KMS Technologies – KJT Enterprises Inc.

2013

Electromagnetics

A ideal tool for

shale reserves

K.M. Strack, 2013, USC Distinguished Lecture

Electromagnetics
A ideal tool for
shale reserves

K. Strack[1-3]

USC presentation March 28 2013

- *KMS Technologies &*
- *University of Houston, USA (ECE & Geosciences)*
- *Mahidol University, Bangkok, Thailand*

To show how NEW array electromagnetics can address some issues for shale resources

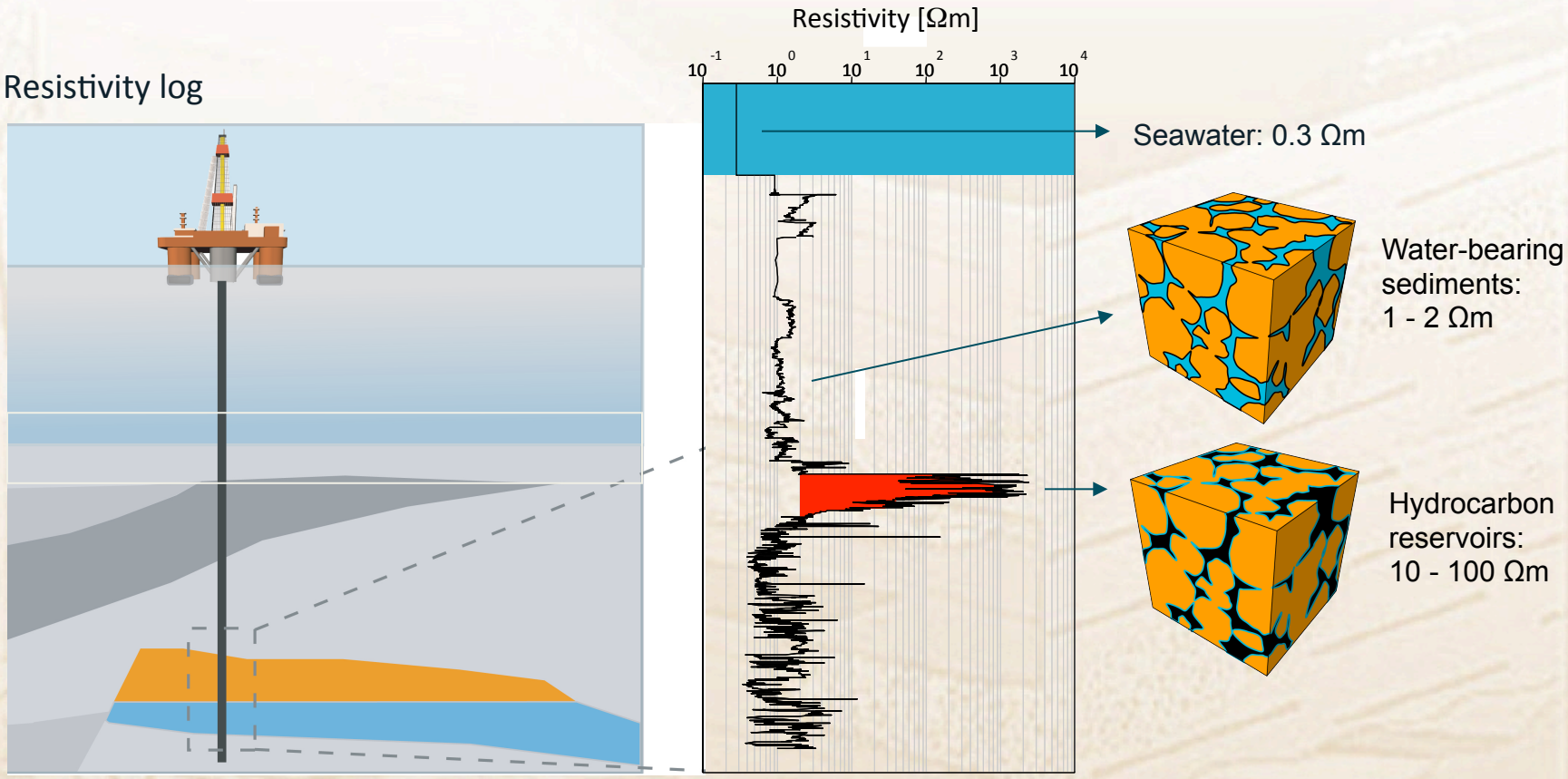
Shale resources issues

- Shale gas/oil
  - Oil/gas is inside shales
  - Reservoirs are thin
  - Low porosity/permeability → fracturing
  - Drilling → horizontal / highly deviated wells
  - Fractures & structure → anisotropy

Shale resources issues translated to EM geophysics

- Shale gas/oil
  - Oil/gas is inside shales – **Resistor in a conductor**
  - Reservoirs are thin – **Thin resistive layer effect – DHI for surface data, 3D induction log for well**
  - Low porosity/perm. → fracturing **Larger volume**
  - Drilling → horizontal / highly deviated wells - **geosteering** ← **NOT covered today**
  - Fractures → anisotropy – **3D EM anisotropy**

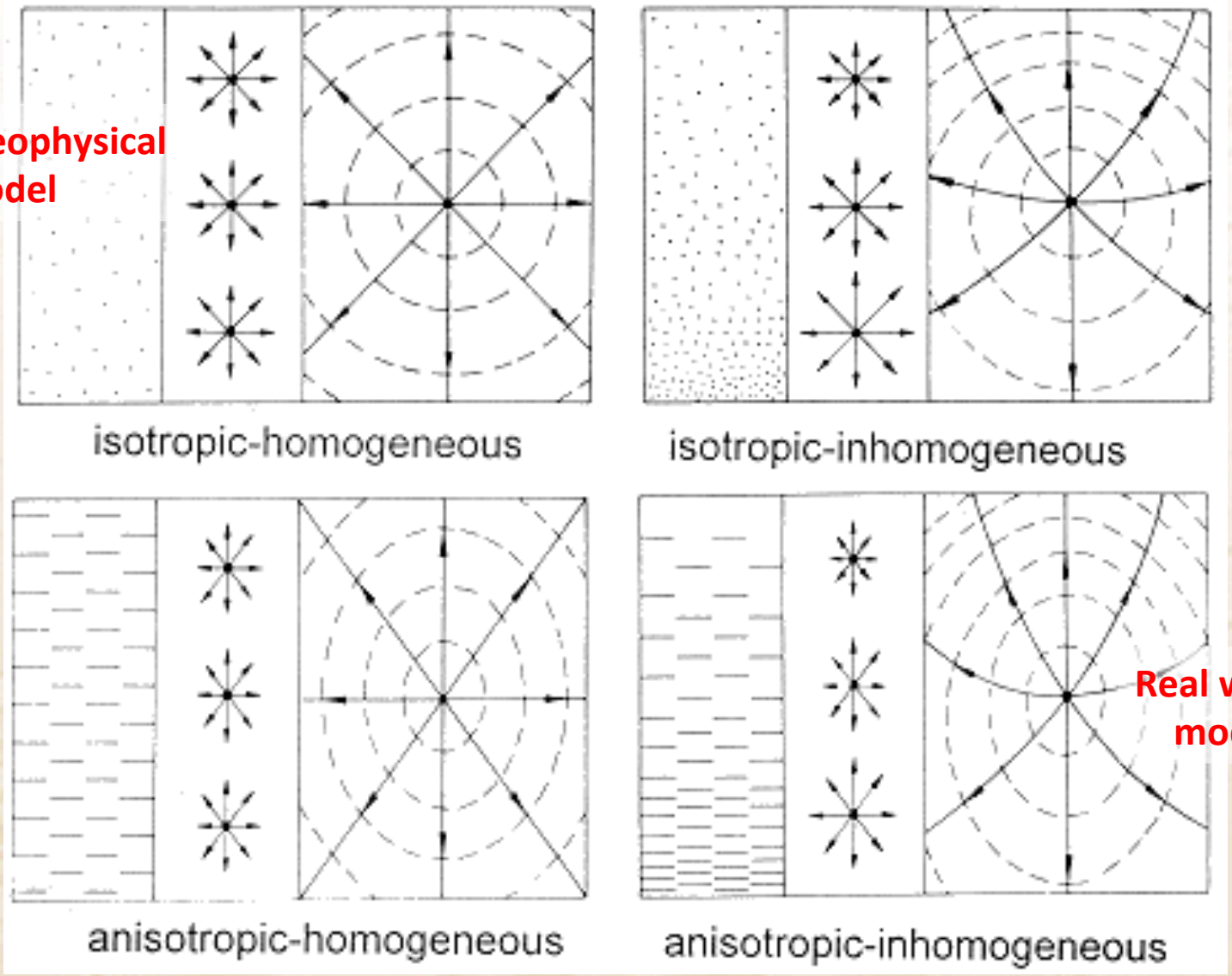
Hydrocarbons are resistive!



Courtesy EMGS

Isotropy - Anisotropy Homogeneity - Inhomogeneity

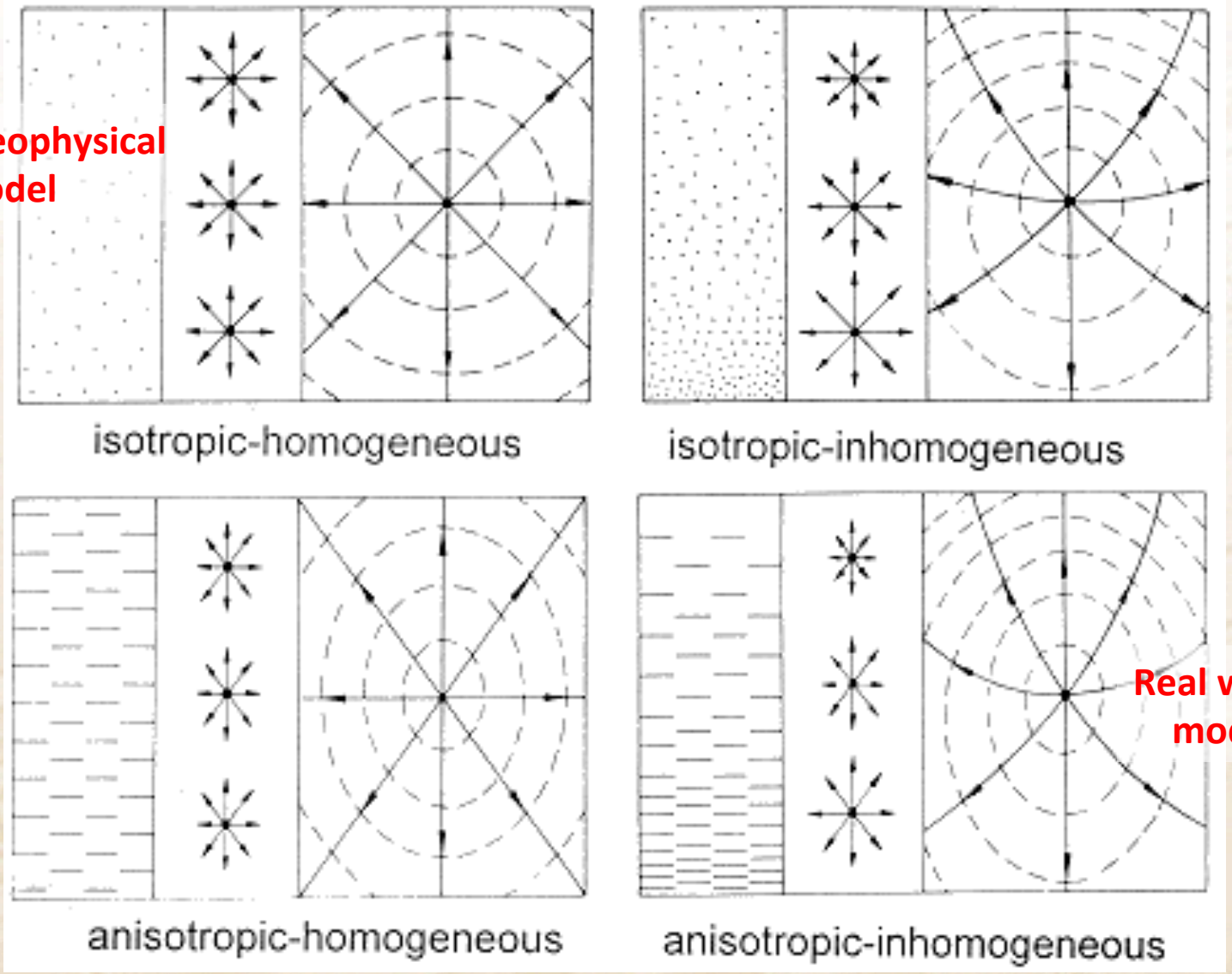
Simple geophysical model



Real world model

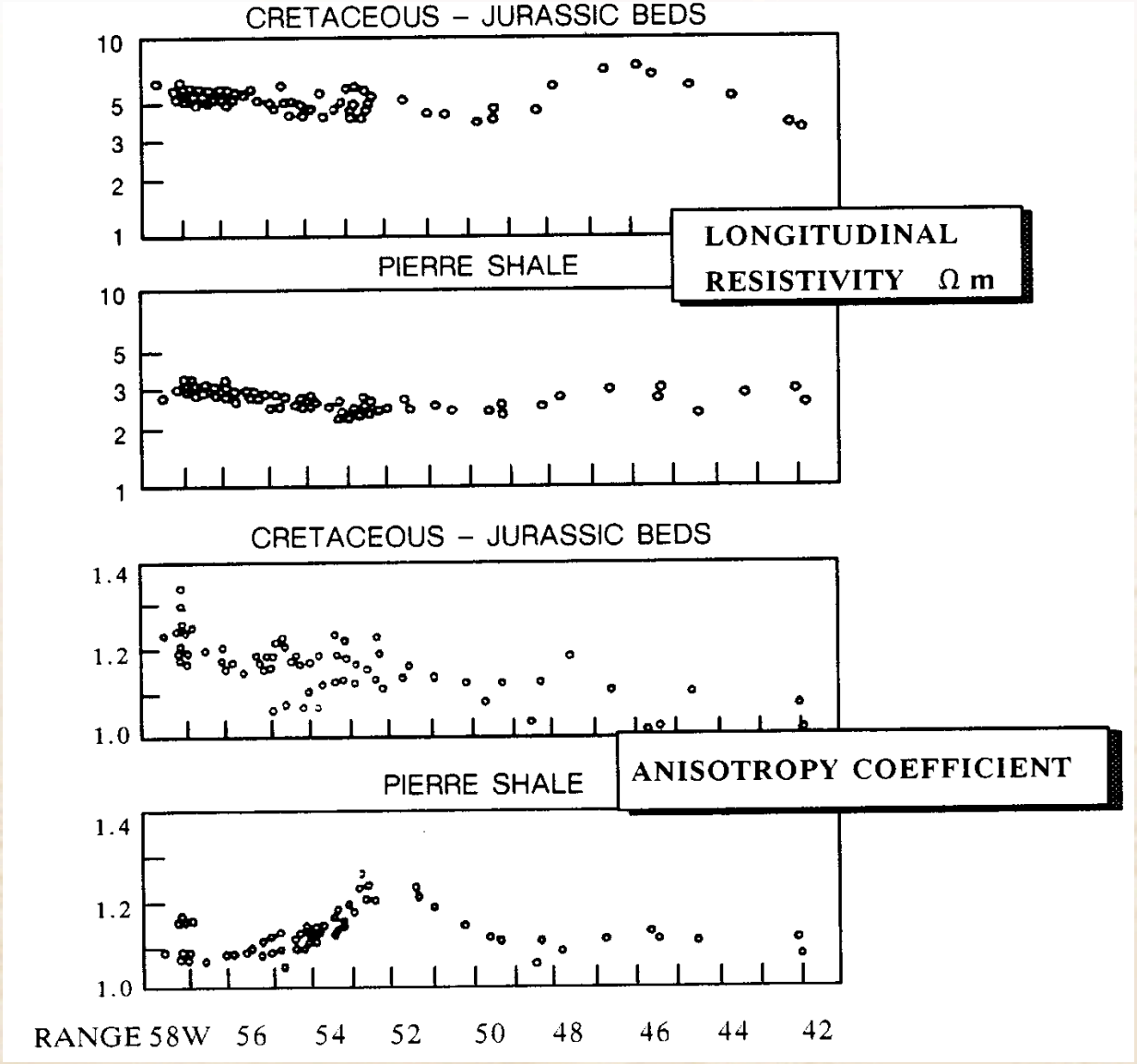
Isotropy - Anisotropy Homogeneity - Inhomogeneity

Simple geophysical model



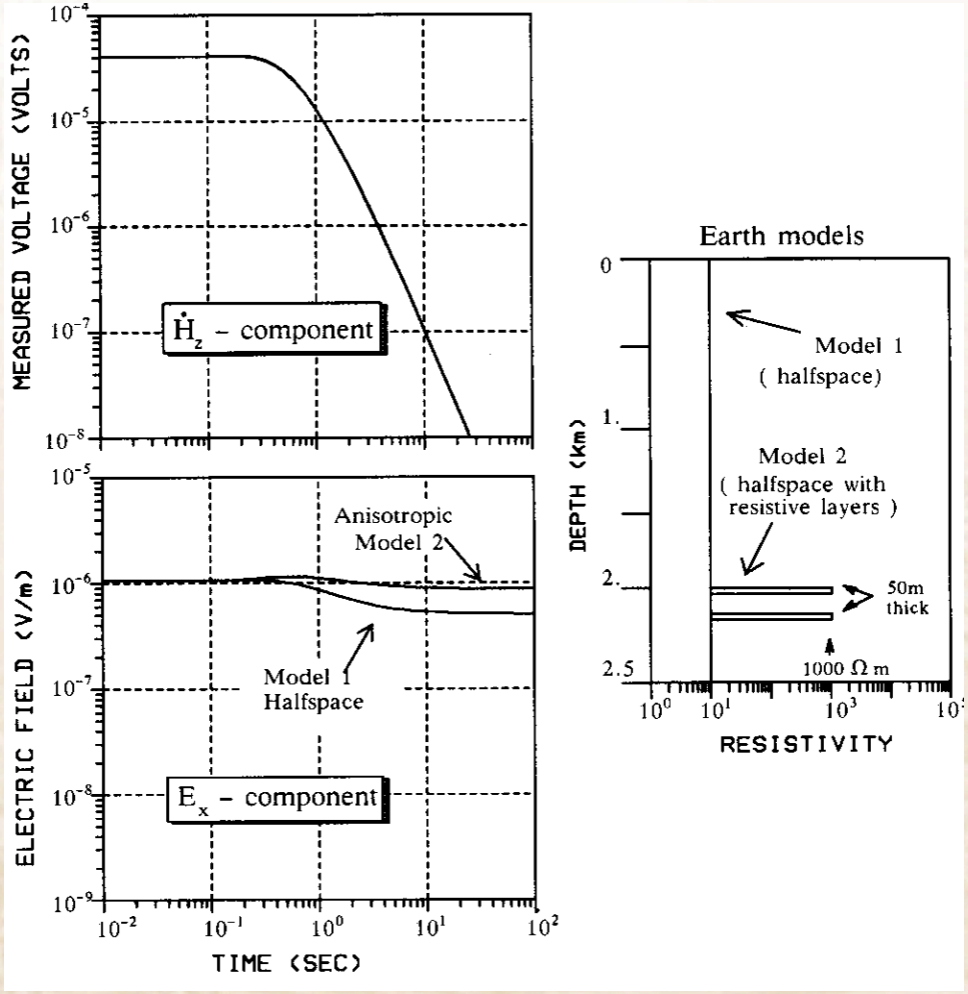
Real world model

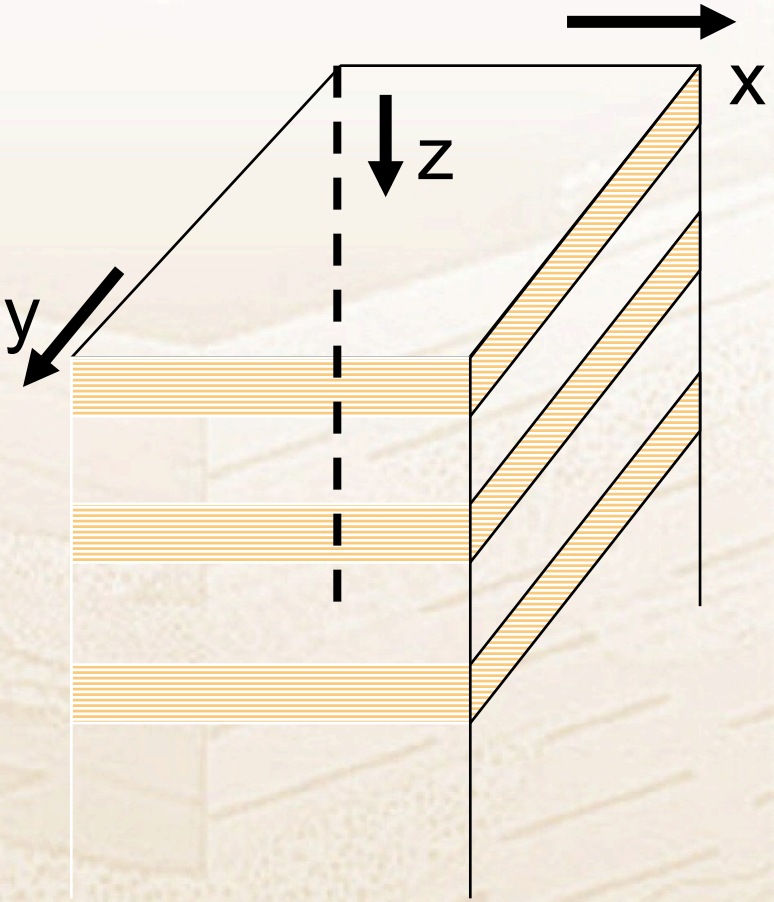
DJ Basin: Resistivity distribution from logs



After Harthill 1967

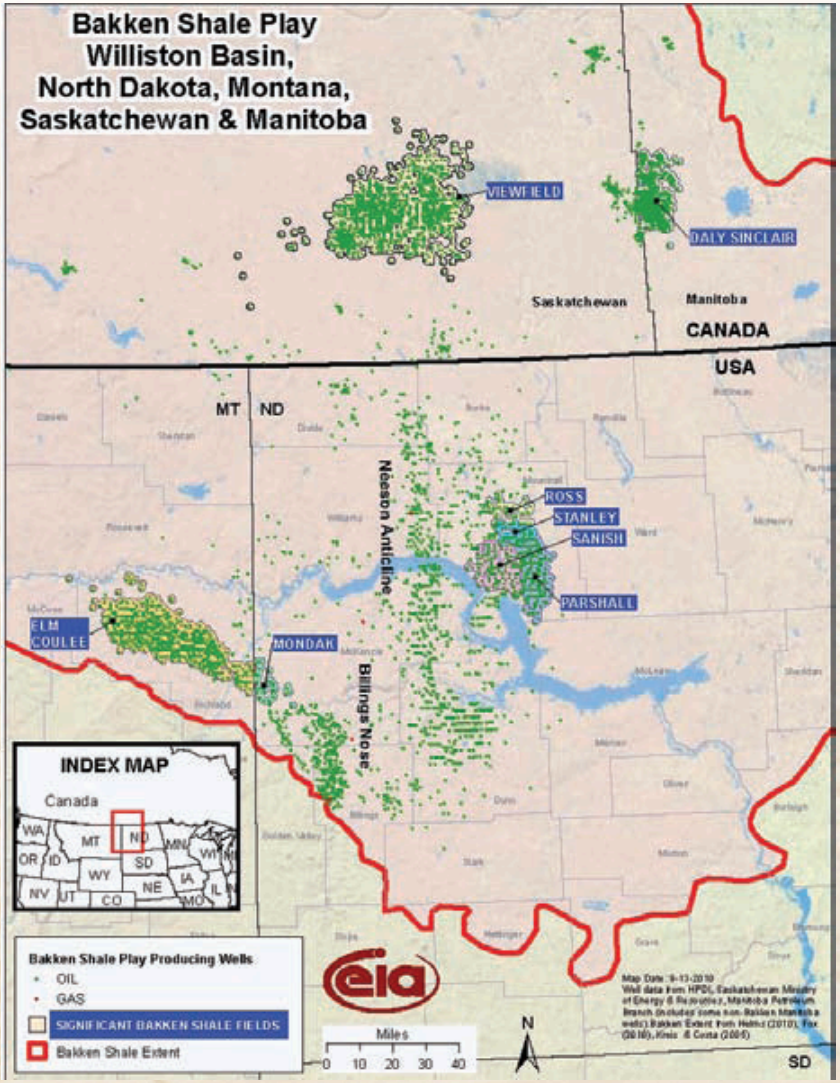
Anisotropy: Layer cake geology → anisotropy





(after Strack 1992)

How did we get started?

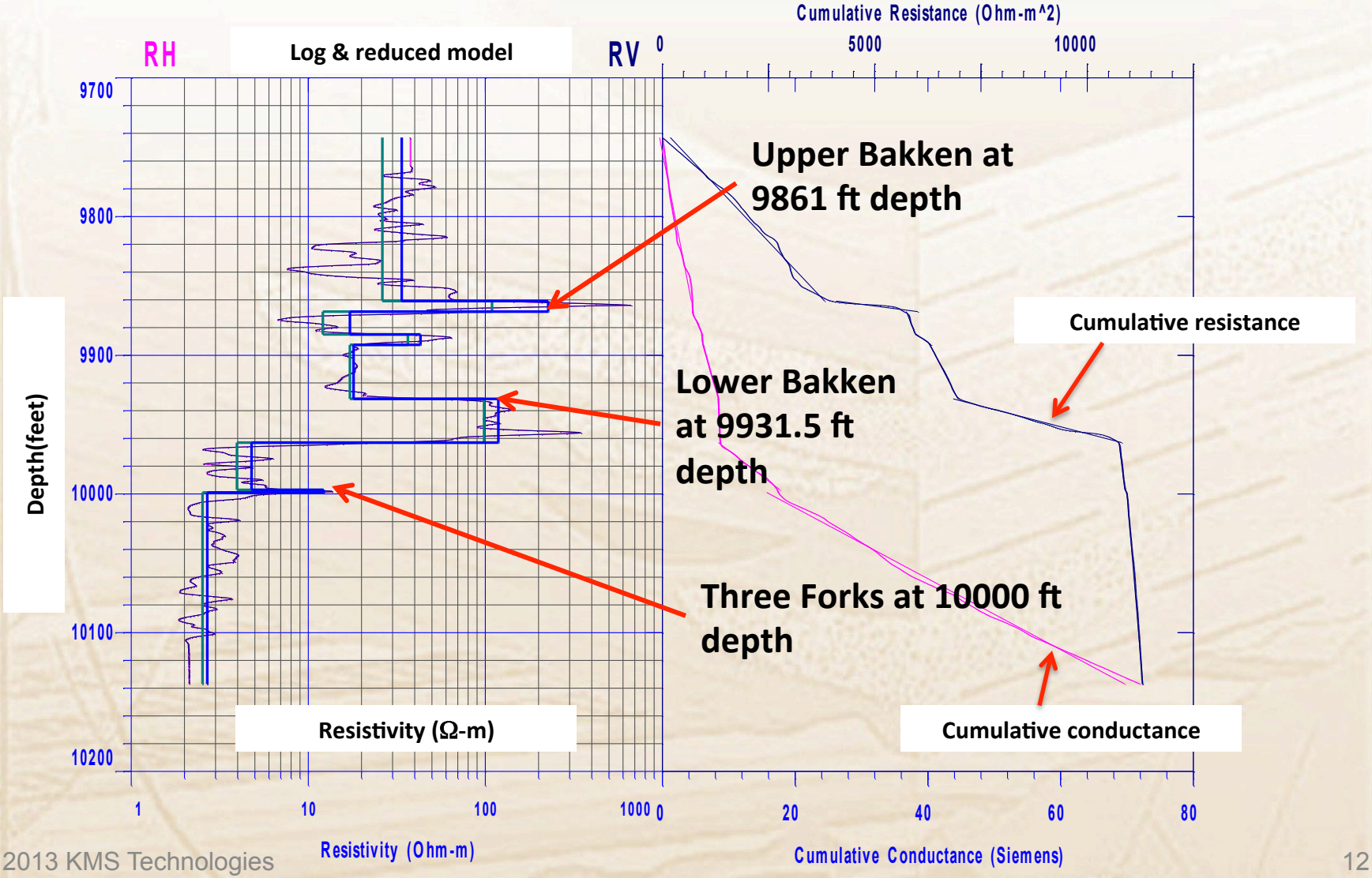


Mississippian	Lodgepole Formation	"False Bakken"
		Pelmatozoan limestone
Devonian	Bakken Formation	upper
		middle
		lower
	Three Forks Formation	"Sanish"

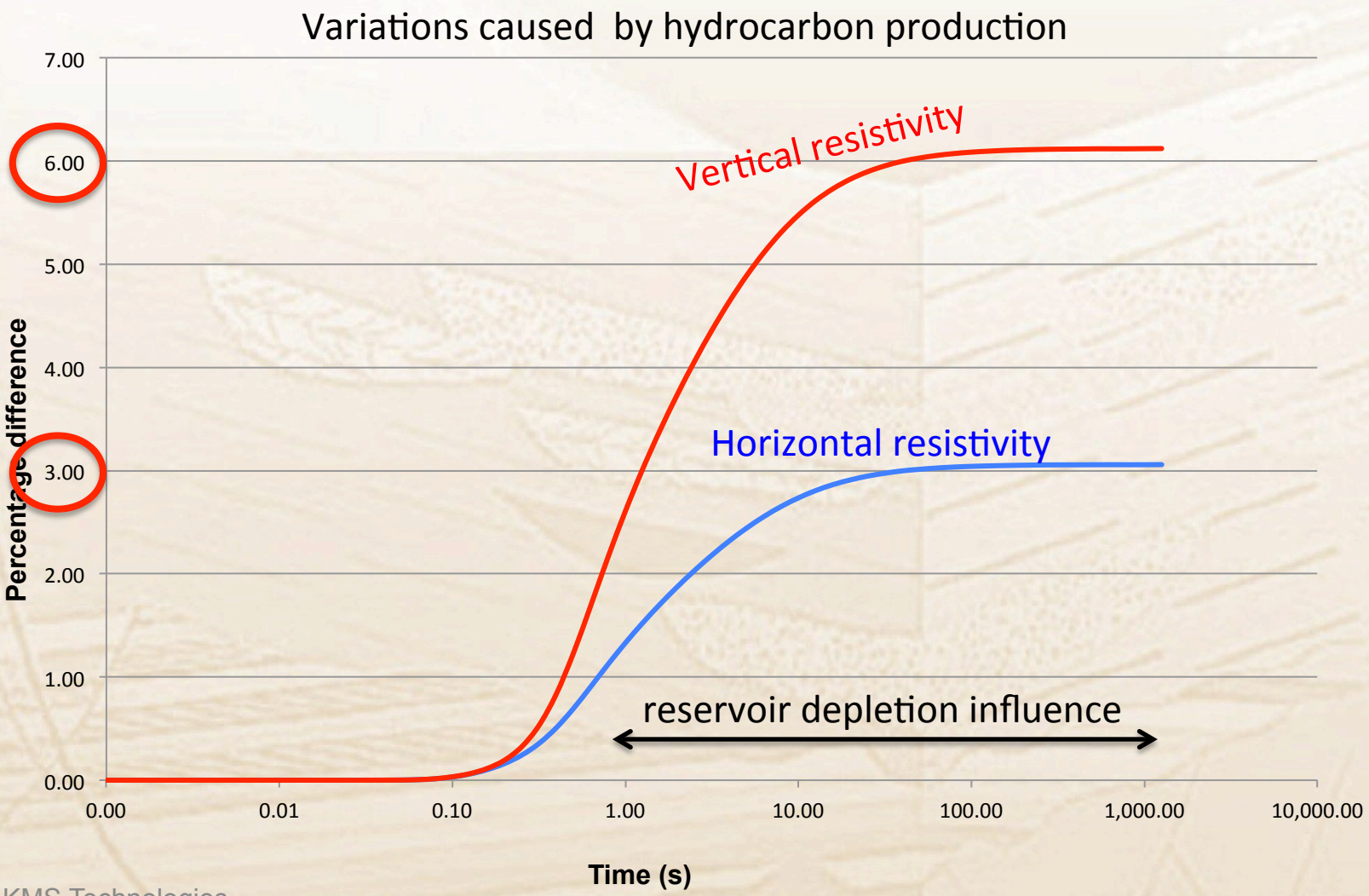
After US Dept. of Energy, & Le Fever, 2005

From a log to an anisotropic model

Log data courtesy of Microseismics Inc.



CSEM time lapse: before & after production



How do we get there? EM Methods

- Magnetotellurics – **passive not detailed enough**
- Controlled Source Electromagnetics (CSEM)

  (the ONLY way to get vertical current flow)

  - Time domain EM – a single signal generating event
  - Frequency domain EM – a fixed frequency continuous event

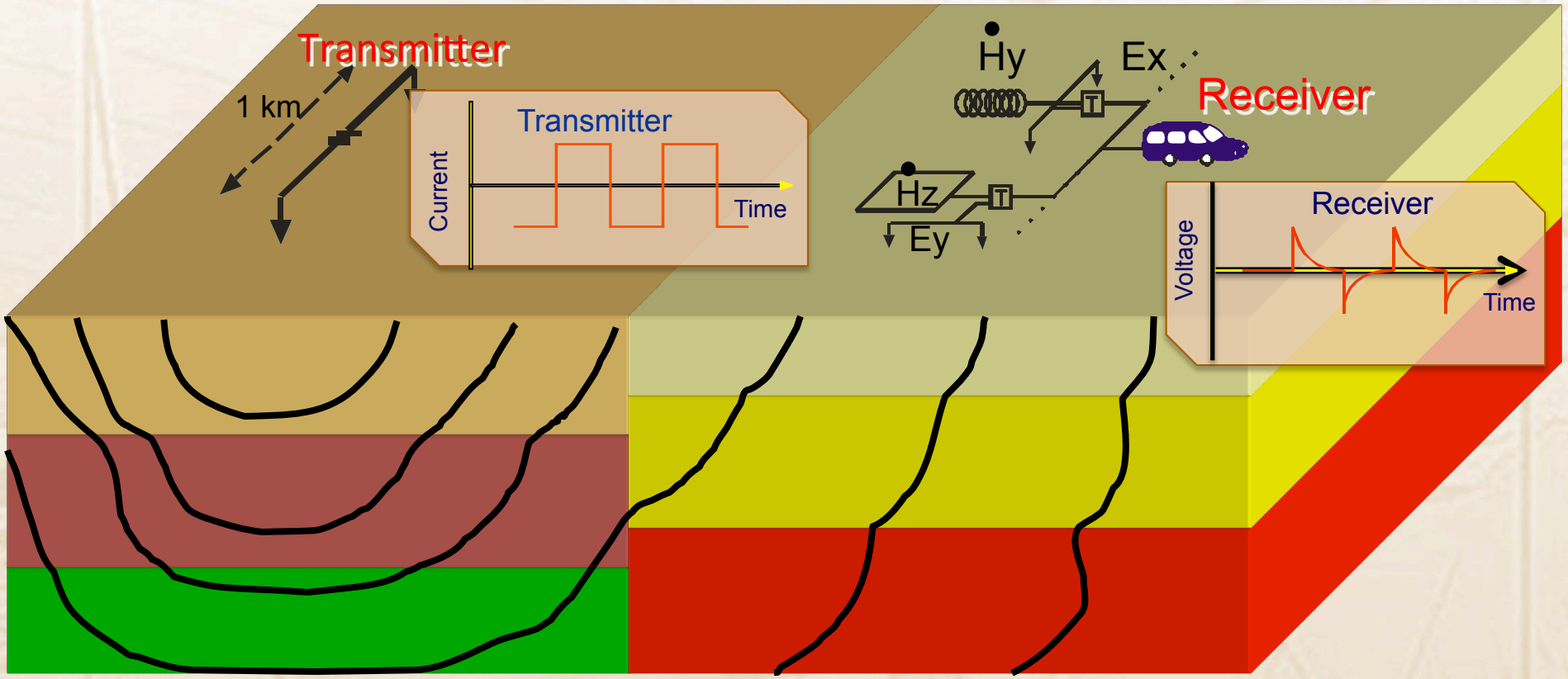
How do we get there? EM Methods

- Magnetotellurics – **passive not detailed enough**
- Controlled Source Electromagnetics (CSEM)

  (the ONLY way to get vertical current flow)

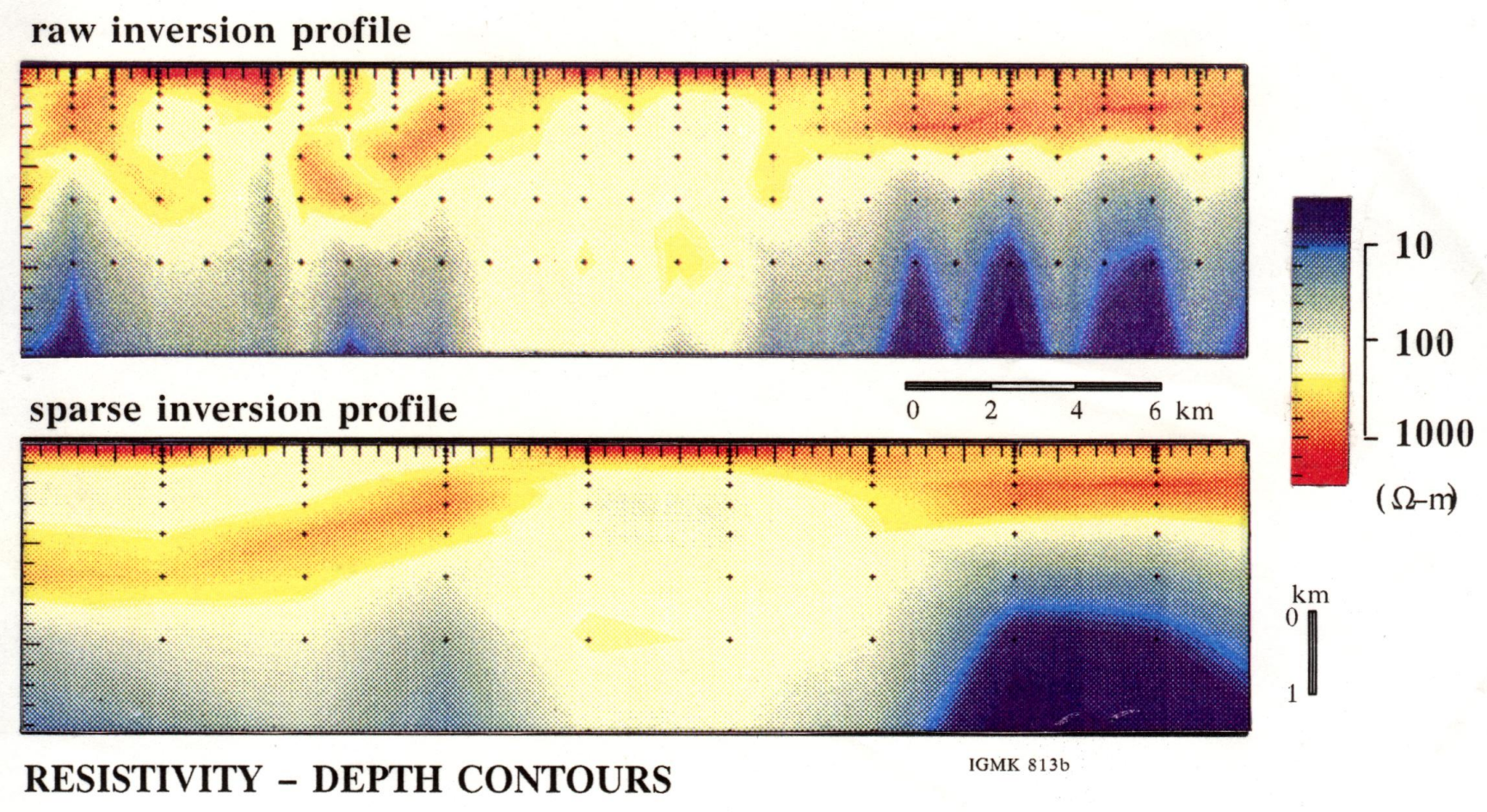
  - Time domain EM – a single signal generating event
  - Frequency domain EM – a fixed frequency continuous event

- Magnetotellurics – **passive not detailed enough**
- Controlled Source Electromagnetics (CSEM)
  - **Time domain EM – a single signal generating event**
  - EM – a fixed frequency continuous event



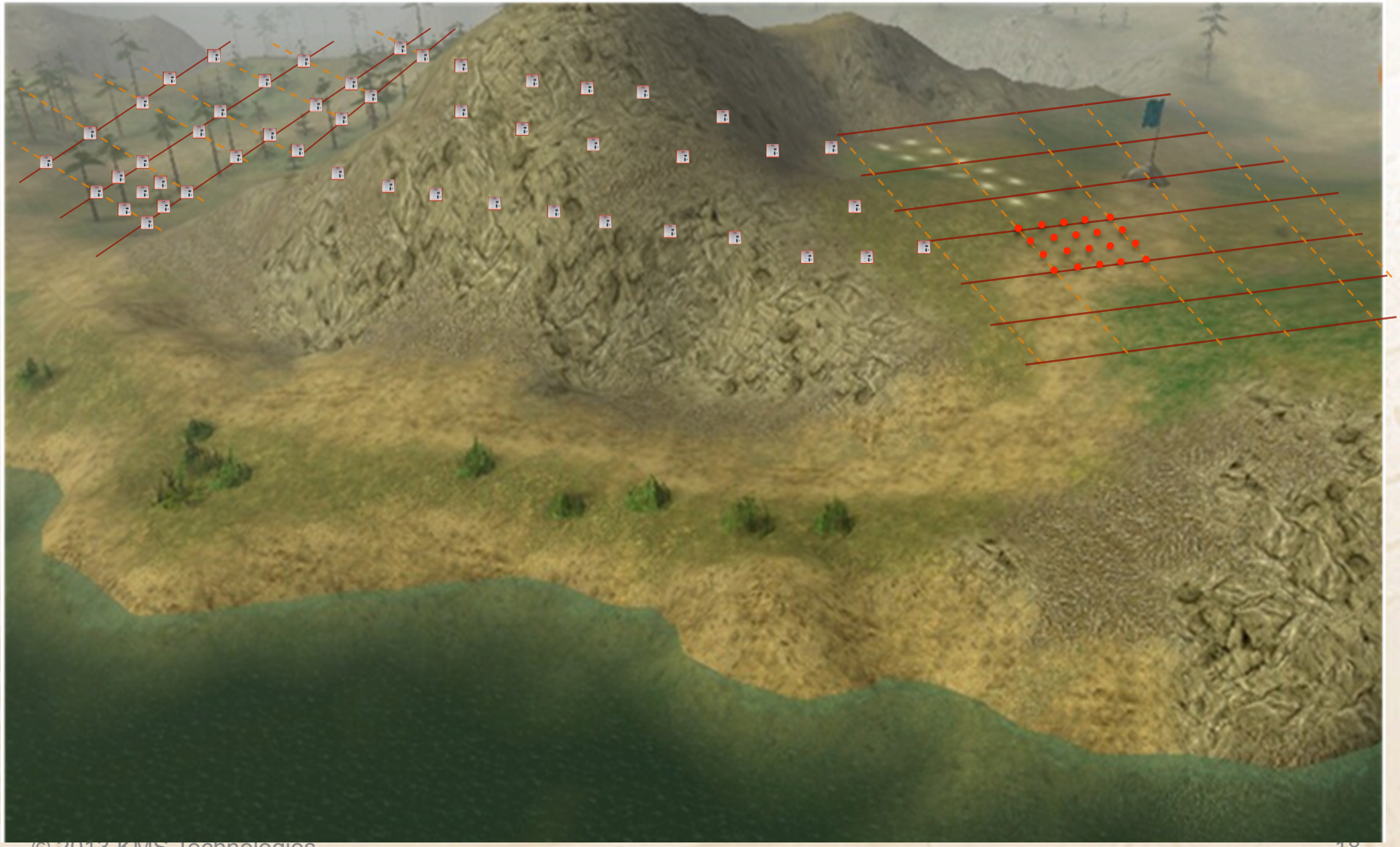
Courtesy Hoerdt

We need dense data!



Data from Saurashtra, India, courtesy ONGC

New ARRAY acquisition → better images

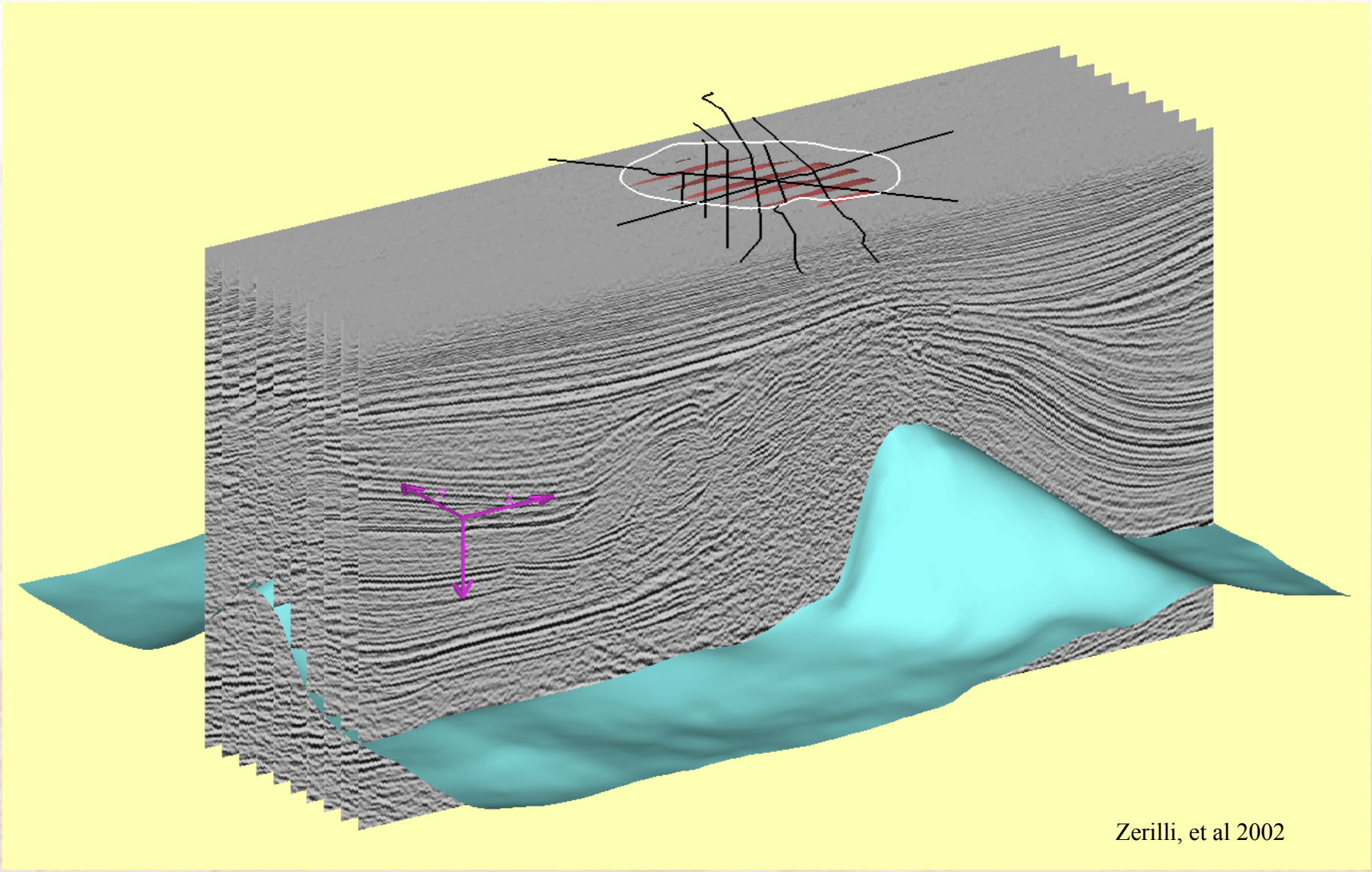


New ARRAY acquisition → better images

- Wireless
- True array system
- Large dynamic range
- High bandwidth

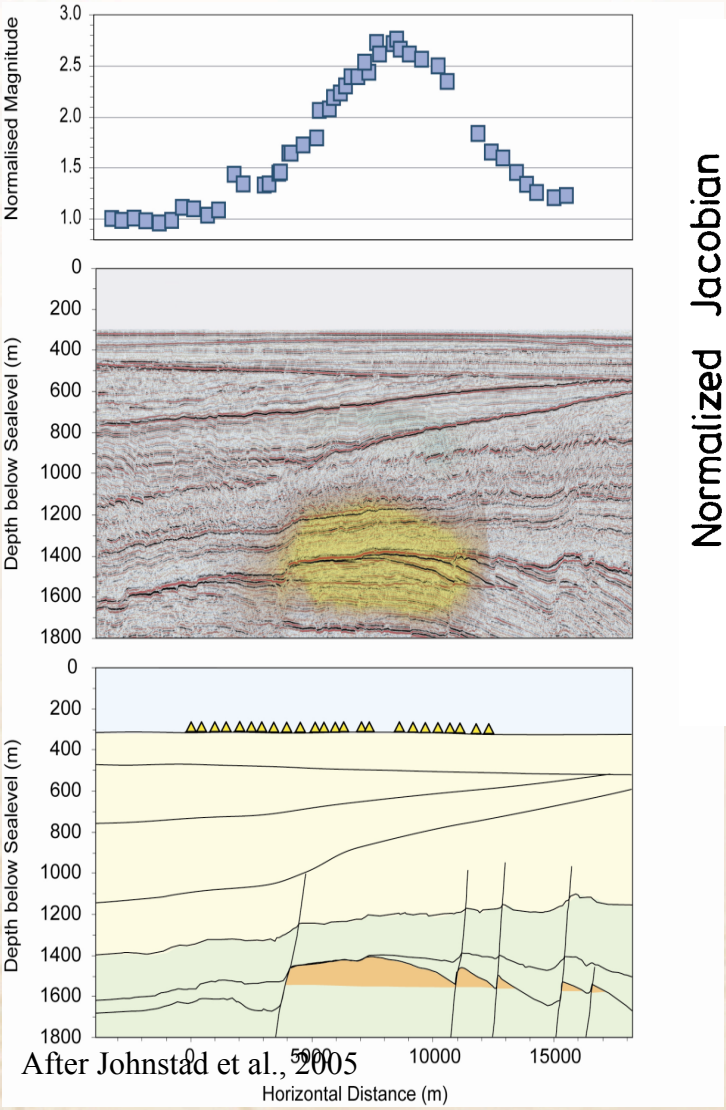

Wireless controller

Dense acquisition (Δx = 50 m) → better images

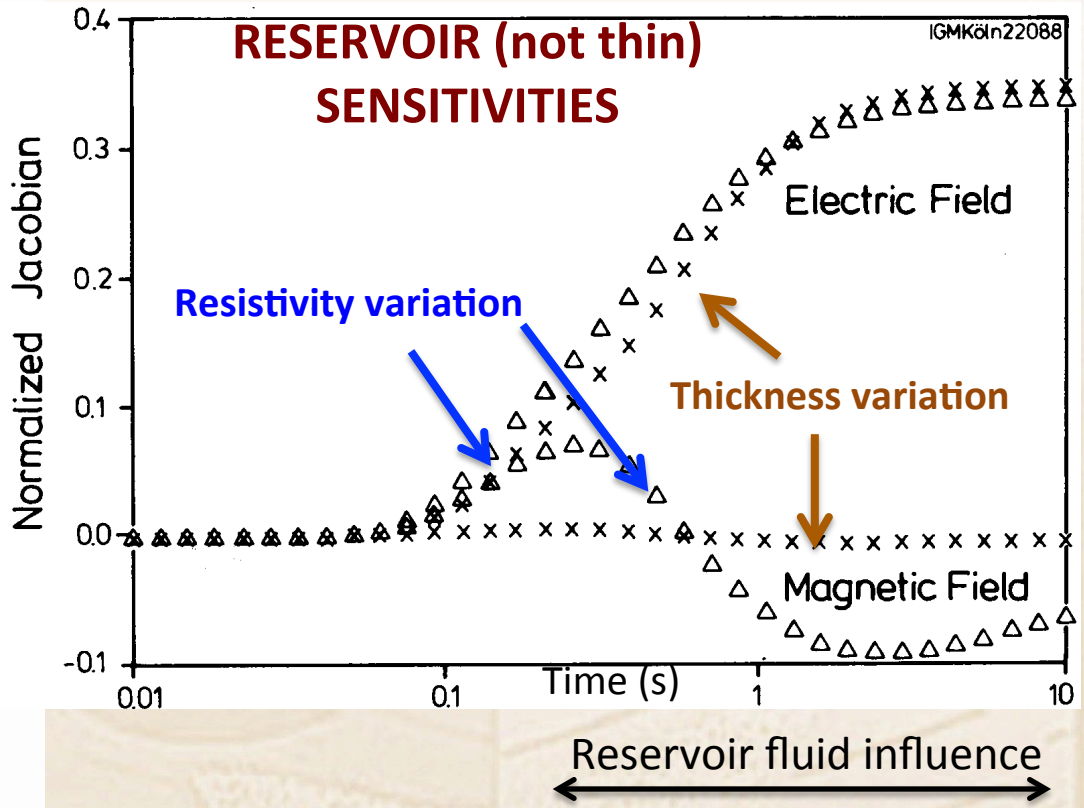


Zerilli, et al 2002

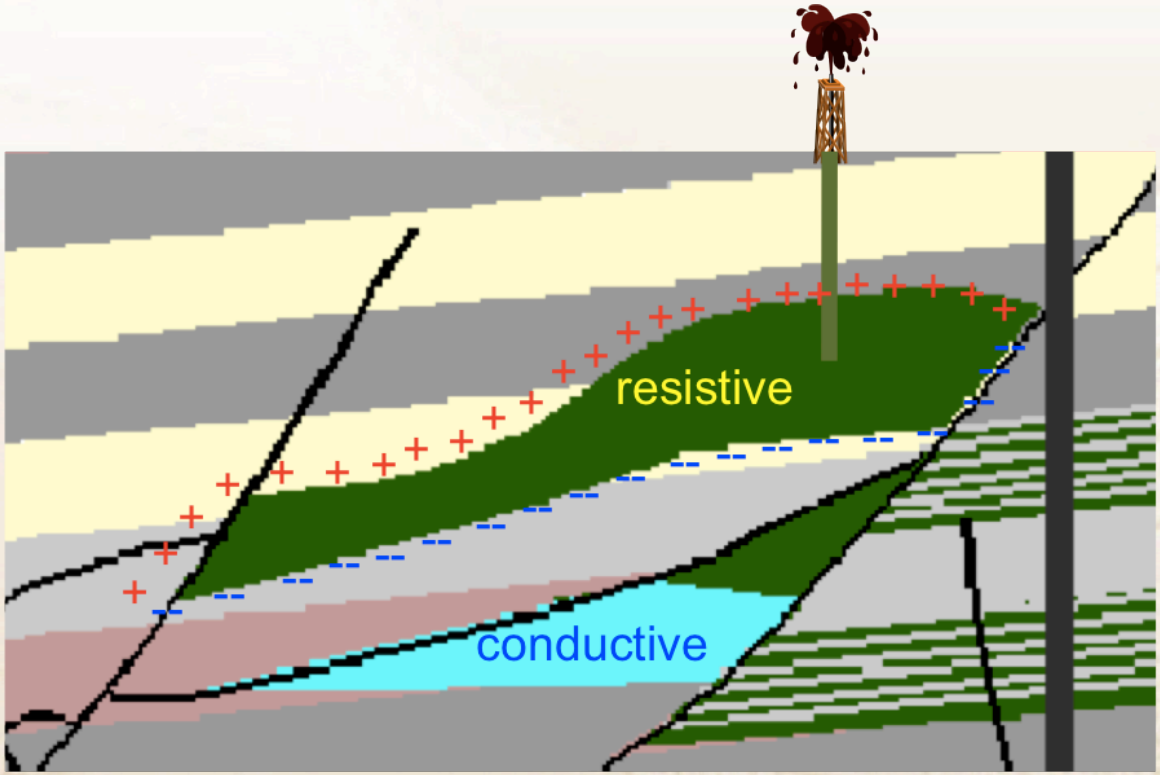
DHI & Resistors in conductors



After Johnstad et al., 2005

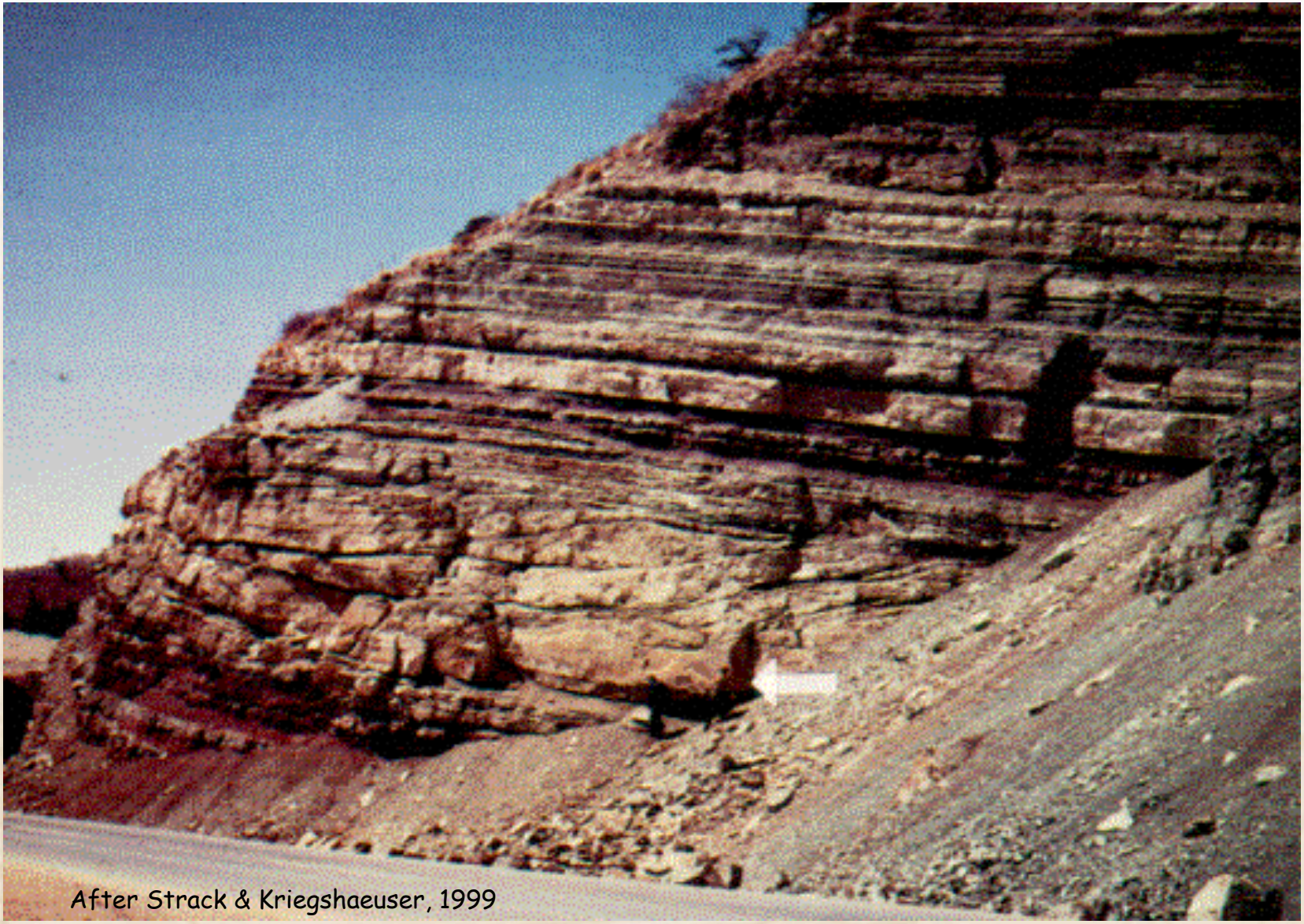


DHI & Resistors in conductors

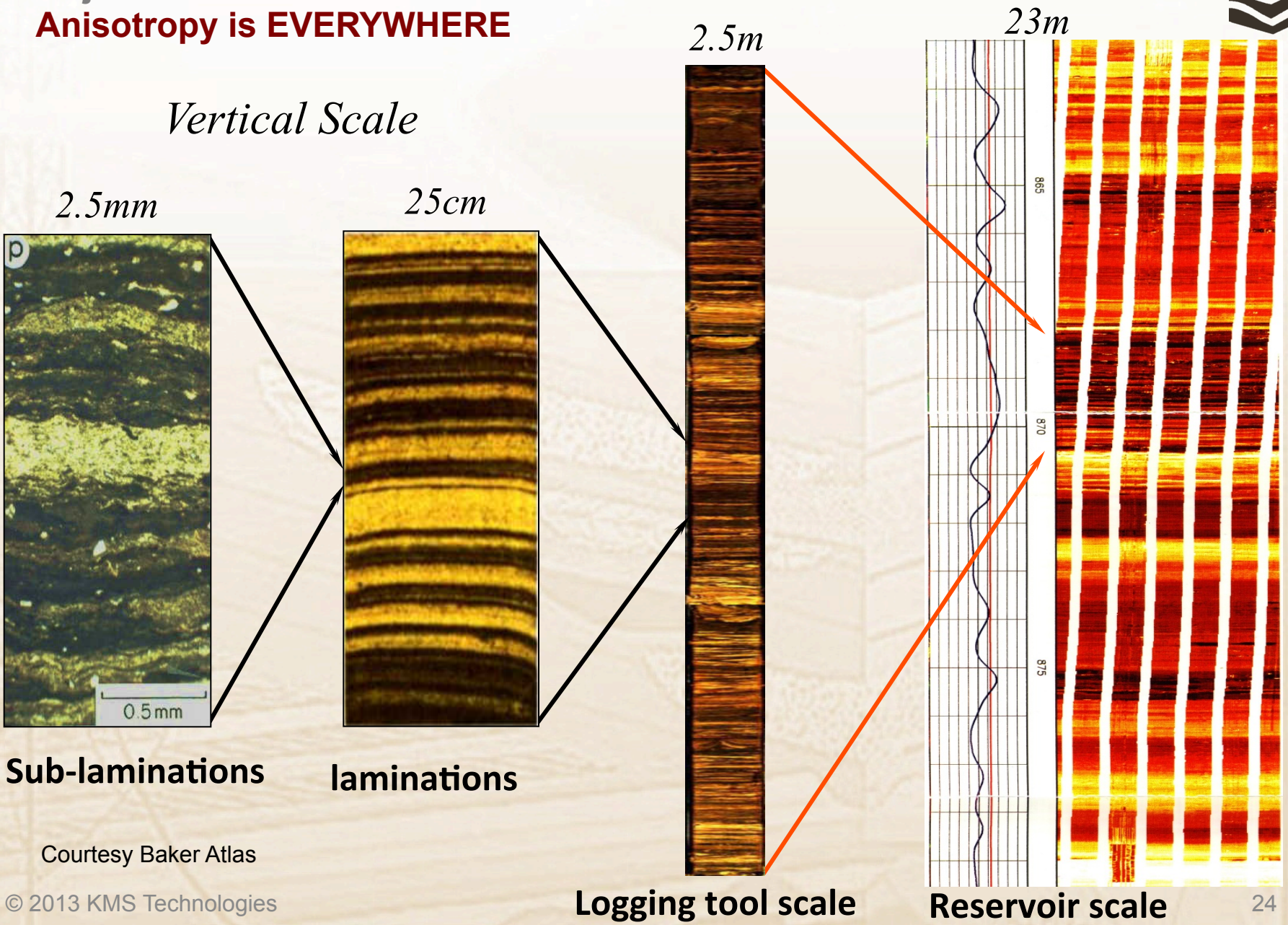


After Johnstad et al., 2005

Anisotropy is EVERYWHERE

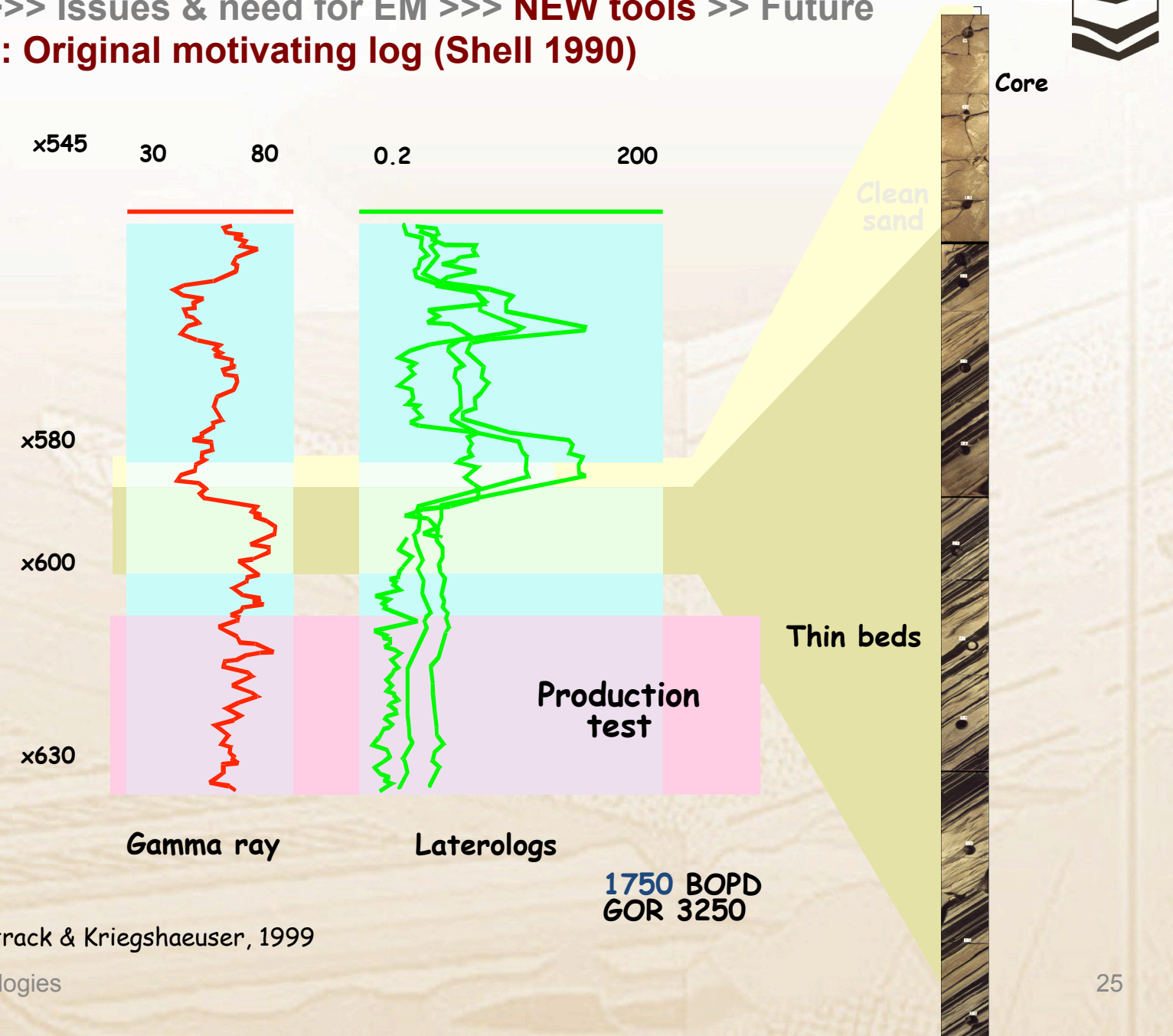


Anisotropy is EVERYWHERE



Courtesy Baker Atlas

Anisotropy: Original motivating log (Shell 1990)

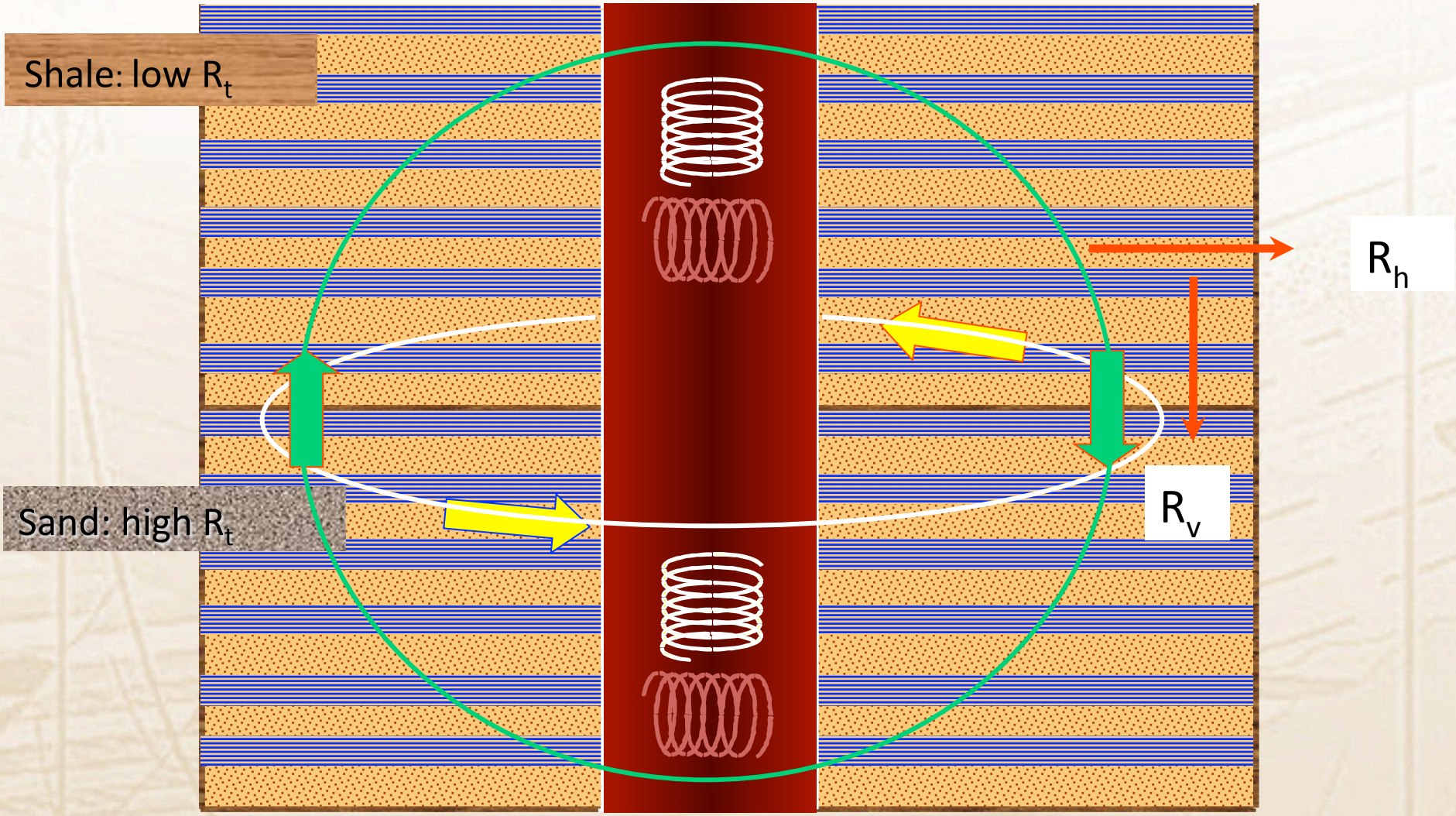


After Strack & Kriegshaeuser, 1999

Extended from laminations to turbidites

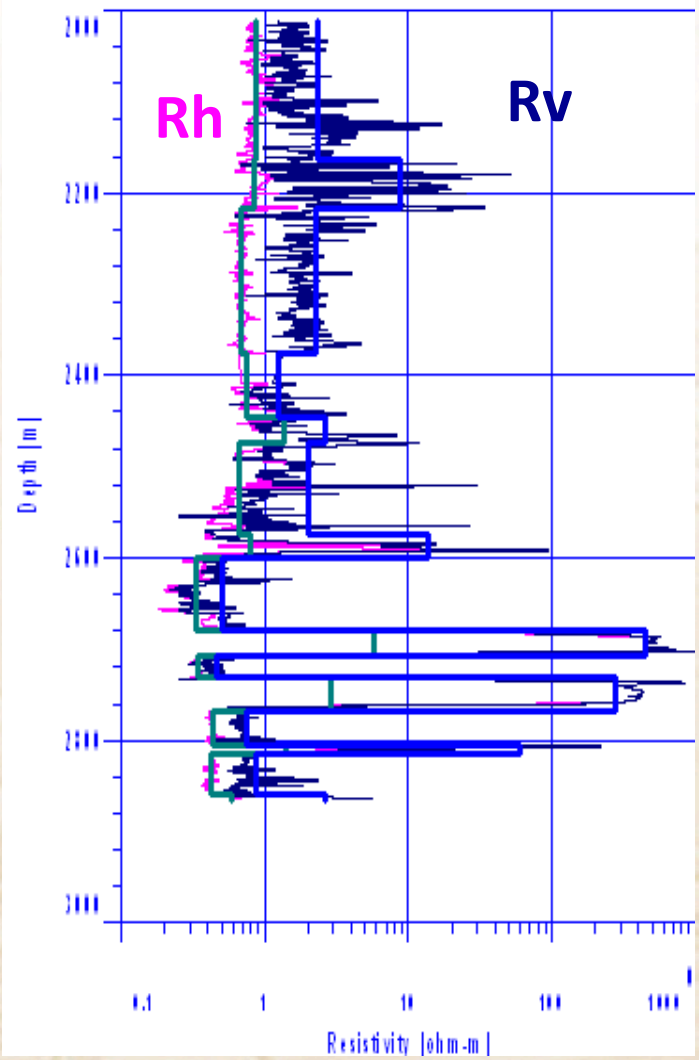
After Blackbourn & Thomson, 2000

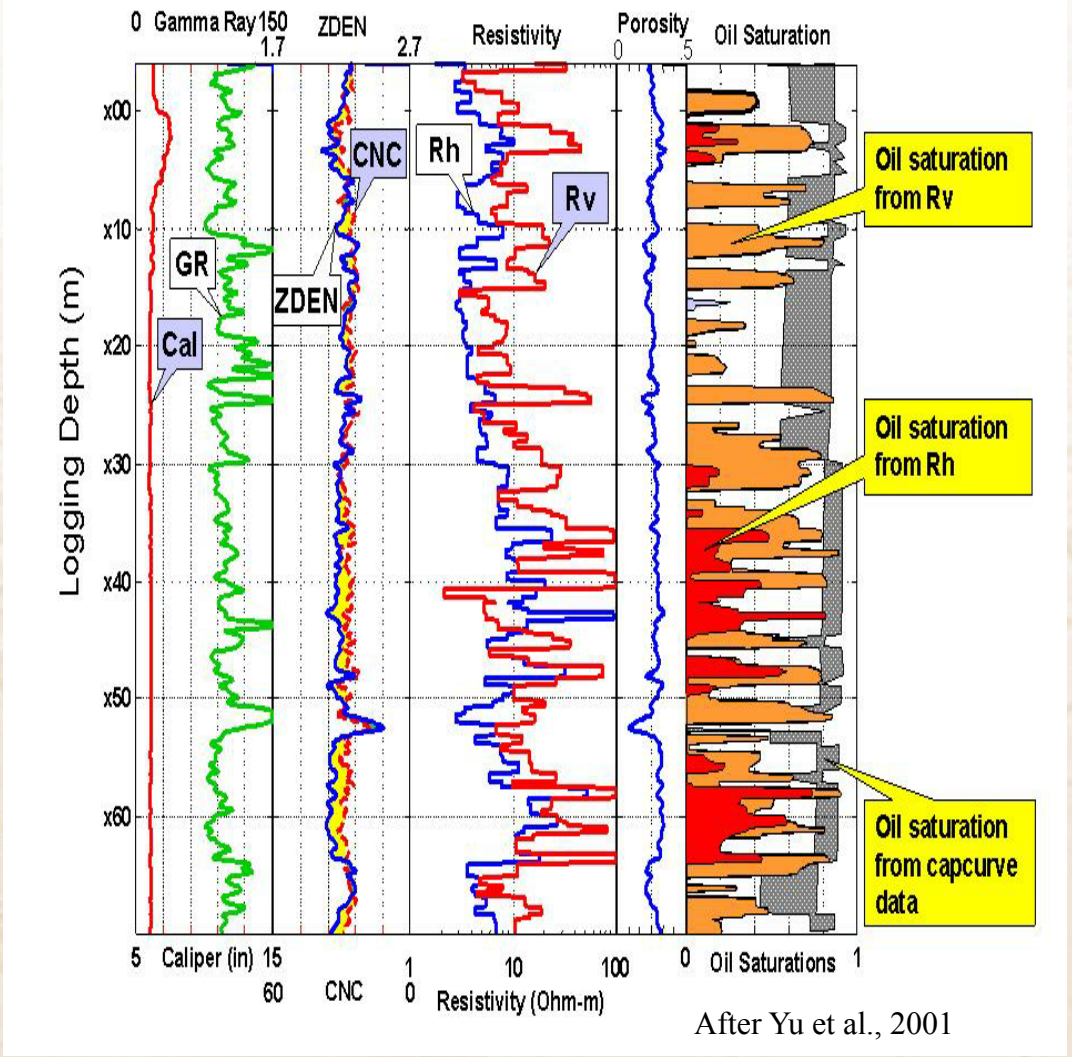
Transverse Induction logging principle



After Kriegshaeuser et al, 2000

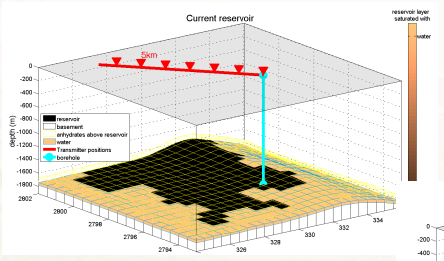
ADD BOREHOLE: Fractures → anisotropy

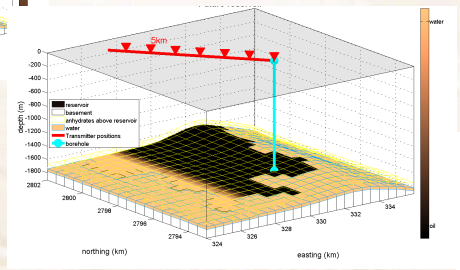


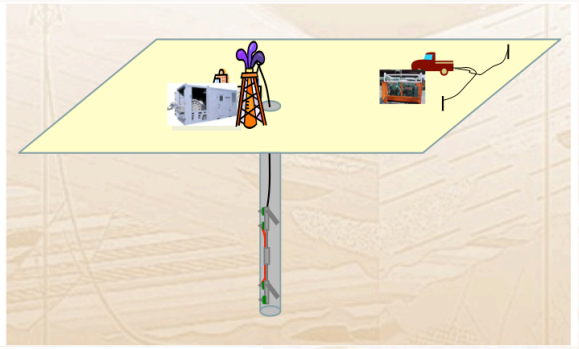


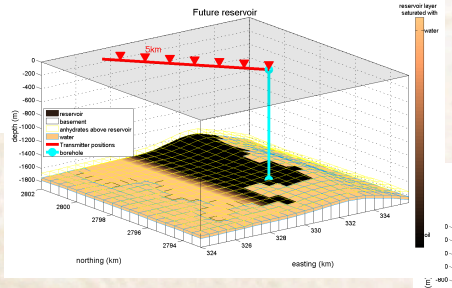
After Yu et al., 2001

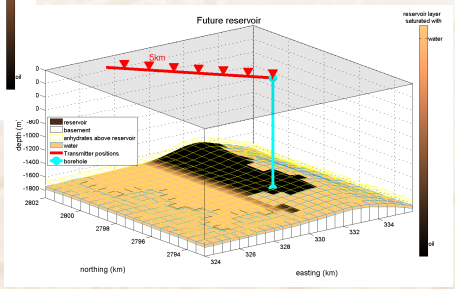
ADD BOREHOLE: Integration!

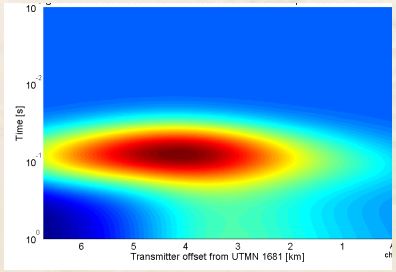


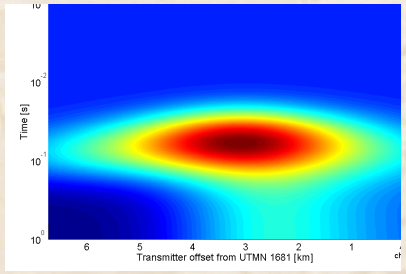


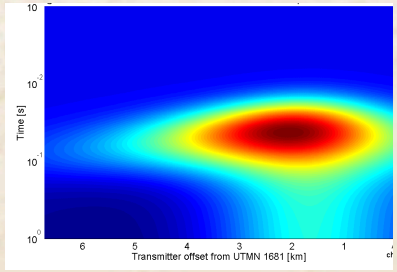


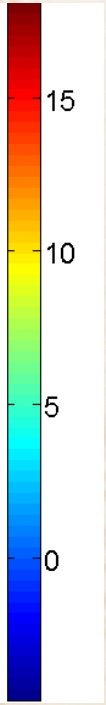








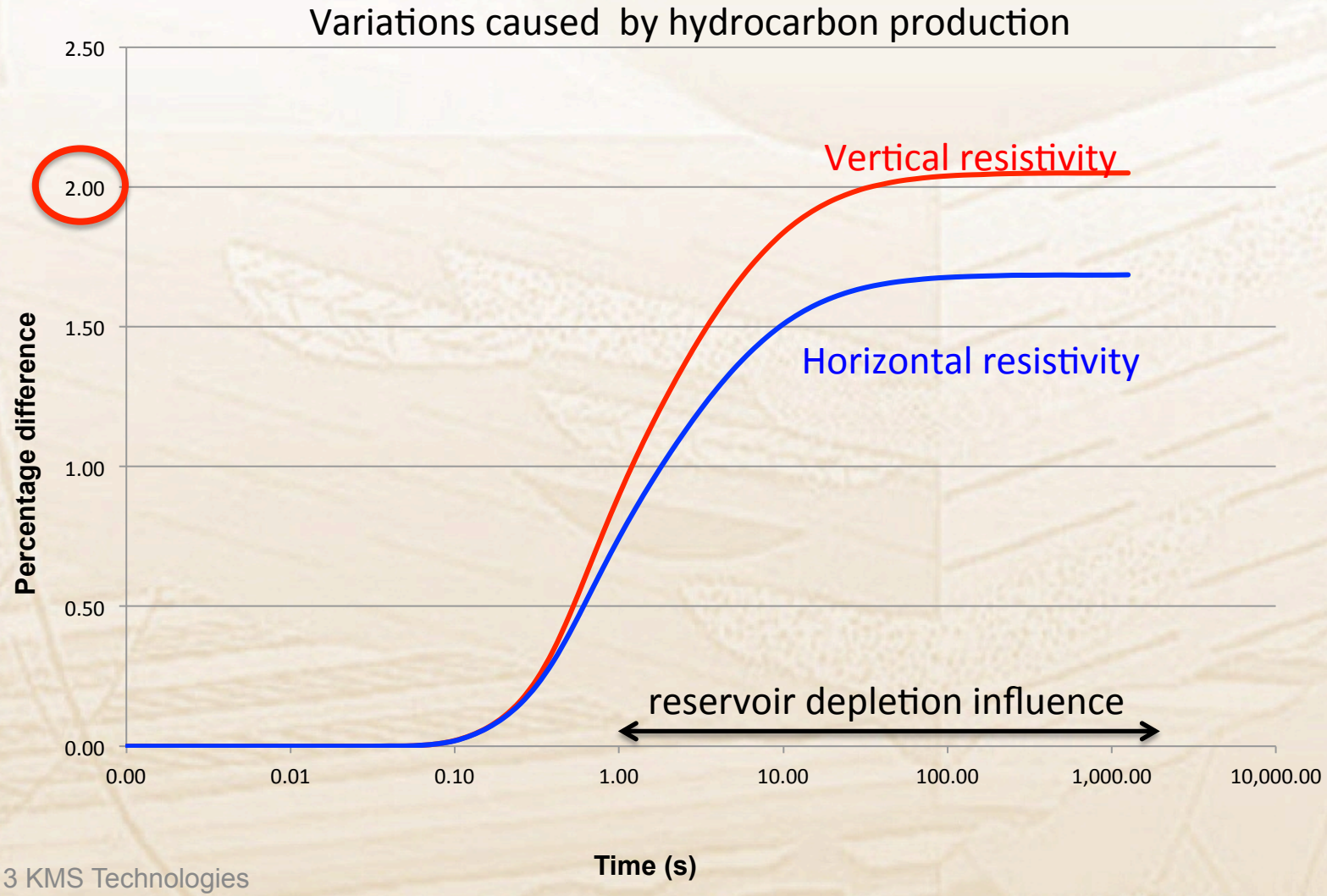




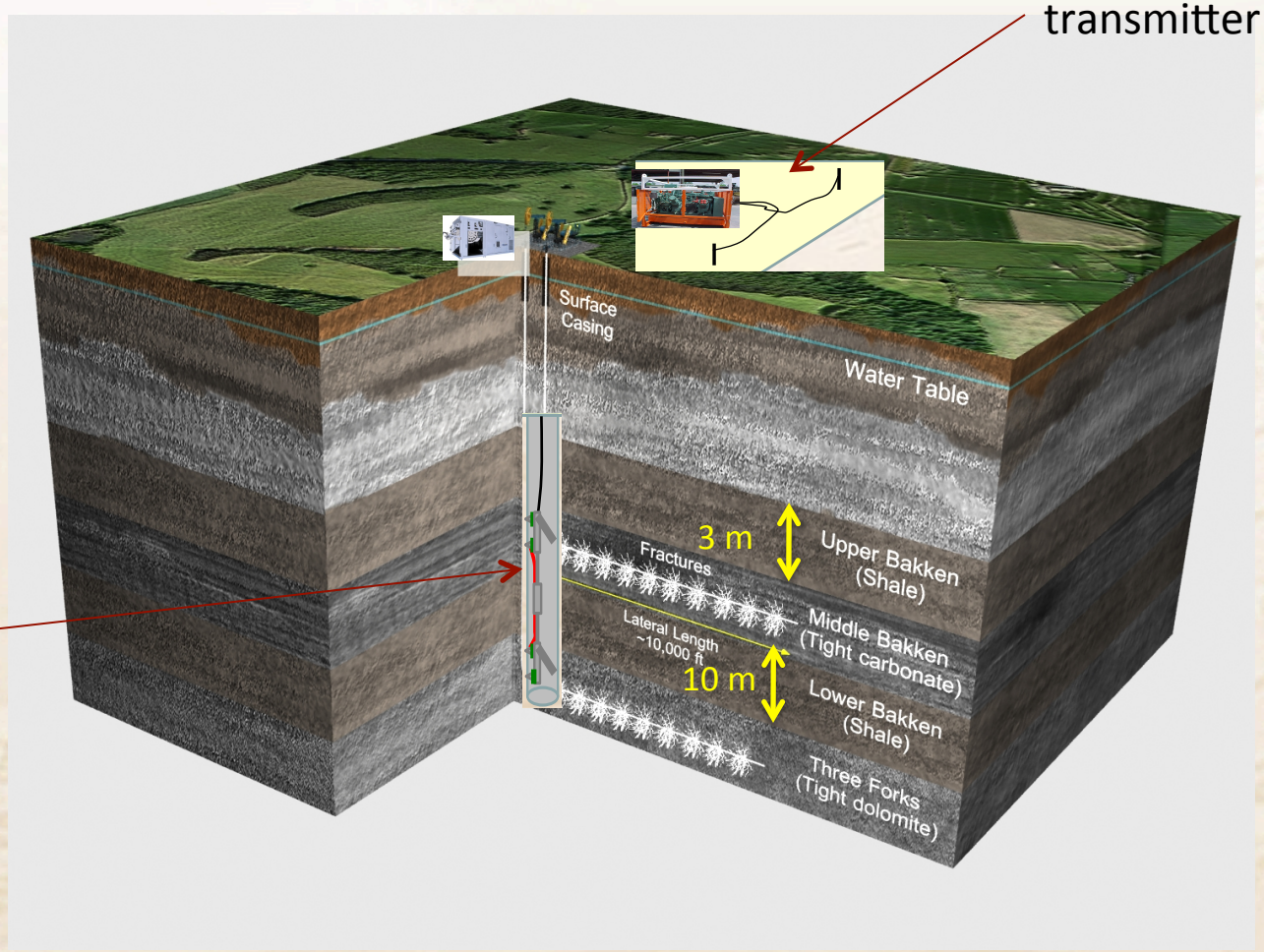
Period of 5 years

After Colombo et al. 2010

CSEM time lapse: before & after… LOWER BAKKEN

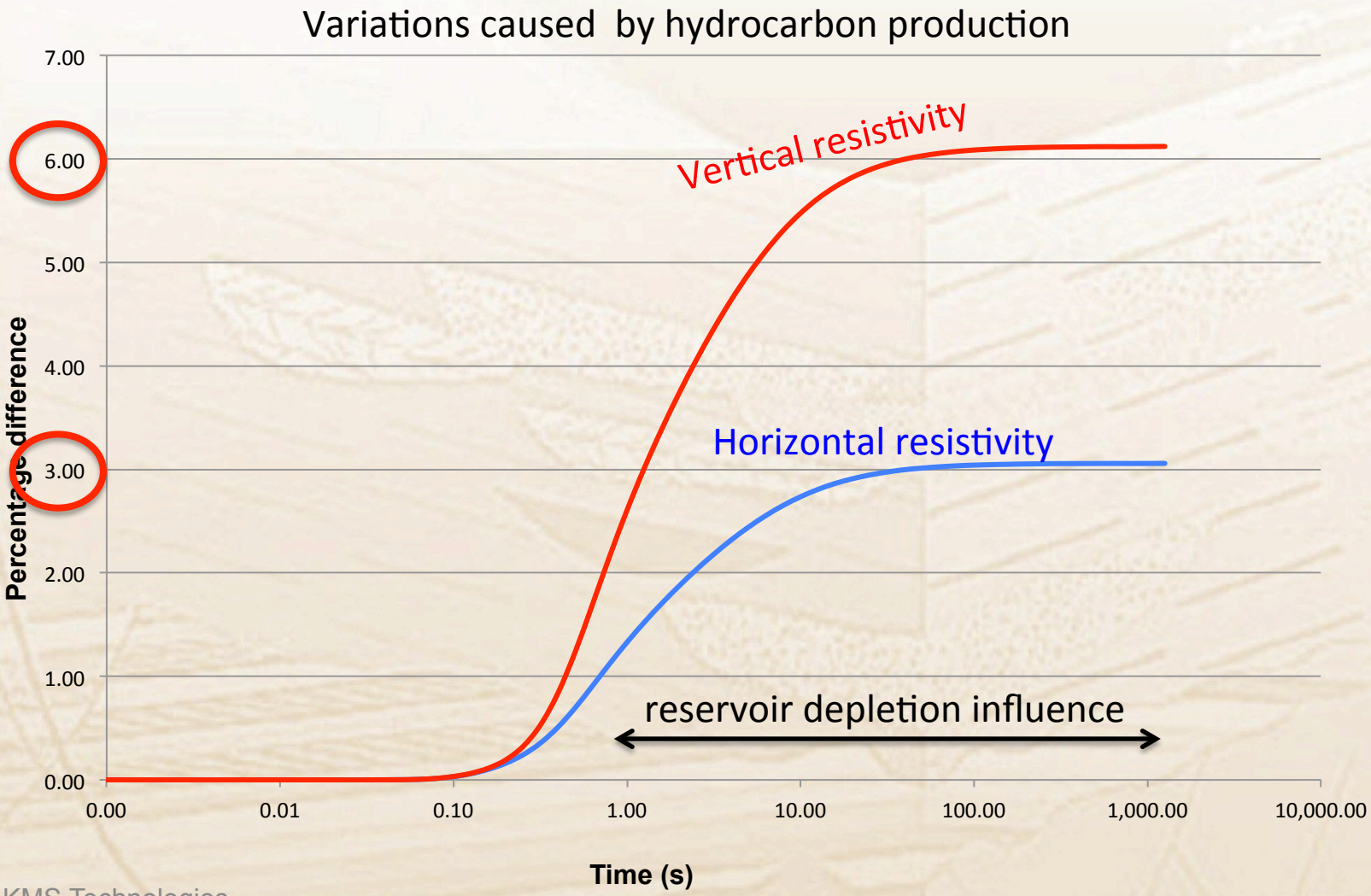


Future: Shale resources: Bakken simulating FRACTURE monitoring

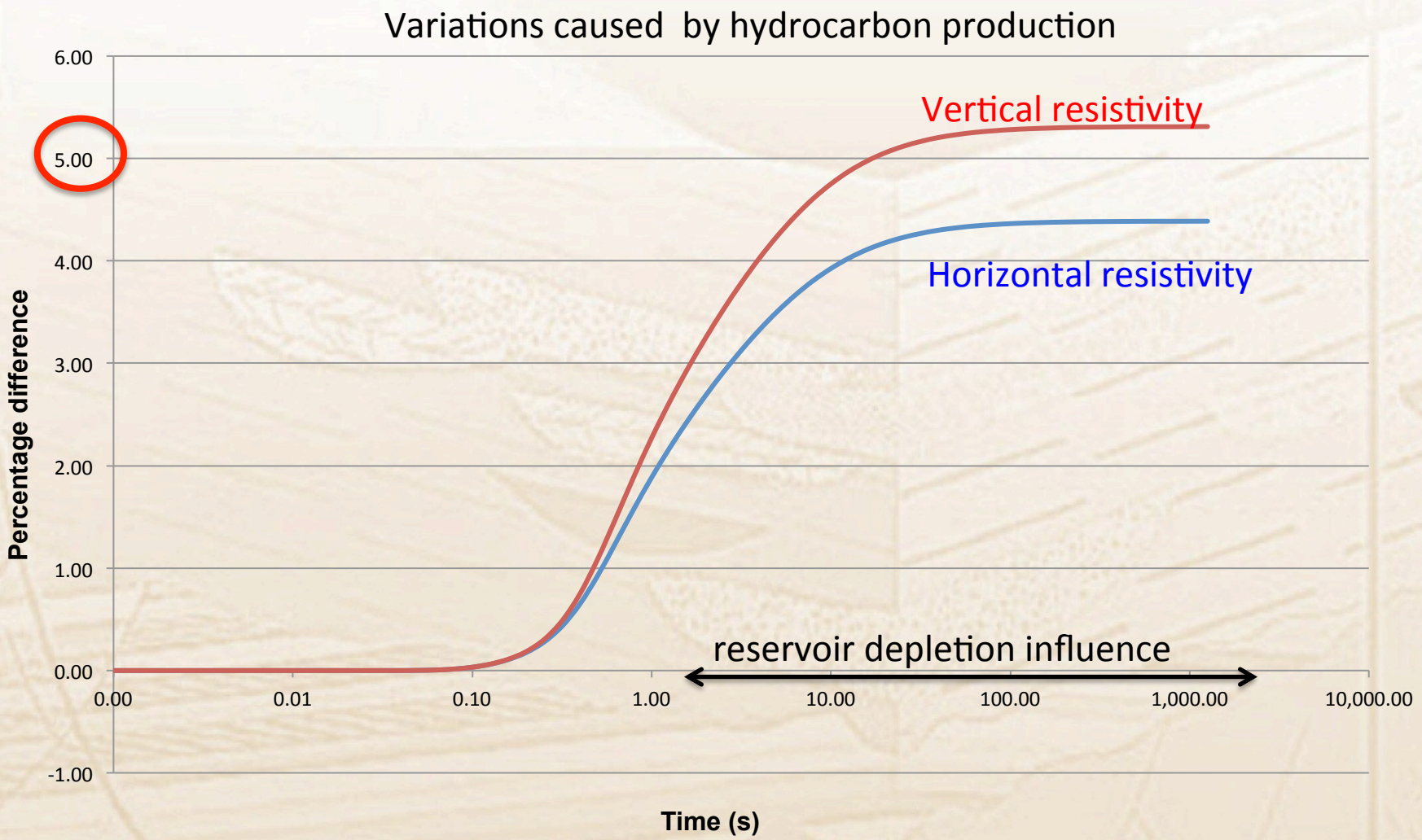


http://www.statoil.com/en/NewsAndMedia/News/2011/Pages/XXX16Oct2011.aspx

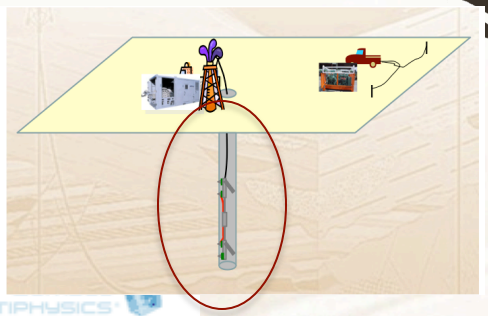
Shale resources: CSEM time lapse: before & after production

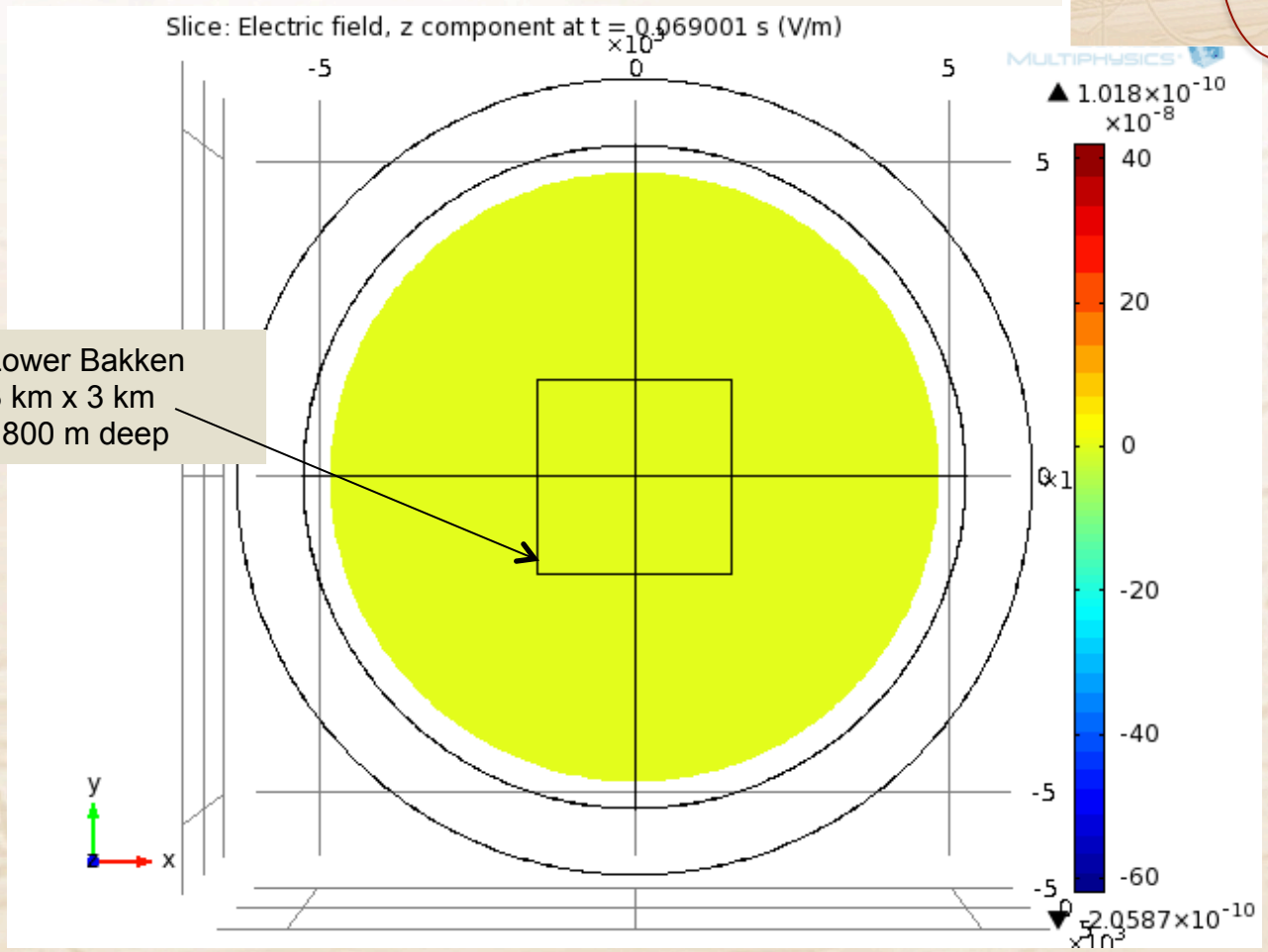


Shale plays: CSEM time lapse: ALL 3 reservoirs, 10% depleted, horiz. well

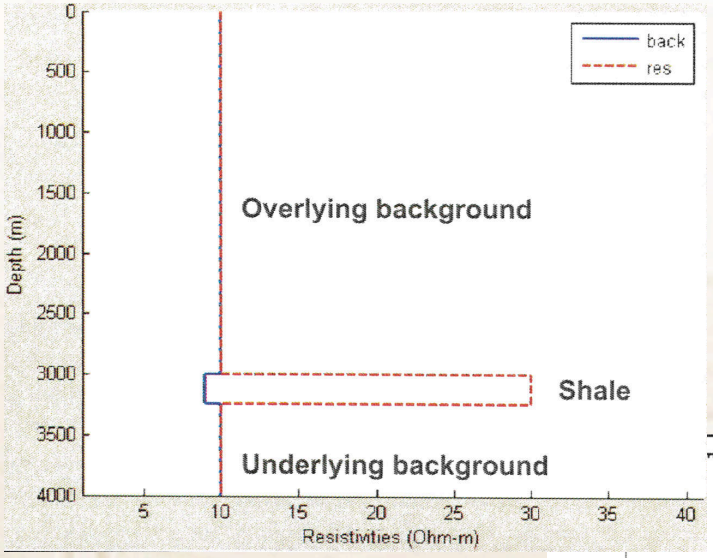


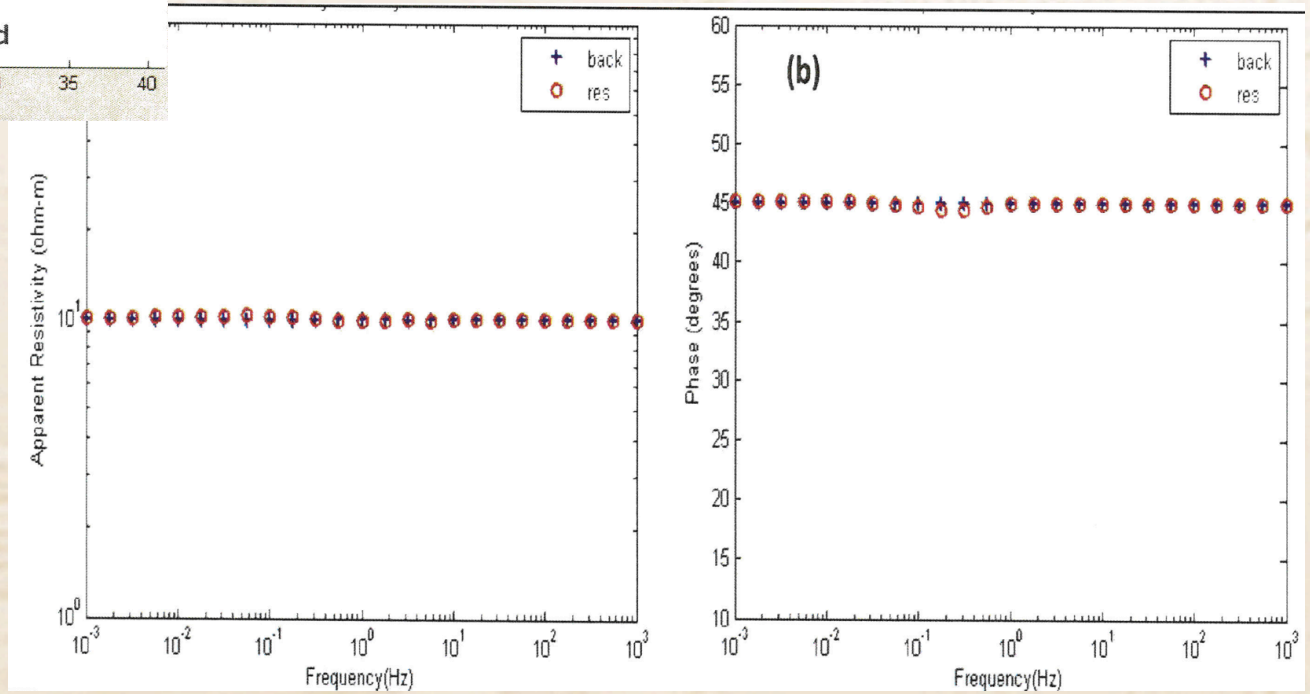
Bakken simulating PRODUCTION monitoring
Borehole-to-surface, Rx at reservoir level





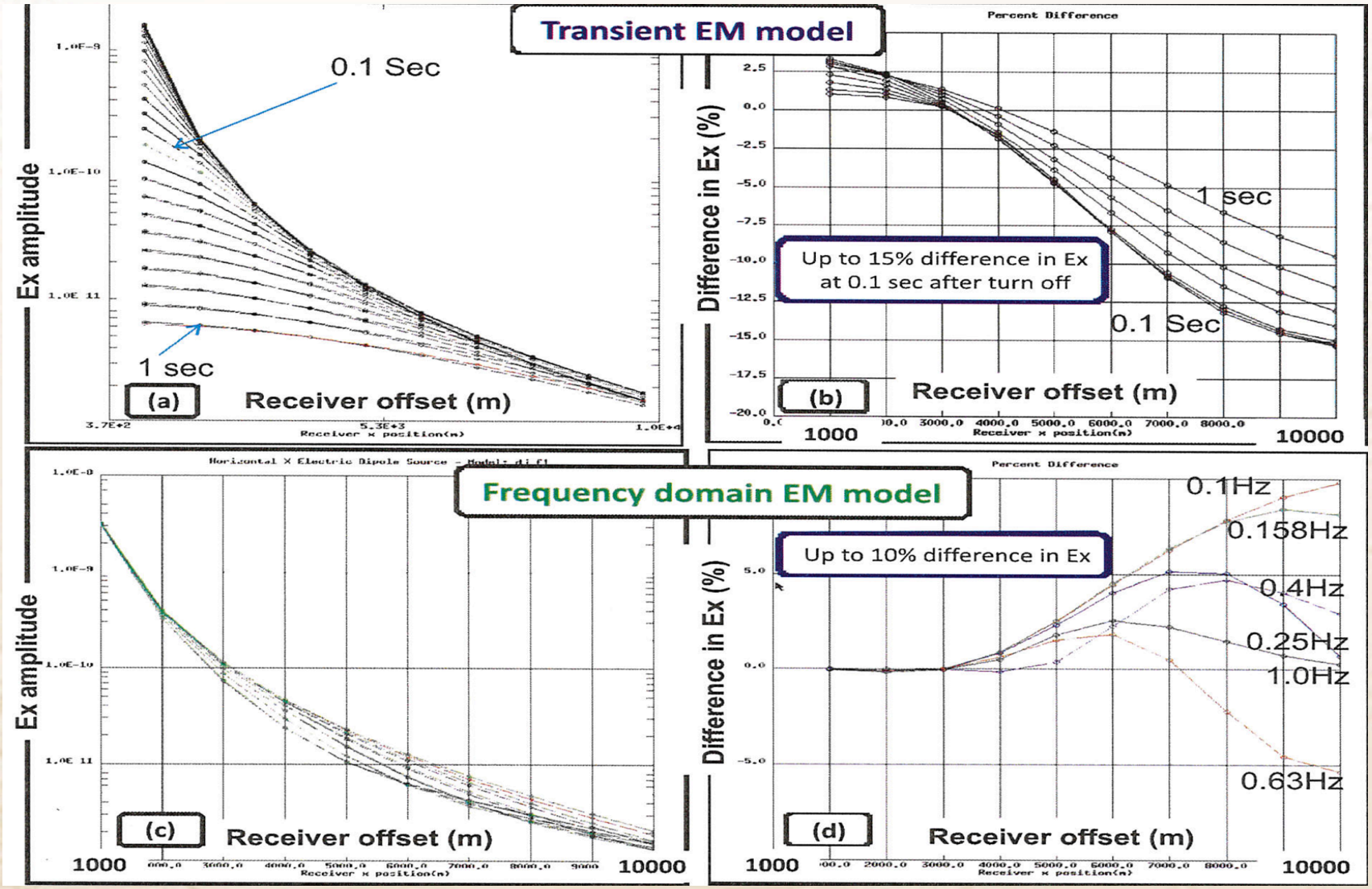
Chevron Haynesville study: EM model & MT response





(after Kumar & Hovesten, 2012)

Shale resources: Chevron Haynesville study



(after Kumar & Hovesten, 2012)

Summary I

- Electromagnetics has potential in shale gas/oil development
- We need NEWEST methods
  - Land CSEM,
  - E & H measurements,
  - 3D induction logs,
  - Surface-to-borehole integration,

- TODAY: we can measure the data from the surface & borehole
- Calibrate with borehole
- Dense data → get better resolution & compare with seismic
- **→ PILOT study is needed!**

THANK YOU!

Acknowledgements:

Aramco; Baker Hughes; BGP; BP; W. Doerner; LBNL; Mannvit; Microseismics Inc.; Northern Hill University, India; ONGC; RWE-Dea; RXT; SSB, China; University of Hawaii; A. Zerilli.

KMS Technologies

Innovating Solutions

KMS Technologies – KJT Enterprises Inc.
6420 Richmond Ave, #610
Houston, TX 77057, USA
Tel: +1.713.532.8144
Fax: +1.832.204.8418
info@kmstechnologies.com

www.kmstechnologies.com