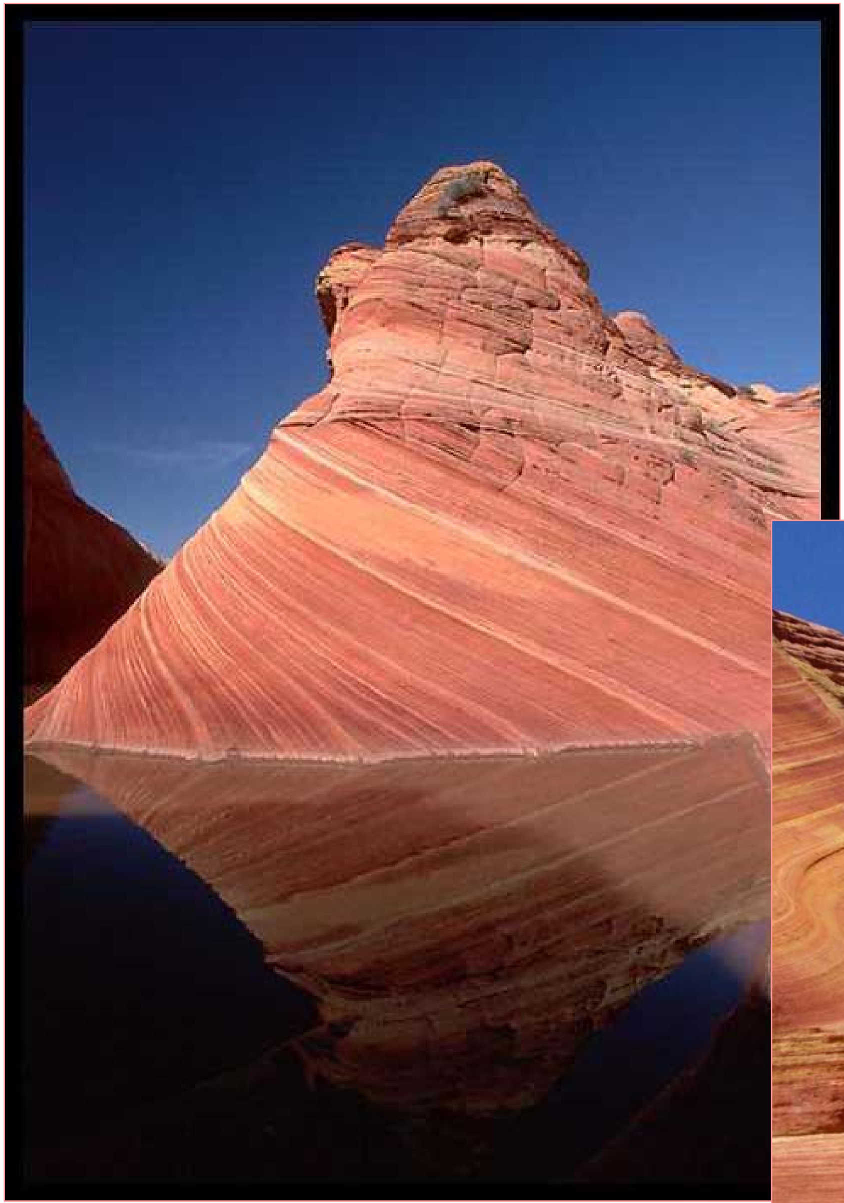
Fluid Typing In Thinly Bedded Reservoirs

10th Offshore Mediterranean Conference – OMC
Ravenna, Italy, March 2011

HALLIBURTON

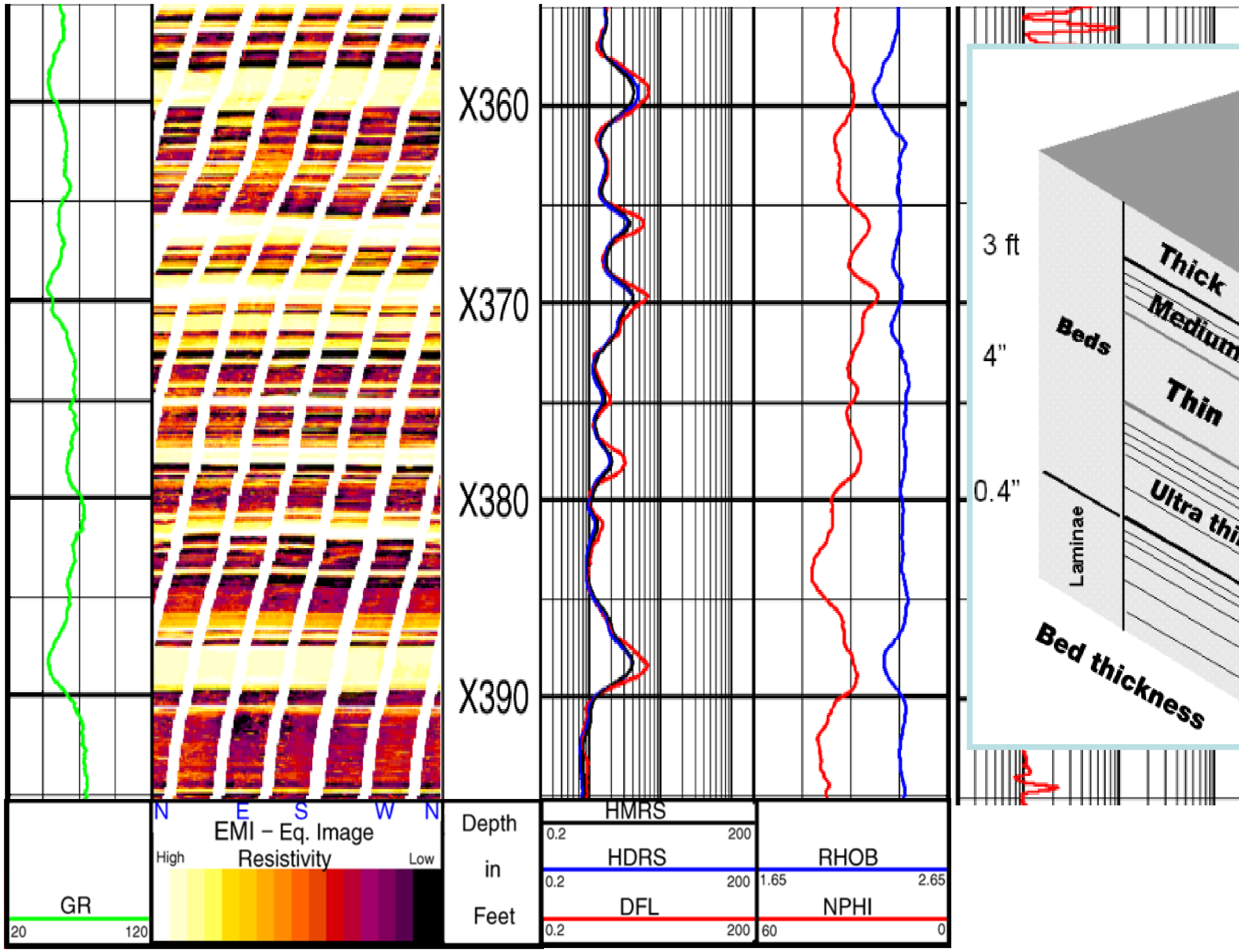
Roland Chemali
Chief Petrophysicist Sperry Drilling
Maged Fam
Halliburton Technology Manager

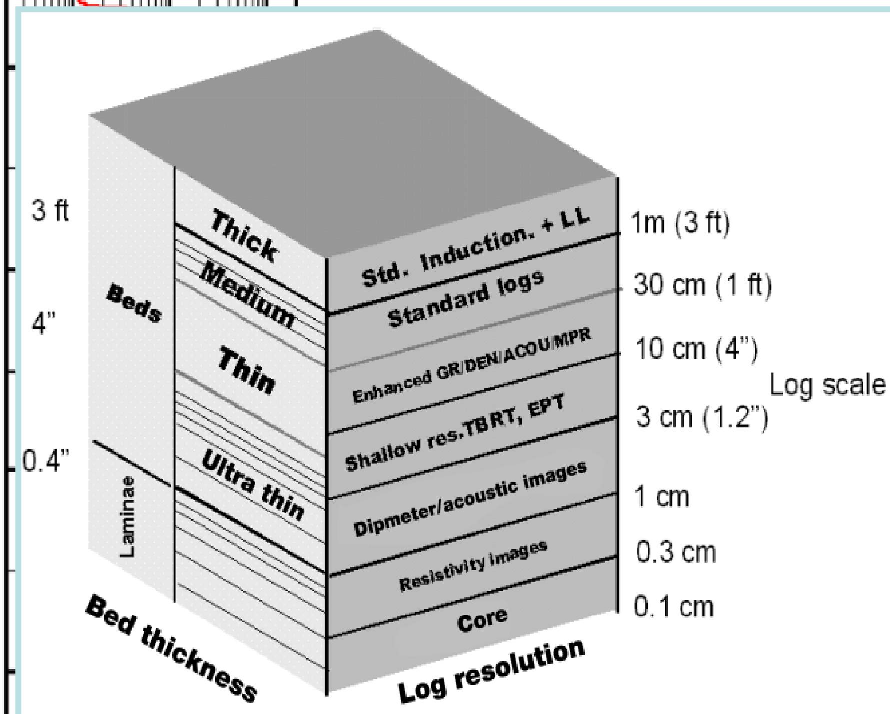
Laminated Formations



Laminated Reservoirs

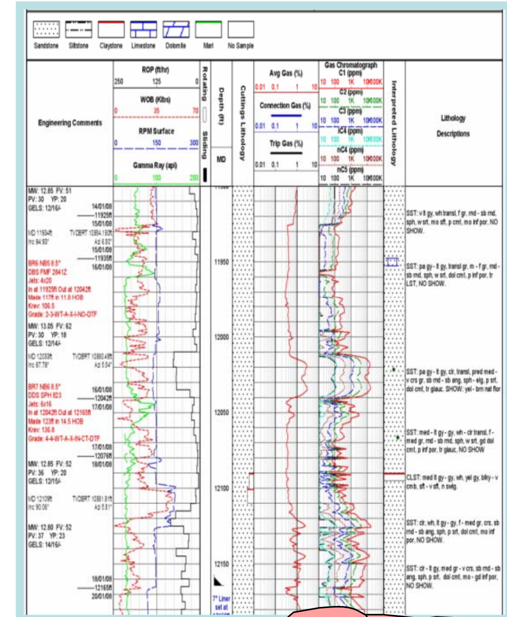
Layers with different petrophysical properties such as interbedded sandstone and shale with thicknesses below the vertical resolution of the logging tool measurement

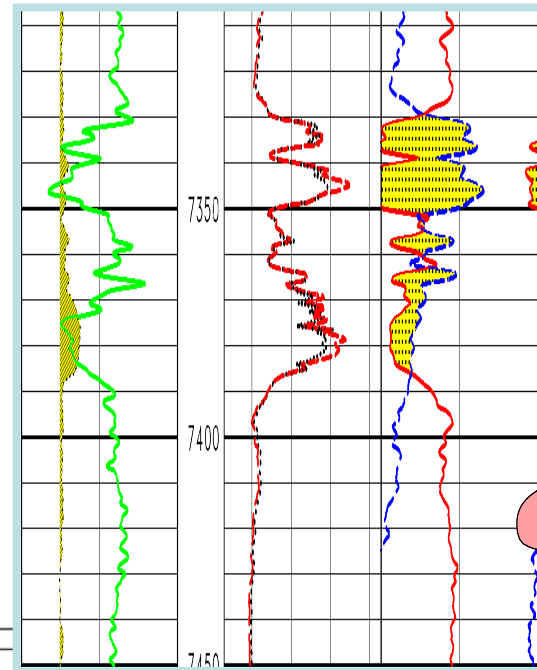


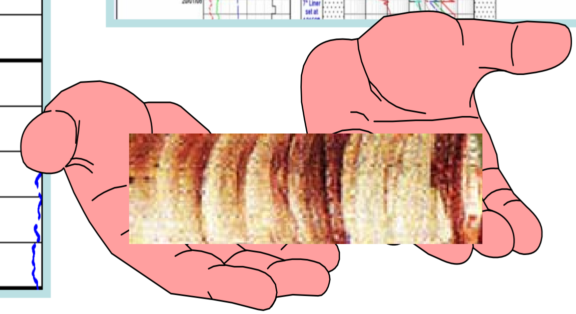


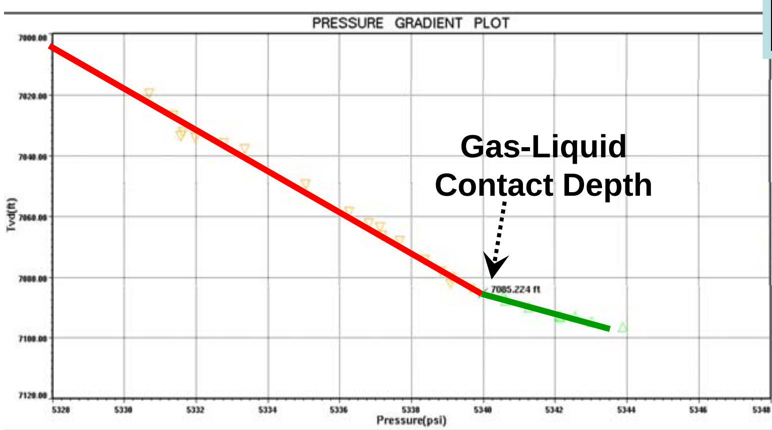
Methods for Reservoir Fluid Typing

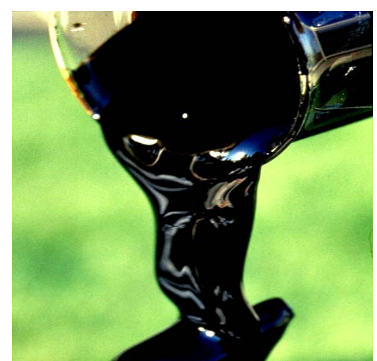
- Mud Logging / Gas Chromatography
- Logs (WL & LWD)
- Pressure Gradient
- Rock Sample
- Fluid Sample











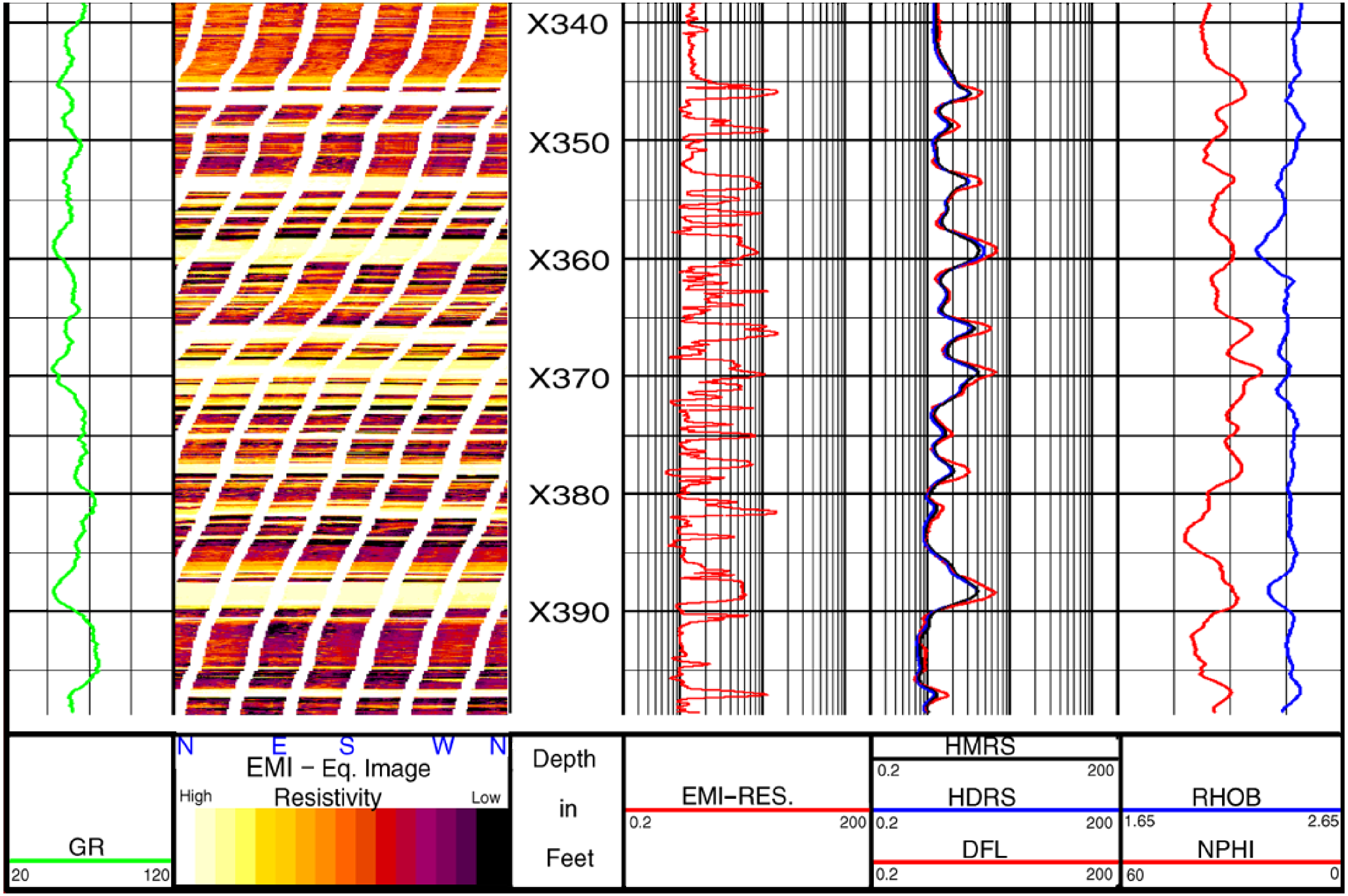
Fluid Typing In Thinly Bedded Reservoir

1. "Visible Laminations"
   - Imaging
   - Deconvolutions Methods

2. "Very Thin Laminations"
   - Electrical Anisotropy
   - Thomas Steibert

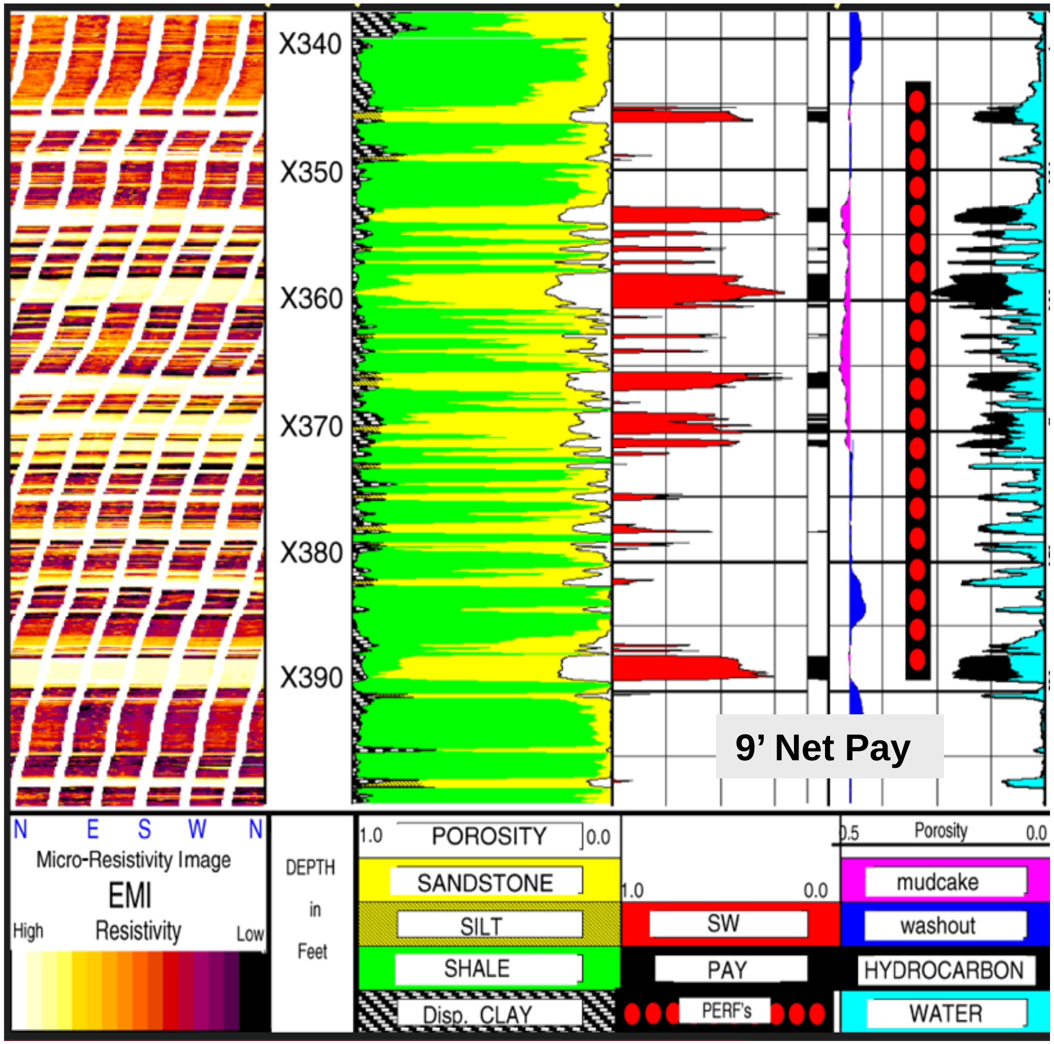
3. Methods for both "Visible" and "Very Thin" Laminations
   - Magnetic Resonance
   - Sampling

Standard vs. High Resolution Tool Response in Laminated Shaly Sand Reservoirs

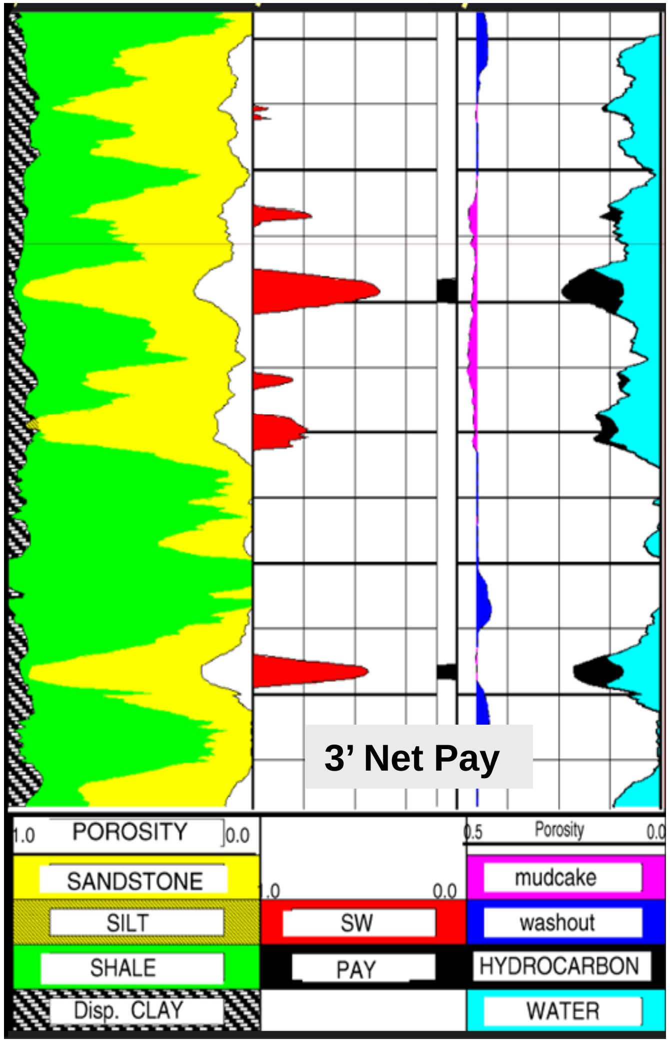


SPE 30608

Standard vs. High Resolution Interpretation in Laminated Shaly Sand Reservoirs



High Resolution



Standard Resolution

SPE 30608

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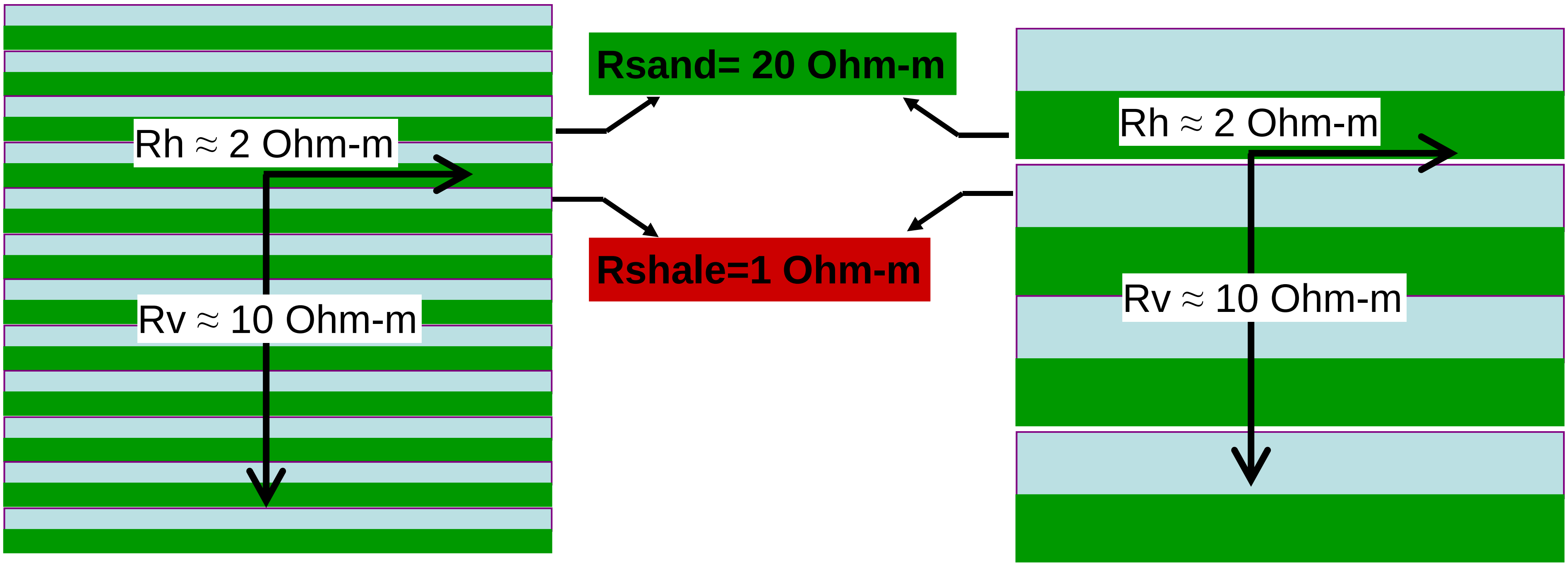
Anisotropy in Turbidites and Laminations

Rv = "Vertical" Resistivity
Rh = "Horizontal" Resistivity

→ Anisotropy Ratio = Rv/Rh

Anisotropy in Sand Shale Sequences

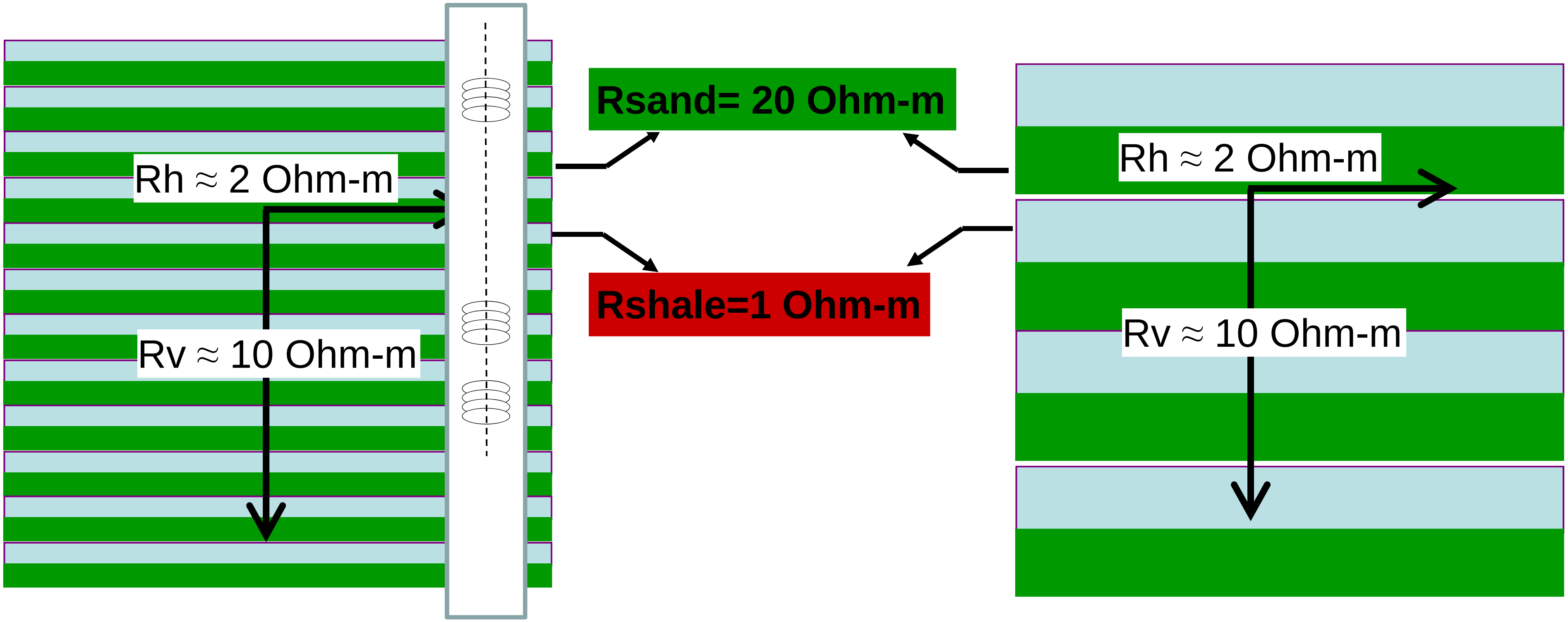
The Difference Between Micro-Anisotropy and Macro-Anisotropy
is Subjective and Depends On Measuring Instrument



Anisotropy Ratio = ? On right hand side
Anisotropy Ratio = ? On left hand side

Anisotropy in Sand Shale Sequences

The Difference Between Micro-Anisotropy and Macro-Anisotropy is Subjective and Depends On Measuring Instrument



The Vertical Coil Array
Measures Only Rh i.e. 2 Ohm-m i.e. “”Wet”

Anisotropy: Historic Perspective
Anisotropy in the 70's
Paper/Patent for Oil Base Dipmeter

United States Patent [19]
Runge

[54] **TRIPLE COIL INDUCTION LOGGING METHOD FOR DETERMINING DIP, ANISOTROPY AND TRUE RESISTIVITY**

[75] Inventor: **Richard J. Runge,** Anaheim, Calif.

[73] Assignee: **Chevron Research Company,** San Francisco, Calif.

[22] Filed: **Apr. 4, 1973**

[21] Appl. No.: **347,747**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 321,613, Jan. 8, 1973, abandoned, which is a continuation of Ser. No. 795,209, Jan. 30, 1969, abandoned.

[52] **U.S. Cl.** **324/6**
[51] **Int. Cl.** **G01v 3/10,** G01v 3/18
[58] **Field of Search**.................................... 324/6, 8

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3,388,323	6/1968	Stripling	324/8
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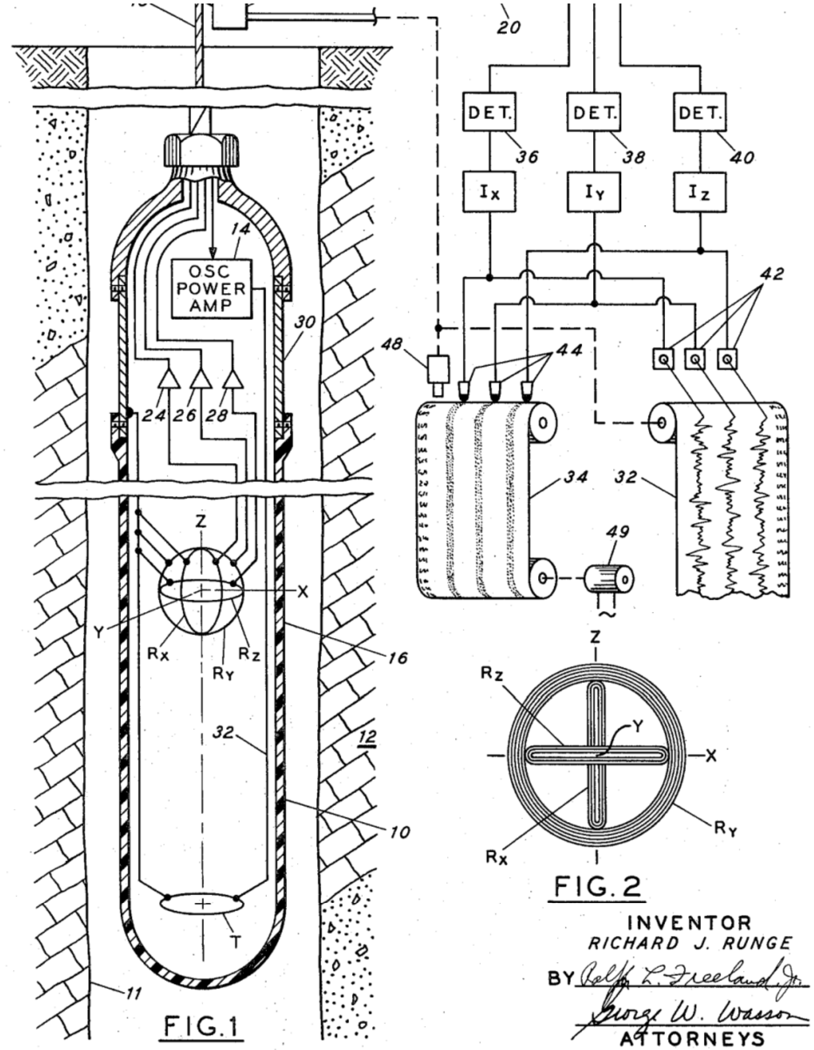
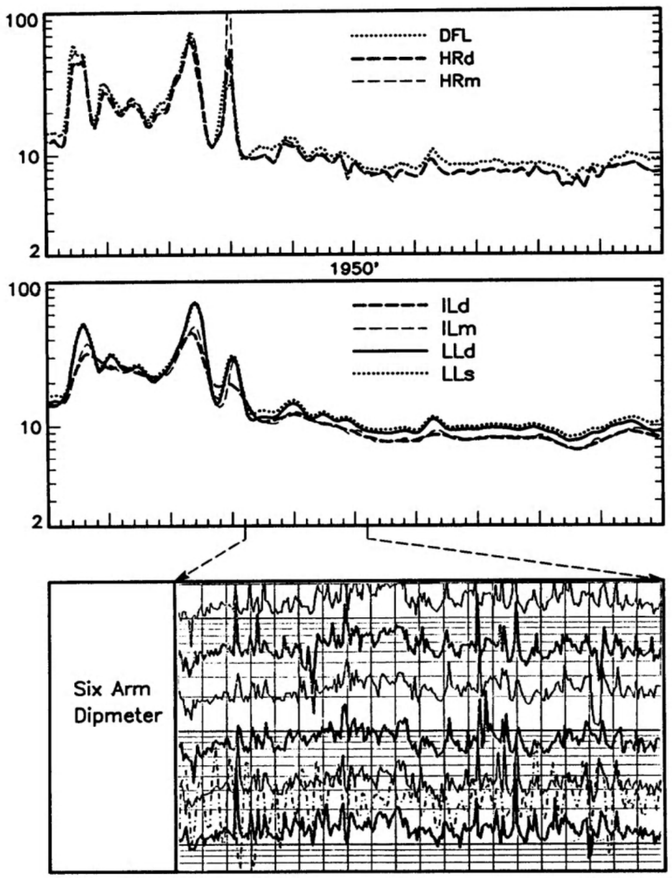
3,609,521	9/1971	Desbrandes	324/6



Anisotropy: Historic Perspective

Anisotropy in the 80's

Explains Separation Between Induction and Laterolog
A Nuisance to Contend With



SPWLA Twenty-Eighth Annual Logging Symposium, June 29-July 2, 1987

THE EFFECT OF SHALE ANISOTROPY ON FOCUSED RESISTIVITY DEVICES

by R. Chemali, S. Gianzero and S.M. Su
Gearhart Industries, Inc., Austin Research Center

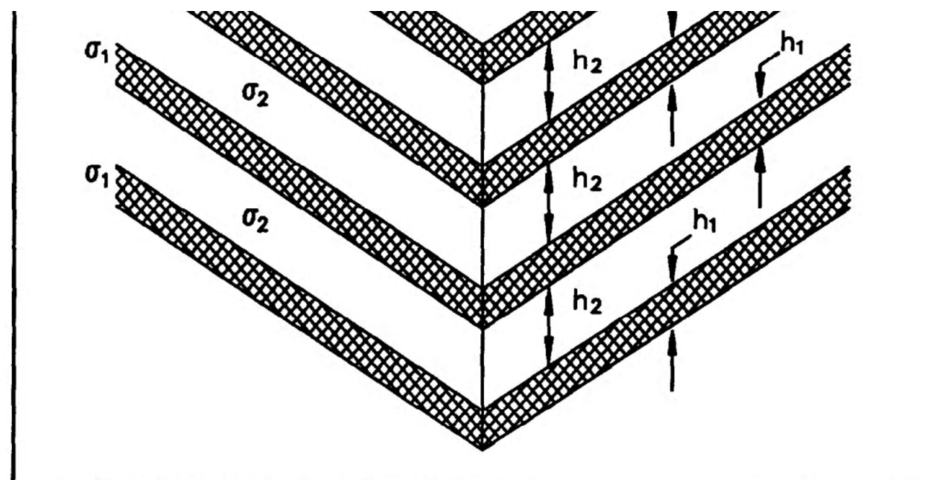


Figure 2b. Macroscopically Anisotropic Formation.

Anisotropy: Historic Perspective
Anisotropy in the 90's
Klein and Mollison Increase Reserves in Kuparuk and Other Reservoirs

SPWLA 37th Annual Logging Symposium, June 16-19, 1996

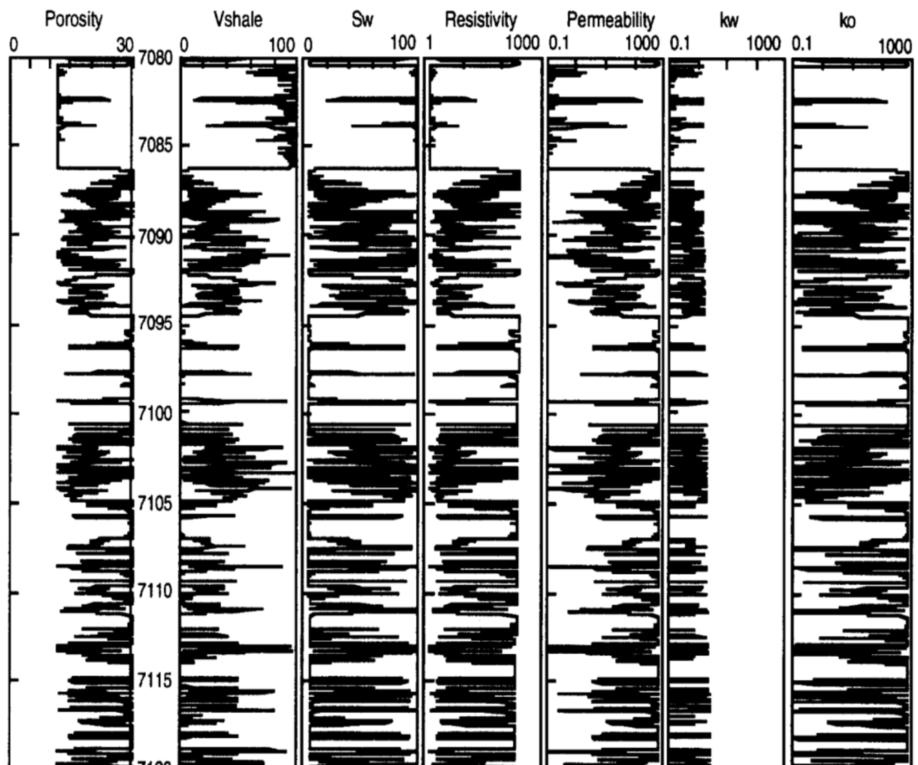


Figure 6. Detailed logs defining the Kuparuk A-Sand model for free water level at 7,200 feet.

A Thin Bed Model for the Kuparuk A Sand KUPARUK RIVER FIELD, NORTH SLOPE, ALASKA

Jerry Sovich, ARCO Exploration and Production Technology
Jim Klein, ARCO Exploration and Production Technology
Neil Gaynor, ARCO Exploration and Production Technology

The Petrophysics of Electrically Anisotropic Reservoirs

J. D. Klein and P. R. Martin
ARCO Exploration and Production Technology
2300 West Plano Parkway, Plano, Texas 75075, USA

D. F. Allen
Schlumberger Well Services
225 Industrial Blvd, Sugar Land, Texas 77478, USA

SPWLA 42nd Annual Logging Symposium, June 17-20, 2001

IMPACT OF MULTICOMPONENT INDUCTION TECHNOLOGY ON A DEEPWATER TURBIDITE SAND HYDROCARBON SATURATION EVALUATION

R.A. Mollison, O.N. Fanini, B.F. Kriegshäuser, L. Yu, *Baker Atlas*, G. Ugueto, Shell Exploration and Production, and J. van Popta, *Shell EP Technology*

From Anisotropy to Saturation in Laminated Reservoirs

1. Measure Rv and Rh

2. Input Rshale

3. Get Rsand and Vshale

Thomas/Steibert/Mollison/..

For a laminated sand/shale sequence, the vertical resistivity, Rv, can be expressed as:

$$Rv = (1 - Vsh) * Rsand + Vsh * Rshale \quad (1)$$

Similarly, the horizontal resistivity, Rh, can be expressed as:

$$Rh = \frac{Rsand * Rshale}{(1 - Vsh) * Rshale + Vsh * Rsand} \quad (2)$$

Solving equations (1) and (2) for Rsand, in terms of Rv, Rh, and Rshale, reduces to:

$$Rsand = Rh * \left(\frac{Rv - Rshale}{Rh - Rshale} \right) \quad (3)$$

Assume water saturation can be expressed as:

$$Sw = \frac{1}{\Phi} * \sqrt{\frac{Rw}{Rt}} \quad (4)$$

Example:

Assume Rw = 0.05 Ω-m and Φ = 30%. Also, assume shale lamina's resistivity, Rshale, = 1.0 Ω-m.

If the deep phase shift resistivity of 3.8 Ω-m is used as Rt in equation (4), then:

$$Sw = 38\%$$

If anisotropy processing is used, then:

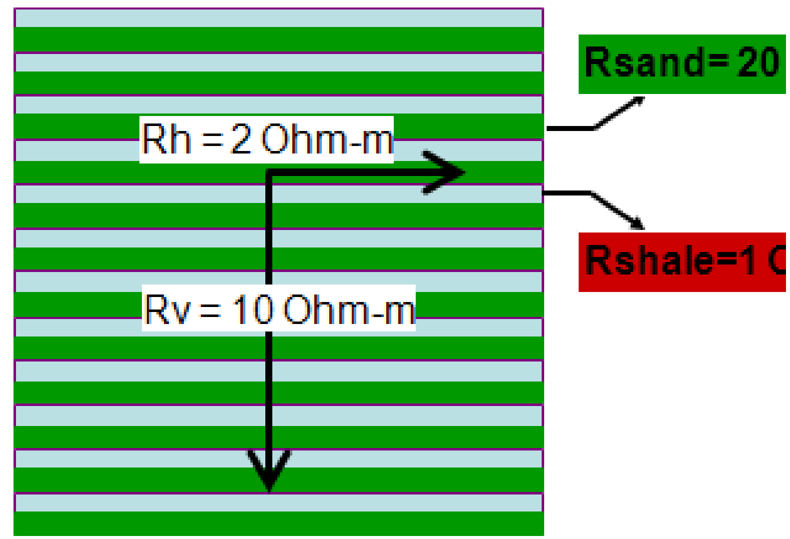
$$Rv = 5.0\ \Omega\text{-m}$$
$$Rh = 1.8\ \Omega\text{-m}$$

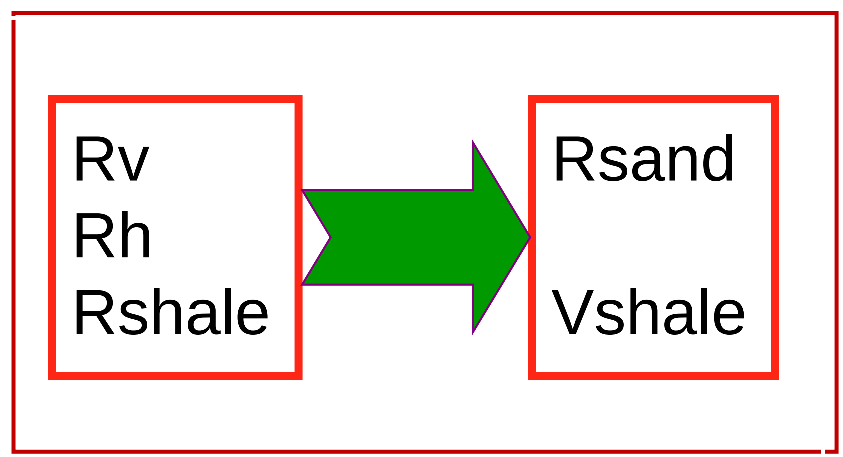
and substituting in Equation (3) along with Rshale produces:

$$Rsand = 9.0\ \Omega\text{-m}$$

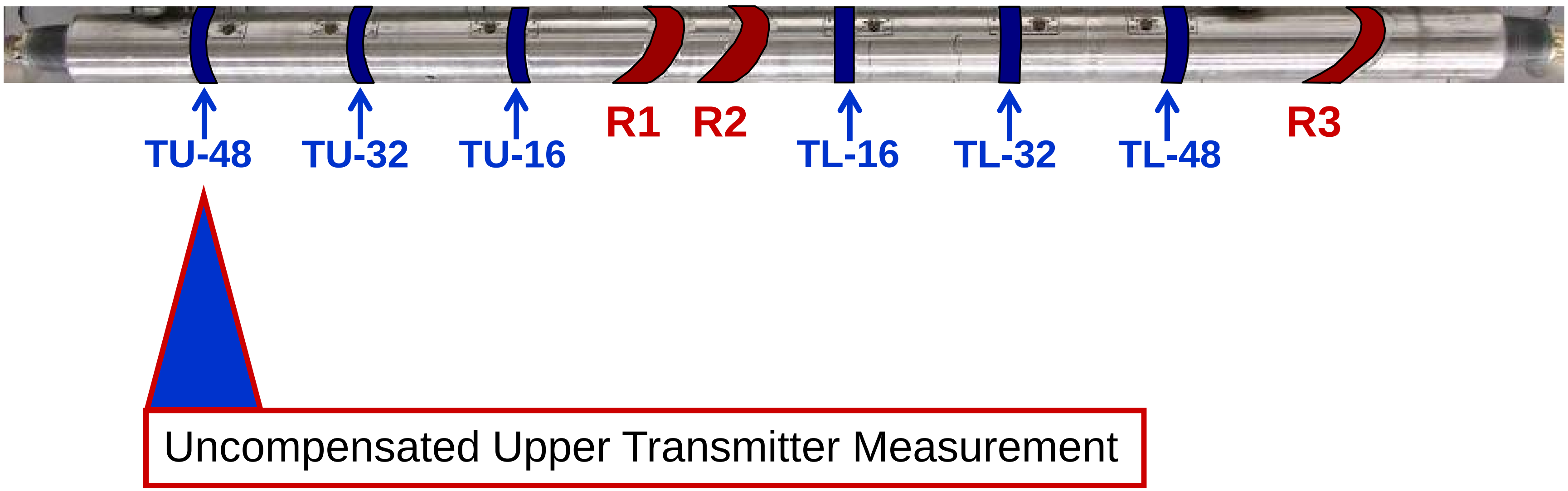
Using Rsand as Rt in Equation (4), then:

$$Sw = 25\%$$



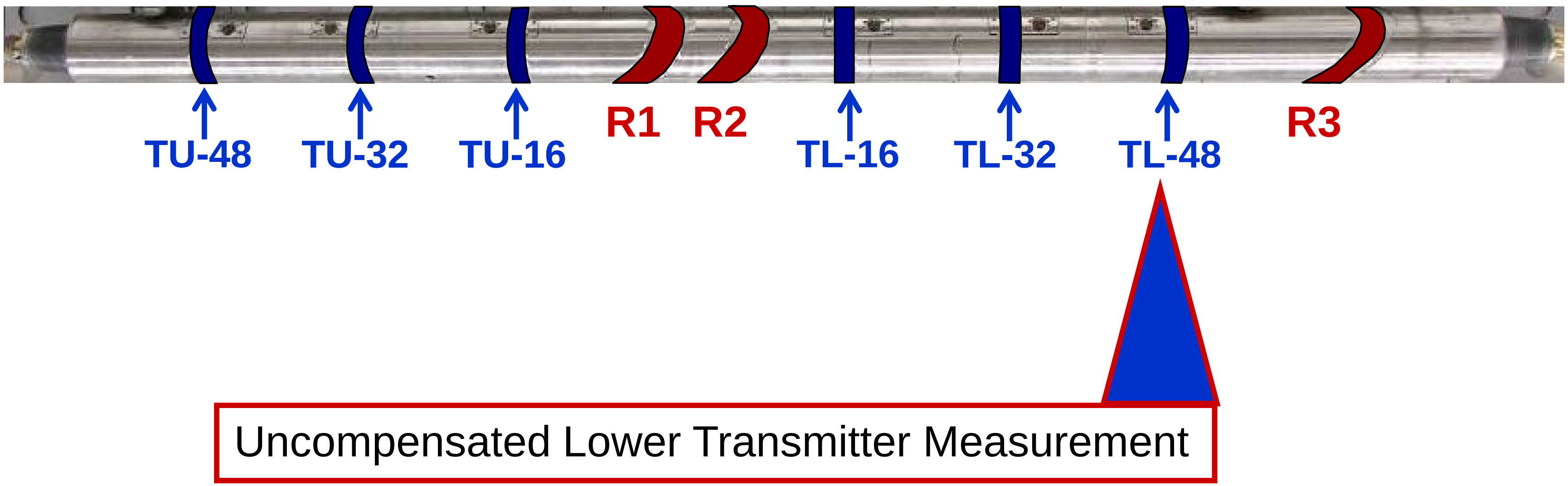


Azimuthal Deep Resistivity
Uncompensated Upper Transmitter Measurement



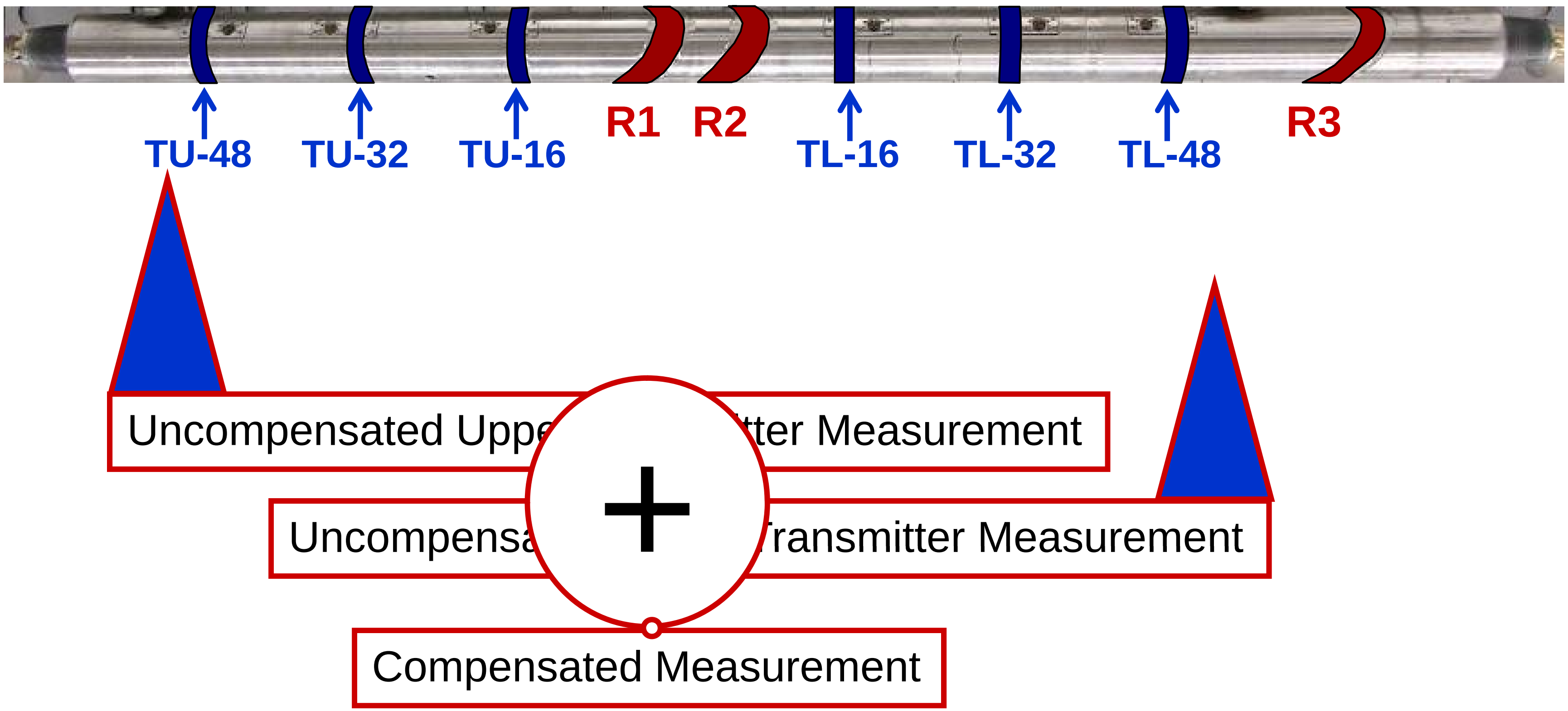
Measuring Electrical Anisotropy with ADR

Azimuthal Deep Resistivity
Uncompensated Lower Transmitter Measurement

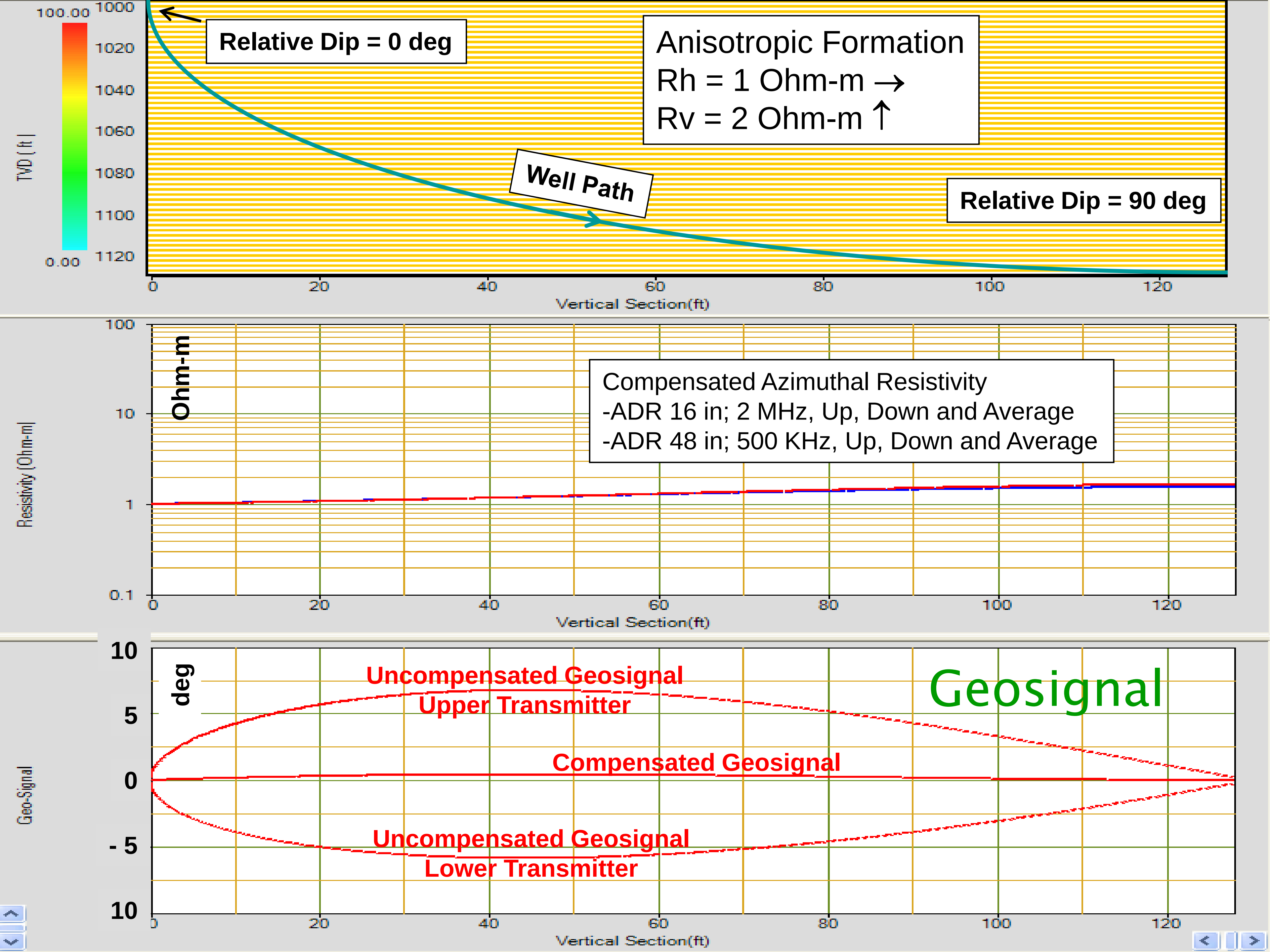


Measuring Electrical Anisotropy with ADR

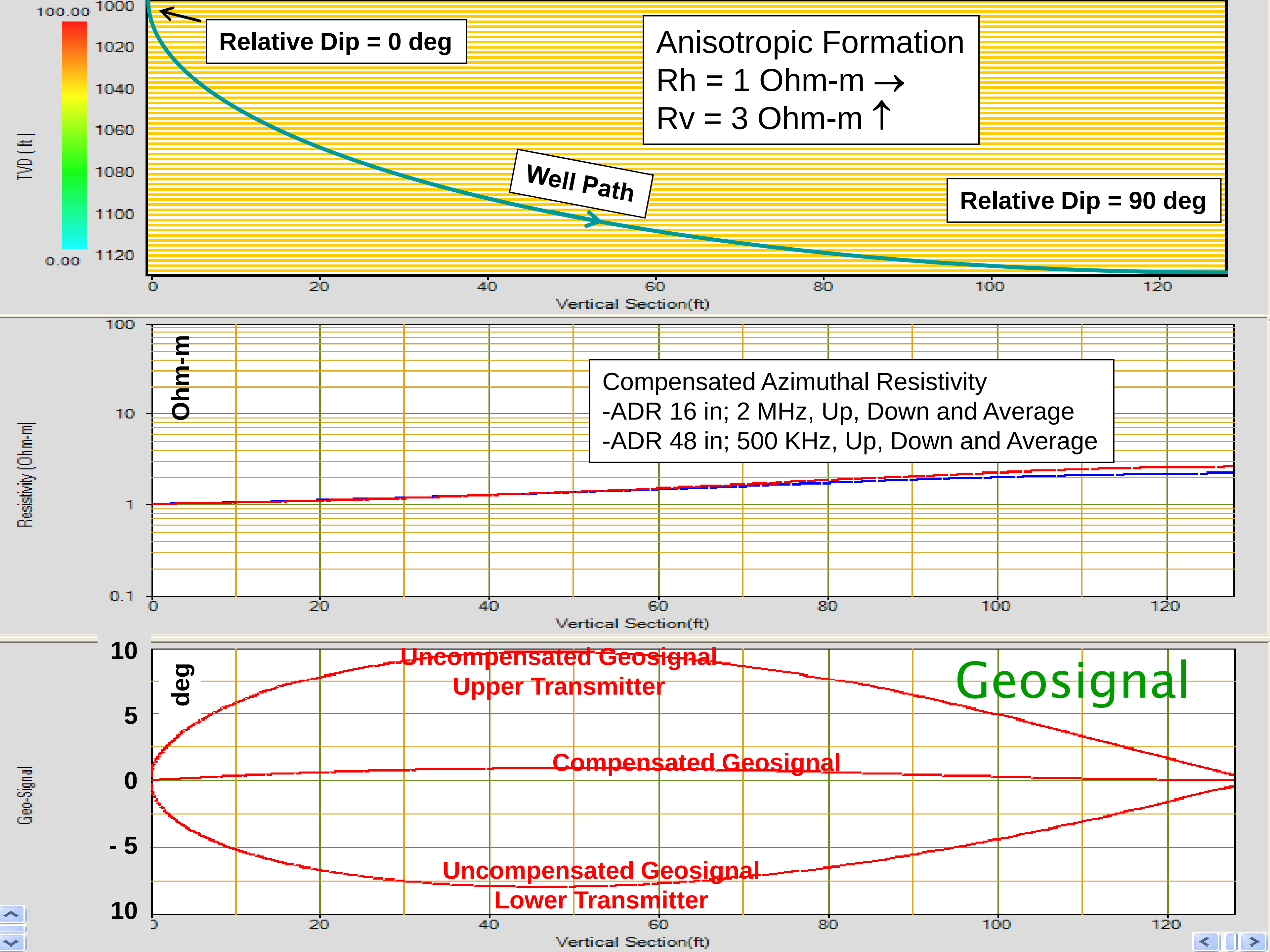
Azimuthal Deep Resistivity
Compensated Measurement

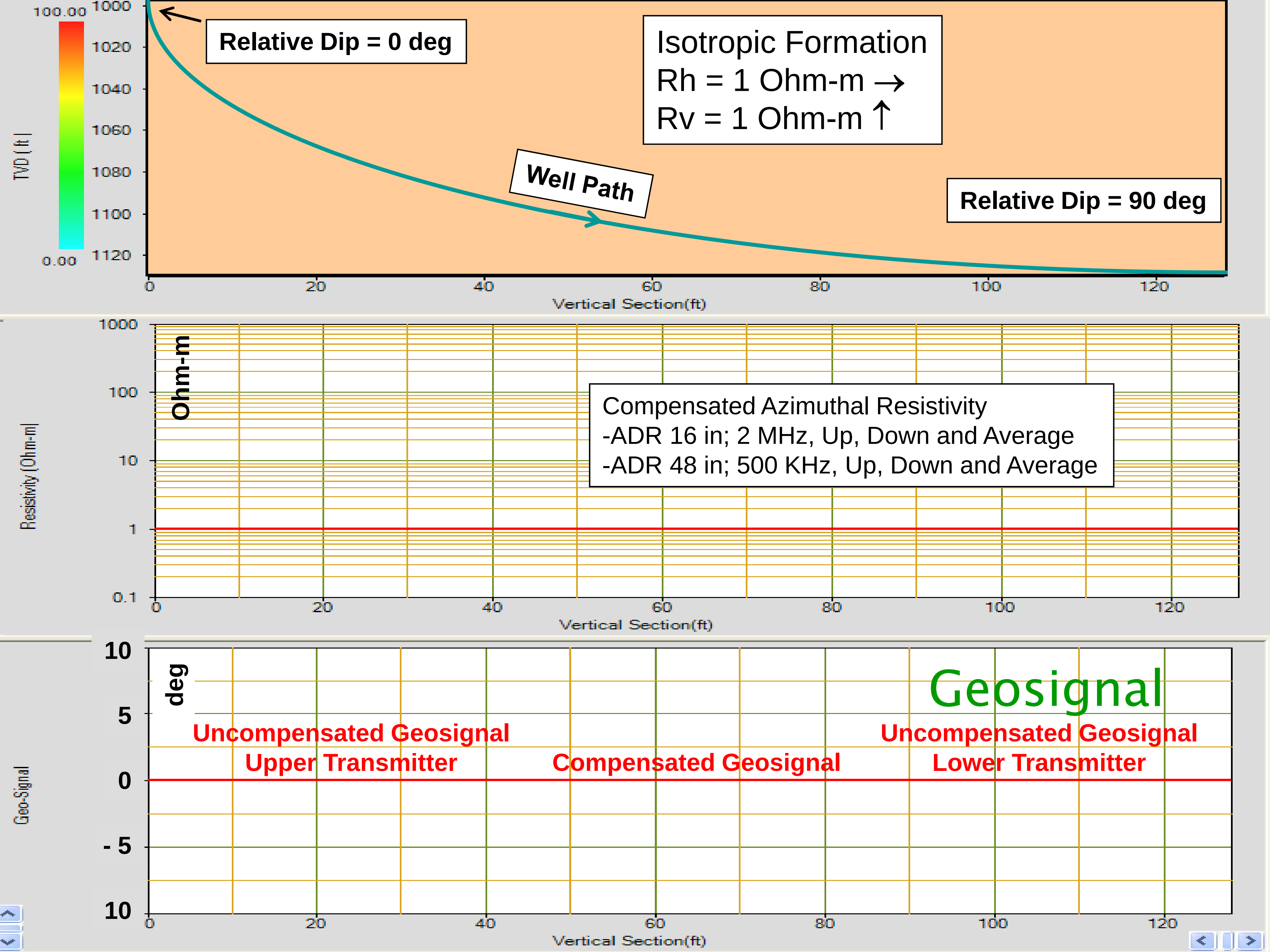


Measuring Electrical Anisotropy with ADR



Relative Dip = 0 deg
Anisotropic Formation
Rh = 1 Ohm-m →
Rv = 2 Ohm-m ↑
Well Path
Relative Dip = 90 deg
TVD [ft]
100.00
0.00
Vertical Section(ft)
Ohm-m
Compensated Azimuthal Resistivity
-ADR 16 in; 2 MHz, Up, Down and Average
-ADR 48 in; 500 KHz, Up, Down and Average
Resistivity [Ohm-m]
Vertical Section(ft)
deg
Uncompensated Geosignal
Upper Transmitter
Geosignal
Compensated Geosignal
Uncompensated Geosignal
Lower Transmitter
Geo-Signal
Vertical Section(ft)

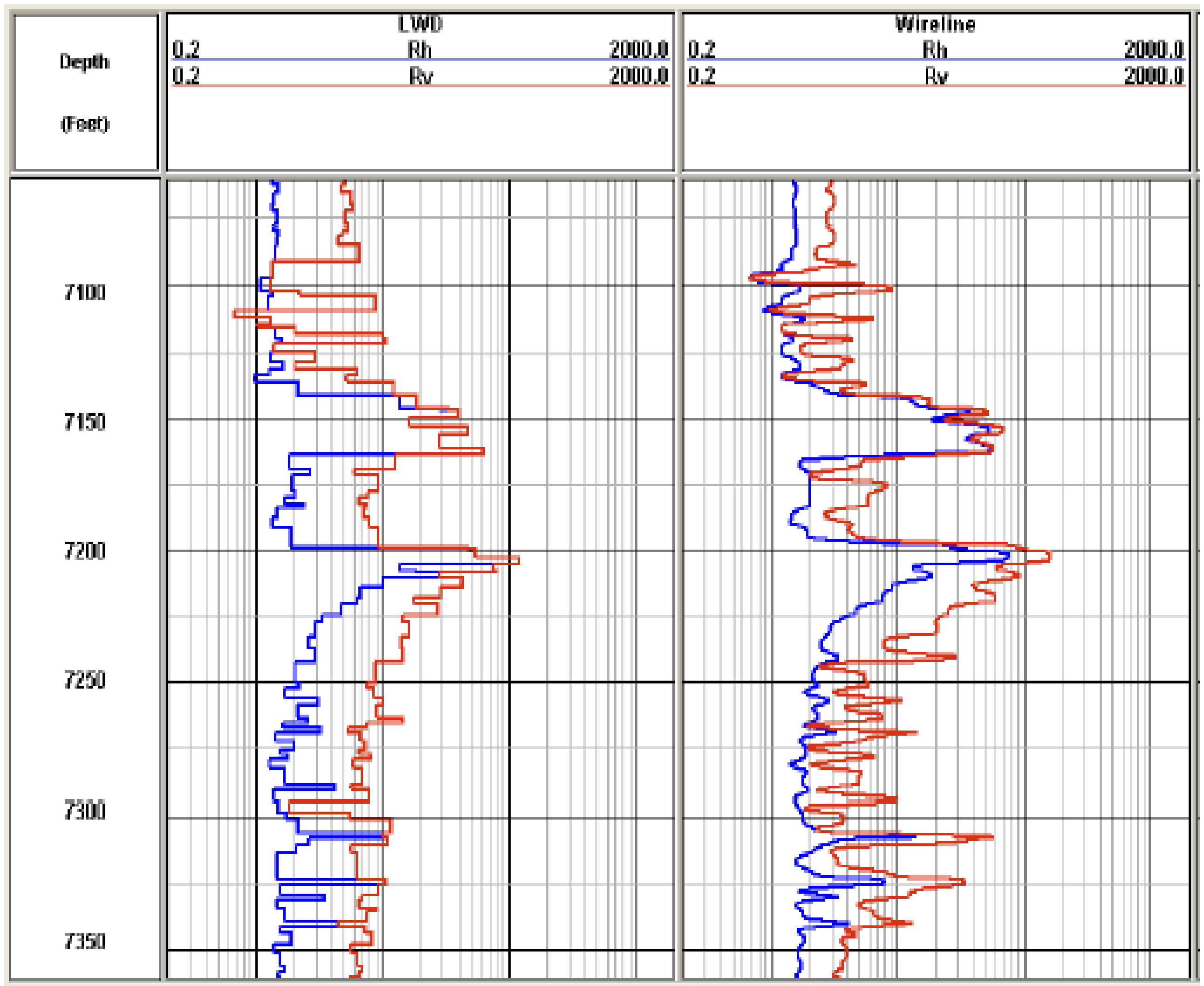

Relative Dip = 0 deg
Anisotropic Formation
Rh = 1 Ohm-m →
Rv = 3 Ohm-m ↑
Well Path
Relative Dip = 90 deg
TVD [ft]
Vertical Section(ft)
Ohm-m
Compensated Azimuthal Resistivity
-ADR 16 in; 2 MHz, Up, Down and Average
-ADR 48 in; 500 KHz, Up, Down and Average
Resistivity [Ohm-m]
Uncompensated Geosignal
Upper Transmitter
Geosignal
deg
Compensated Geosignal
Uncompensated Geosignal
Lower Transmitter
Geo-Signal


Relative Dip = 0 deg
Isotropic Formation
Rh = 1 Ohm-m →
Rv = 1 Ohm-m ↑
Well Path
Relative Dip = 90 deg
TVD [ft]
Vertical Section(ft)
Ohm-m
Compensated Azimuthal Resistivity
-ADR 16 in; 2 MHz, Up, Down and Average
-ADR 48 in; 500 KHz, Up, Down and Average
Resistivity [Ohm-m]
Vertical Section(ft)
deg
Geosignal
Uncompensated Geosignal
Upper Transmitter
Compensated Geosignal
Uncompensated Geosignal
Lower Transmitter
Geo-Signal
Vertical Section(ft)

SPE 123890

Laminated Sand-Shale Formation Evaluation Using Azimuthal LWD Resistivity

Richard Bootle and Matthew Waugh, BG Group, and Michael Bittar, SPE, Frode Hveding, SPE,
William E. Hendricks, SPE, and Shivanand Pancham, Halliburton



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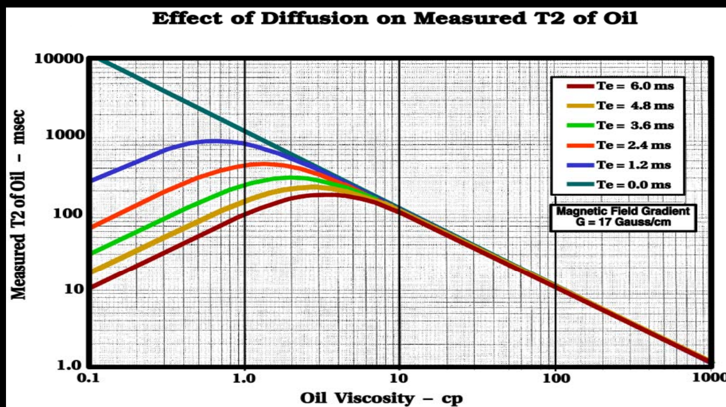
MRIL T1 & T2 Response to Fluids & Reservoir Conditions

- Fluid Type



Water:

$$T_{2B} \cong T_{1B} \cong \frac{3T}{298\,.\,\eta}$$

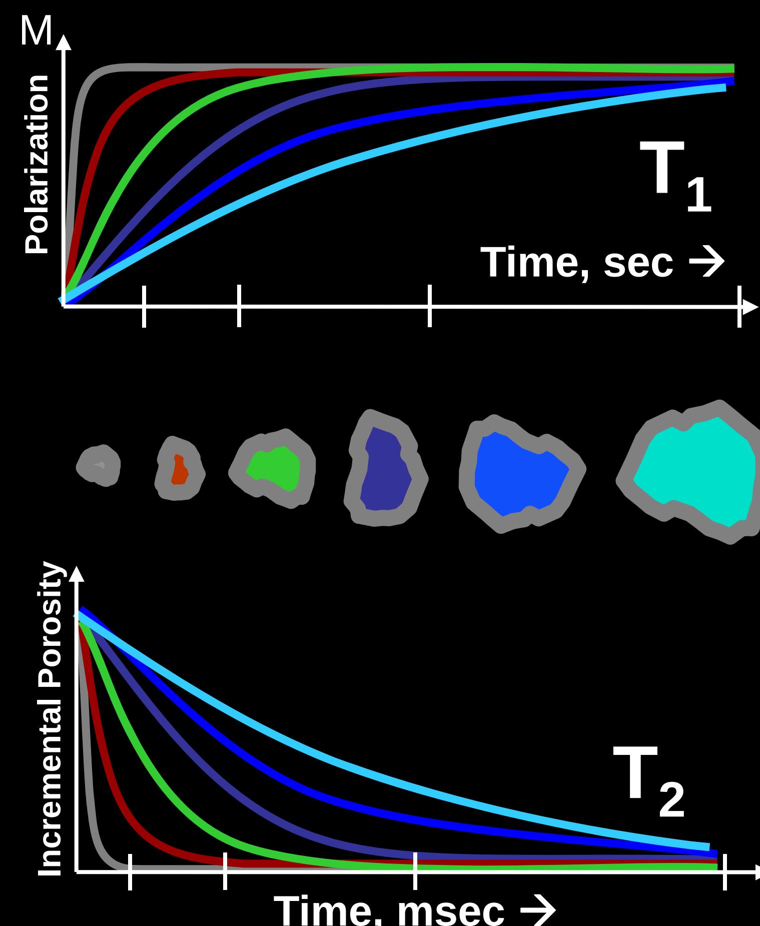
Oil:

$$T_{2B} \cong T_{1B} \cong \frac{1.2T}{298\,.\,\eta}$$

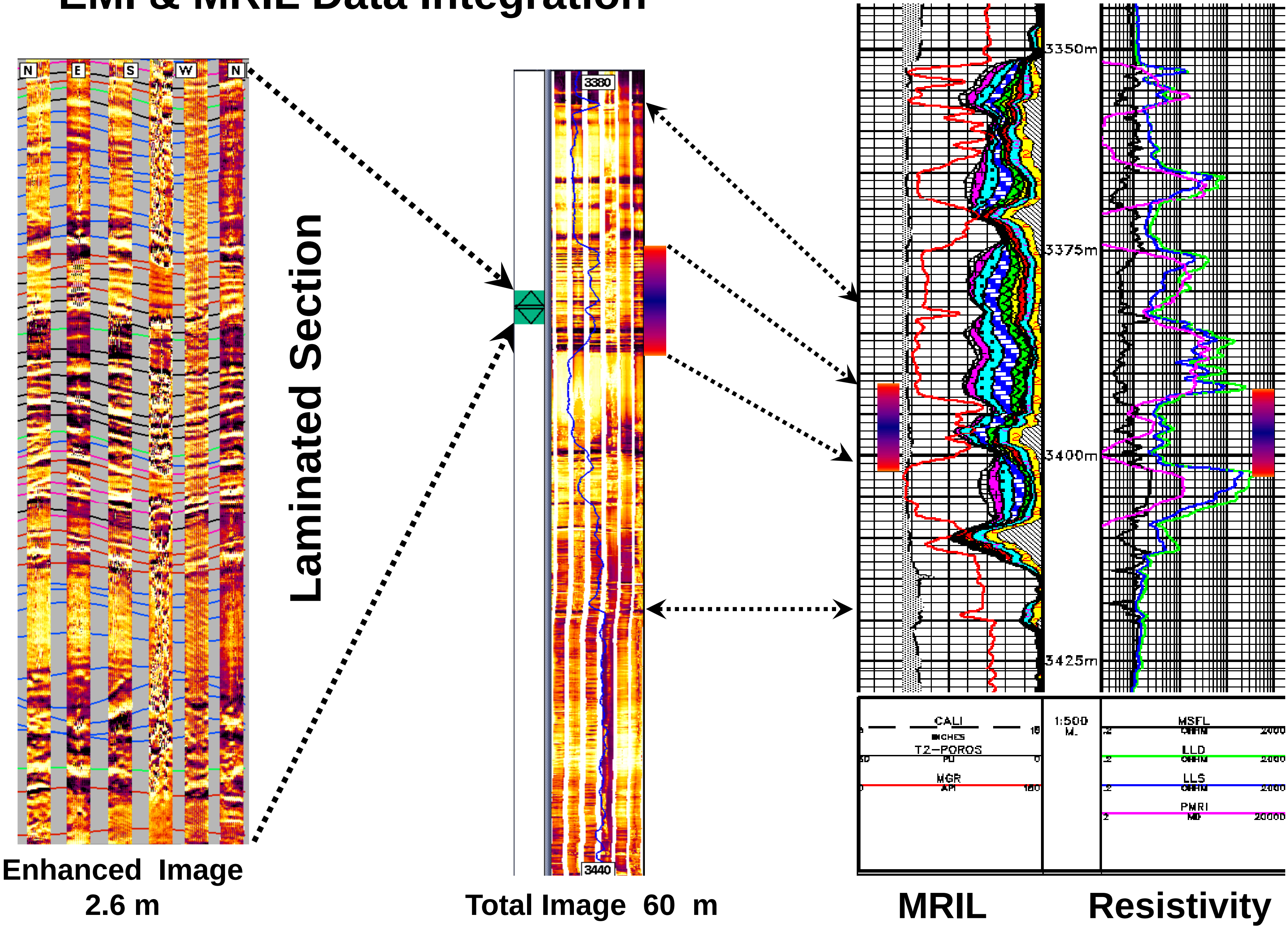
Gas:

$$T_{2B} \cong T_{1B} \cong \frac{25 \times 10^{3} \cdot \rho}{T^{1.17}}$$

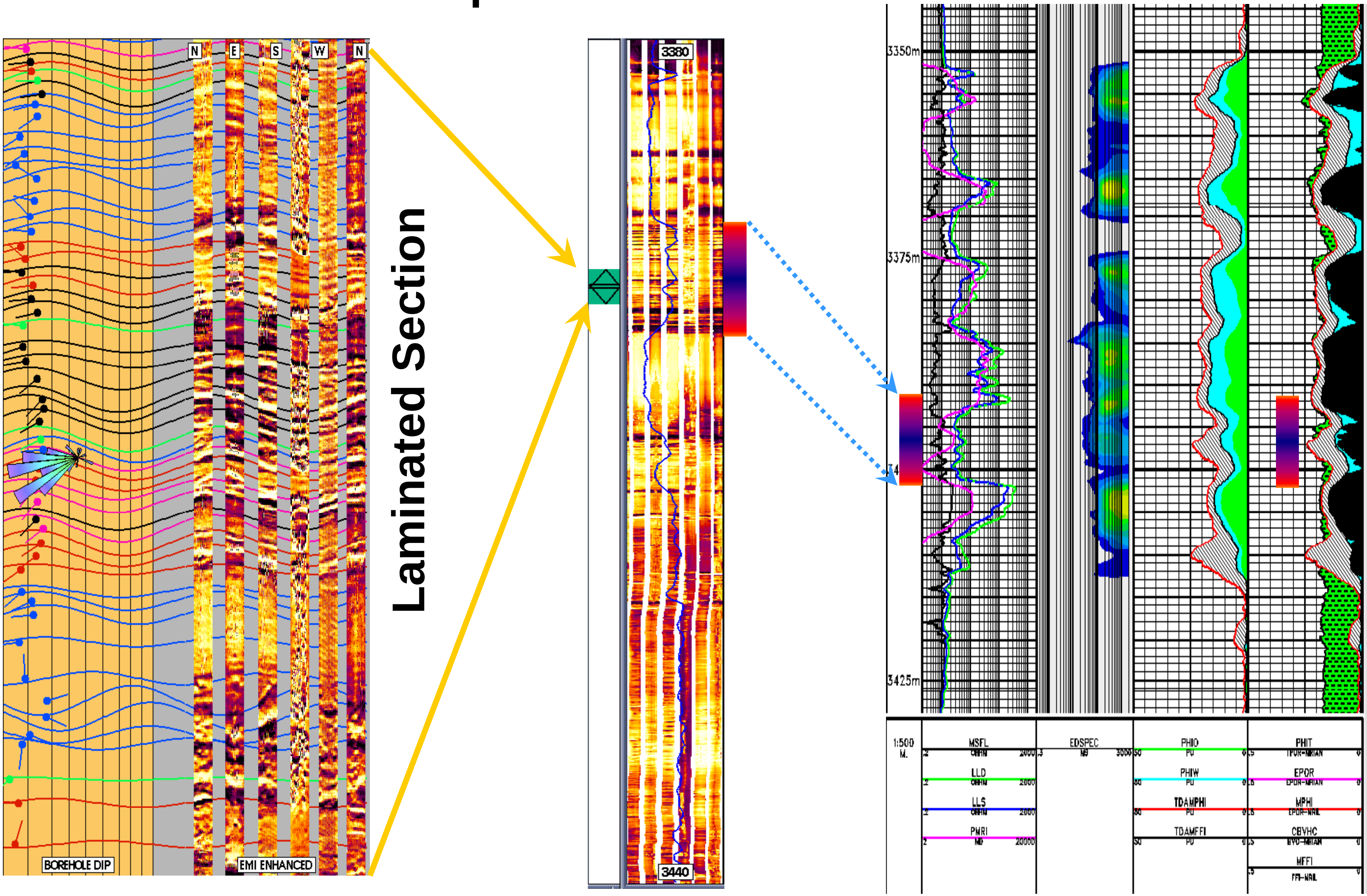
- Pore Size



EMI & MRIL Data Integration



EMI & MRIL Interpretation



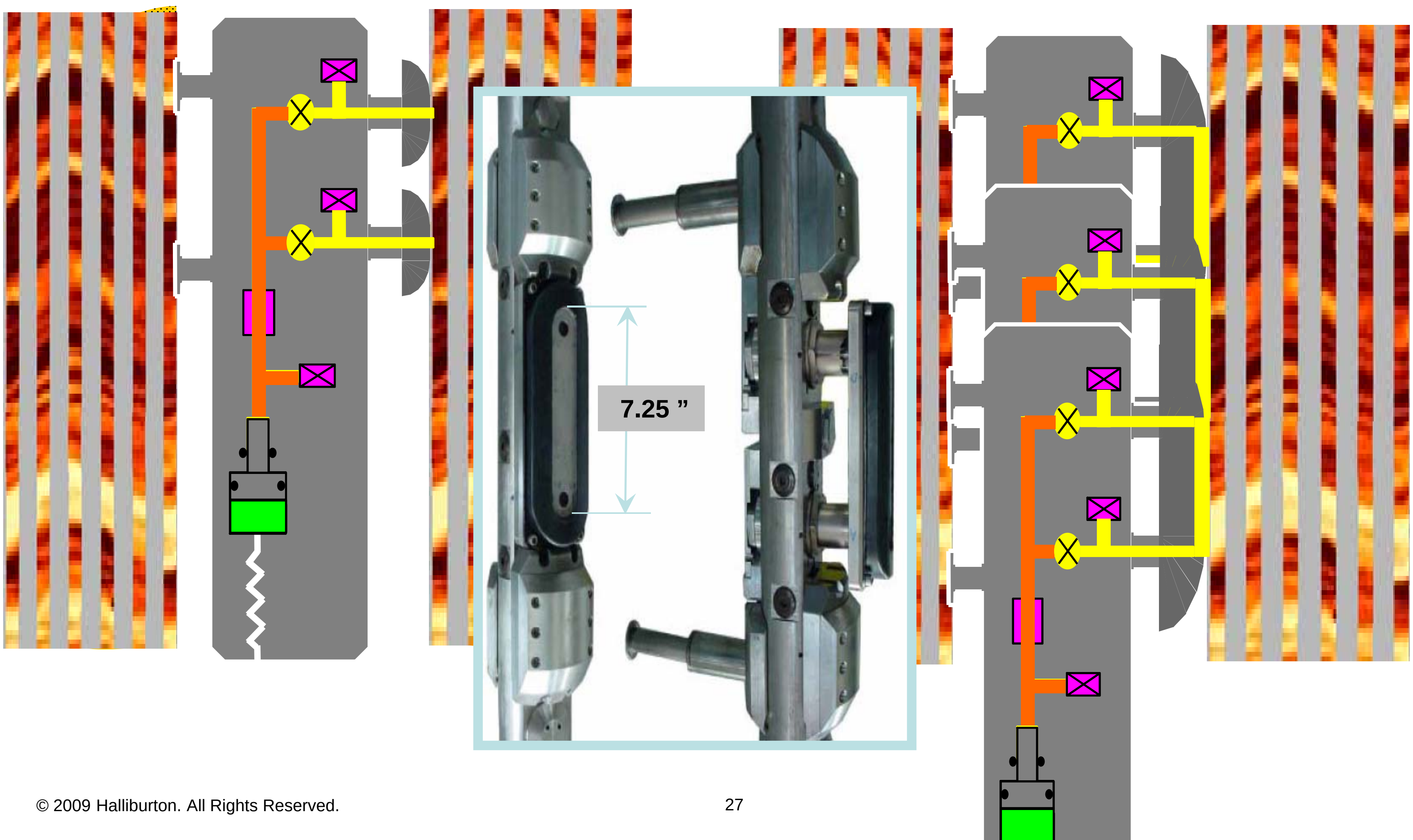
EMI DIP Enhanced Image

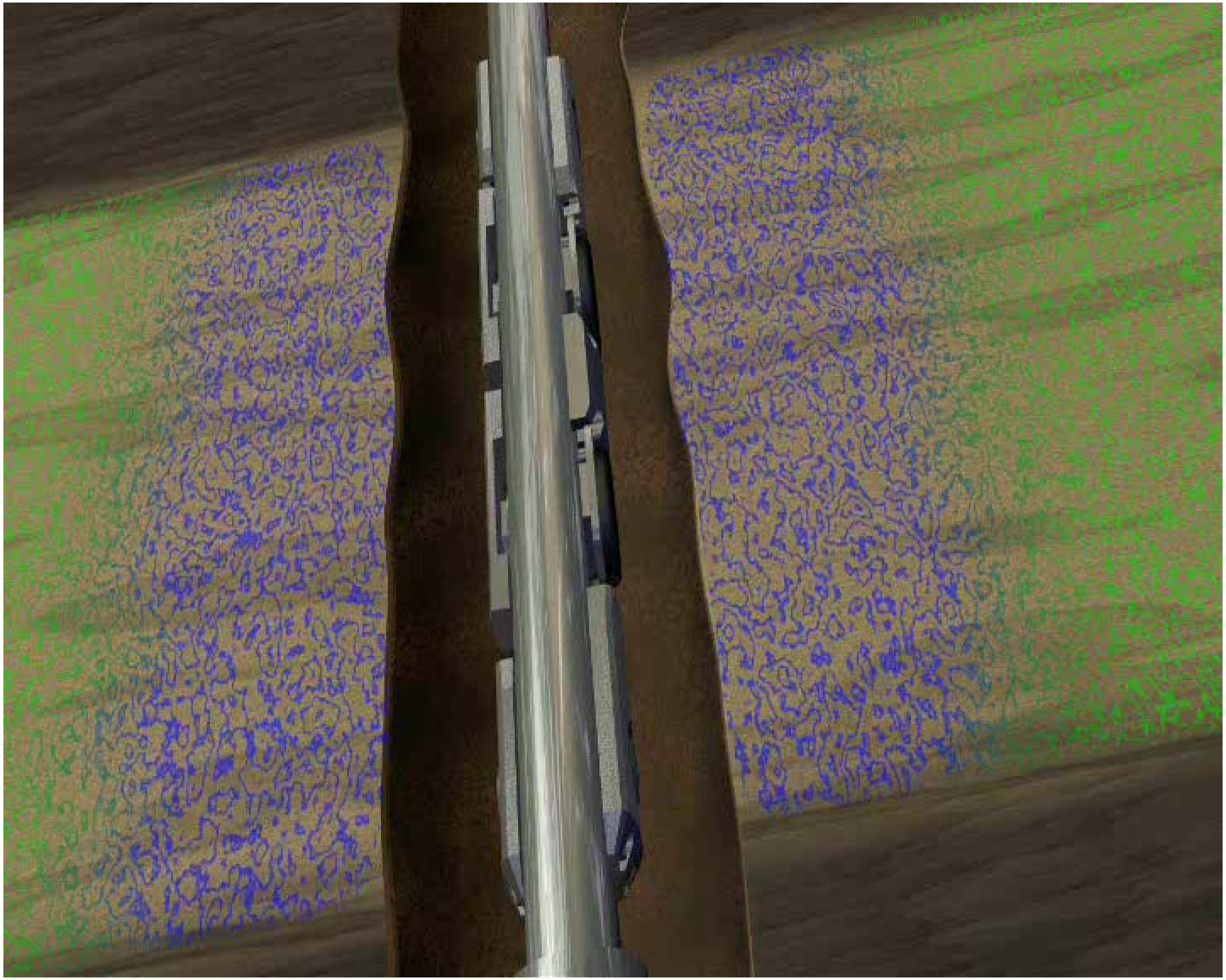
MRIL Interpretation

Fluid Typing & Sampling in Laminated Reservoirs

RDT
Dual Probe 1”

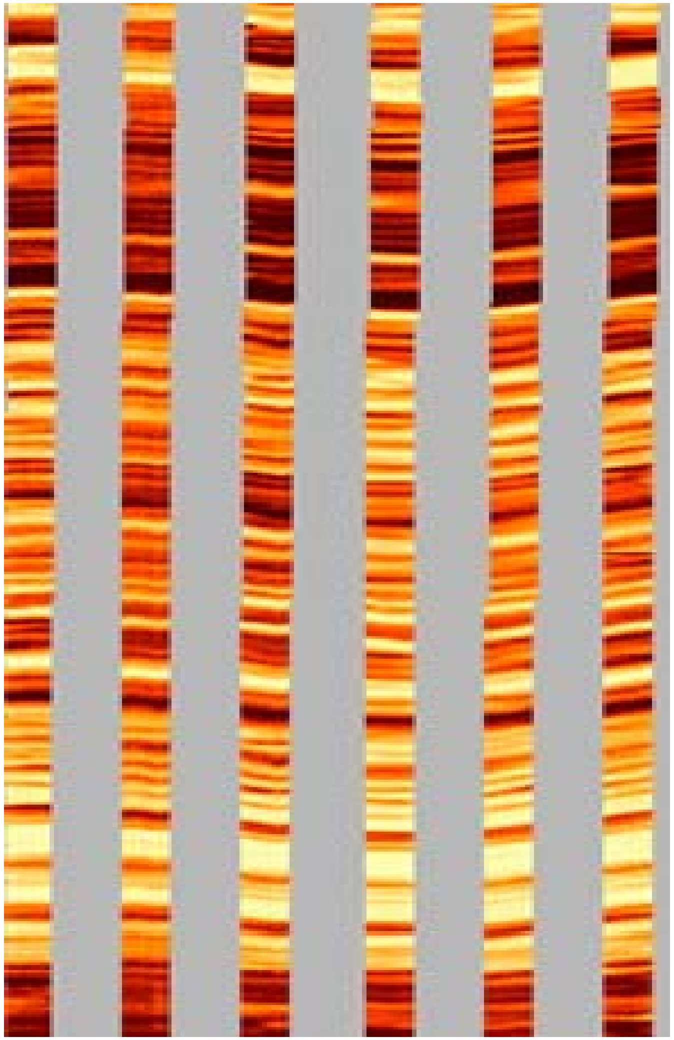
RDT
Oval Pad 7.25”





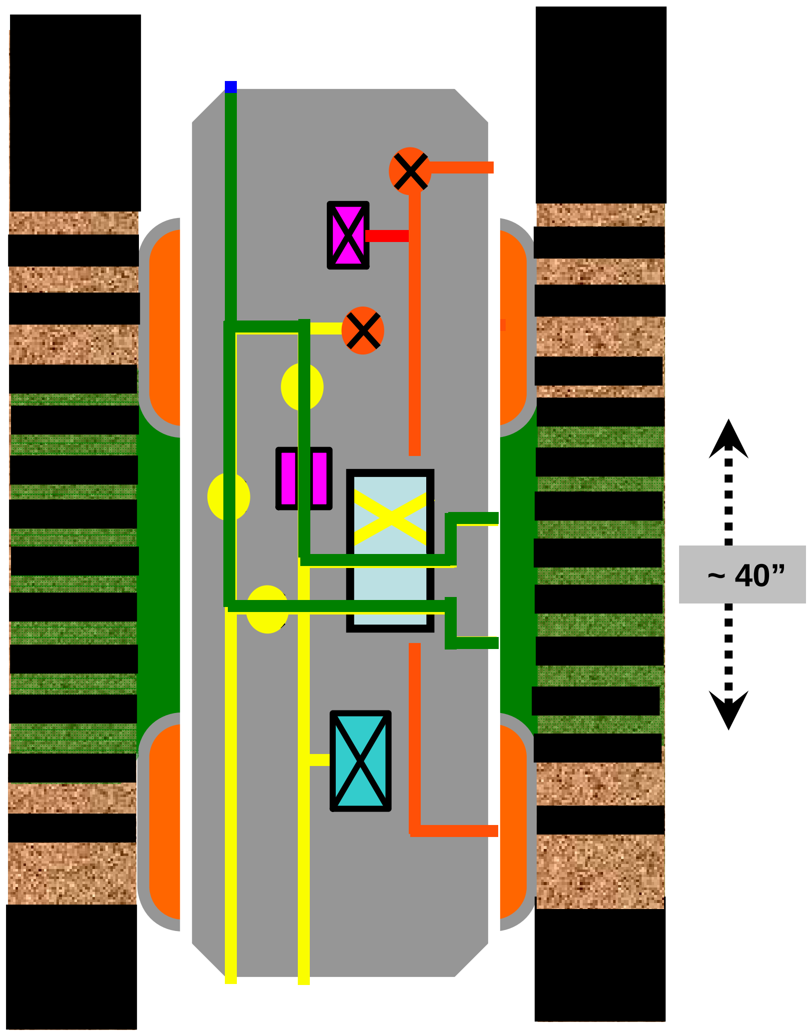
Fluid Typing & Sampling in Laminated Reservoirs

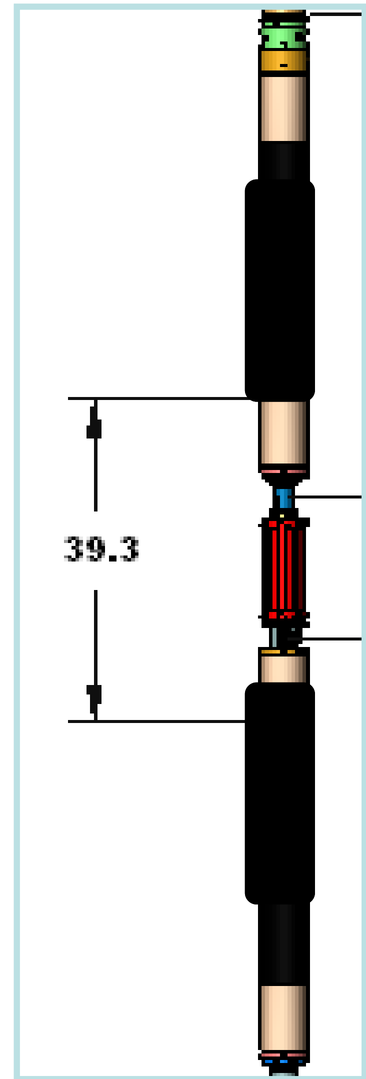
LWD GeoTap IDS Oval Pad Option



Fluid Typing & Sampling in Laminated Reservoirs

RDT - Dual Packer / Straddle Packer Option





Fluid Typing In Thinly Bedded Reservoir

Thank You

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   ethods

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   - Thomas Steibert

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