



# **Electromagnetics**

## **A ideal tool for shale reserves**

K.M. Strack, 2013, Muenster, Germany Kolloqium

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# Electromagnetics

## A ideal tool for shale reserves

**K. Strack<sup>1-3</sup>**

Muenster Kolloqium 27. May 2013

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





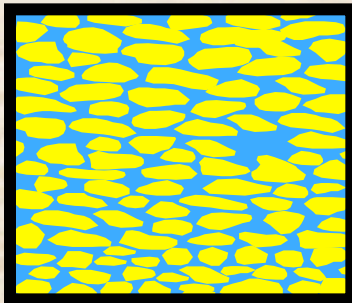
To show how NEW array electromagnetics  
can address some issues for  
shale resources



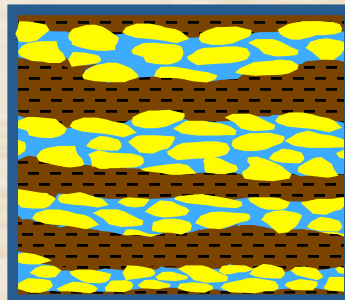
## ➤ Shale gas/oil

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

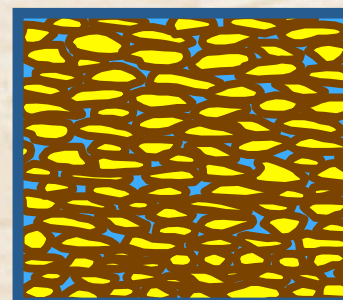
*Clean Sand  
Porosity*



*Laminar Shale*



*Dispersed Shale*







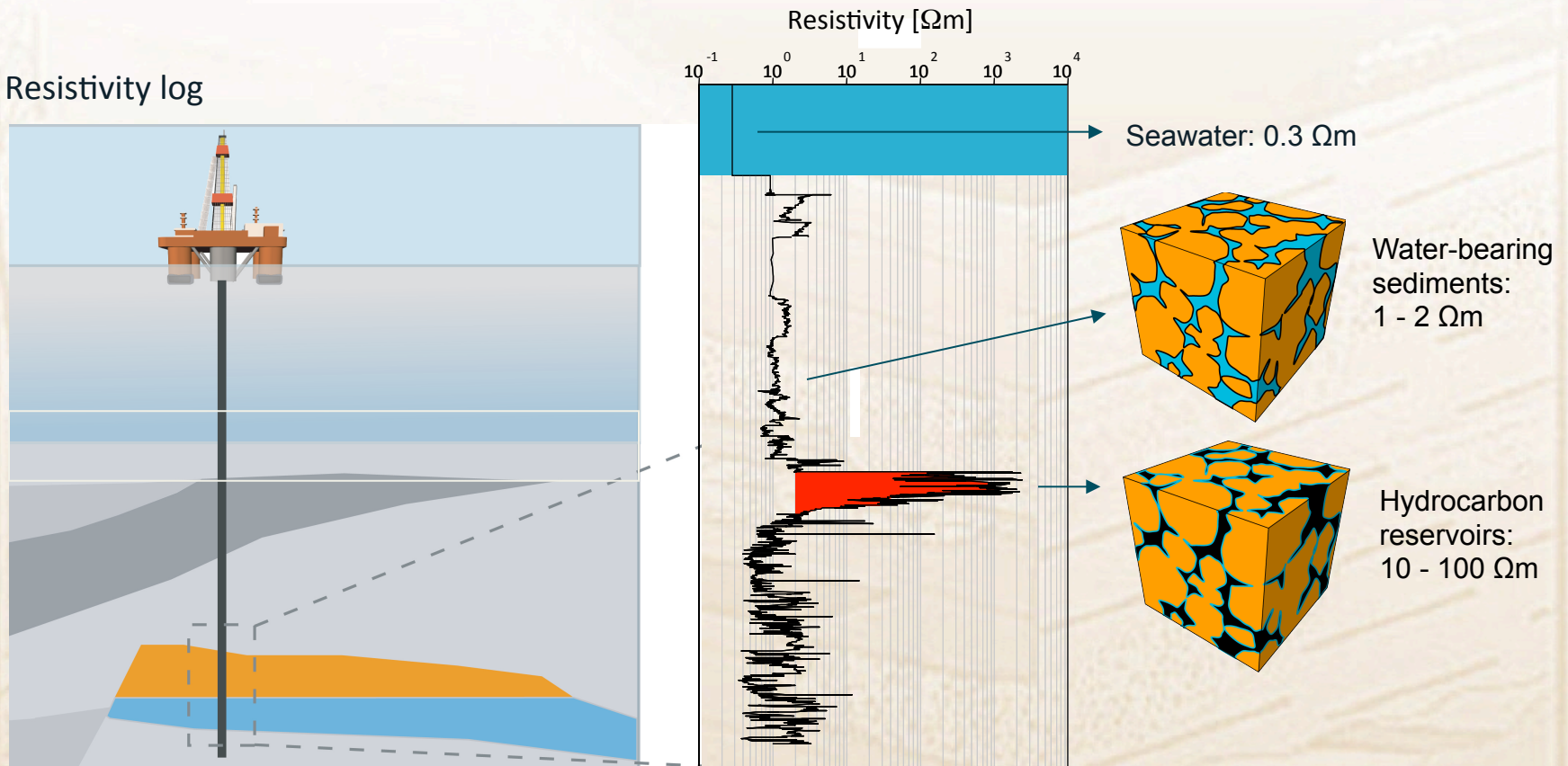
## ➤ Shale gas/oil

- 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**
- Fractures → anisotropy – **3D EM anisotropy**

# Objective >>> Issues & need for EM >>> NEW tools >> Future Hydrocarbons are resistive!



Resistivity log



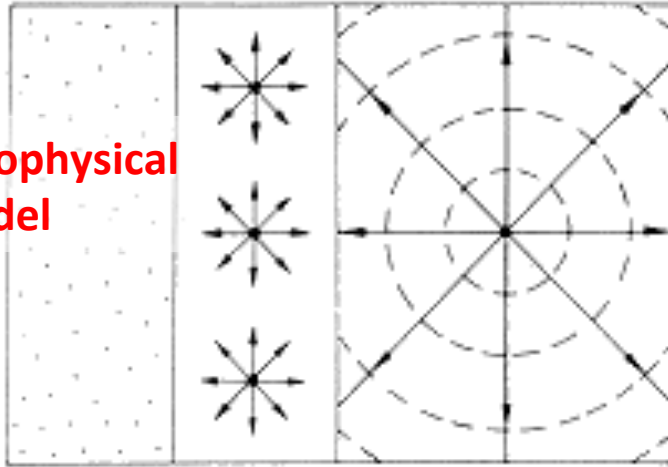
Courtesy EMGS



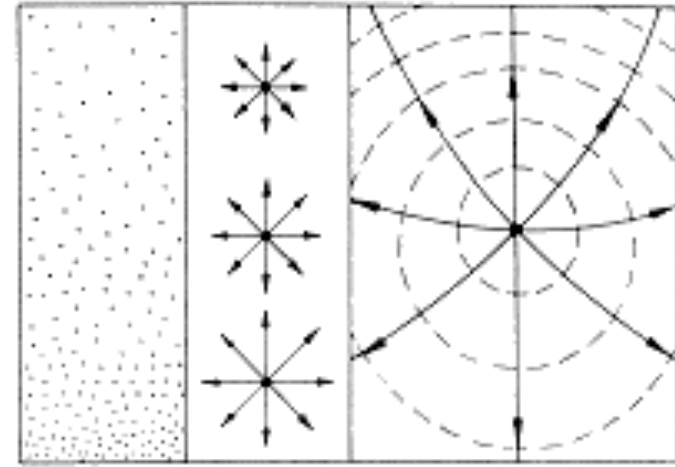
Objective >>> Issues & need for EM >>> NEW tools >> Future  
Isotropy - Anisotropy Homogeneity - Inhomogeneity



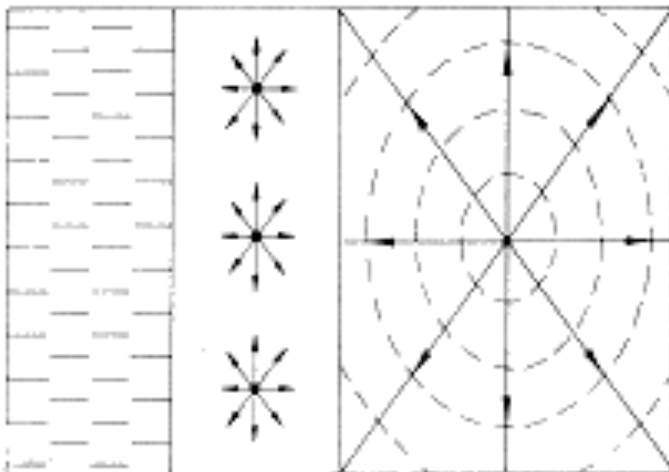
Simple geophysical model



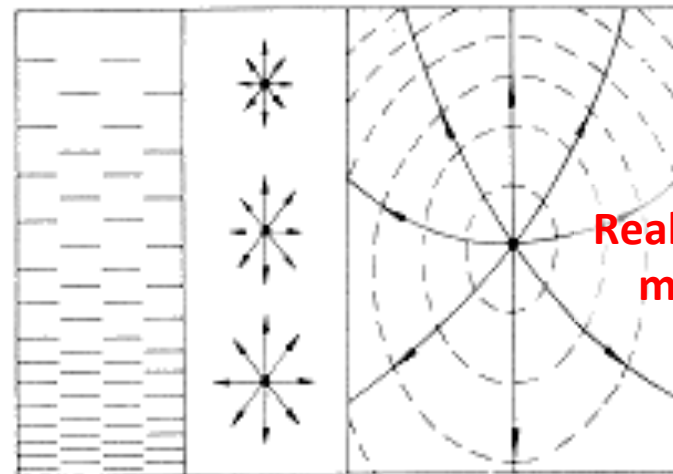
isotropic-homogeneous



isotropic-inhomogeneous



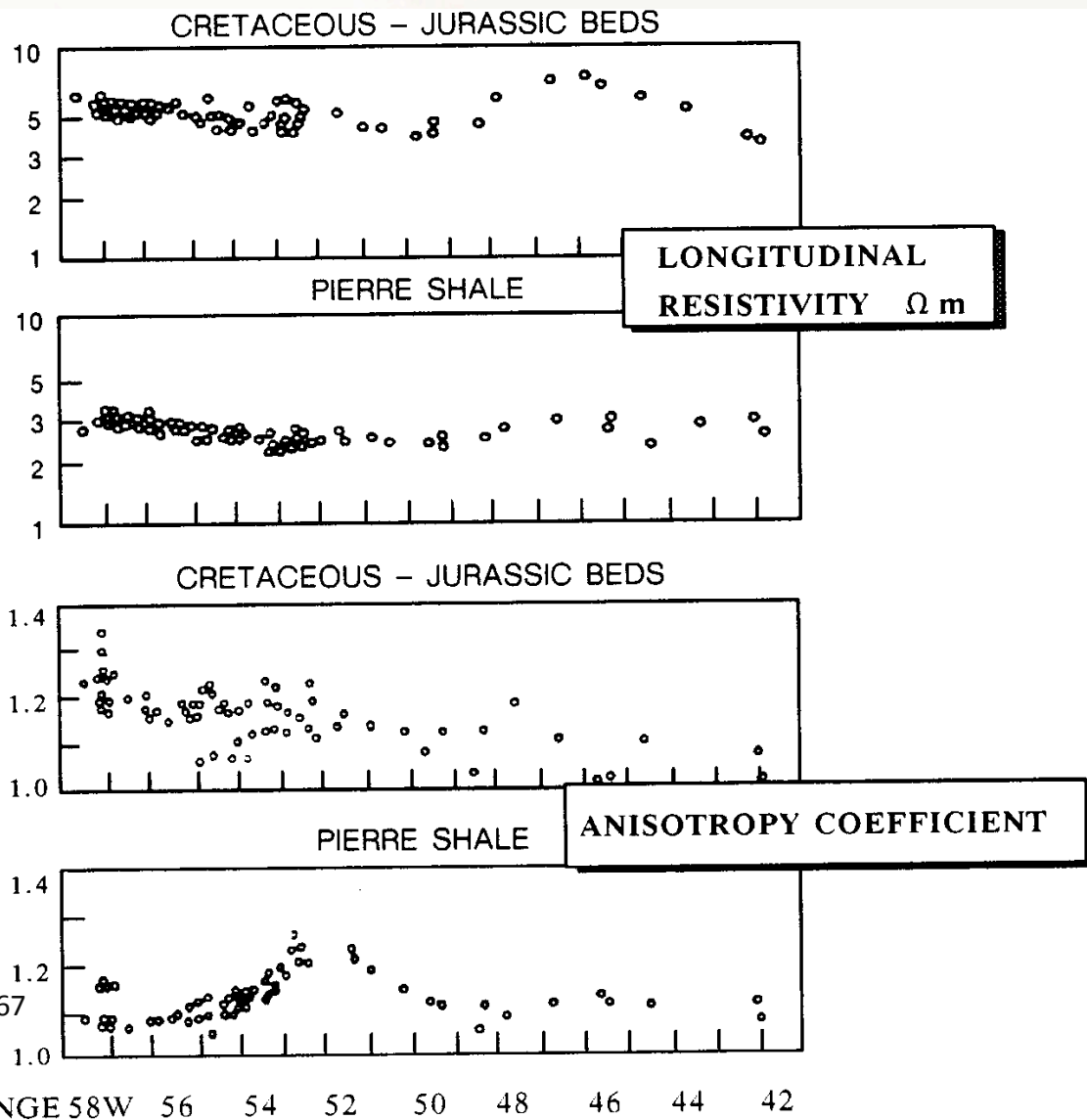
anisotropic-homogeneous



anisotropic-inhomogeneous

Real world model

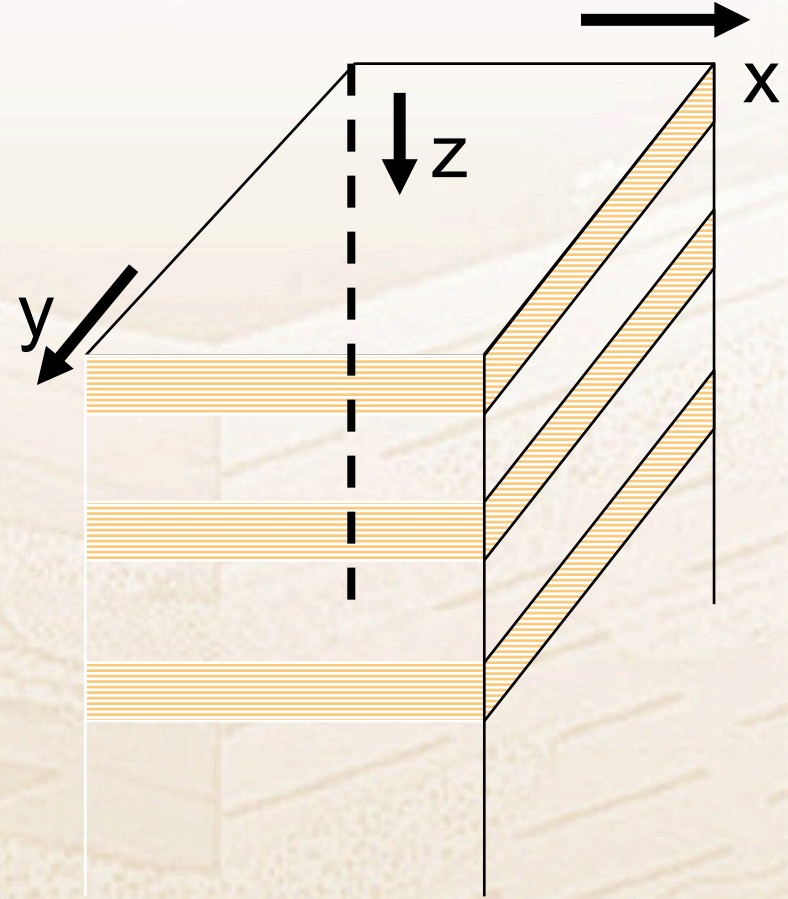
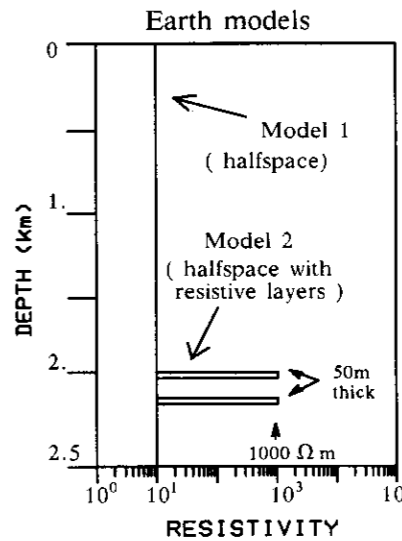
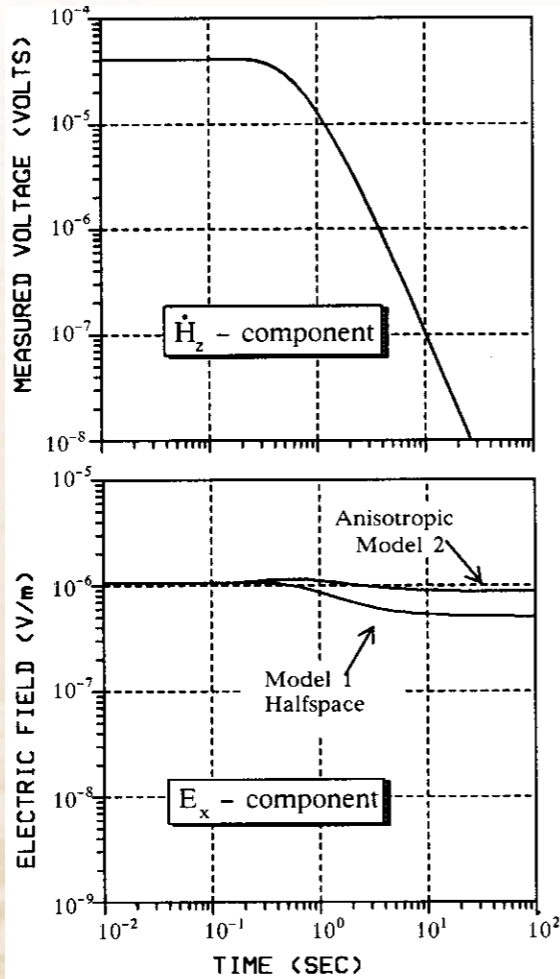
# Objective >>> Issues & need for EM >>> New tools >>> Future DJ Basin: Resistivity distribution from logs



After Harthill 1967



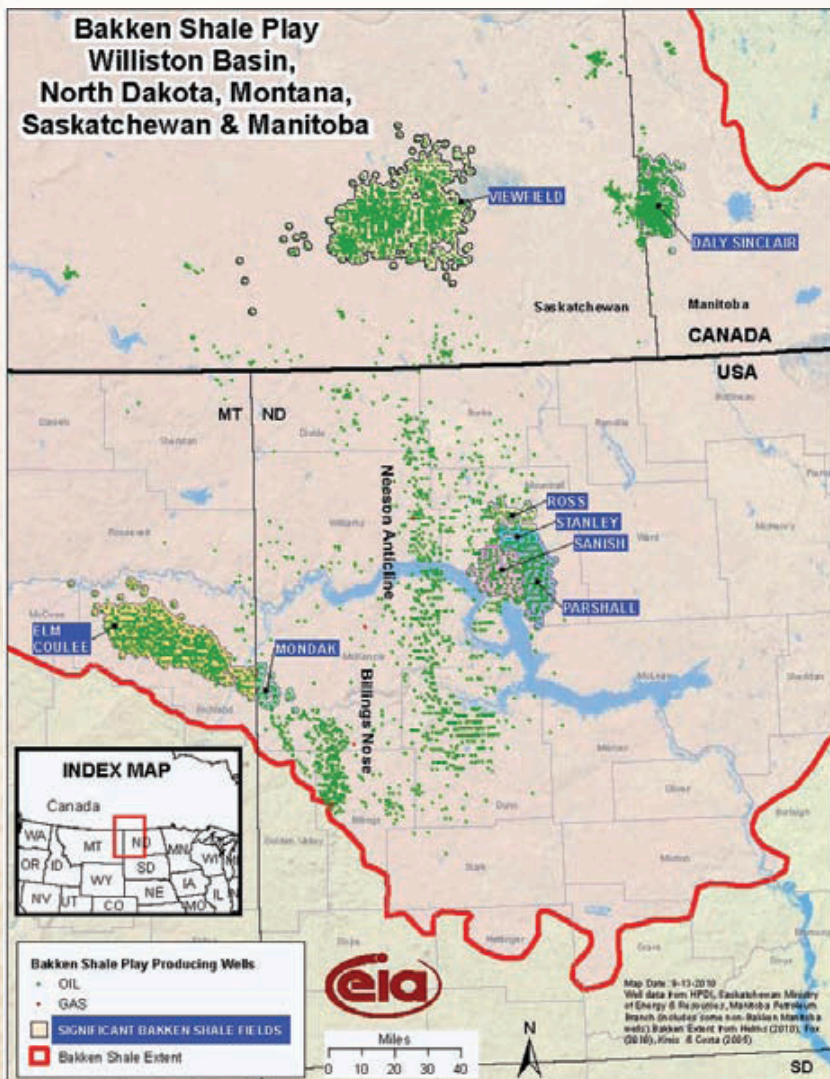
Objective >>> **Issues & need for EM** >>> New tools >>> Future  
**Anisotropy: Layer cake geology → anisotropy**



(after Strack 1992)

# Objective >>> Issues & need for EM >>> NEW tools >> Future

## How did we get started?



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

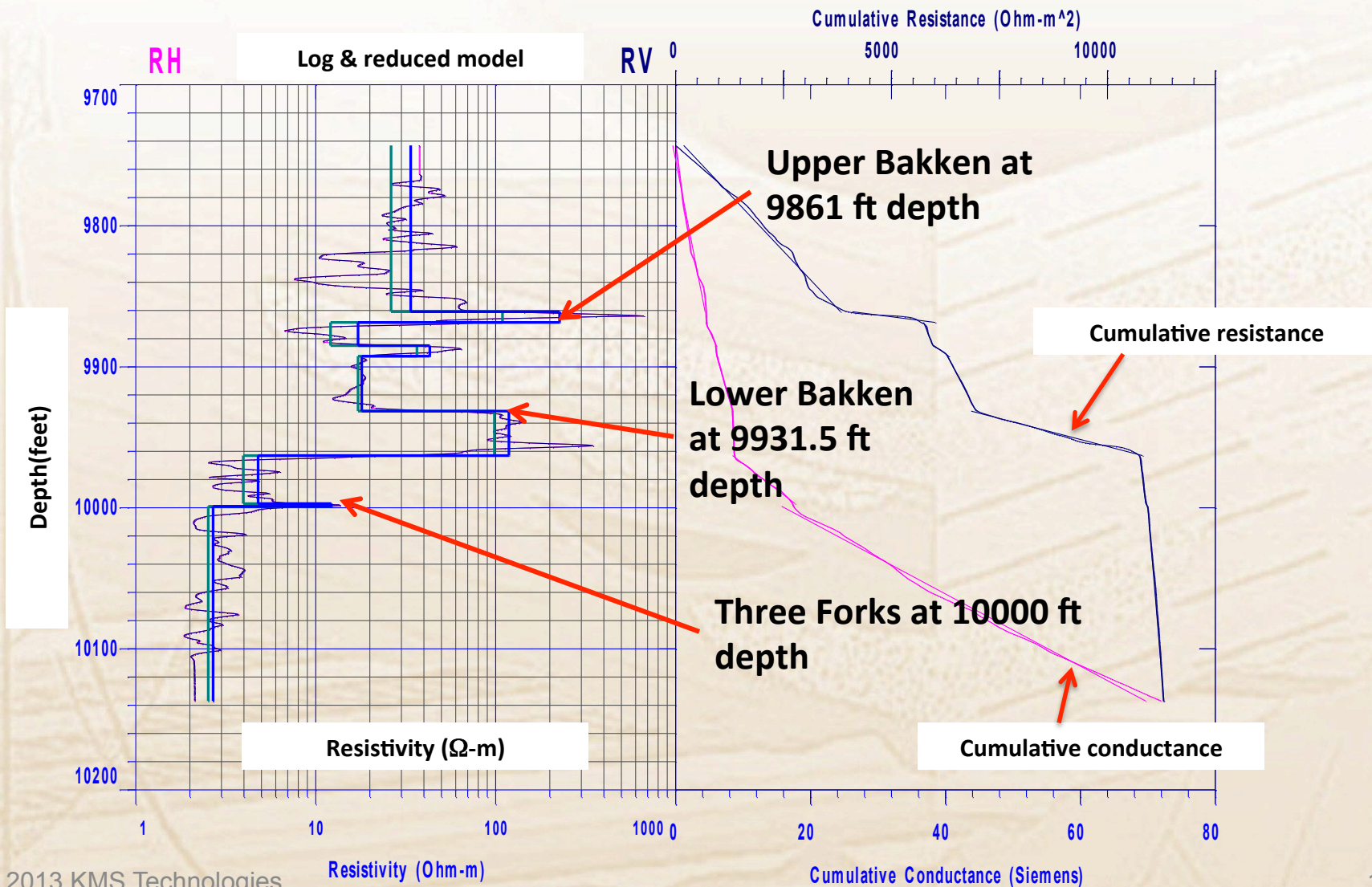
After US Dept. of Energy, & Le Fever, 2005



# Objective >>> Issues & need for EM >>> NEW tools >> Future From a log to an anisotropic model



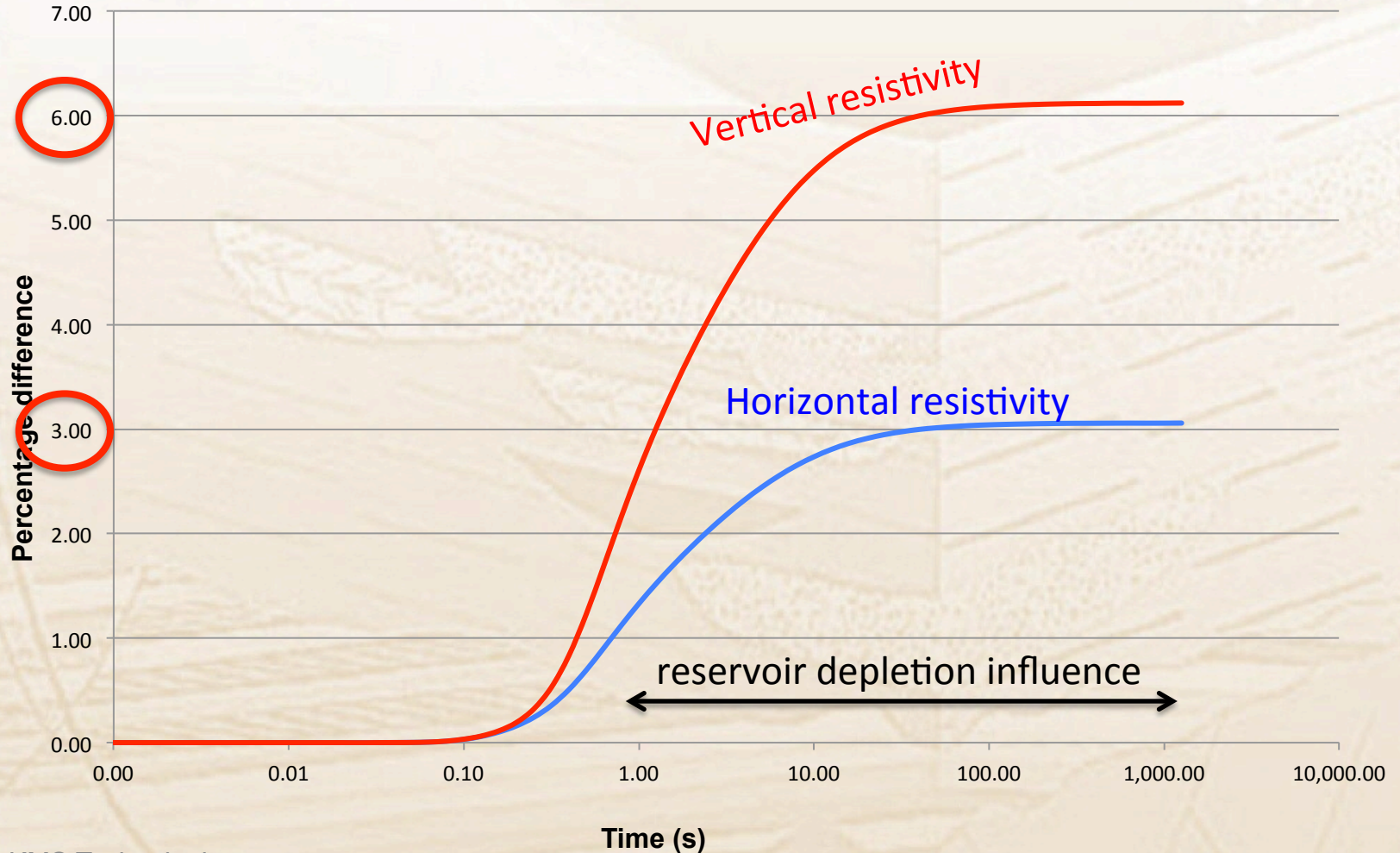
Log data courtesy of Microseismics Inc.



Objective >>> **Issues & need for EM** >>> NEW tools >> Future  
**CSEM time lapse: before & after production**



Variations caused by hydrocarbon production







- 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





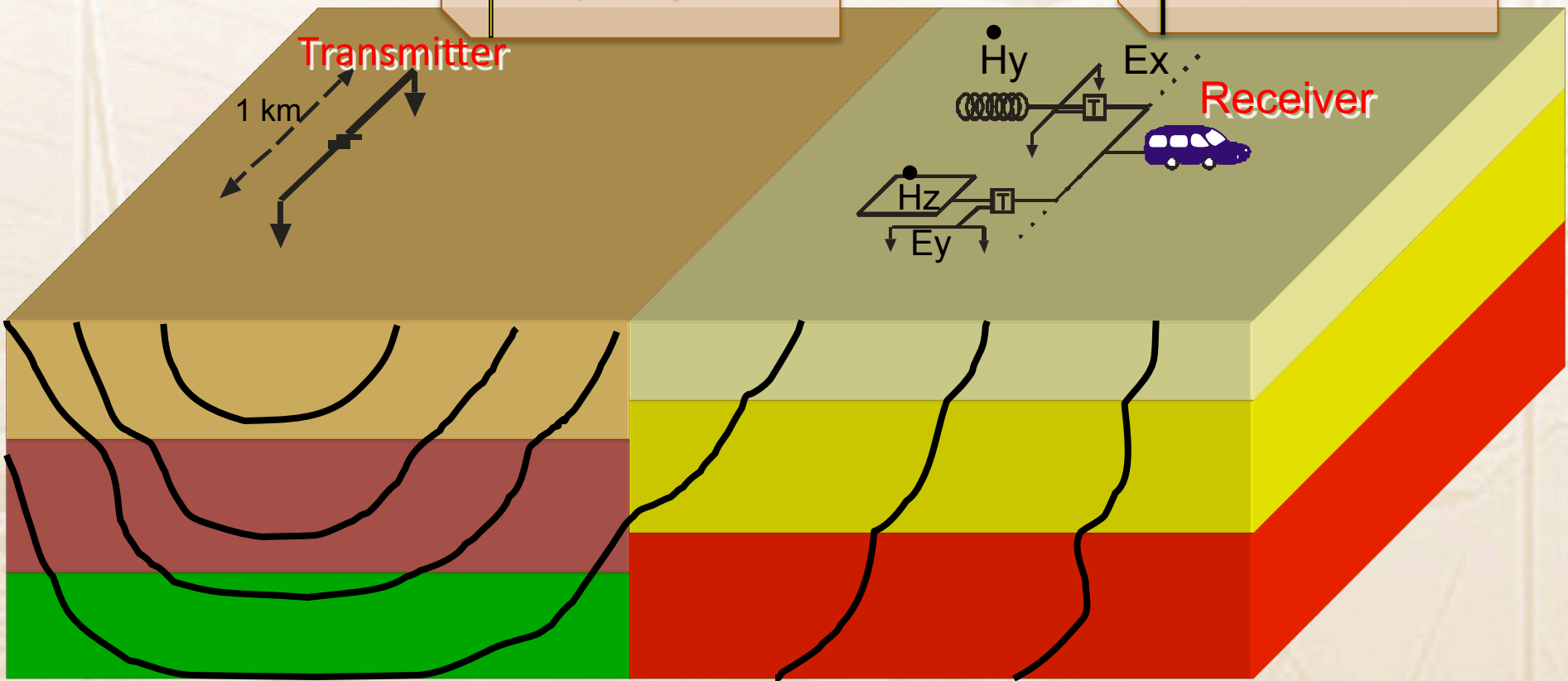
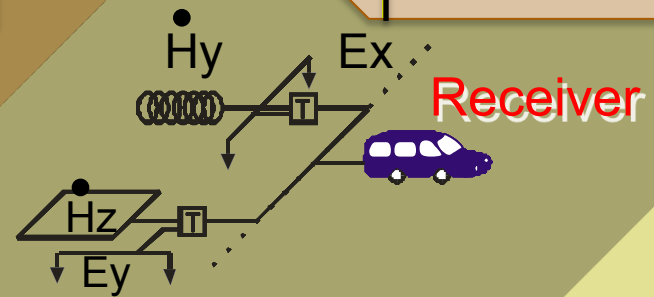
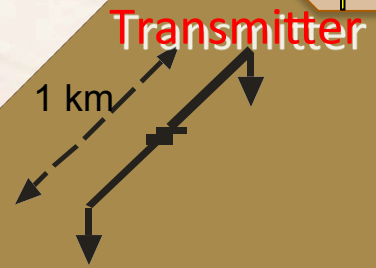
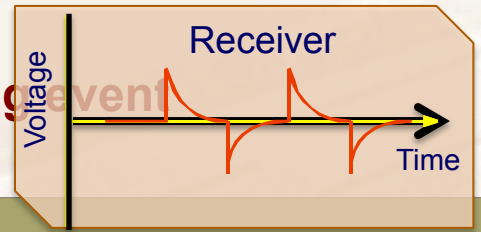
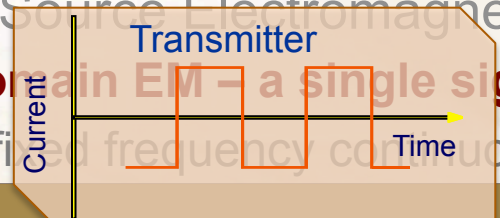
- Magnetotellurics – **passive not detailed enough**
- Controlled Source Electromagnetics (CSEM)  
(the **ONLY** way to get vertical current flow)
  - Time domain EM – a single signal generating event
  - Frequency domain EM – a fixed frequency continuous event

# Objective >>> Issues & need for EM >>> **NEW tools** >> Future EM Methods



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

- **Time domain EM – a single signal generating event**
- EM – a field frequency continuous event

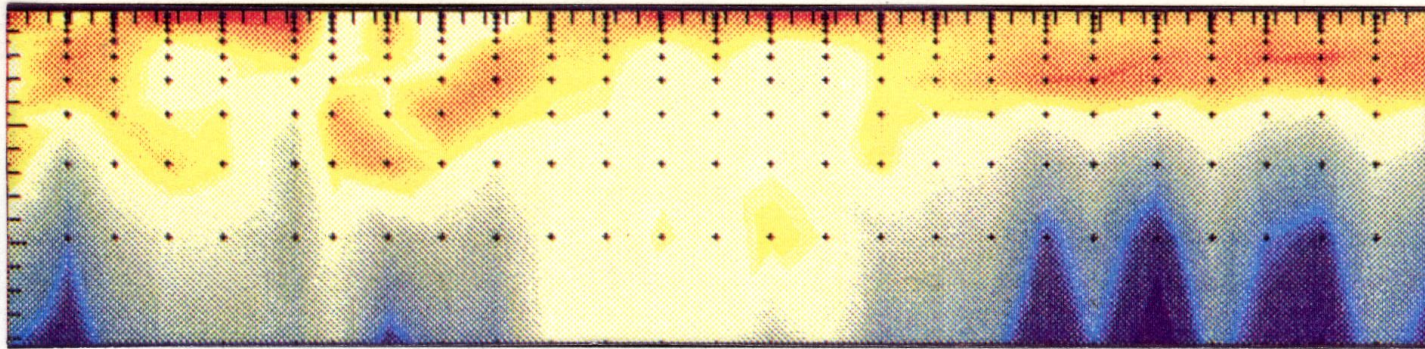




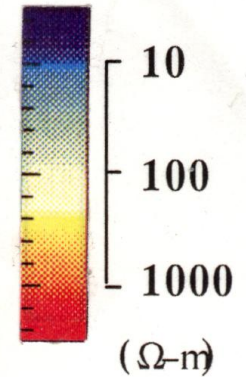
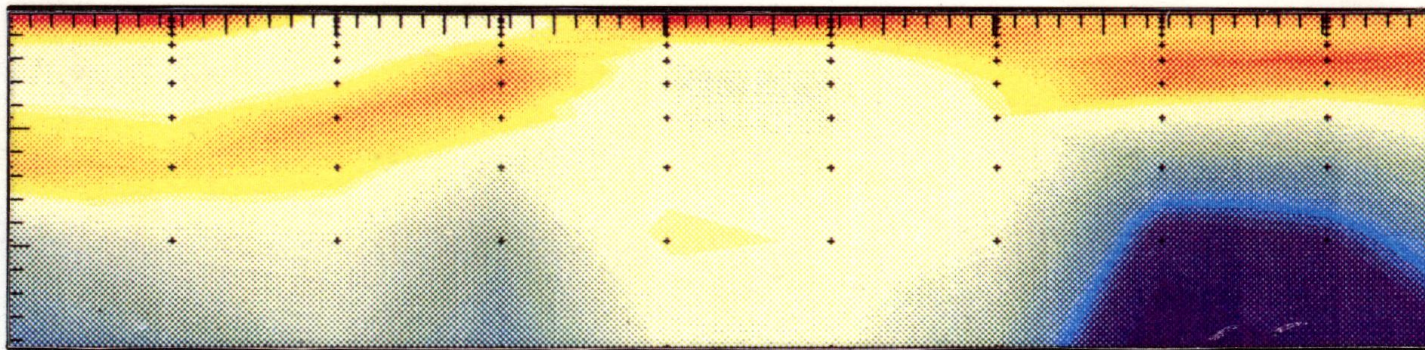
Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**We need dense data!**



raw inversion profile



sparse inversion profile



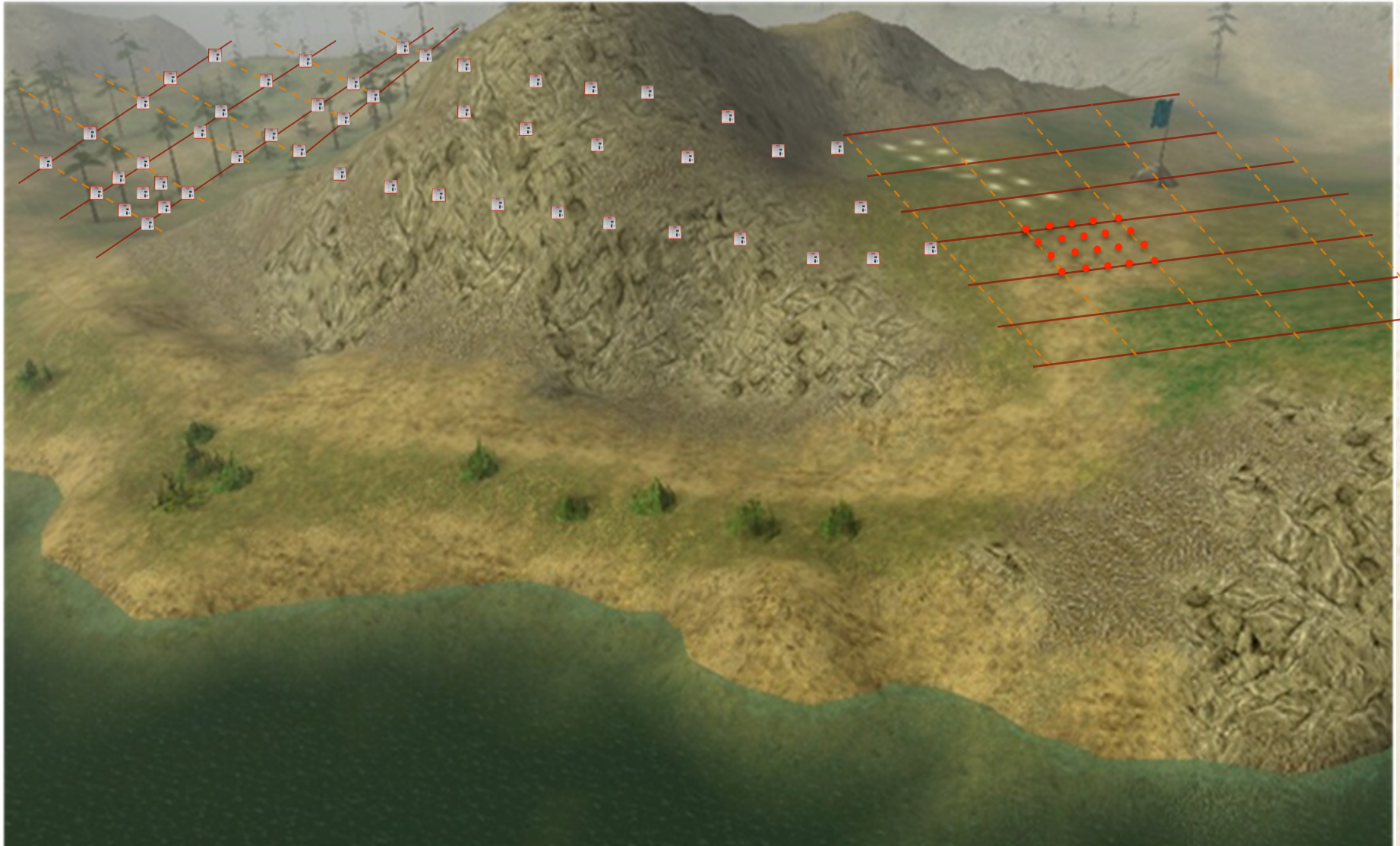
**RESISTIVITY – DEPTH CONTOURS**

IGMK 813b

Data from Saurashtra, India, courtesy ONGC



Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**New ARRAY acquisition** → better images





Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**New ARRAY acquisition** → better images



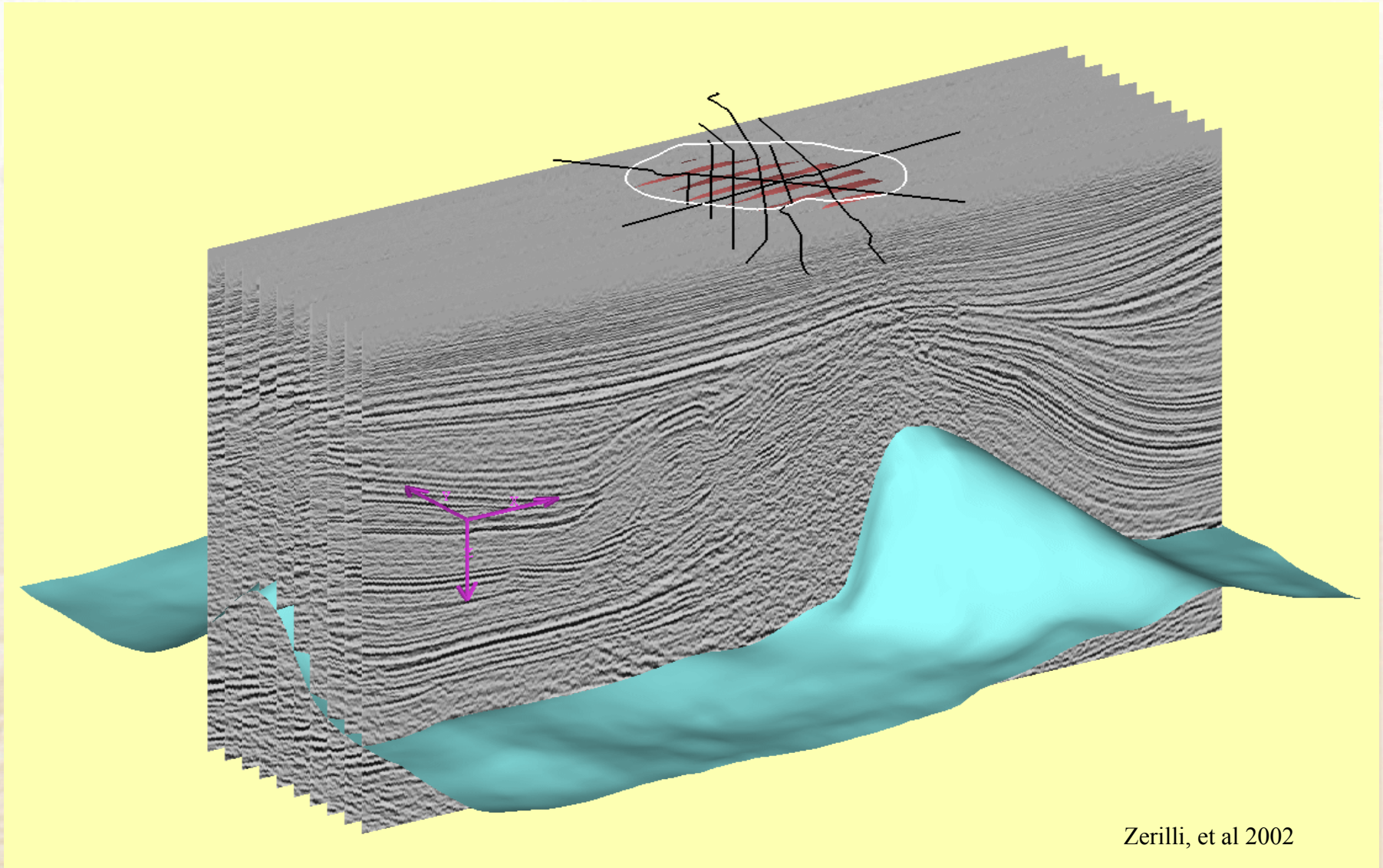
- Wireless
- True array system
- Large dynamic range
- High bandwidth



Wireless controller



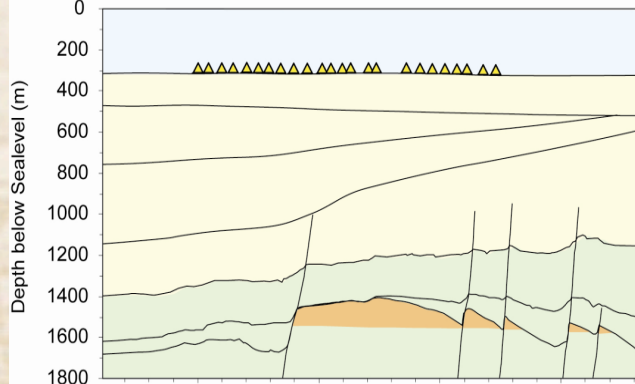
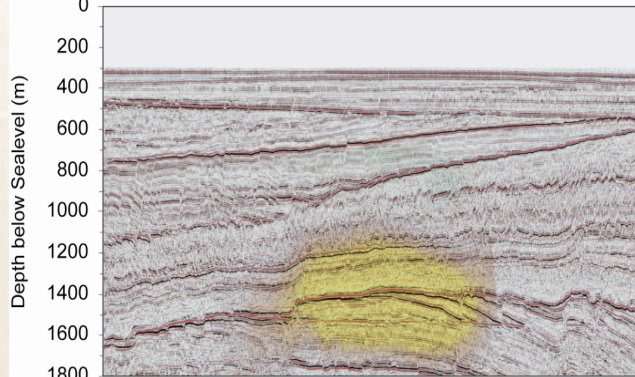
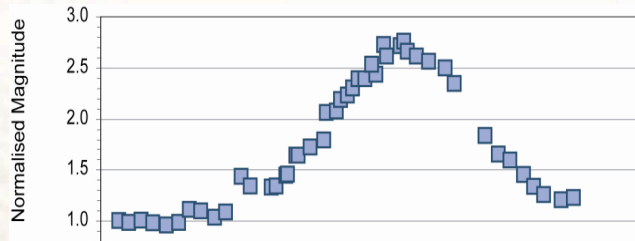
Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**Dense acquisition ( $\Delta x = 50$  m)  $\rightarrow$  better images**



Zerilli, et al 2002

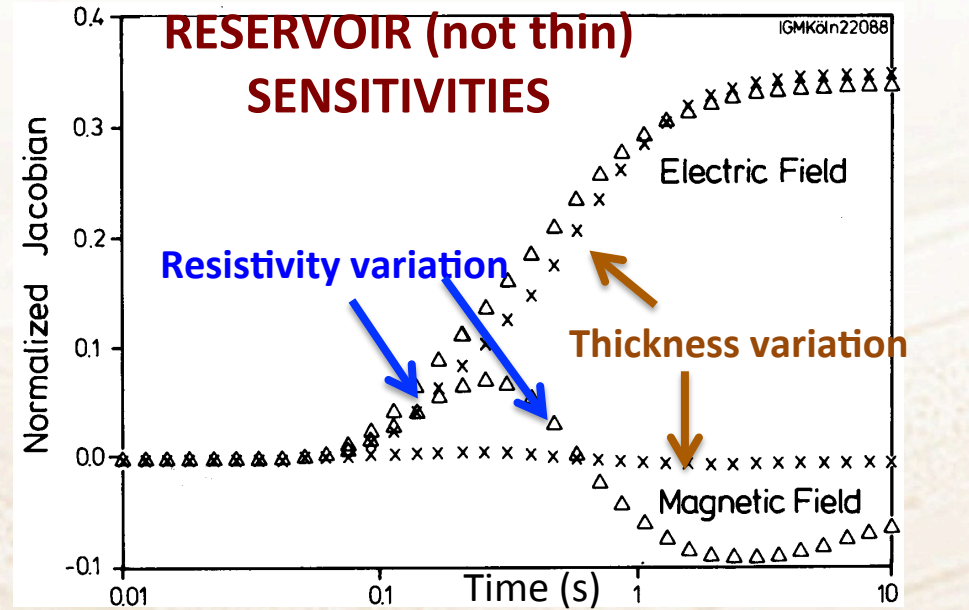


# Objective >>> Issues & need for EM >>> **NEW tools** >> Future DHI & Resistors in conductors

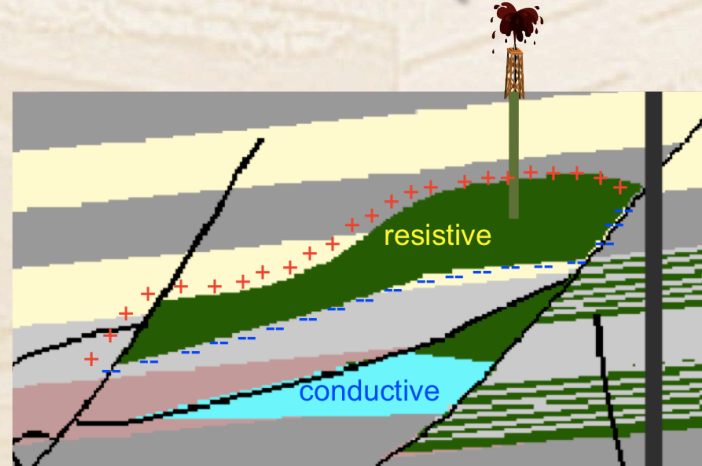


After Johnstad et al., 2005

Horizontal Distance (m)

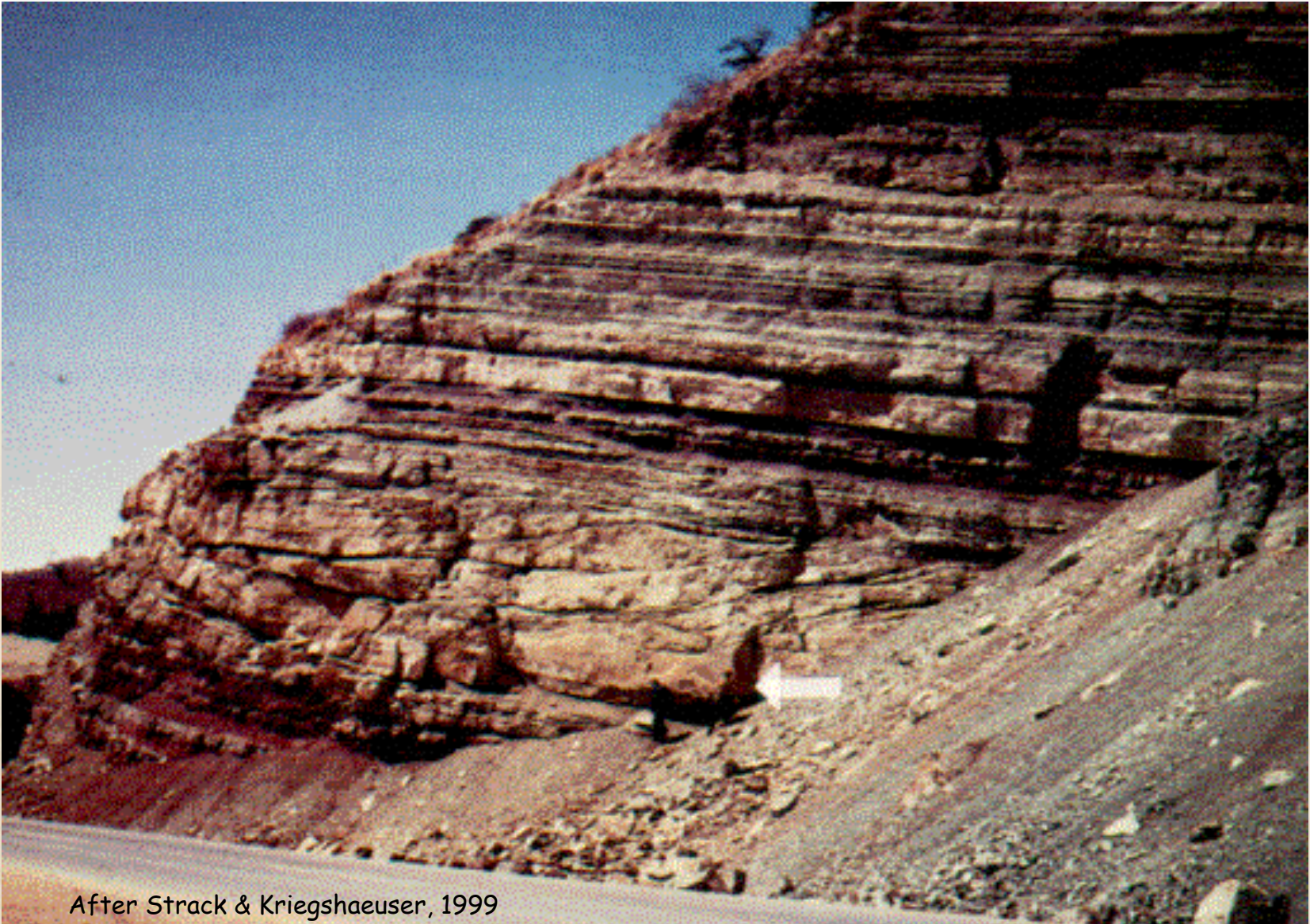


Reservoir fluid influence





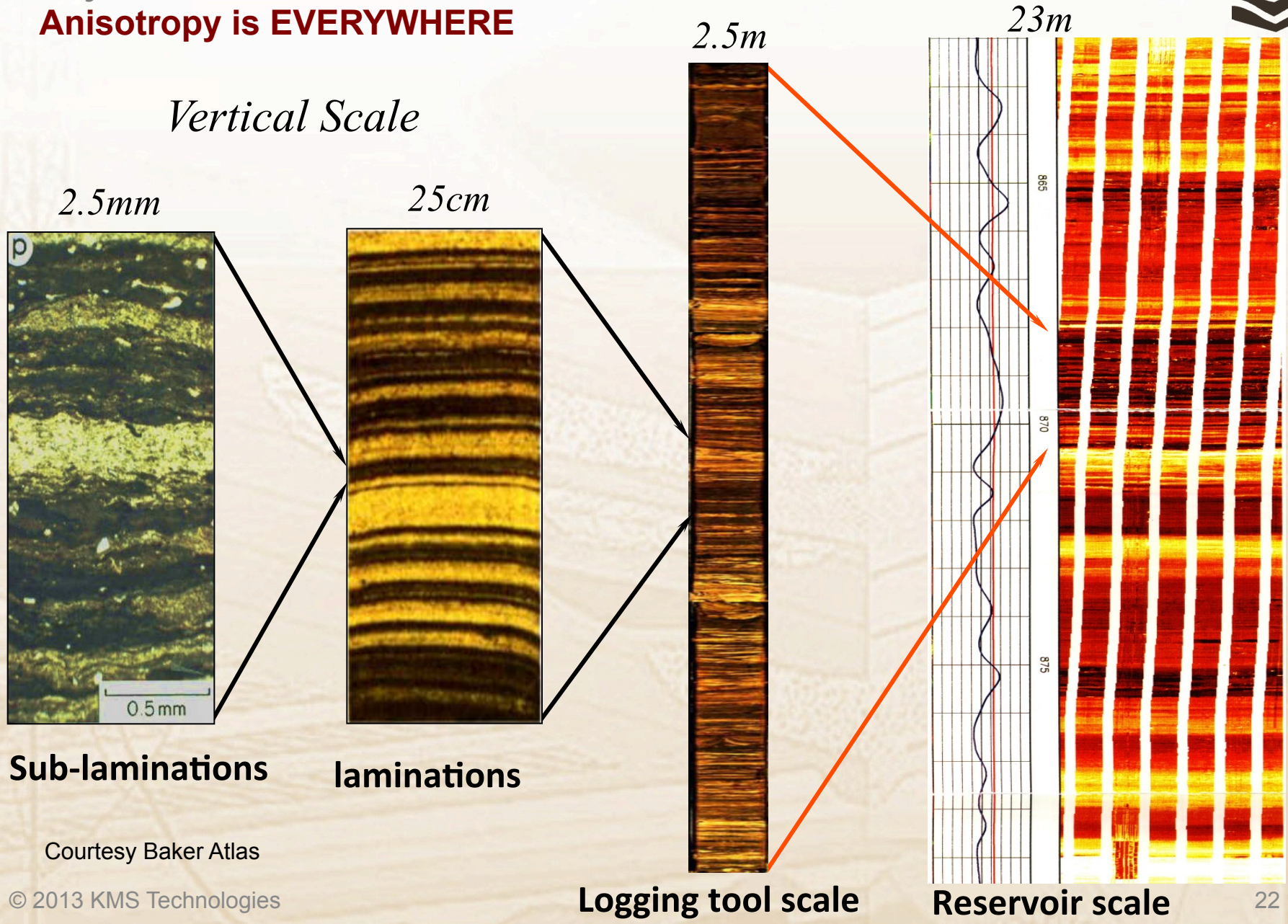
Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**Anisotropy is EVERYWHERE**



After Strack & Kriegshaeuser, 1999



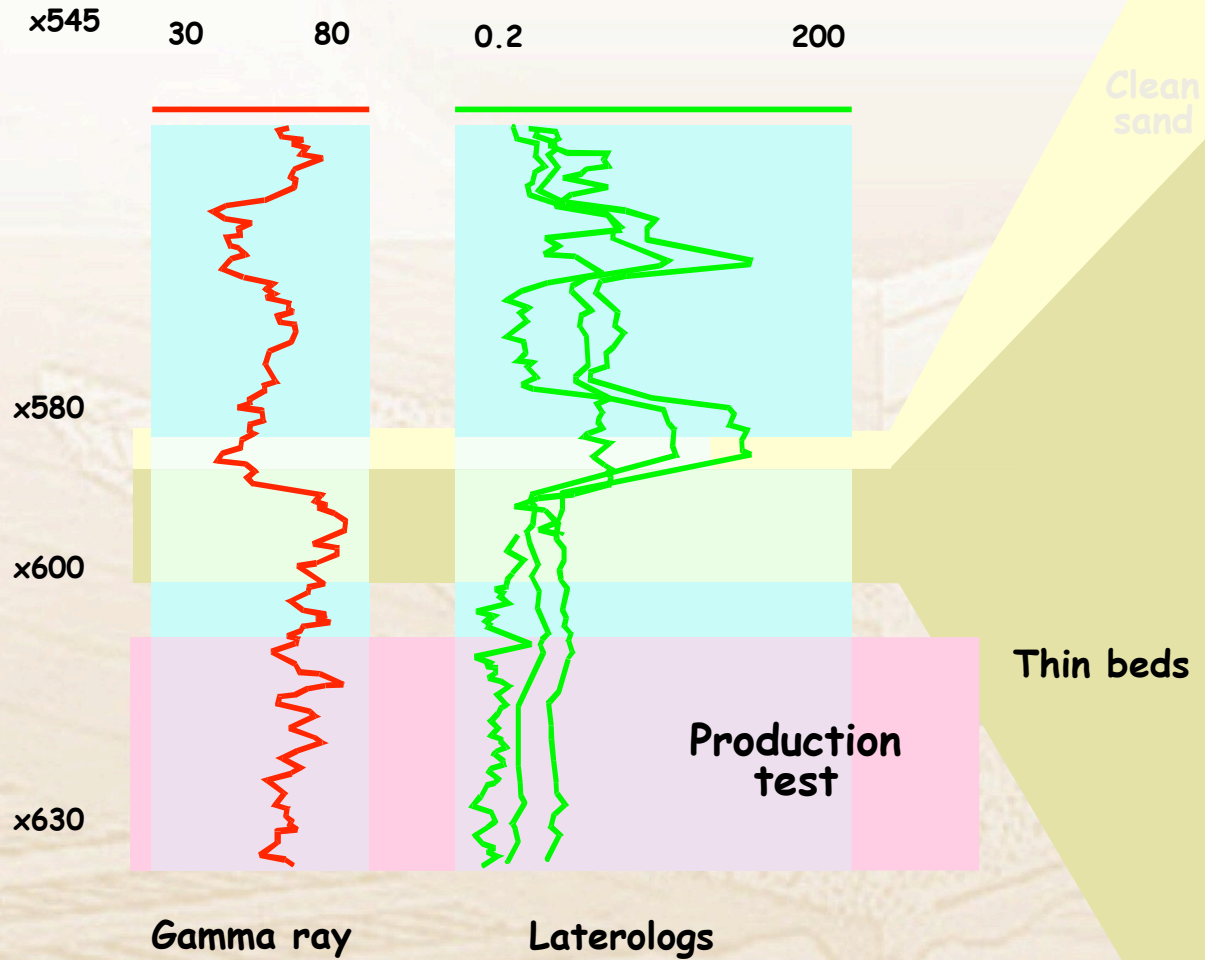
Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**Anisotropy is EVERYWHERE**



Courtesy Baker Atlas



Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**Anisotropy: Original motivating log (Shell 1990)**



Core

1750 BOPD  
 GOR 3250

After Strack & Kriegshaeuser, 1999



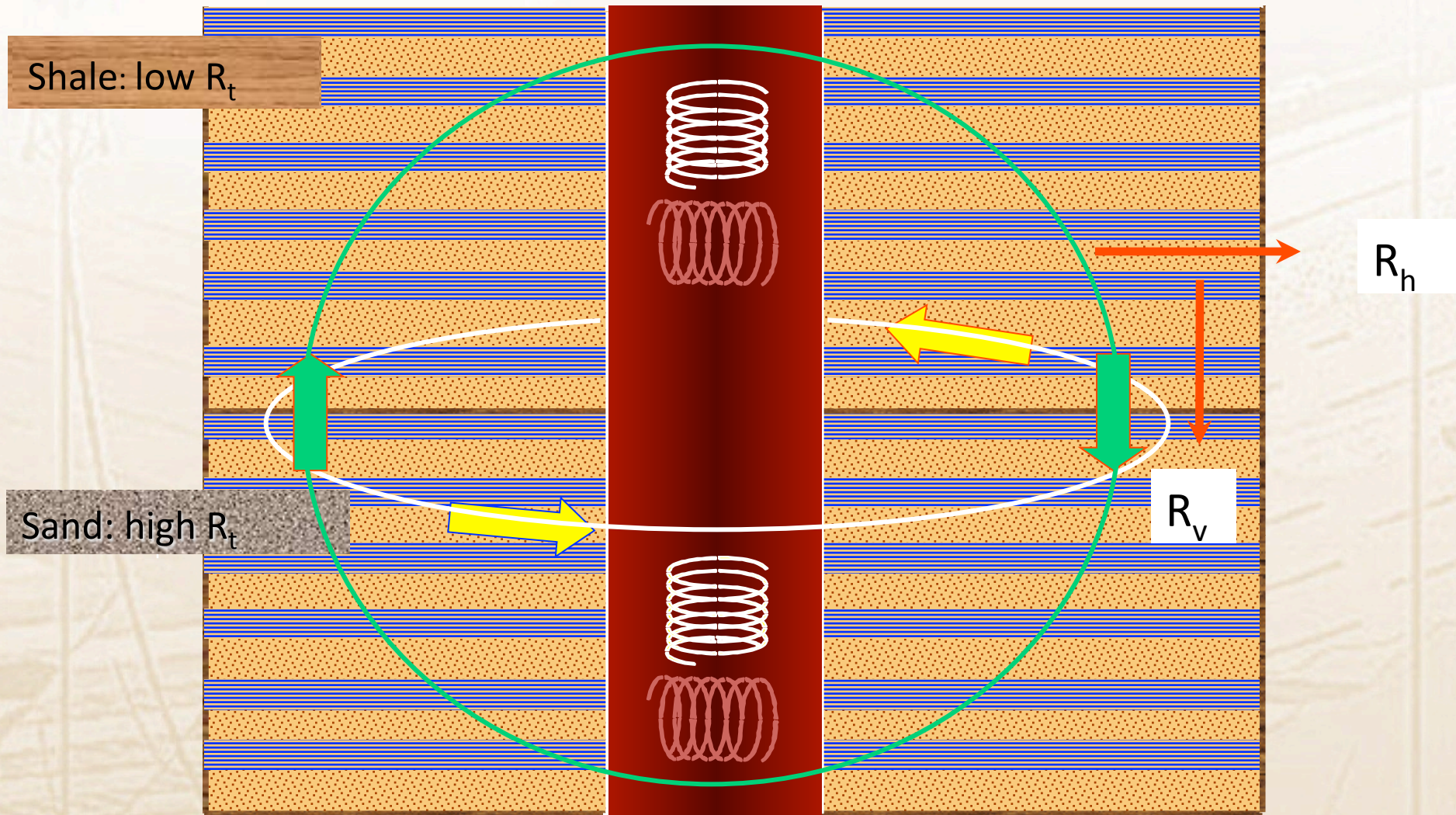
Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**Extended from laminations to turbidites**



After Blackbourn & Thomson, 2000

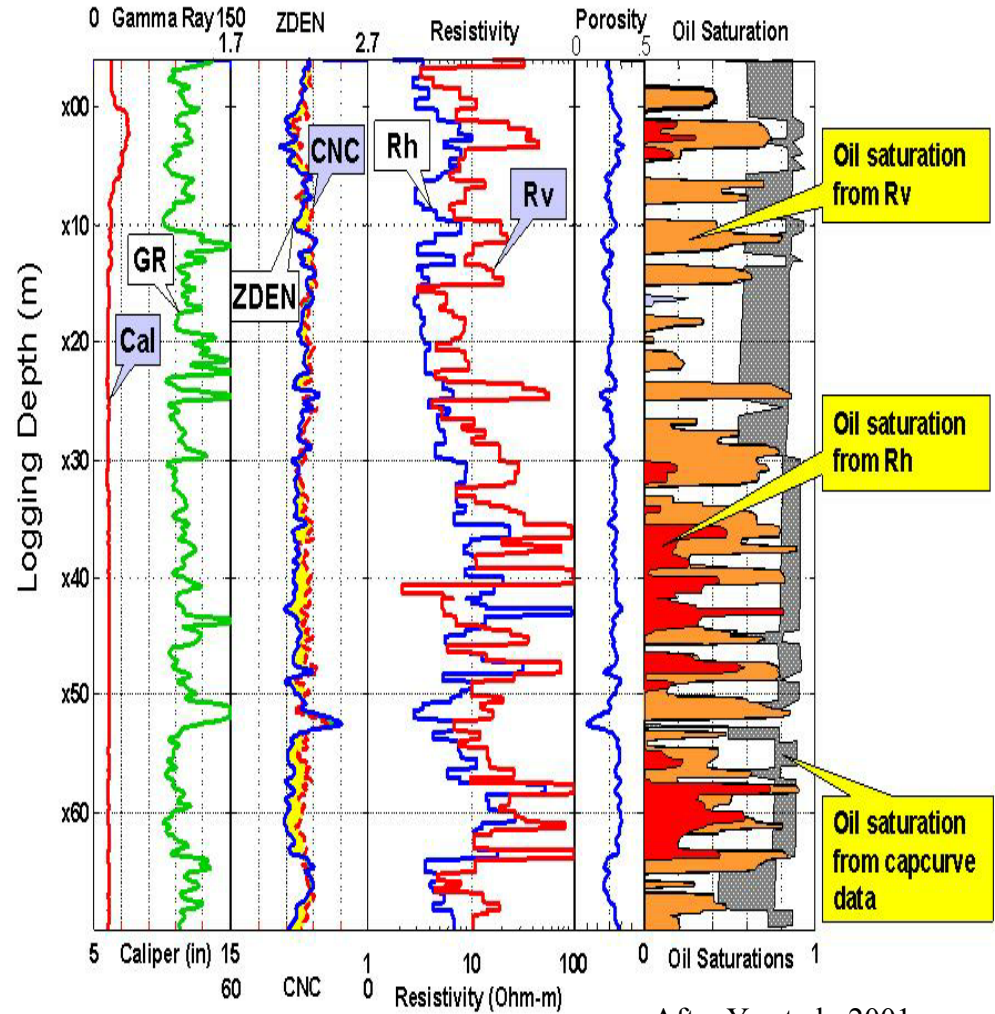
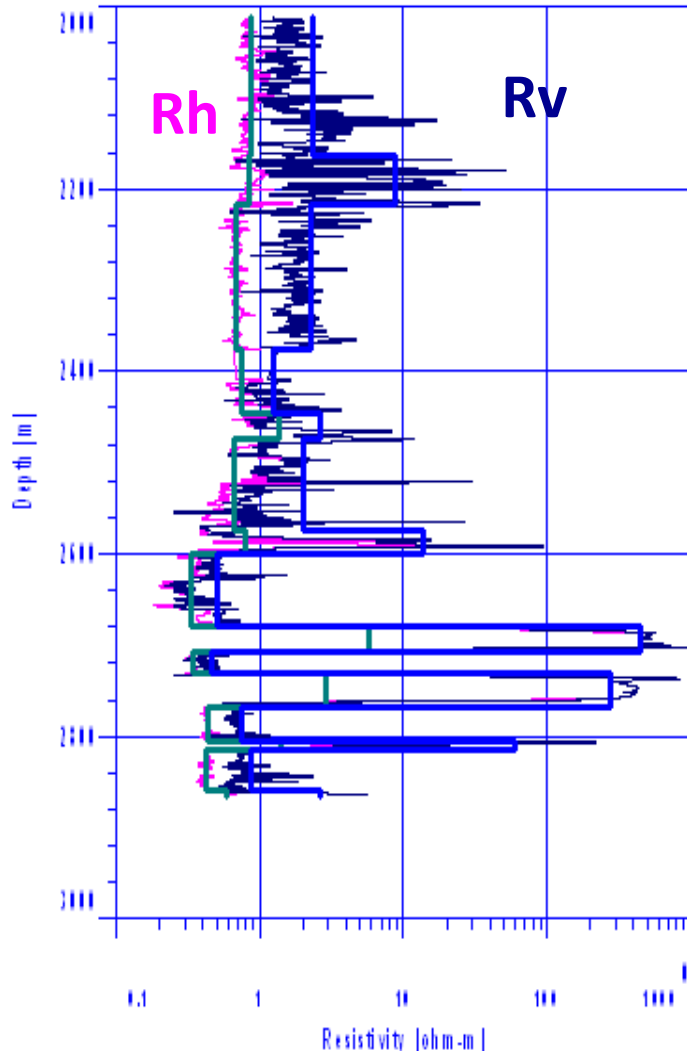


Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**Transverse Induction logging principle**



After Kriegshaeuser et al, 2000

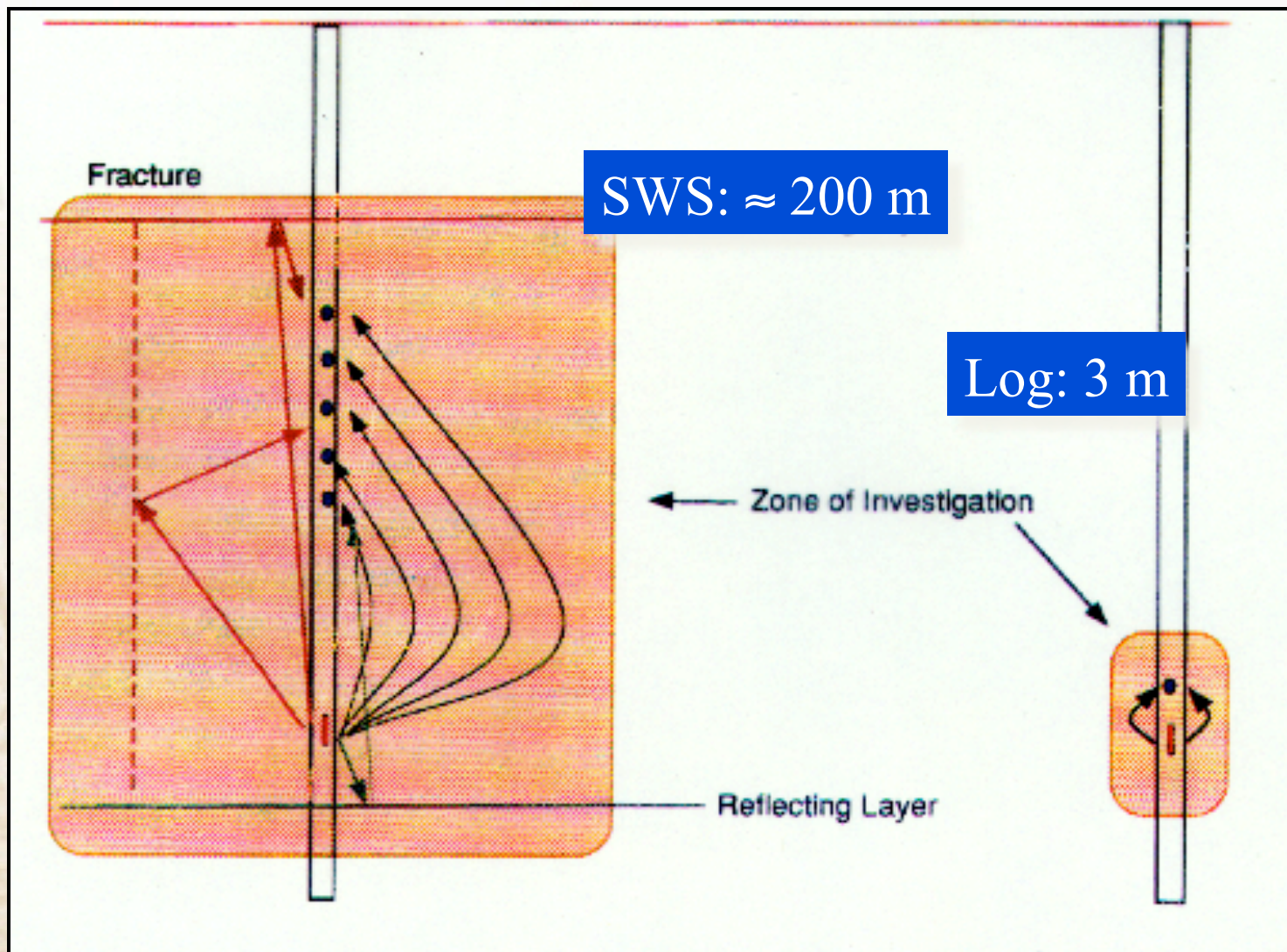
Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**ADD BOREHOLE: Fractures → anisotropy**



After Yu et al., 2001



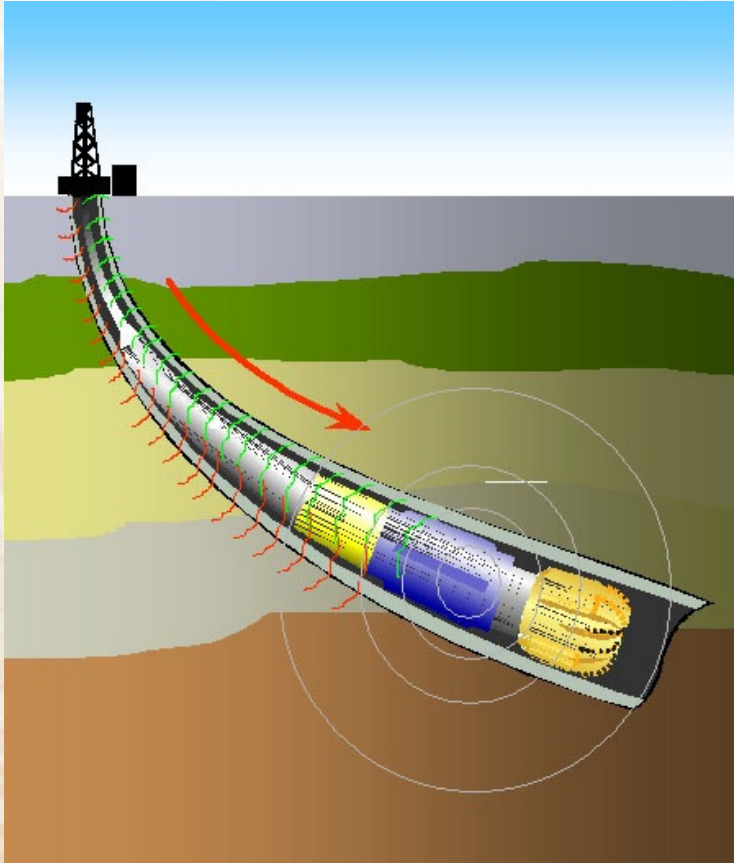
Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**Borehole-to-borehole: Resolution extension**



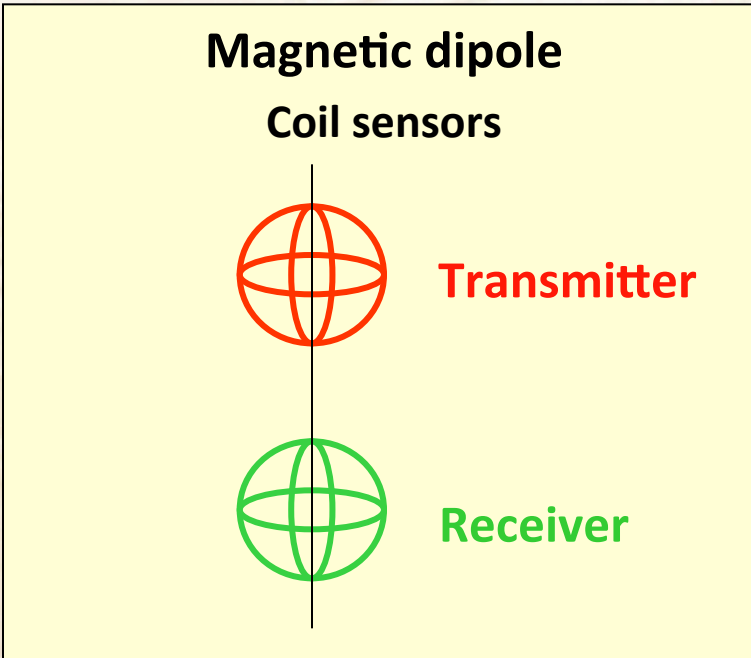
After Majer&Strack, 2000

Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**Deep Reading EM**

*The SWEMS concept...  
Single Well EM System*

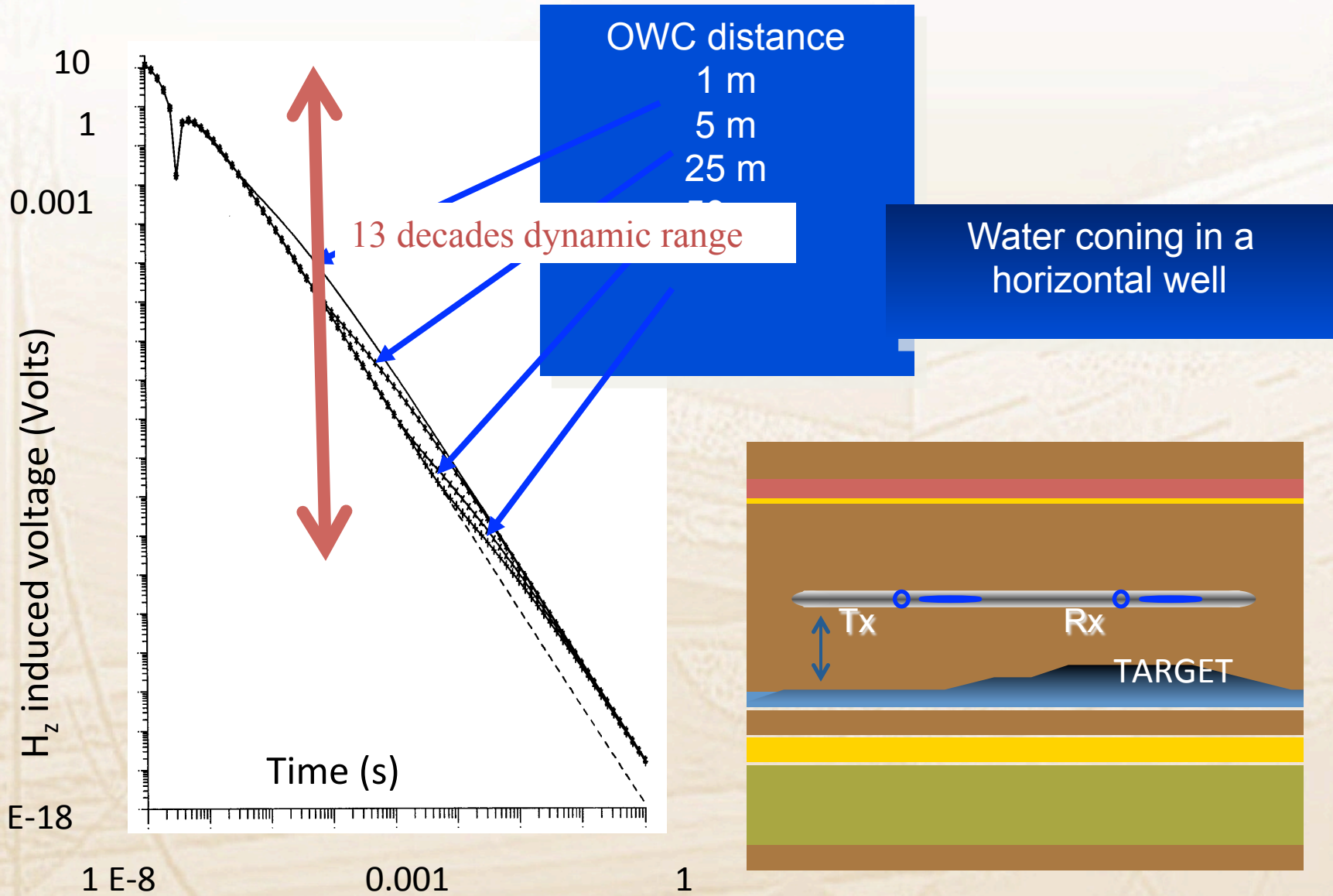


- **Deep reading through  
Transient Electromagnetics**

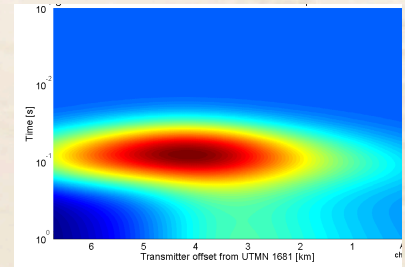
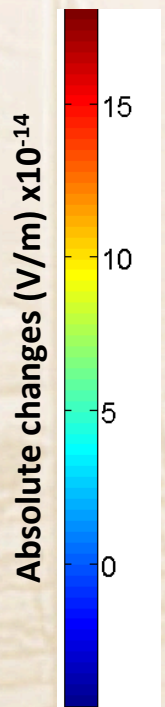
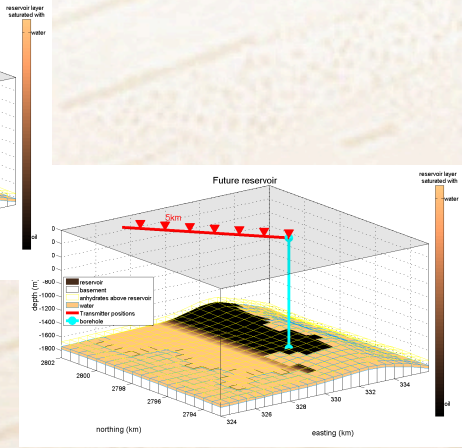
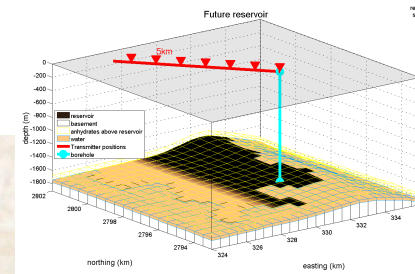
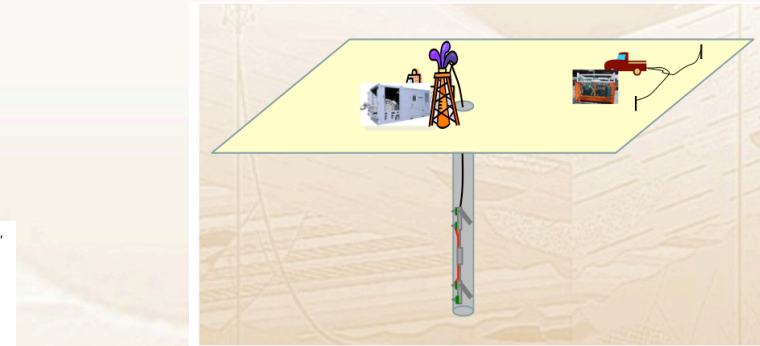
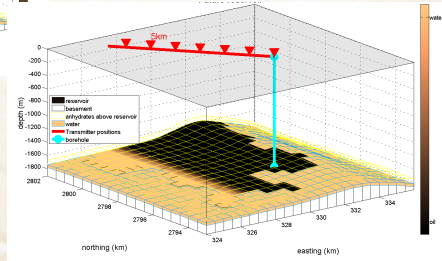
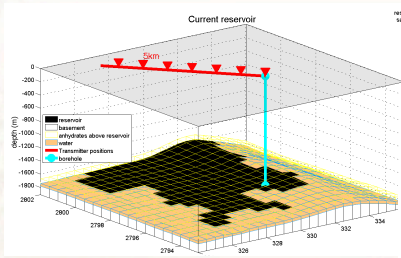




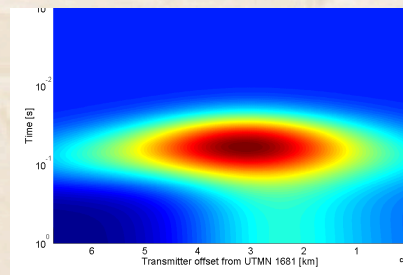
Objective >>> Issues & need for EM >>> **NEW tools** >> Future  
**Extended dynamic range required**



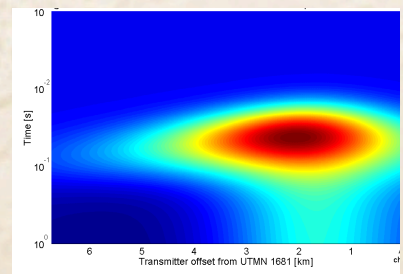
# Objective >>> Issues & need for EM >>> **NEW tools** >> Future **ADD BOREHOLE: Integration!**



Period of 5 years



After Colombo et al. 2010

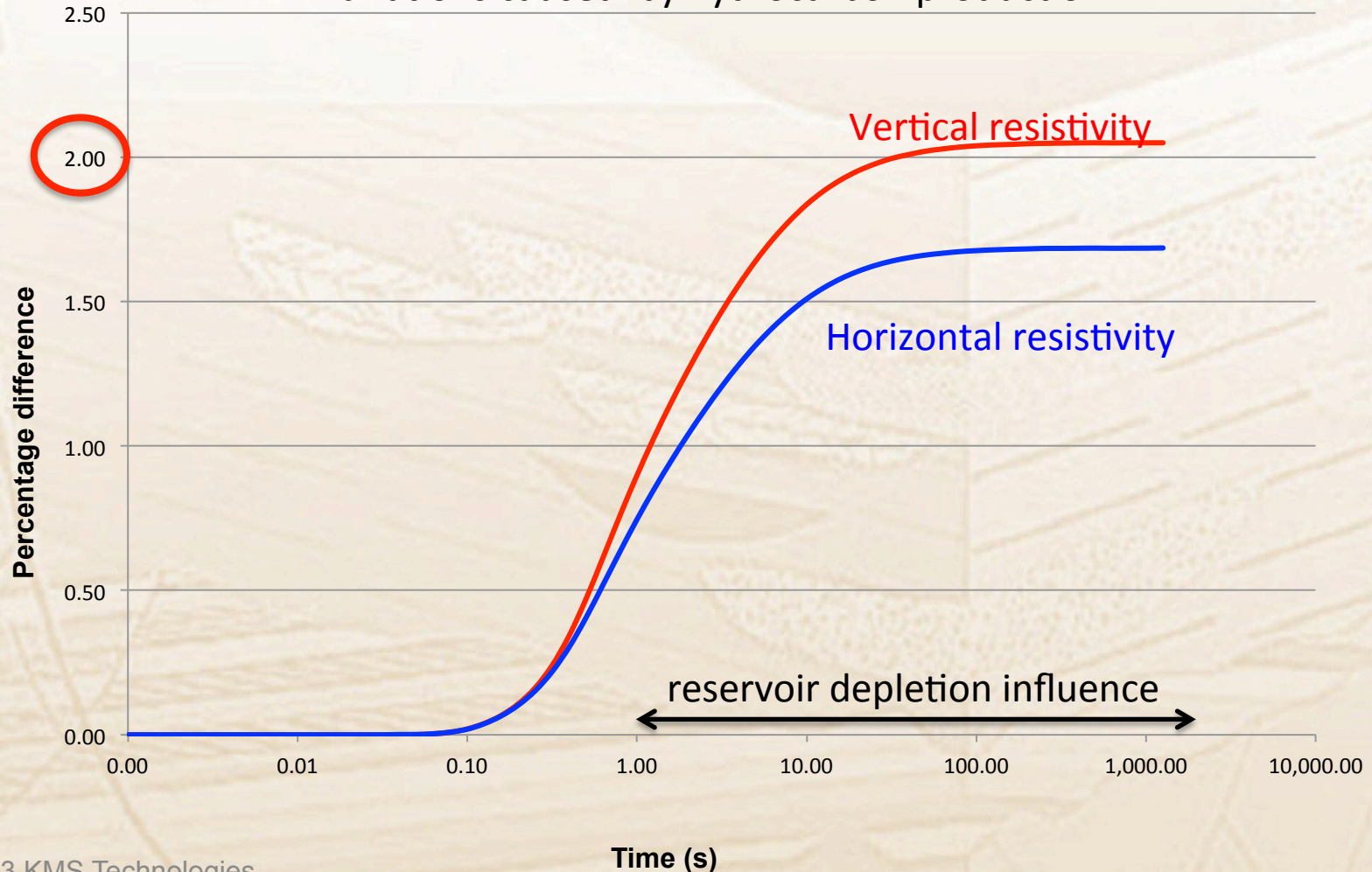




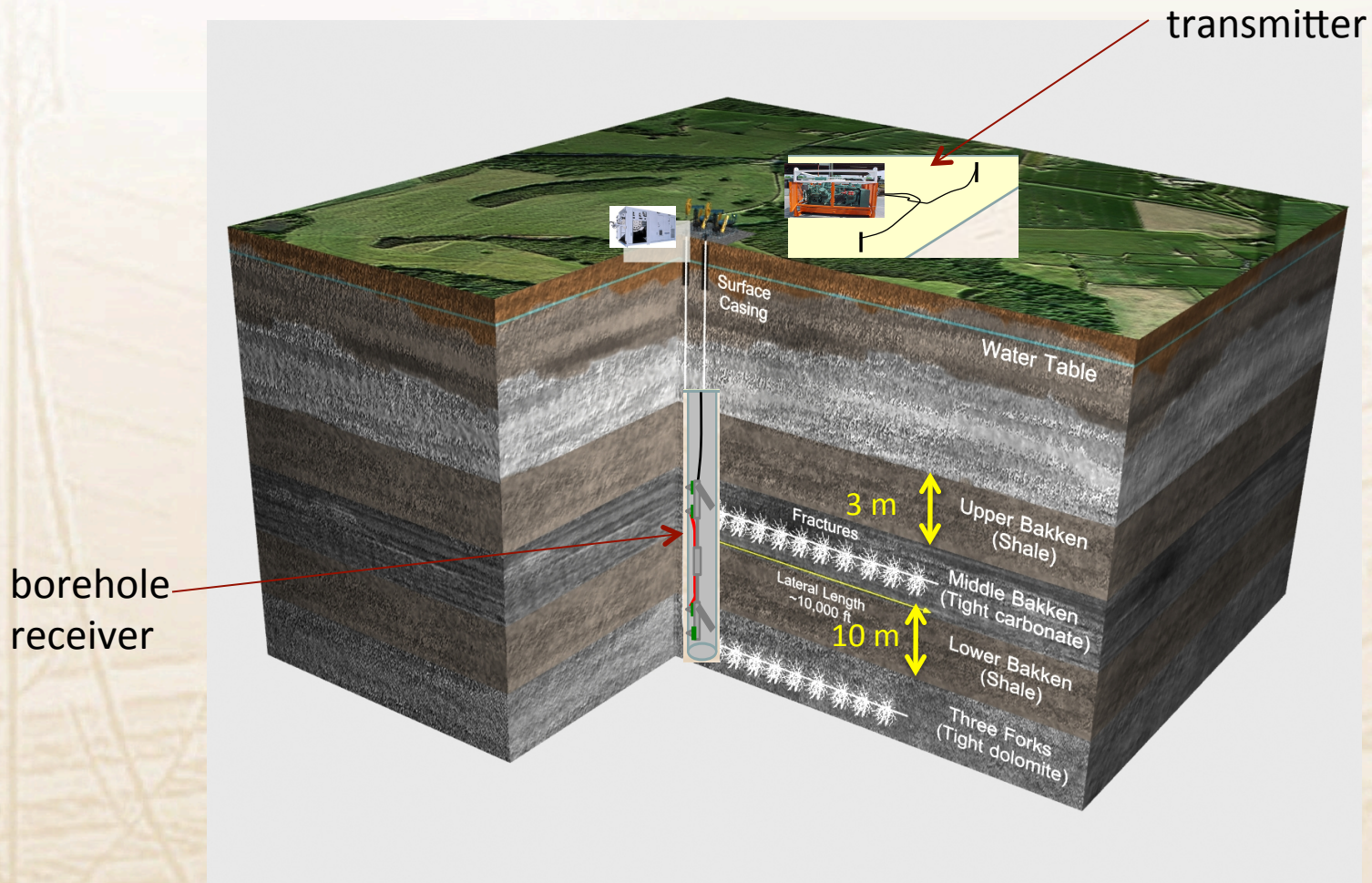
Objective >>> Issues & need for EM >>> NEW tools >> Future  
CSEM time lapse: before & after... LOWER BAKKEN



Variations caused by hydrocarbon production



Objective & drivers >> Requirements >> **Examples** >> Future  
**Future: Shale resources: Bakken simulating FRACTURE monitoring**

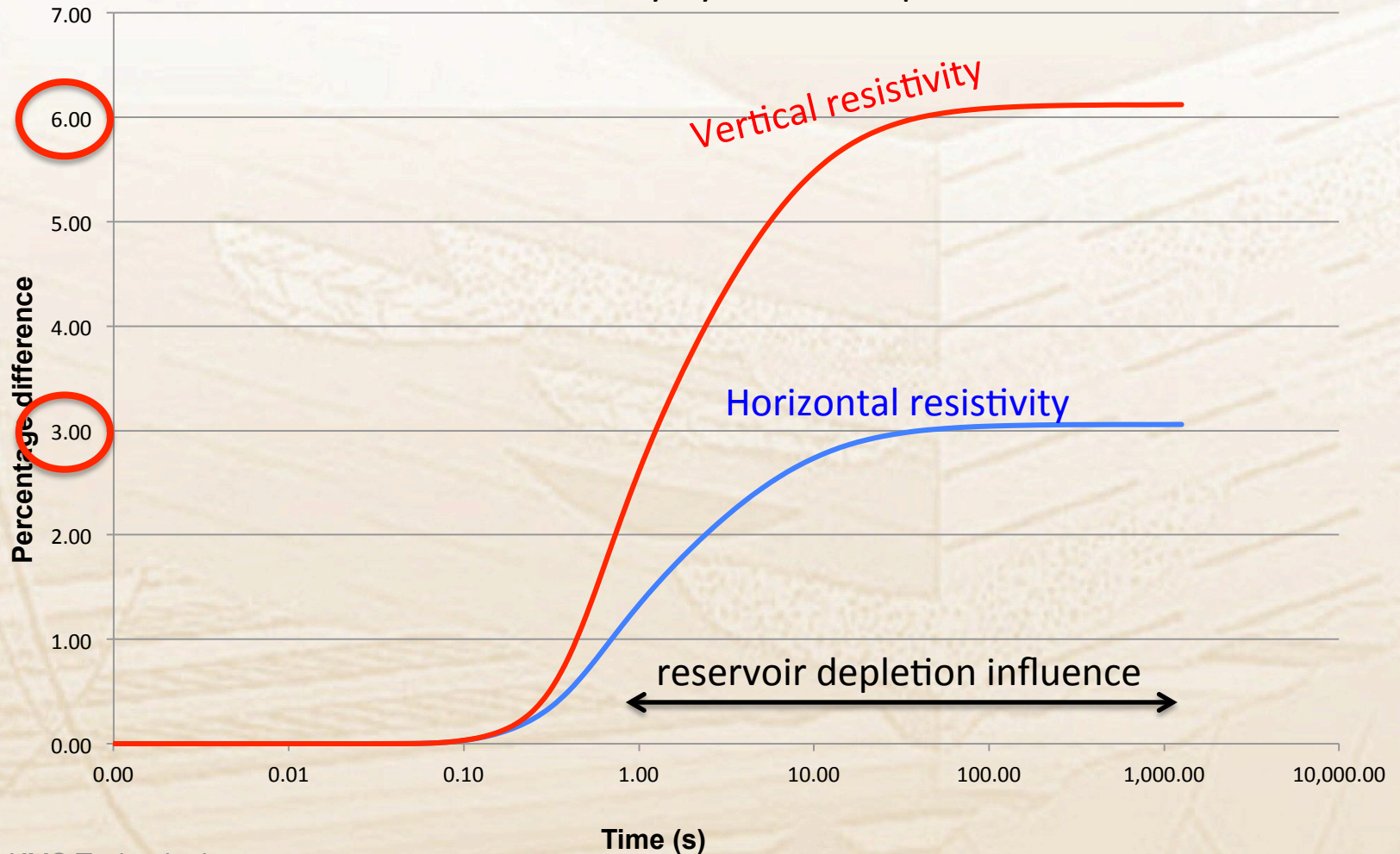


<http://www.statoil.com/en/NewsAndMedia/News/2011/Pages/XXX16Oct2011.aspx>



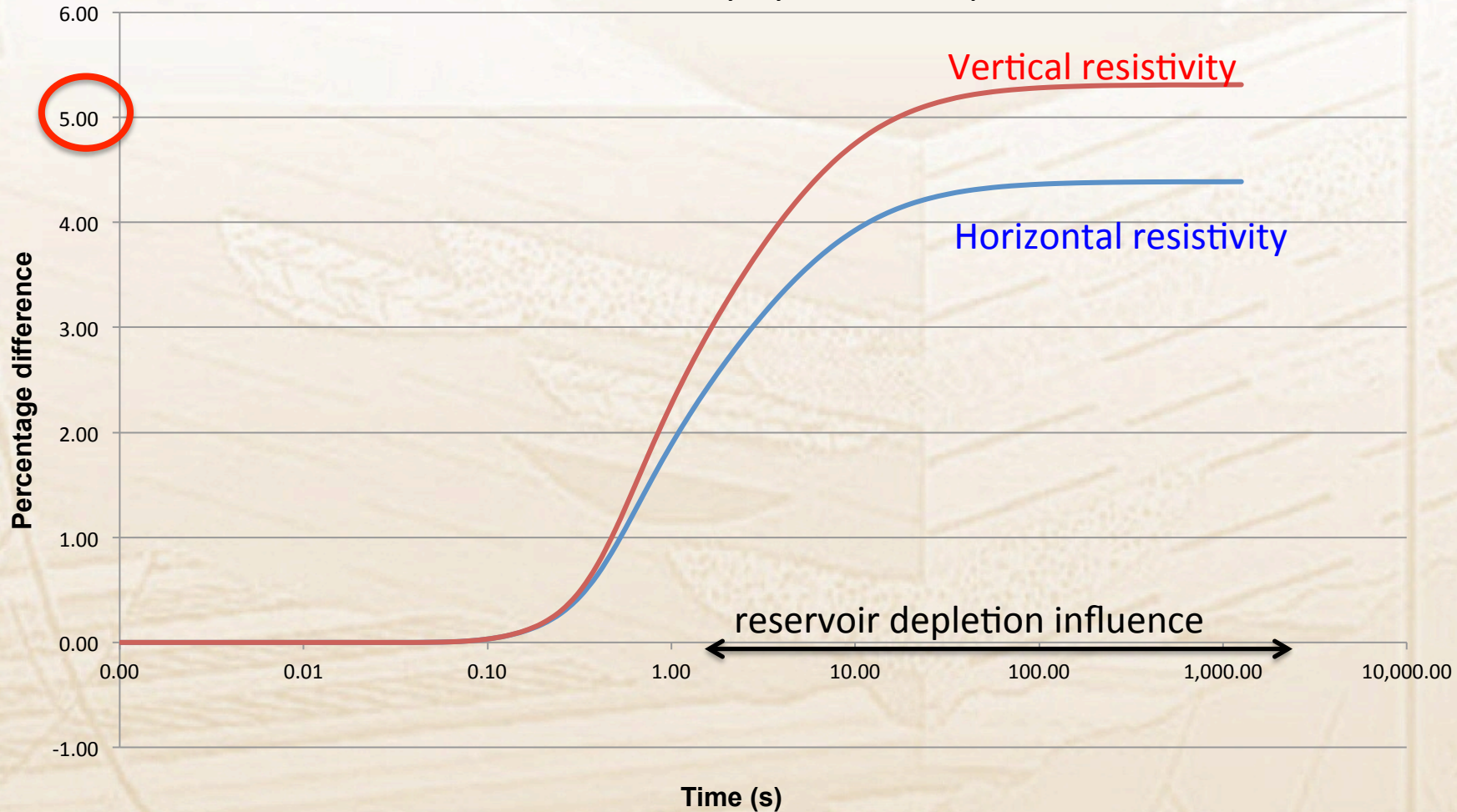


Variations caused by hydrocarbon production



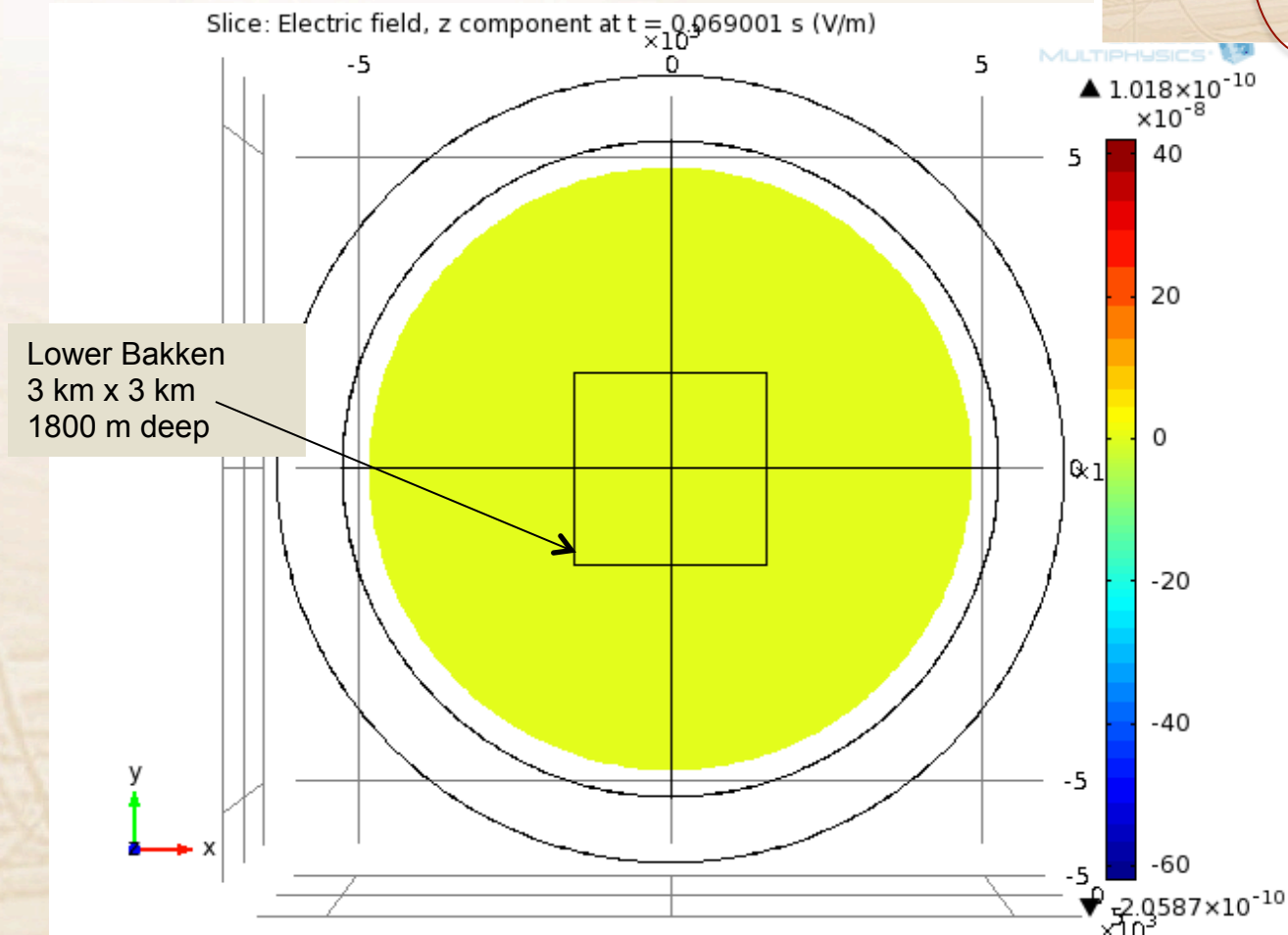
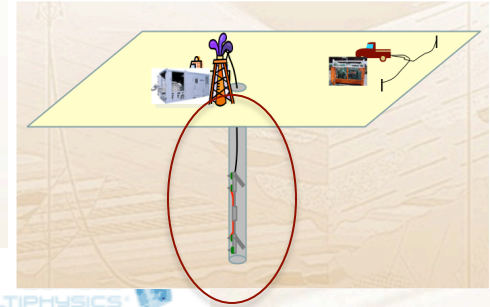


Variations caused by hydrocarbon production





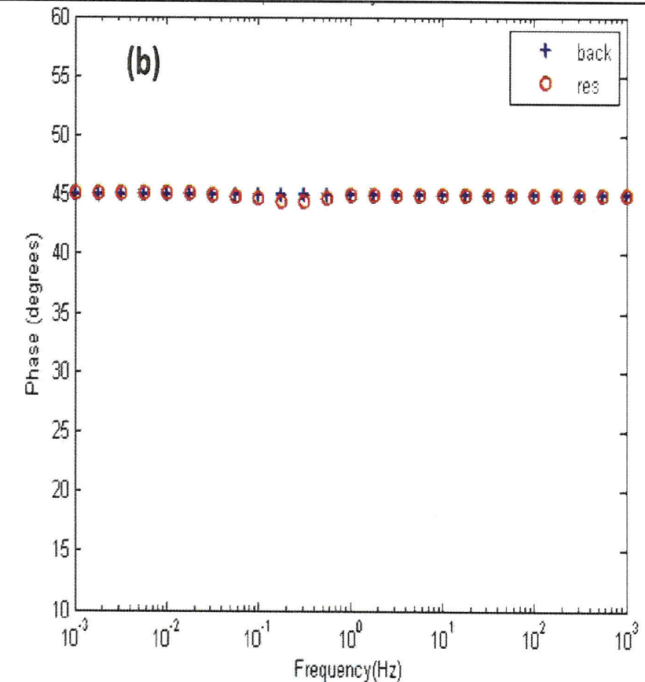
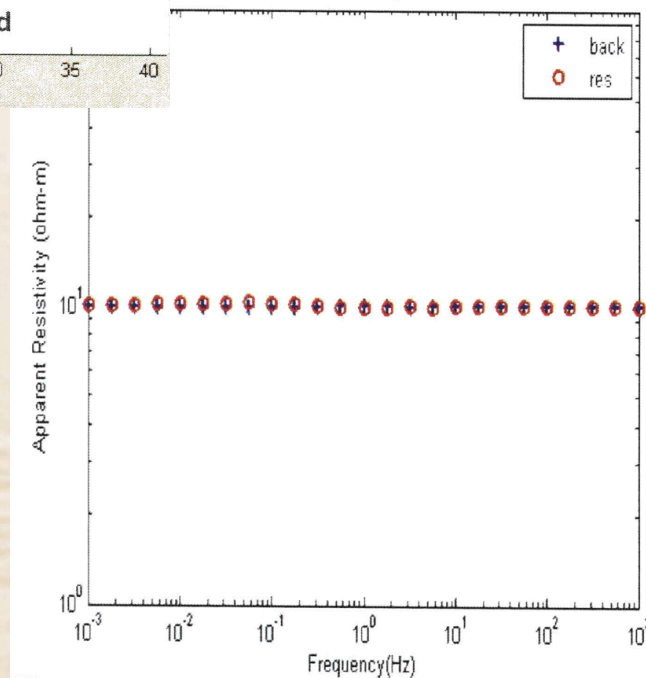
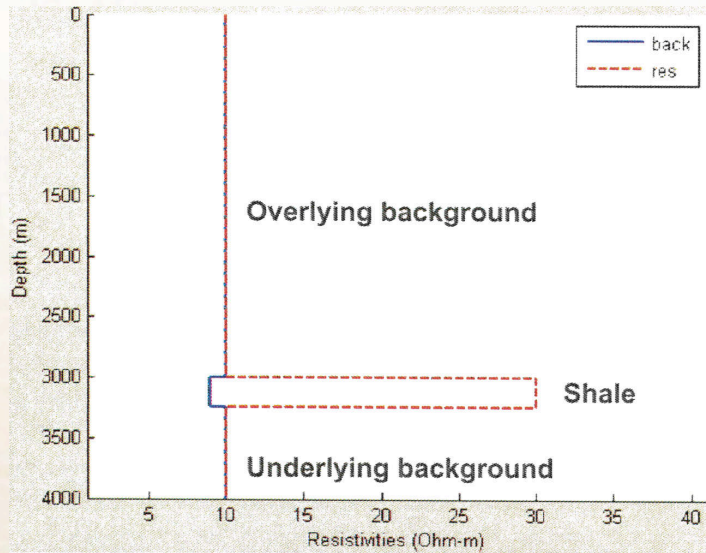
Objective & drivers >> Requirements >> **Examples** >> Future  
**Bakken simulating PRODUCTION monitoring**  
**Borehole-to-surface, Rx at reservoir level**





# Objective >>> Issues & need for EM >>> Applications >>> Future

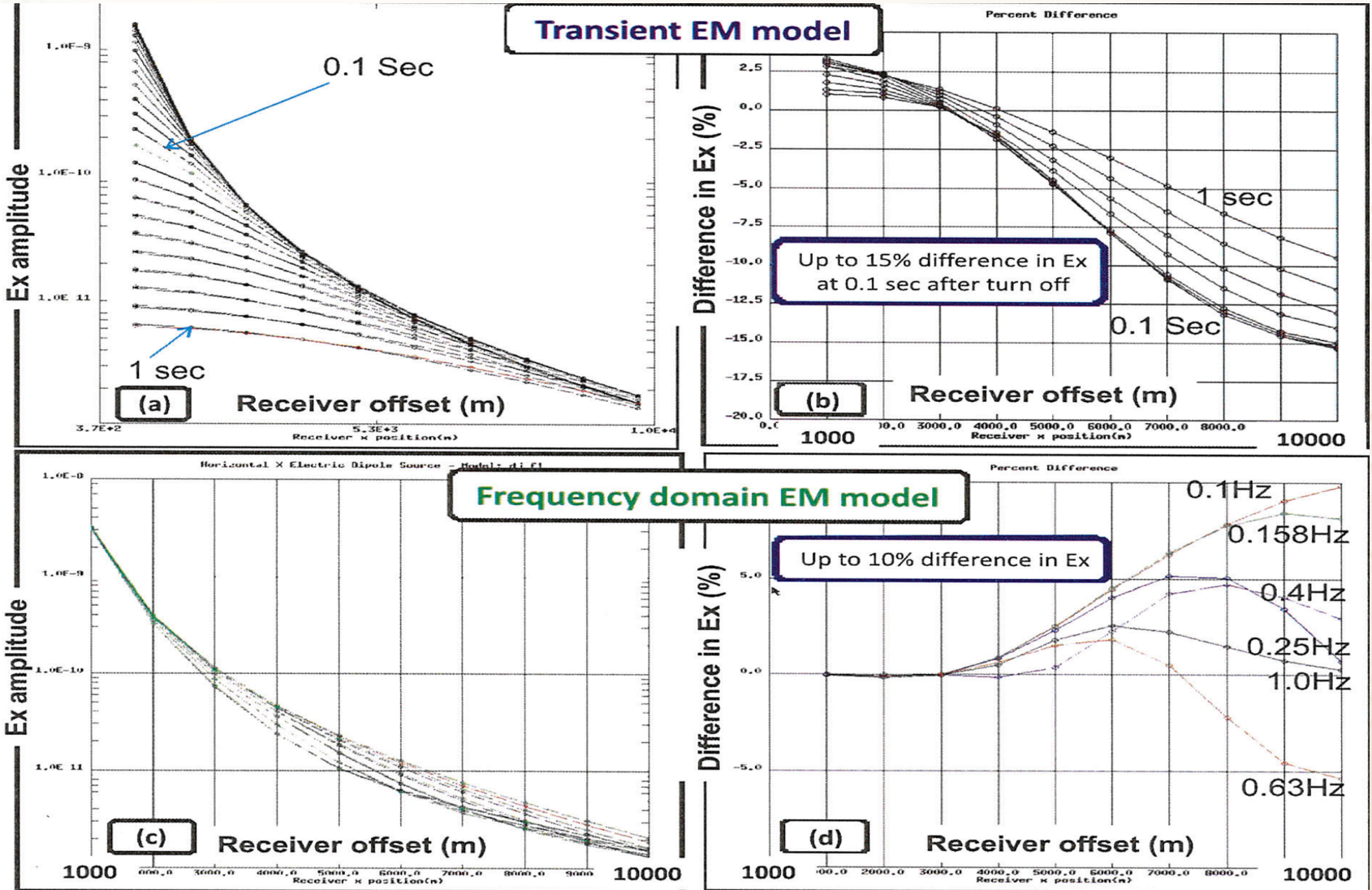
## Chevron Haynesville study: EM model & MT response







# Objective & business drivers >> **Examples** >> NEW tools >> Future Shale resources: Chevron Haynesville study





- 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.



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