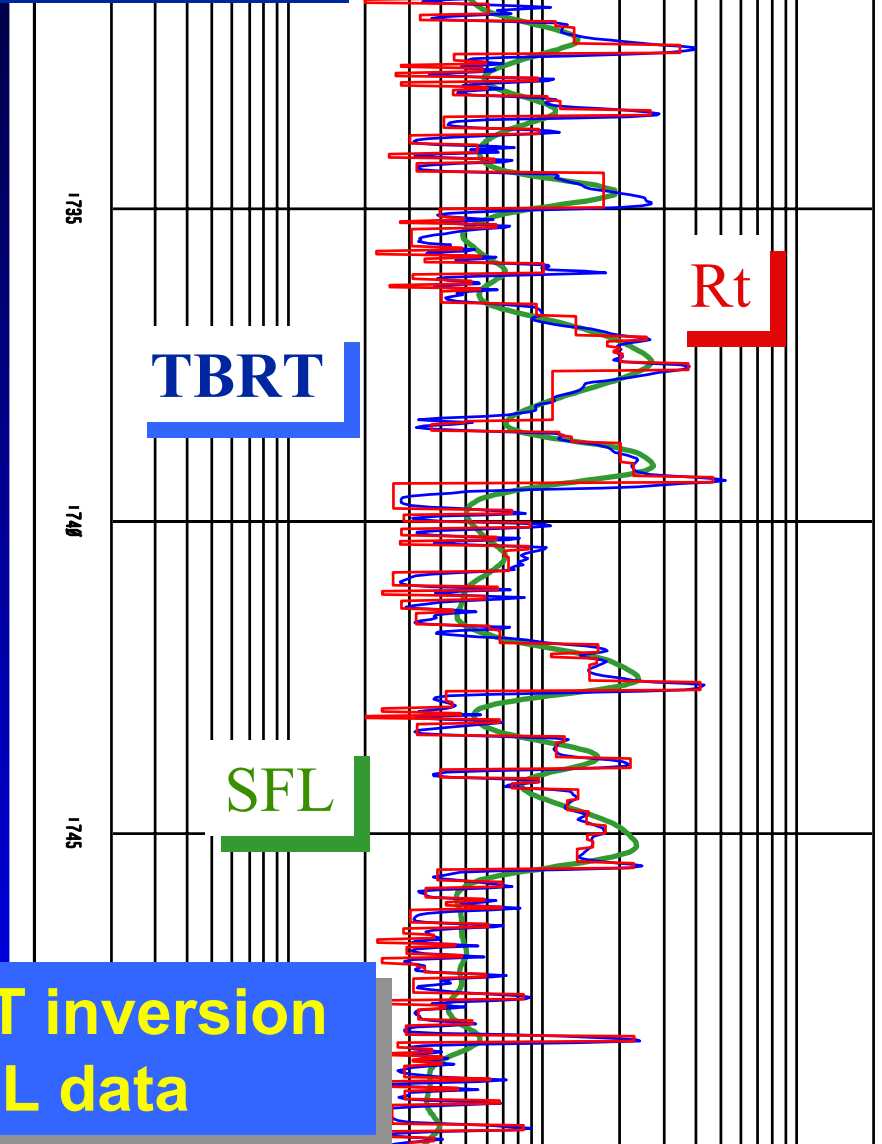
Inversion: 1D versus 2D



Upscaling: Thin bed analysis

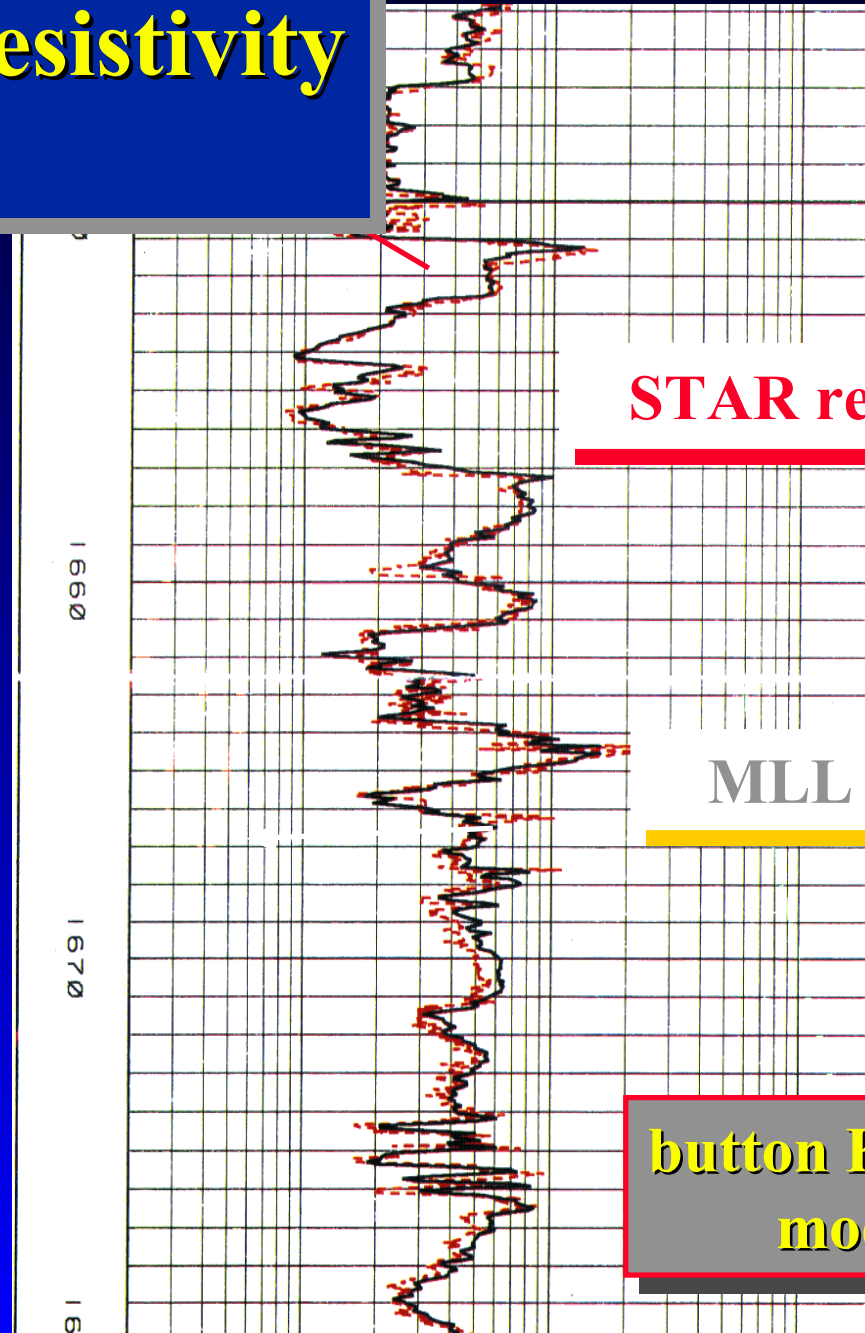


TBRT & SFL data
synthetic fit



TBRT inversion
& SFL data

Upscaling: Image resistivity & Microlaterolog



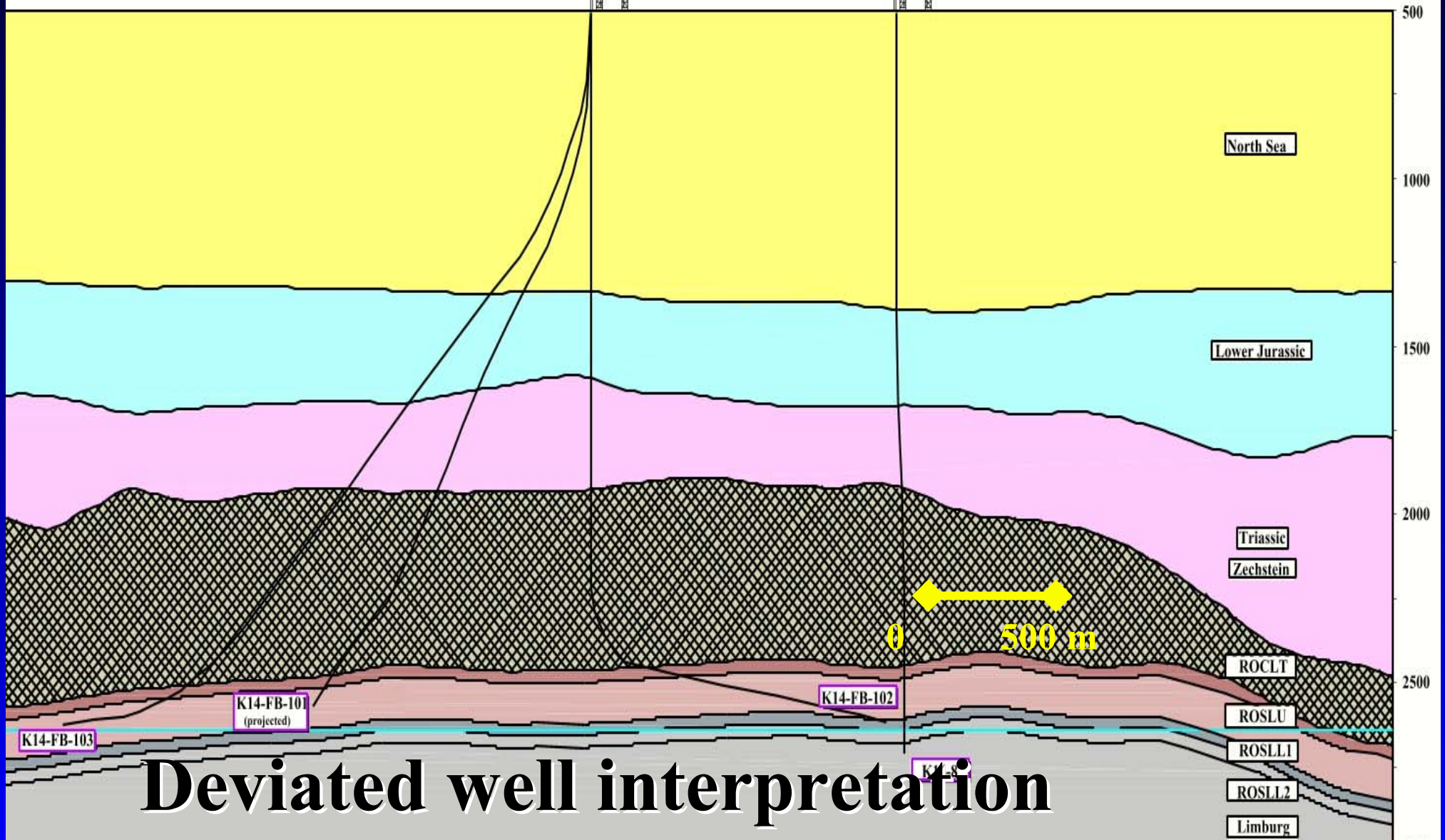
STAR resistivity

MLL resistivity

button K from 3D modeling

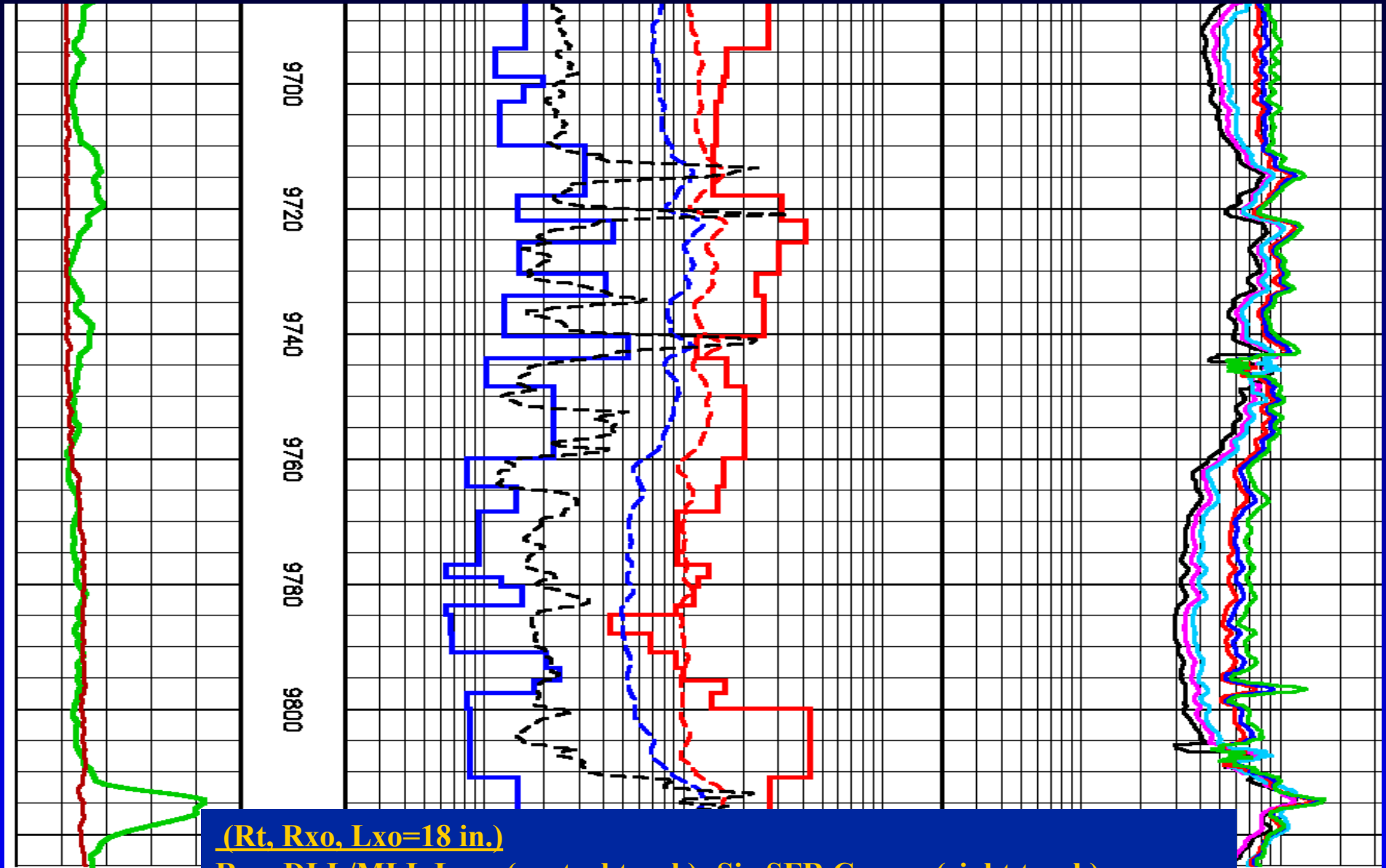
SE →

Depth (m TVMS)



Deviated well interpretation

HDLL horizontal well example



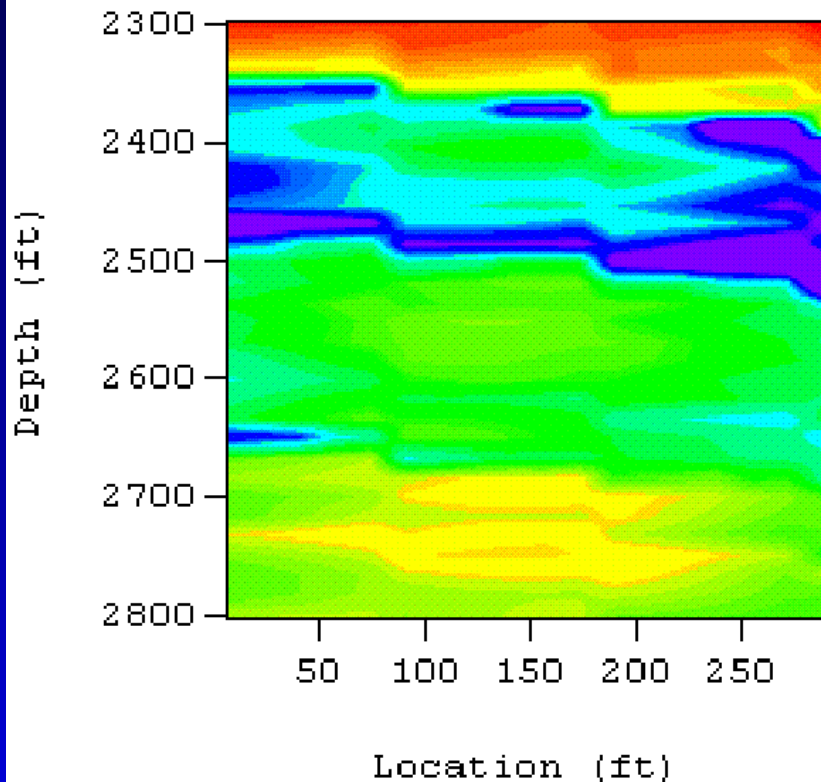
(Rt, Rxo, Lxo=18 in.)

Raw DLL/MLL Logs (central track); Six SFR Curves (right track)

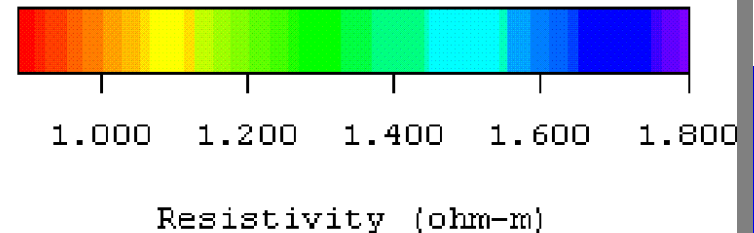
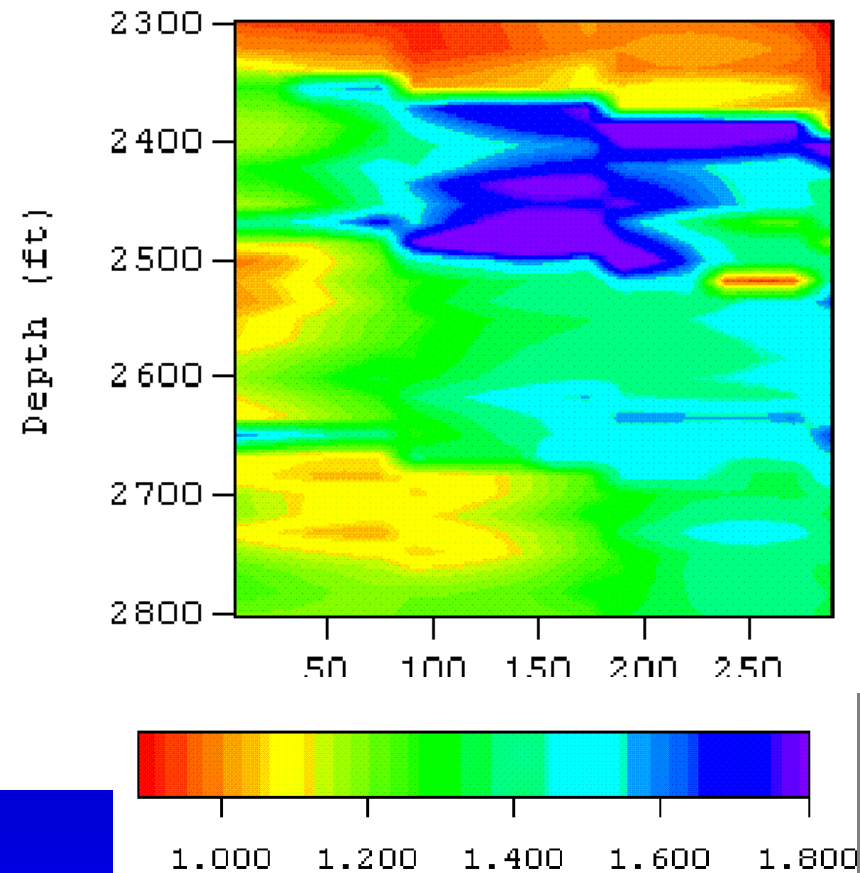
Model parameters: $R_m=0.027$ ohm-m; $dev=78.5$ deg.

Cross-well time lapse measurements

Crosshole EM Resistivity 4/97

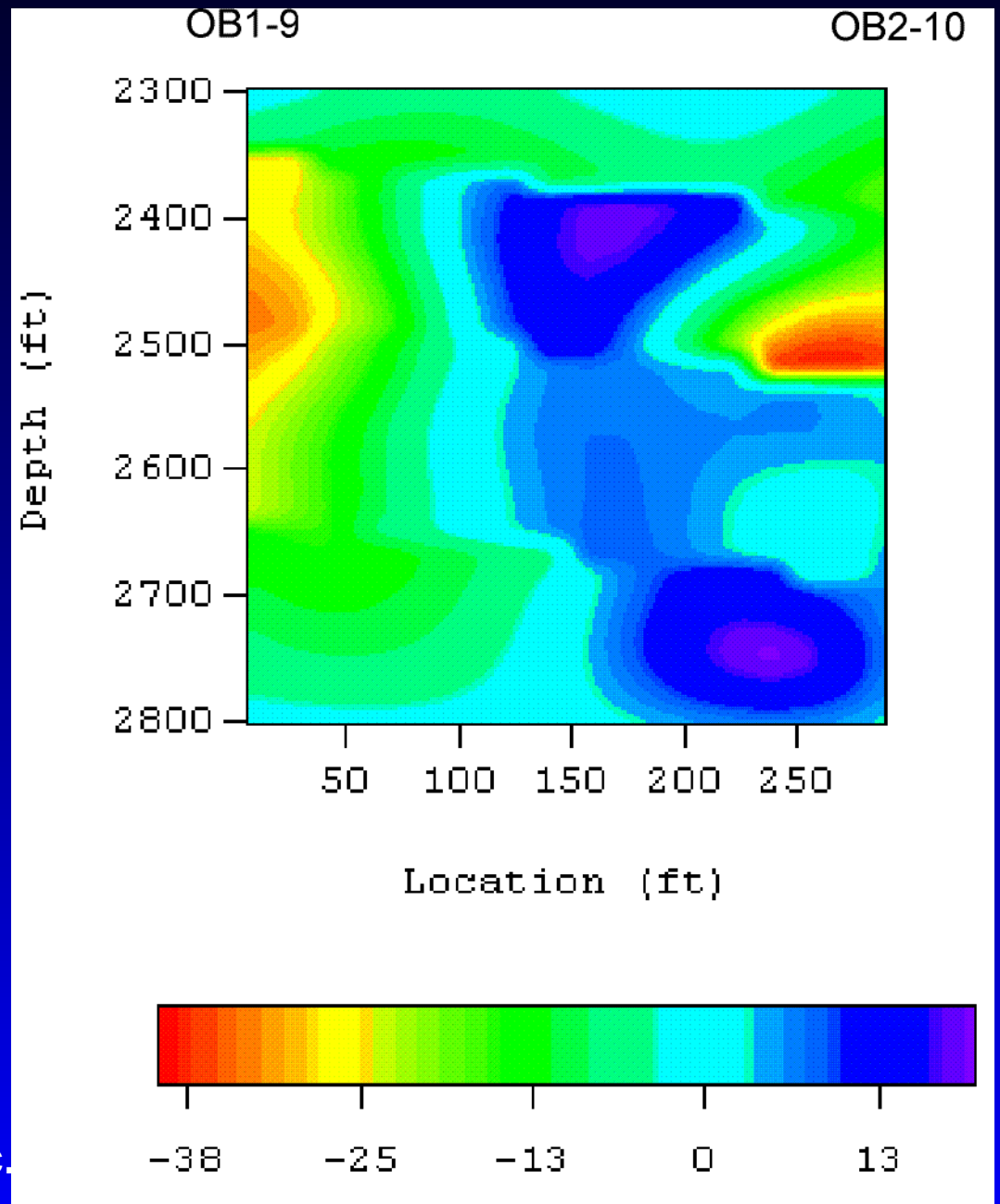


Crosshole EM Resistivity 8/98



Courtesy of EMI Inc.

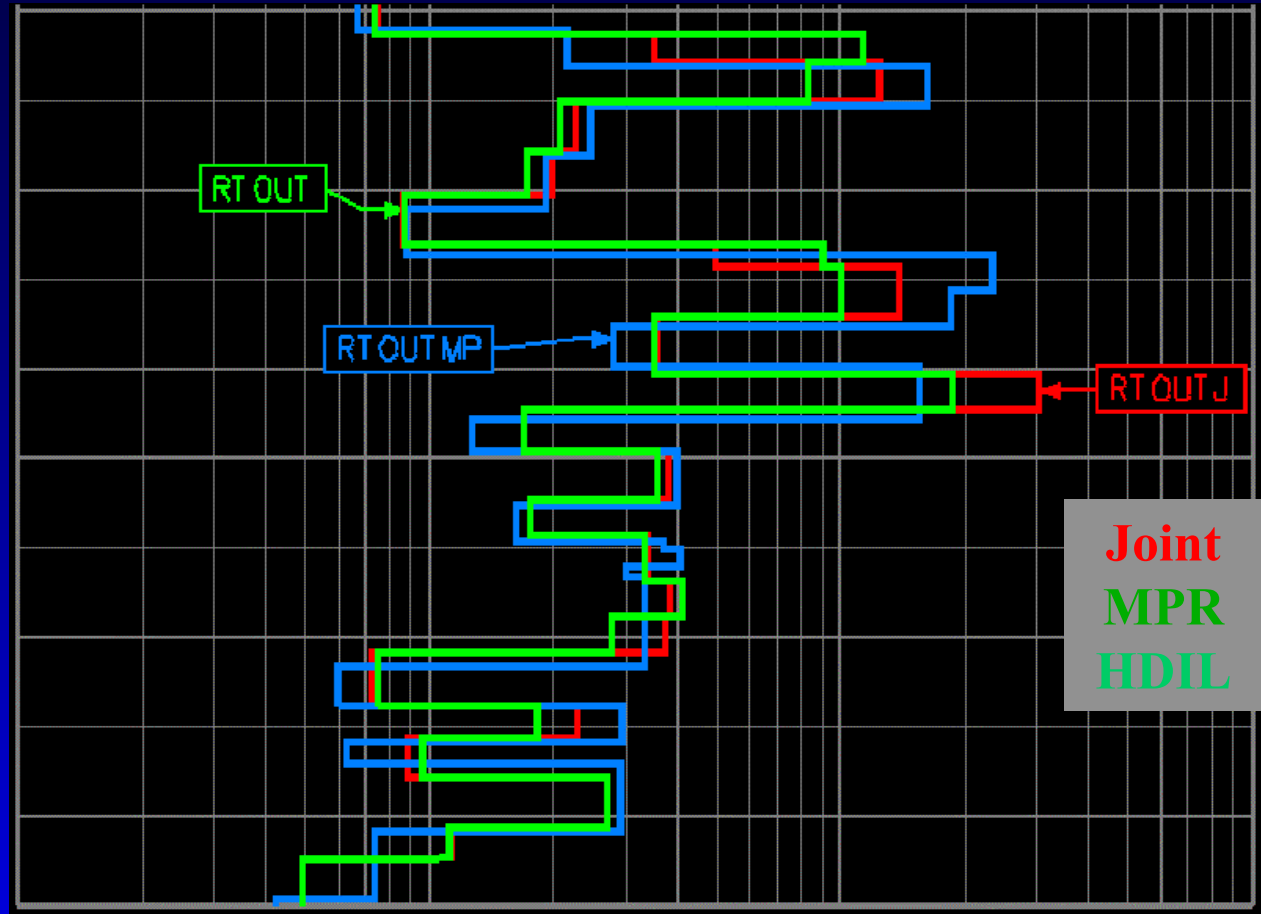
Difference (%)



Courtesy of EMI Inc.

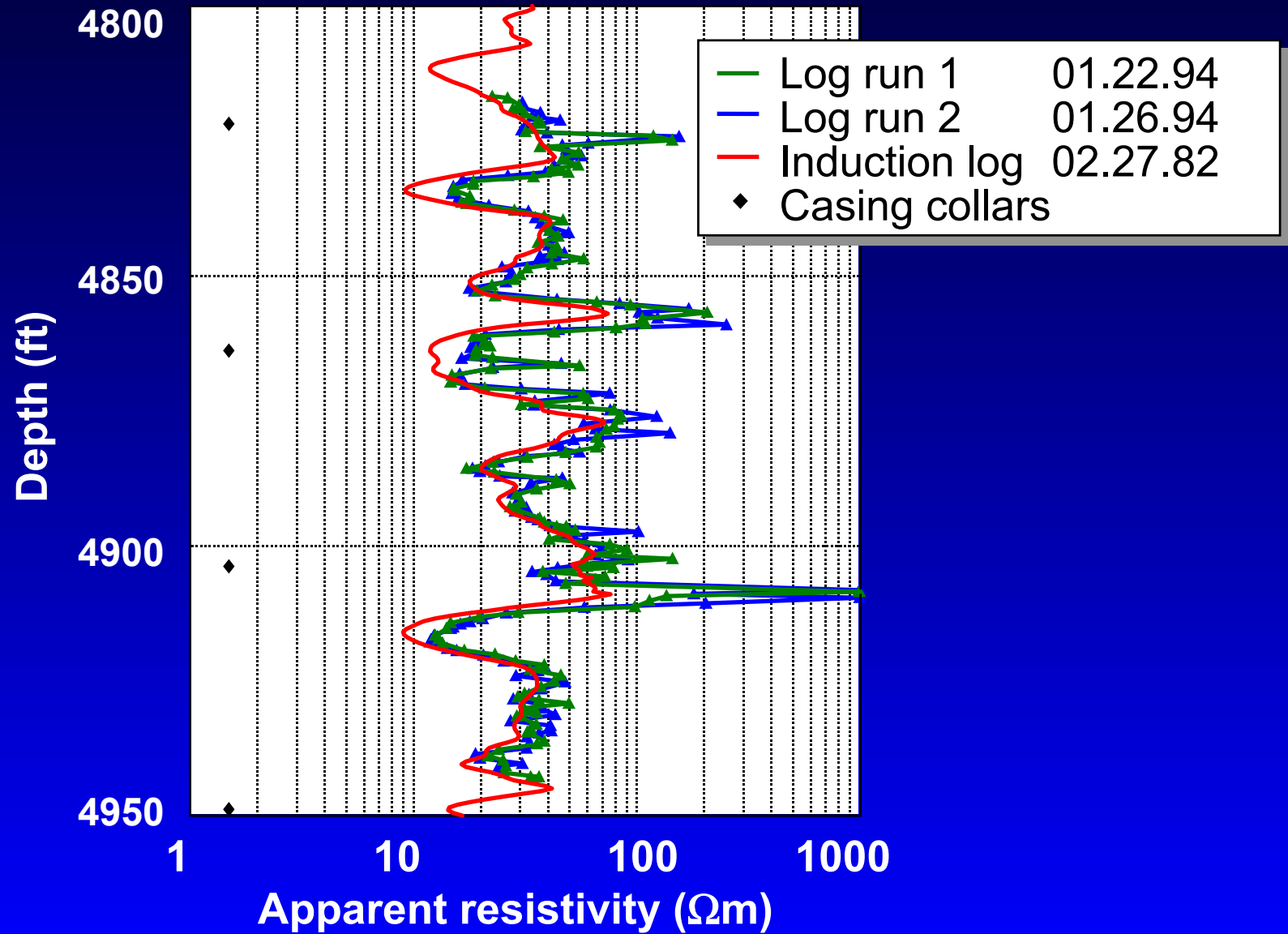
Formation Resistivity - LWD & Wireline

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



Joint inversion of MPR & HDIL data

TCR Colorado test



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Conclusions

- EM measurement make up majority of borehole measurements.
- Ideal sensitivity for fluid typing.
- MWD/LWD is getting more common.
- Inter-well space is reached with deeper single well and cross well measurements.

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