KMS Technologies – KJT Enterprises Inc.

2013

Advances in Electromagnetic Methods for Hydrocarbon Applications

K.M. Strack, 2013, SPG Annual meeting, Kochi, India.

Advances in Electromagnetic Methods for Hydrocarbon Applications

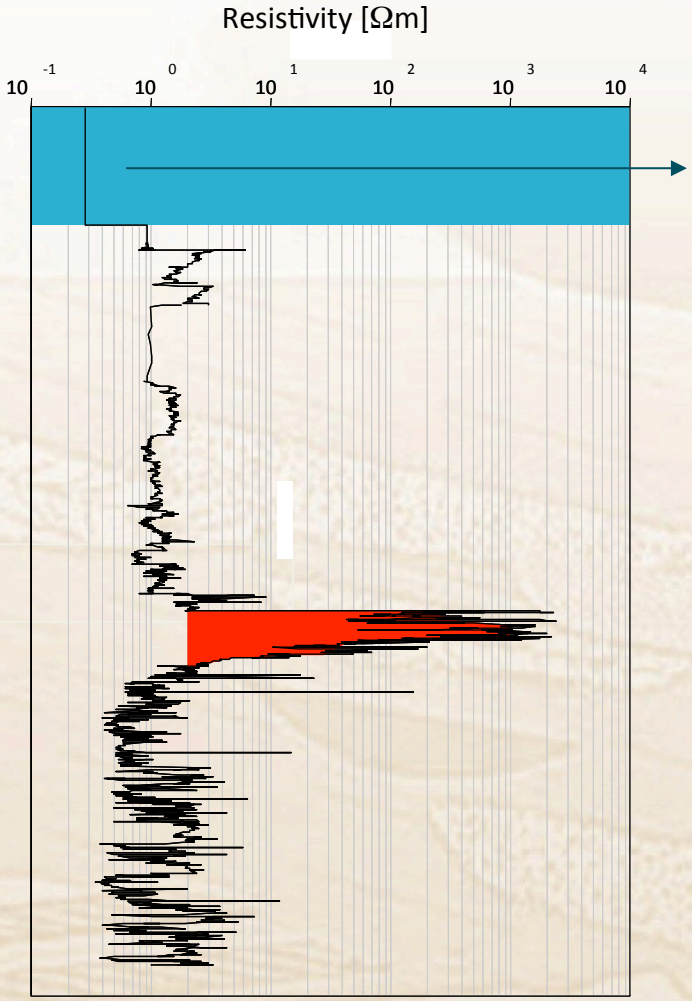
SPG Kochi 2013

K. Strack

KMS Technologies

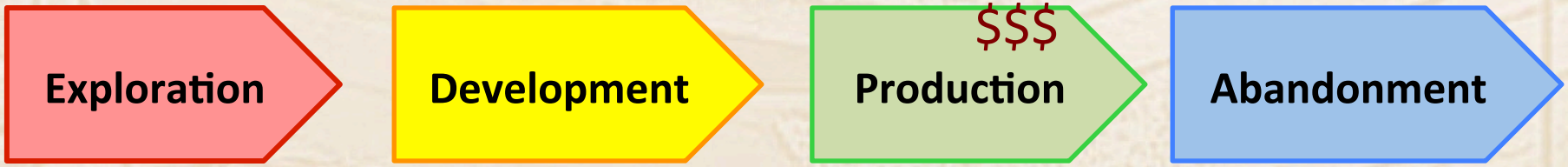
- Give an overview & share a novel idea
- Sliced the EM space
  - Business – reservoir life cycle
  - Technology/methods – borehole; marine; land, airborne
  - NEW applications:
    - shales reserves
    - Reservoir monitoring

Hydrocarbons are resistive!



Courtesy EMGS

Provide a snapshot of state-of-the-art of EM for hydrocarbon applications



- Drill targets
- Seismic support
- Oil/water → reserves
- Risk control

- Infill wells
- Cost optimization
- Facility estimation

- Better recovery factor
- Cost reduction
- Seal integrity

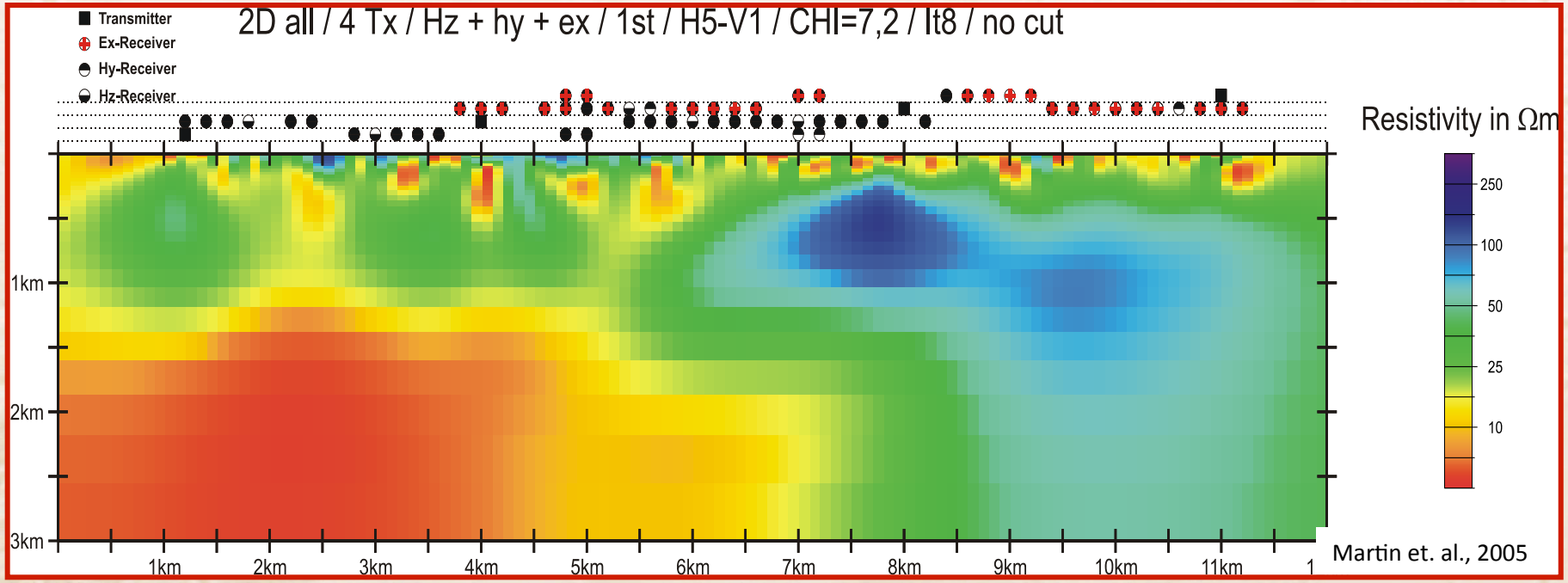
- Sale/redevelop

- Provide an update view of EM for oil applications
- What happened in the past 20 years?
  - Science: Little new, mostly implementation
  - Business: HUGE change
    - Borehole – many new tools → new operating decisions
    - Marine – complete new industry
    - Land was shrinking now starting
      - slowly new applications,
      - less technology now than mid 80s
- Hydrocarbon → market driven

Exploration: drill targets as educated guess

Exploration → **Development** → **Production** → **Abandonment**

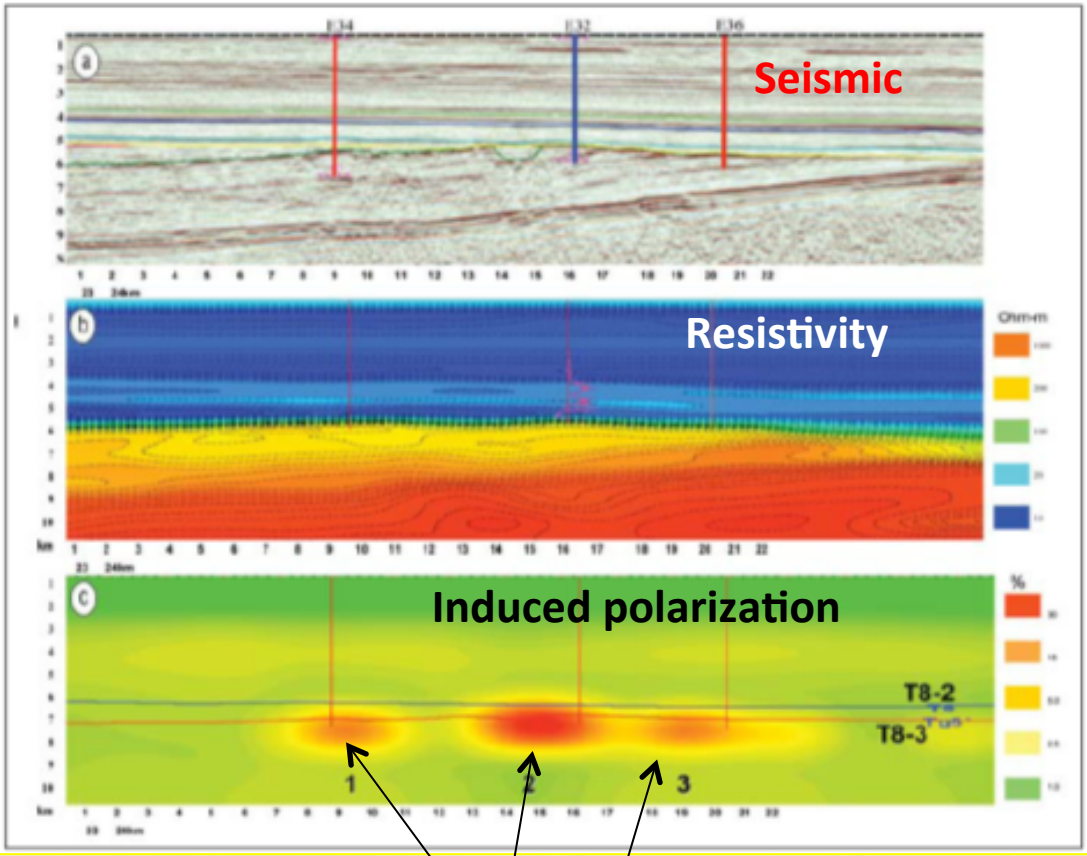
Land 2-D CSEM inversion image for structural imaging



Development: find sweet spots use calibration

Exploration → **Development** → **Production** → **Abandonment**

LOTEM & IP (induced polarization) for prospect identification

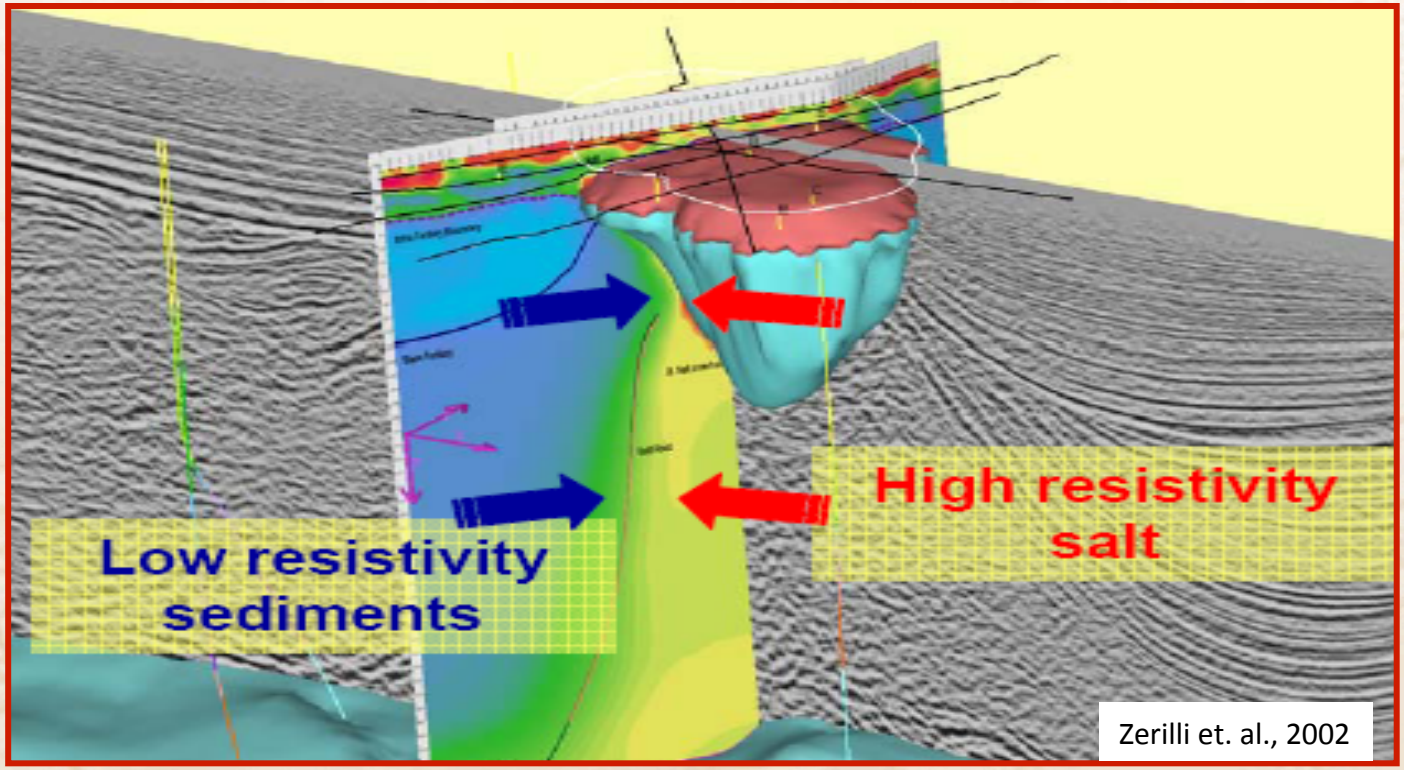


He et. al., 2007

Exploration: drill targets as educated guess

Exploration → Development → Production → Abandonment

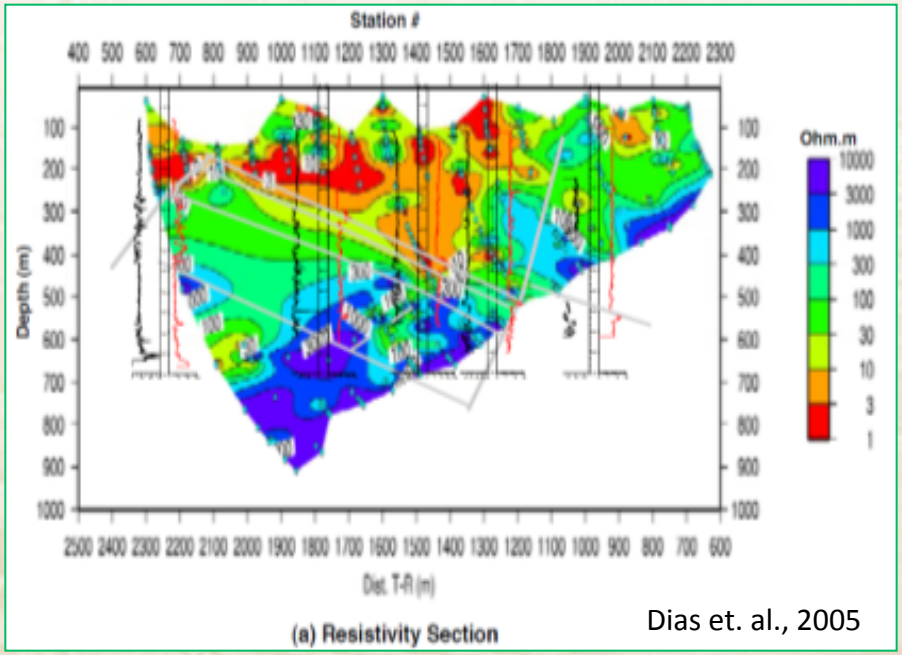
High density 3-D MT for salt structural imaging



Production: increase recovery factor; decrease lifting cost

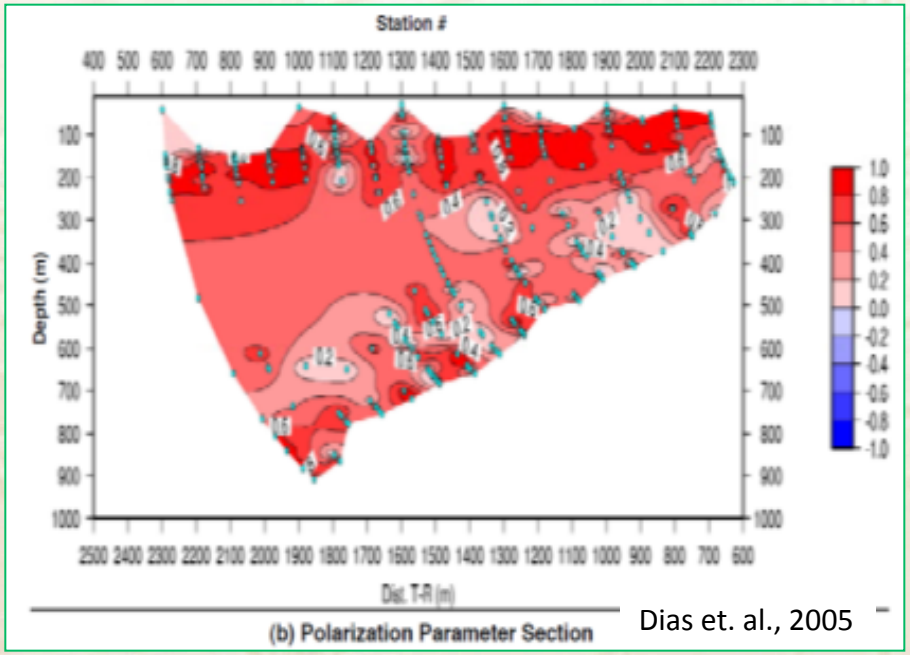
Exploration → Development → **Production** → Abandonment

Steam flood monitoring for reservoir @ 300-700 m depth



Dias et. al., 2005

Resistivity section

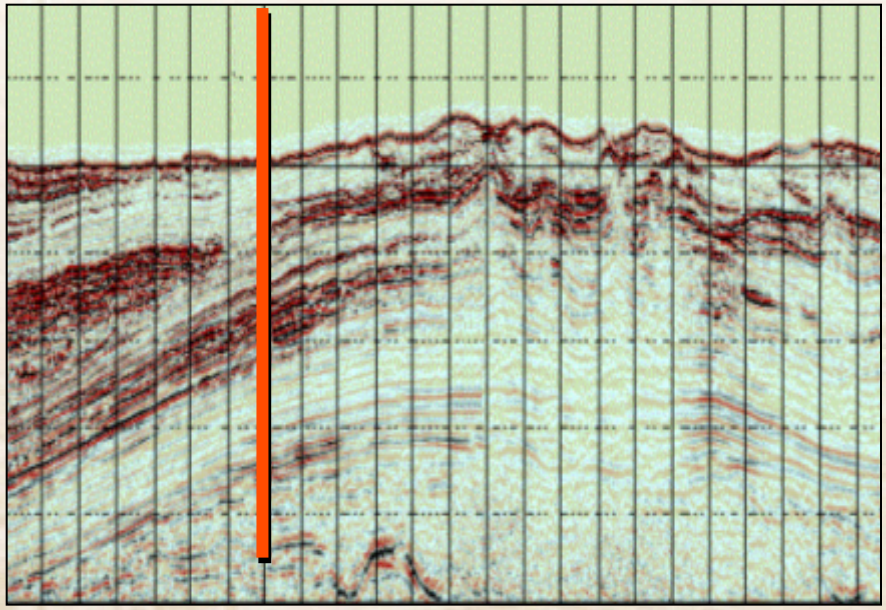


Dias et. al., 2005

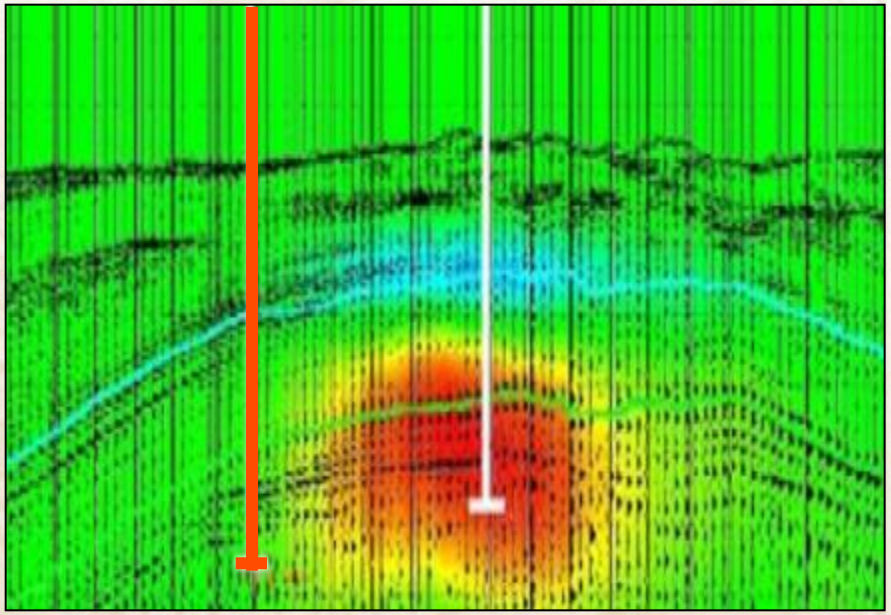
Induced polarization section

Abandonment: Sale or opportunity?.. Marine example

Exploration → Development → Production → Abandonment



Initial failure → operator ready to abandon asset



CSEM acquired → leads to up dip discovery

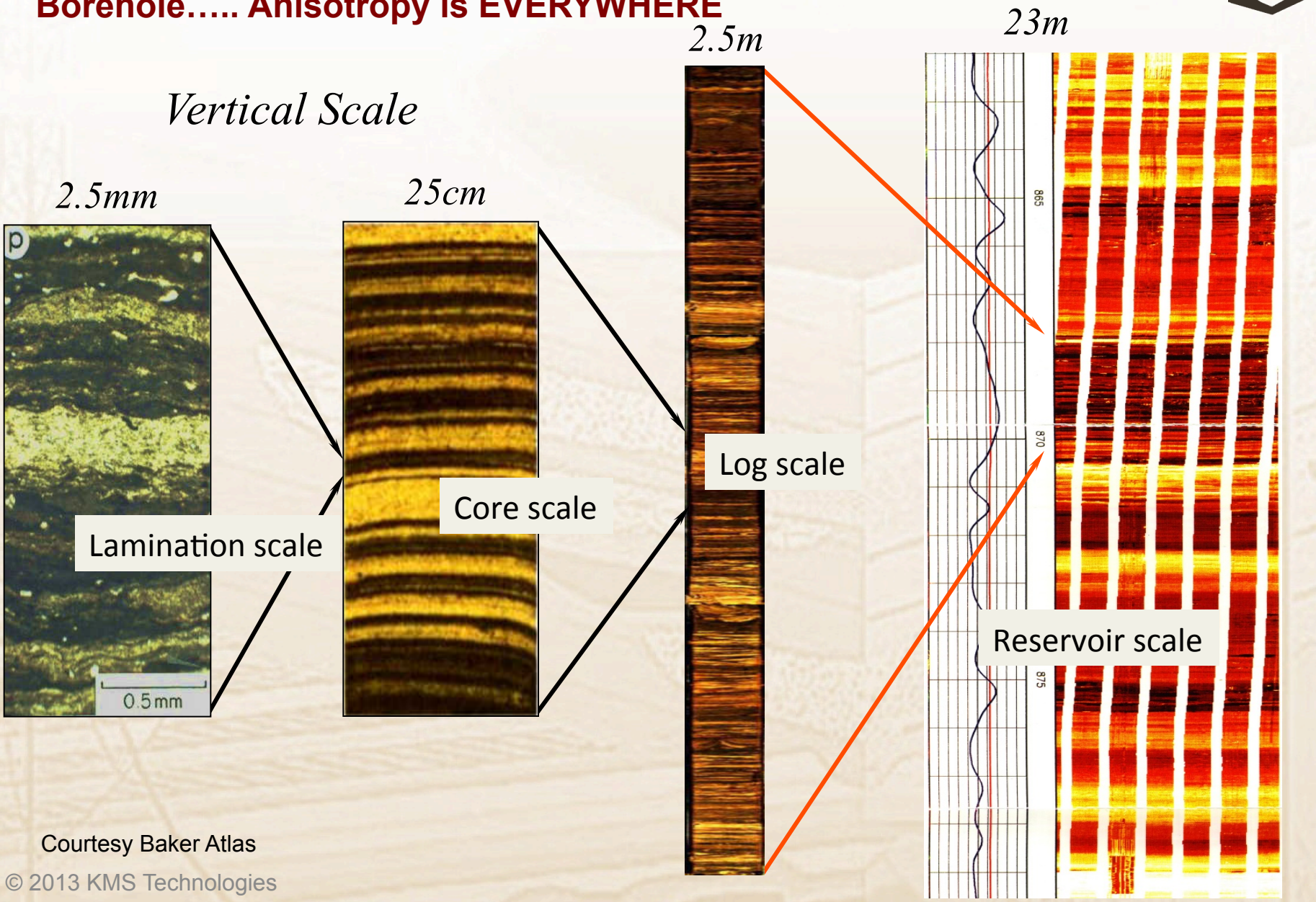
Markets	(in Million US $)
➢ Borehole	> 1, 000
➢ Marine	≈ 200
➢ Land	≈ 50
➢ Airborne	≈ 150

➢ NOVEL markets: small initially, BUT pull through
- Integration
- Shale applications
- Monitoring

Methods overview

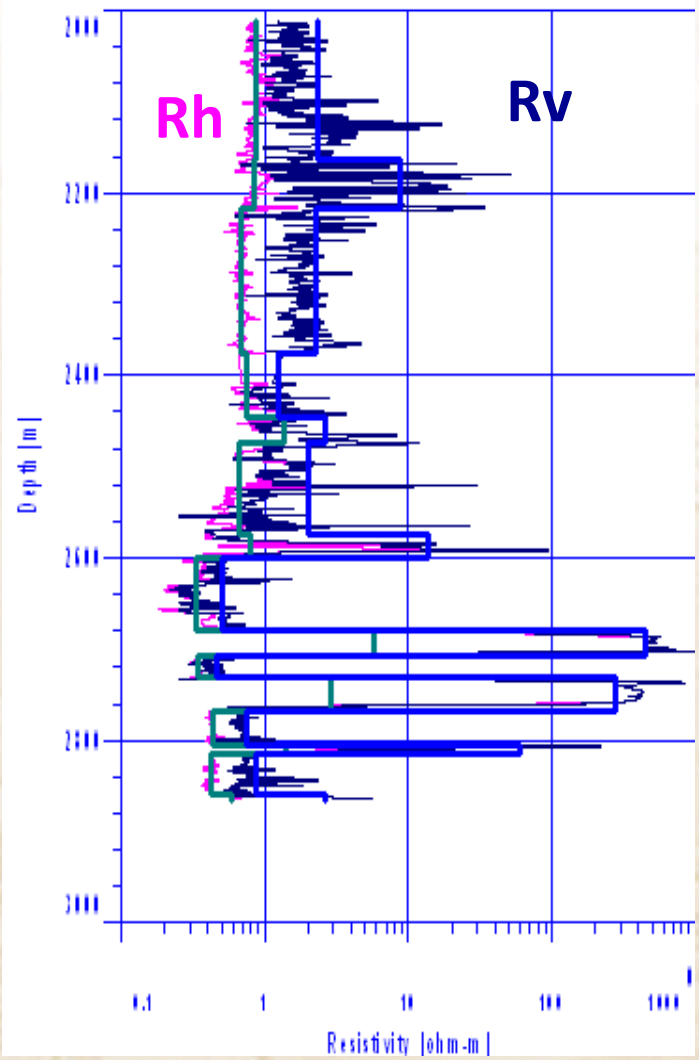
- Borehole
  - 3D induction — $$$↑ → calibration, **more reserves**
  - Array induction/resistivity — $$$↑ new generation
  - Inversion — --↓
  - Through Casing Resistivity — ±
  - Imaging — $$$↑ → geologic image
  - Logging-while-drilling — $$$↑ better data, lower cost
  - Geosteering — $$$↑ **more reservoir/ unit cost**
  - Cross-well — ±
- Marine
  - Marine Controlled Source ElectroMagnetics (CSEM) (frequency) — $$$↑ → **drilling decisions**
  - Marine magnetotellurics (MT) — $$$↑ → framework knowledge
  - Others (tCSEM™, streamer based E-field mapping etc.)
- Land
  - Magnetotellurics — $$$↑ **basin exploration**
  - Controlled source EM — - reservoir mapping, SUB-BASALT
  - Various EM for statics — $$$↑ cost control, enhance seismic
  - CSEM monitoring & shale — **Novel**
- Airborne
  - VTEM — $$$↑ Increased depth → more application
  - Skytem — $$$↑

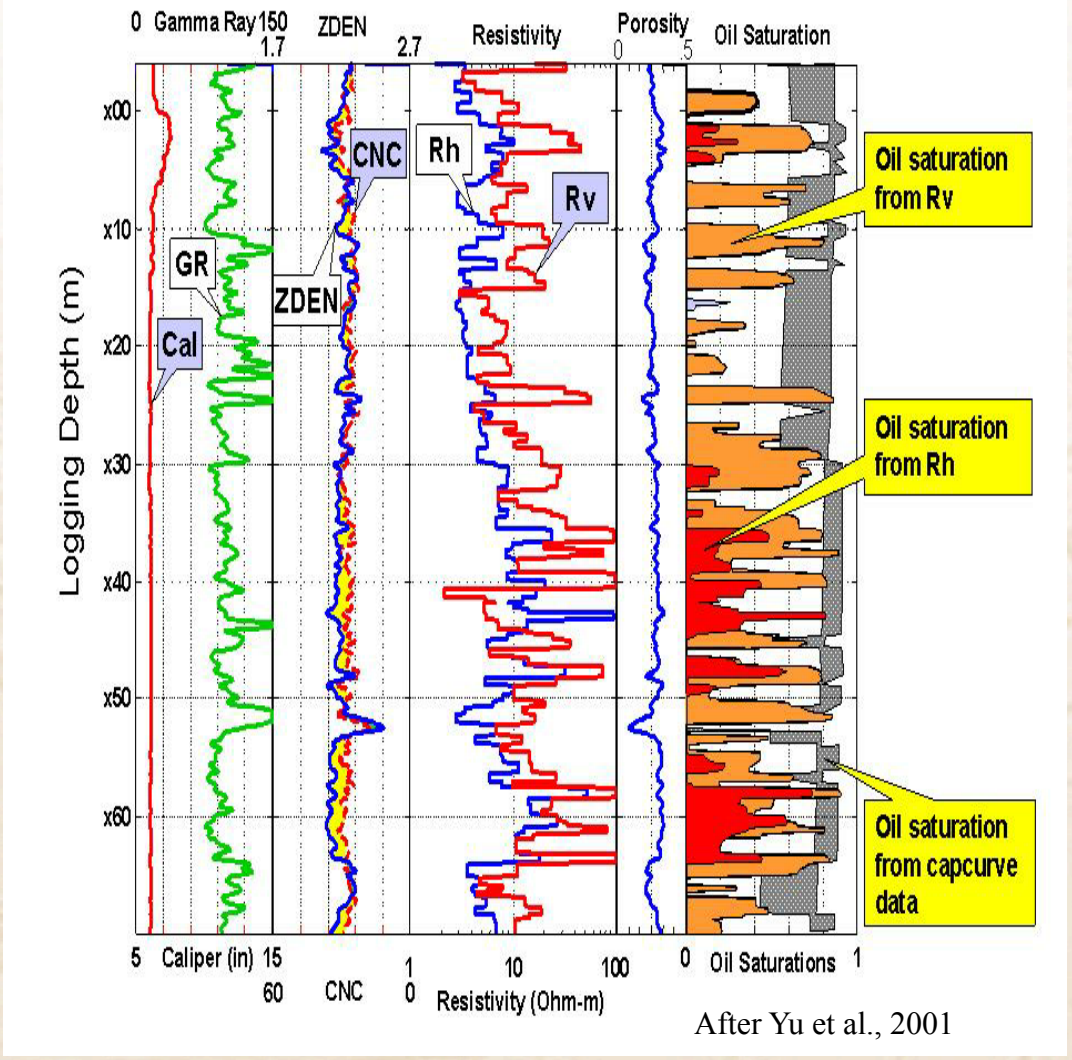
Borehole….. Anisotropy is EVERYWHERE



Courtesy Baker Atlas

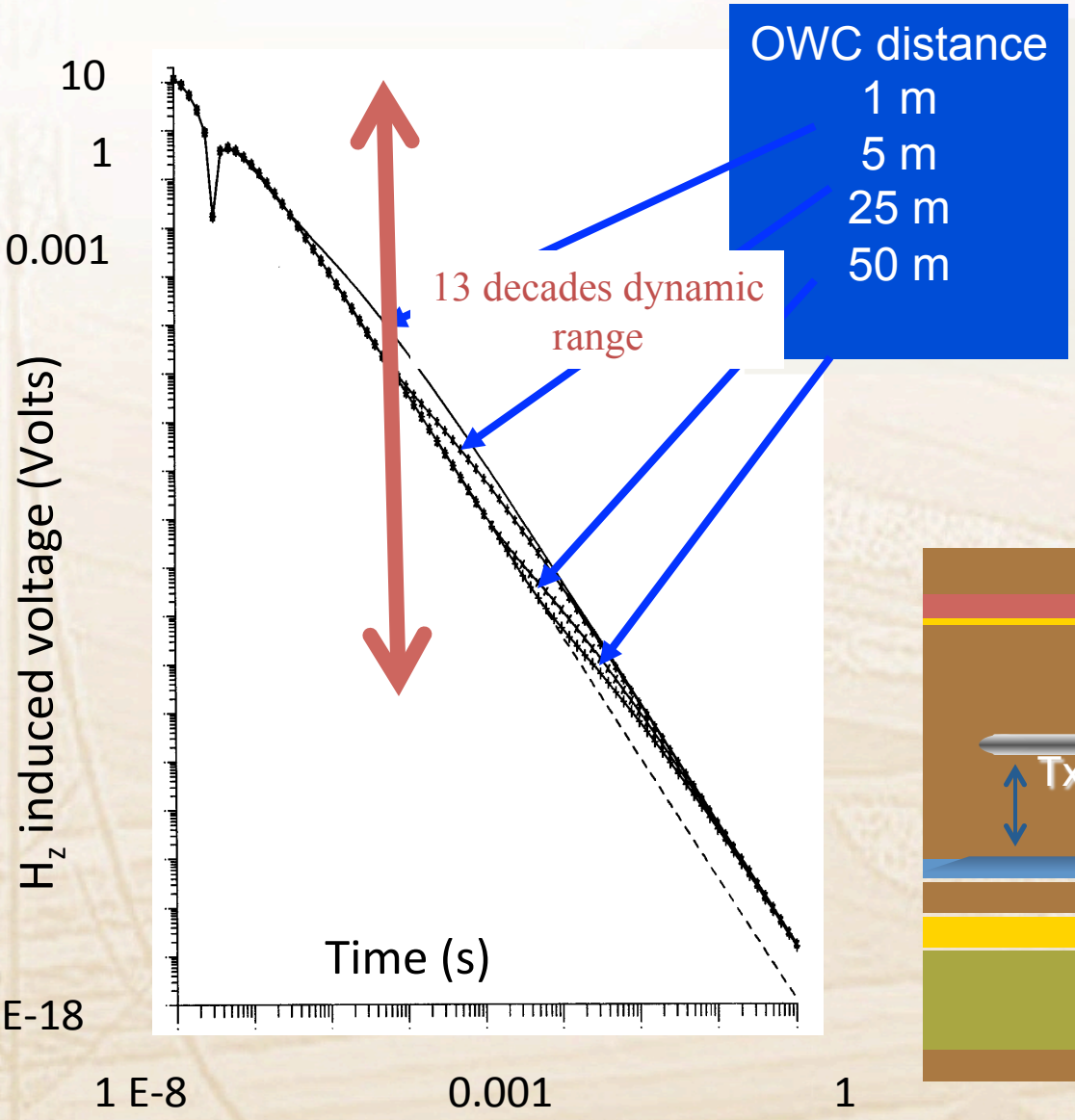
Borehole….. Anisotropy → more oil; fractures etc



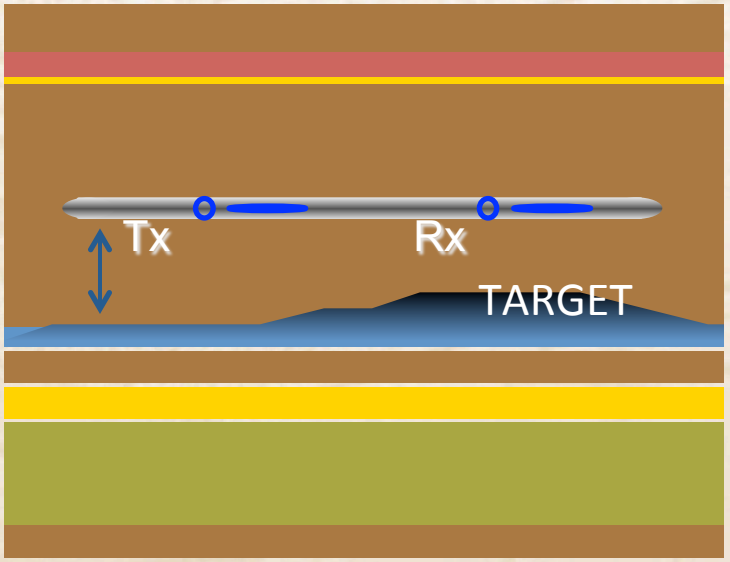


After Yu et al., 2001

Borehole…. Geosteering.. Directing the well path

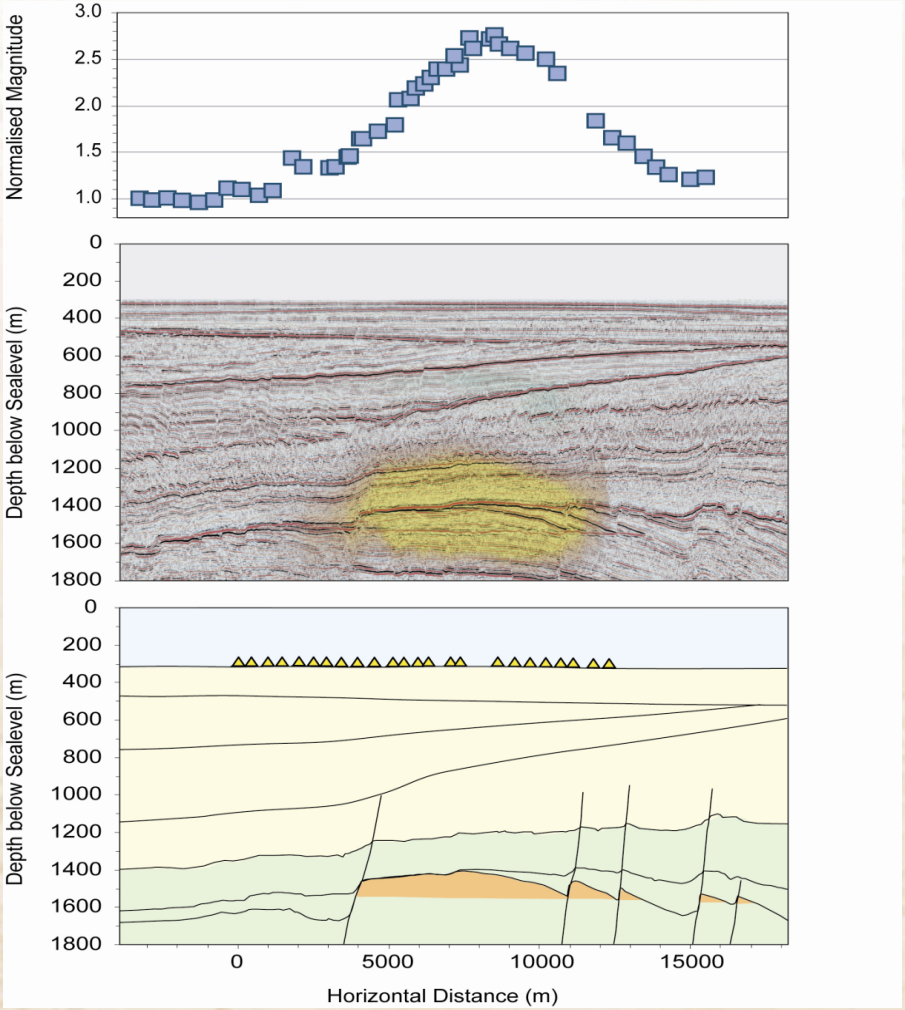


Water coning in a horizontal well



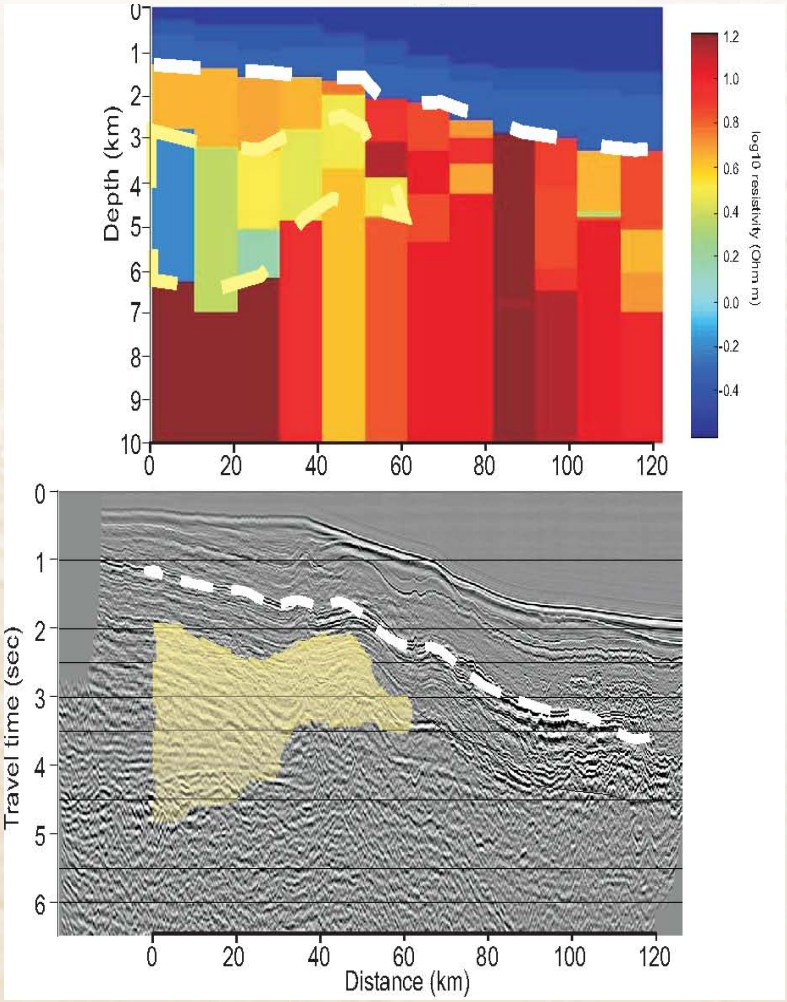
Methods: Marine

TODAY: DHI standard



After Johnstad et al., 2005

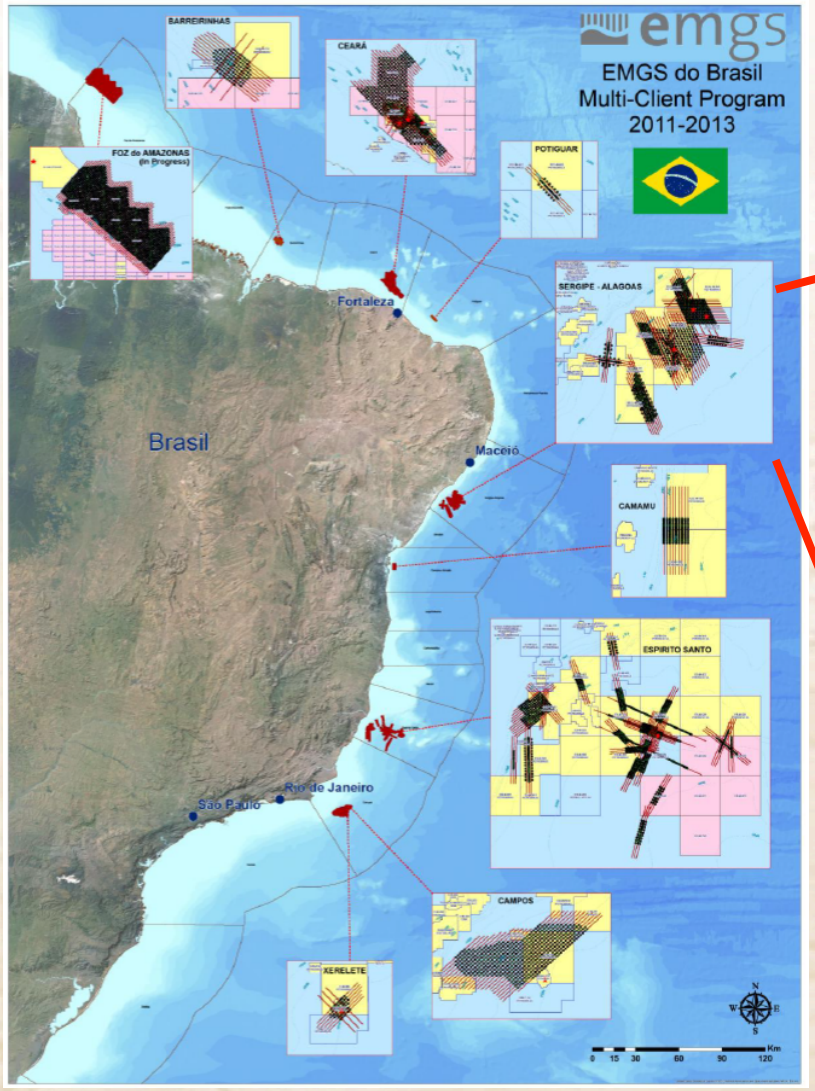
THICK basalt targets ongoing

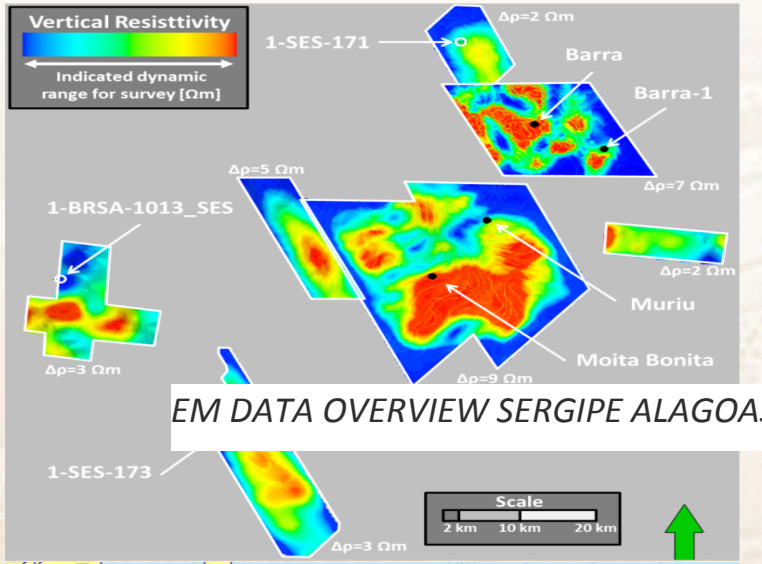


Jegen at al. 2009

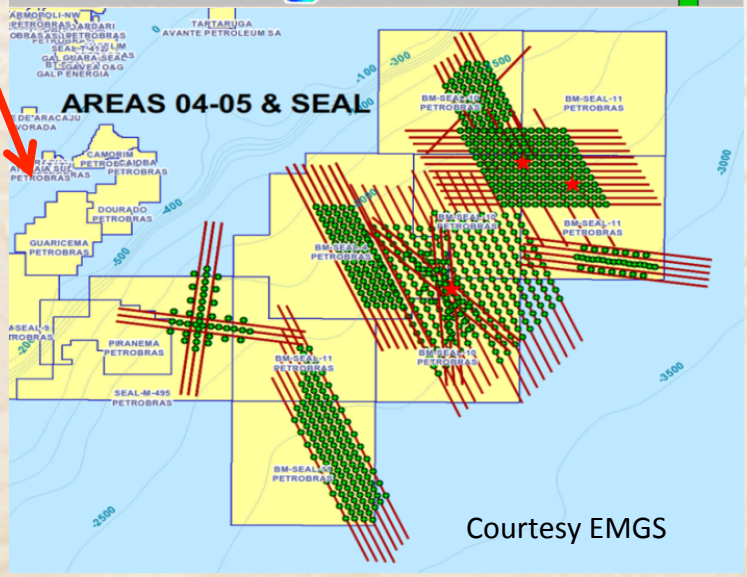
Objective >>> Business drivers >>> Methods >>> Future

Methods: Marine CSEM.. The trend is 3D: EMGS Brazil – multi-client



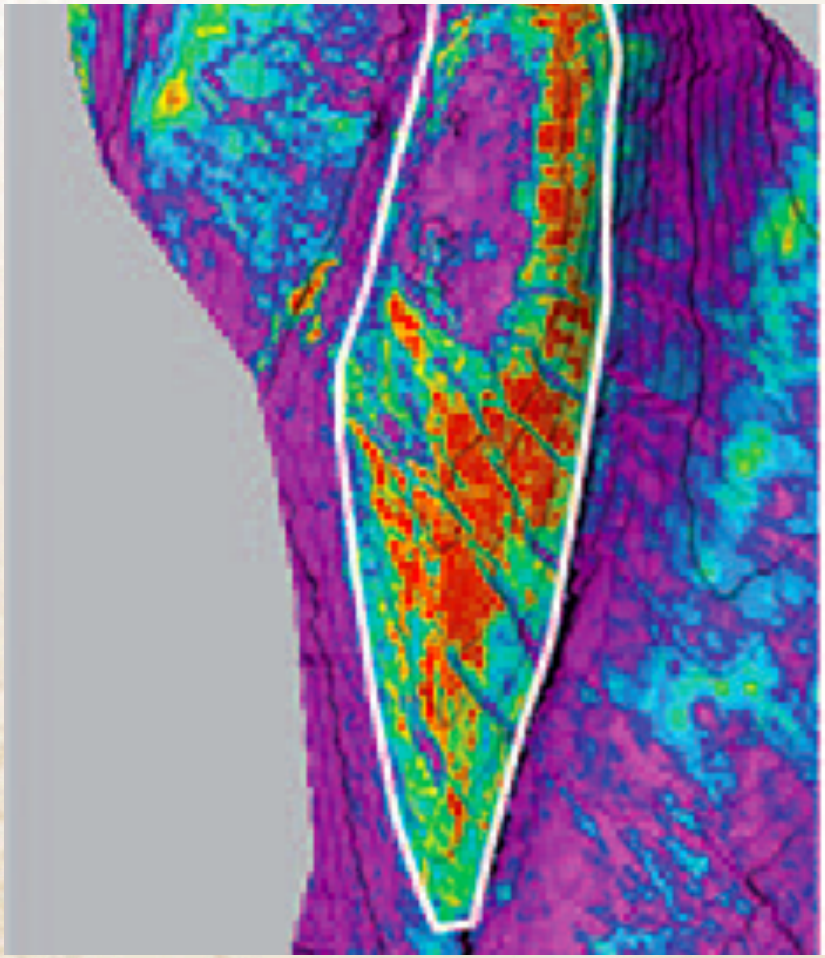


EM DATA OVERVIEW SERGIPE ALAGOAS BASIN

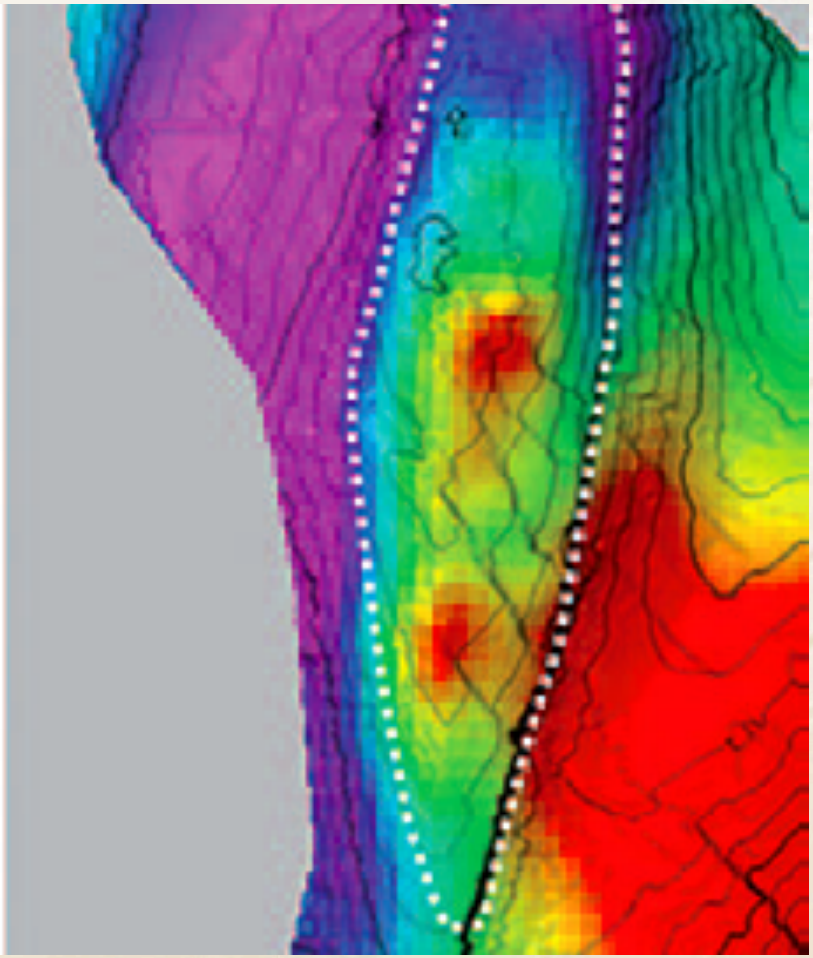


Methods: 3D marine EM compared to seismic

Seismic

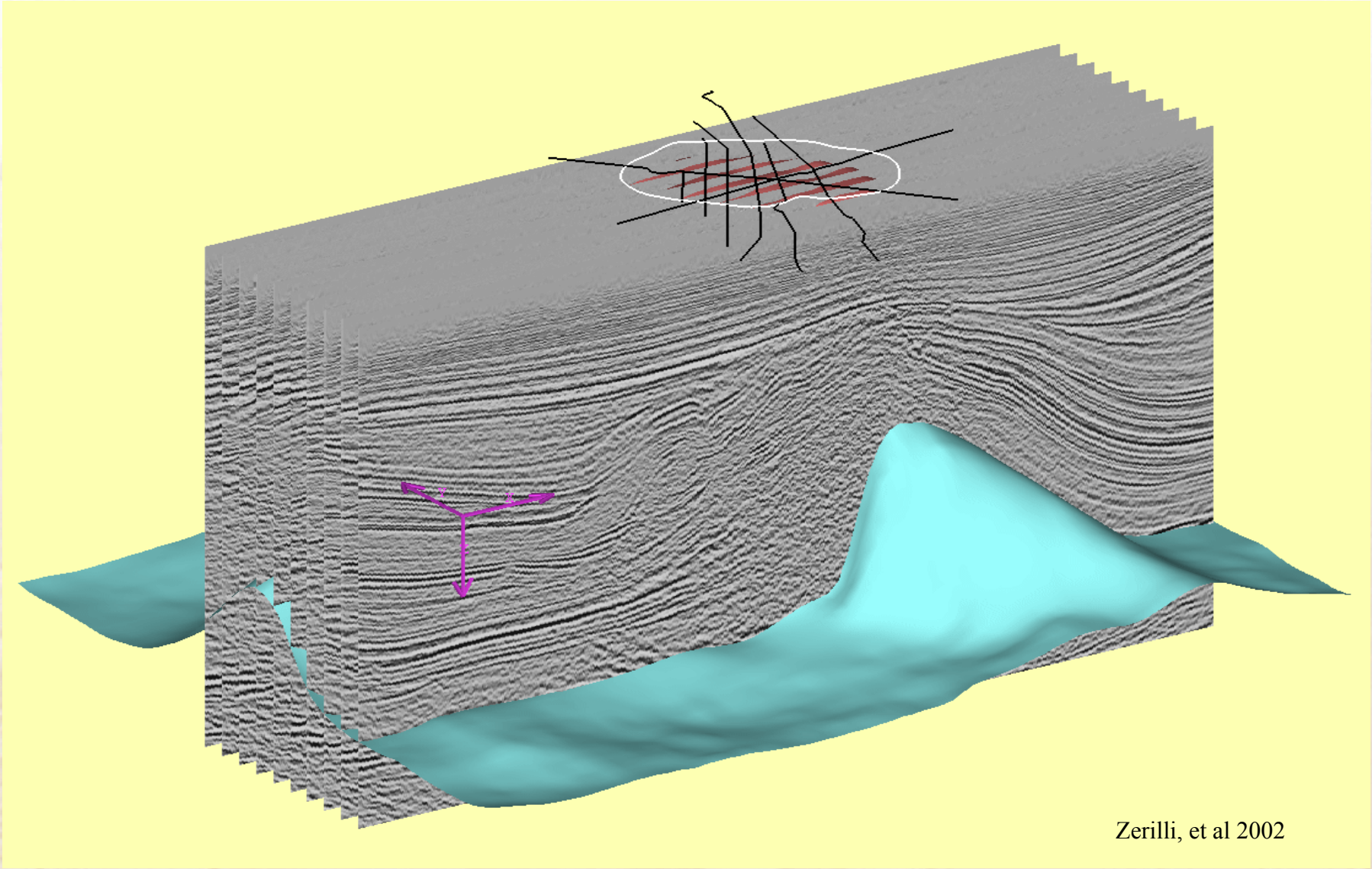


3d CSEM



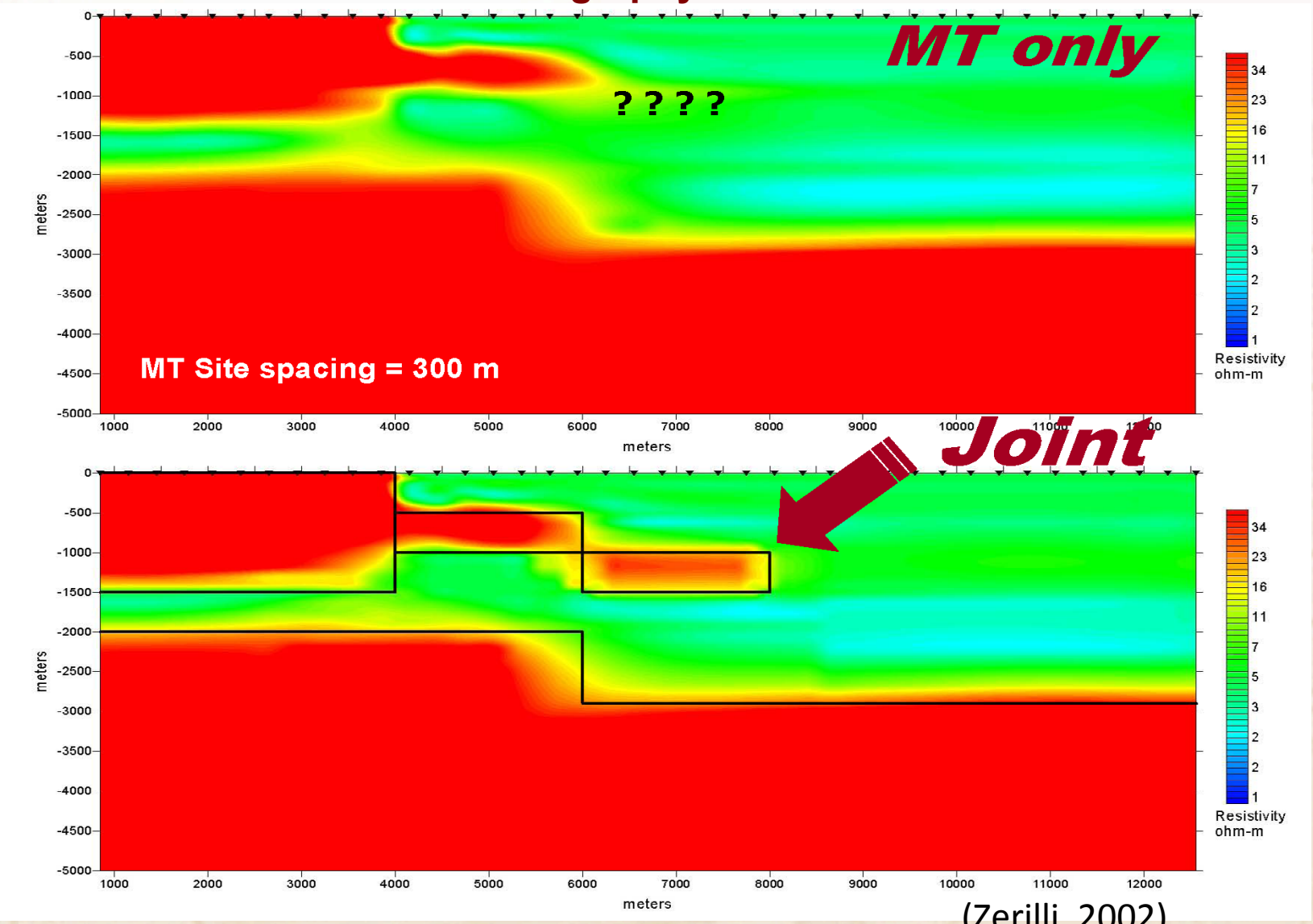
After Alcocer et al. 2013

Land…Dense data (Δx = 50 m) → better images



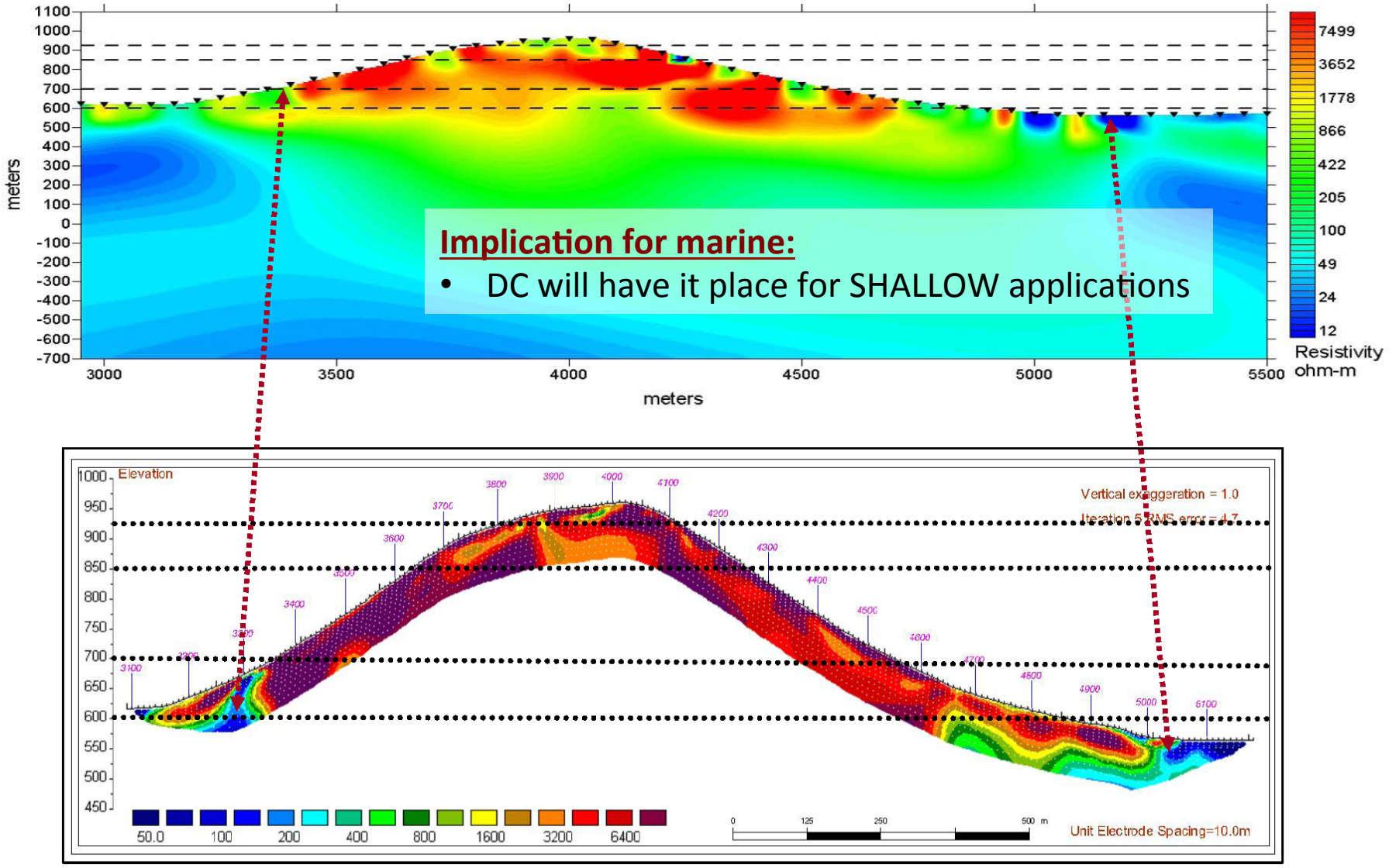
Zerilli, et al 2002

Land…Joint Seismic/EM tomography



(Zerilli, 2002)

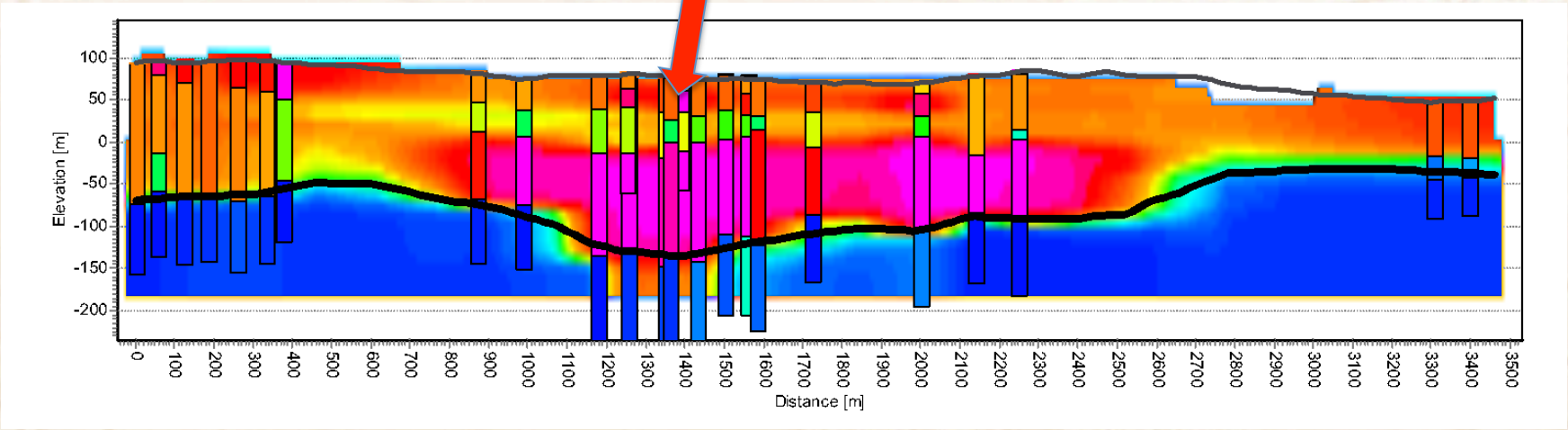
Land…Using High resolution DC for seismic shot point location



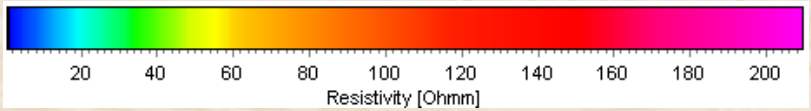
(Zerilli, 2002)

Airborne & Land: First use of Sky TEM for MT statics

TEM inversion



SkyTEM image

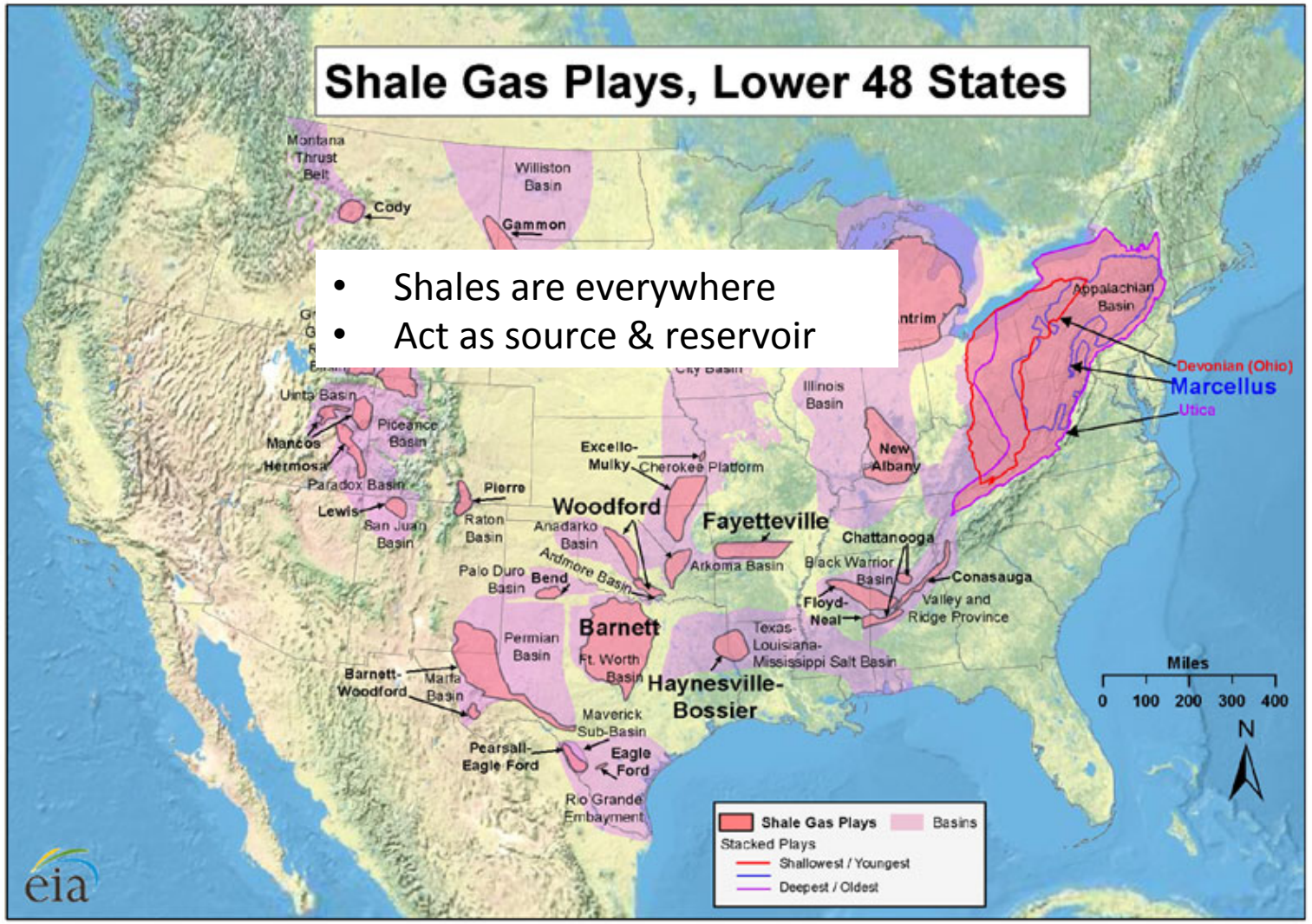


(Zerilli, 2002)

- Borehole: geosteering, look & around bit
- Marine:
  - denser data → images
  - Shallow water
  - Seismic integrated → COST REDUCTION
- Land
  - Integration (seismic, statics etc.).. continuing
  - Shale applications.. novel
  - Monitoring.. in pilot phase

- Borehole: geosteering, look & around bit
- Marine:
  - denser data → images
  - Shallow water
  - Seismic integrated
- Land
  - Integration (seismic, statics etc.)
  - Shale applications
  - Monitoring

Future: Shale is in all transgression/regression & turbidite basins



- Shales are everywhere
- Act as source & reservoir

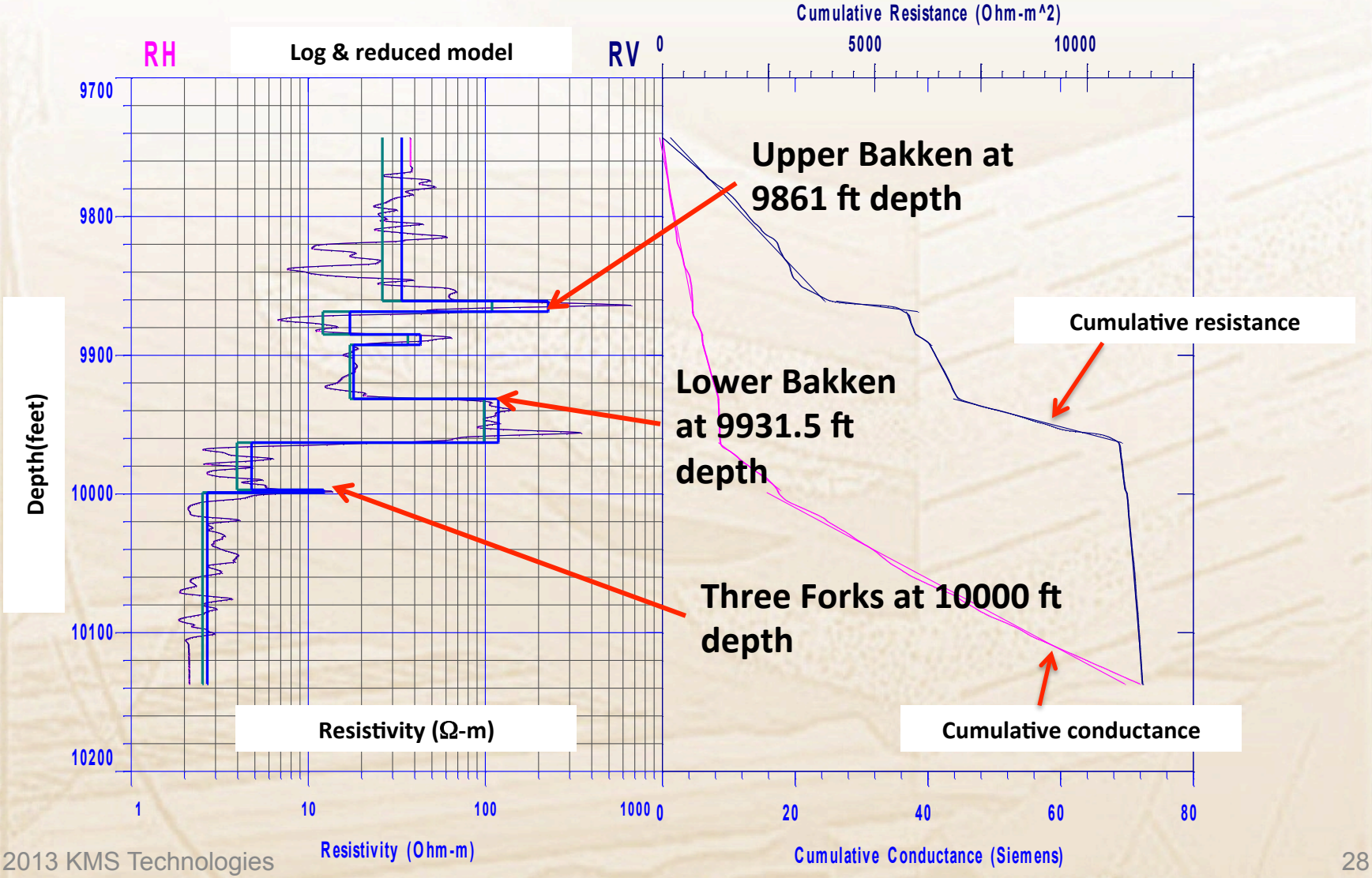
Source: Energy Information Administration based on data from various published studies.
Updated: March 10, 2010

Future -Unconventional resources: issues translated to EM geophysics

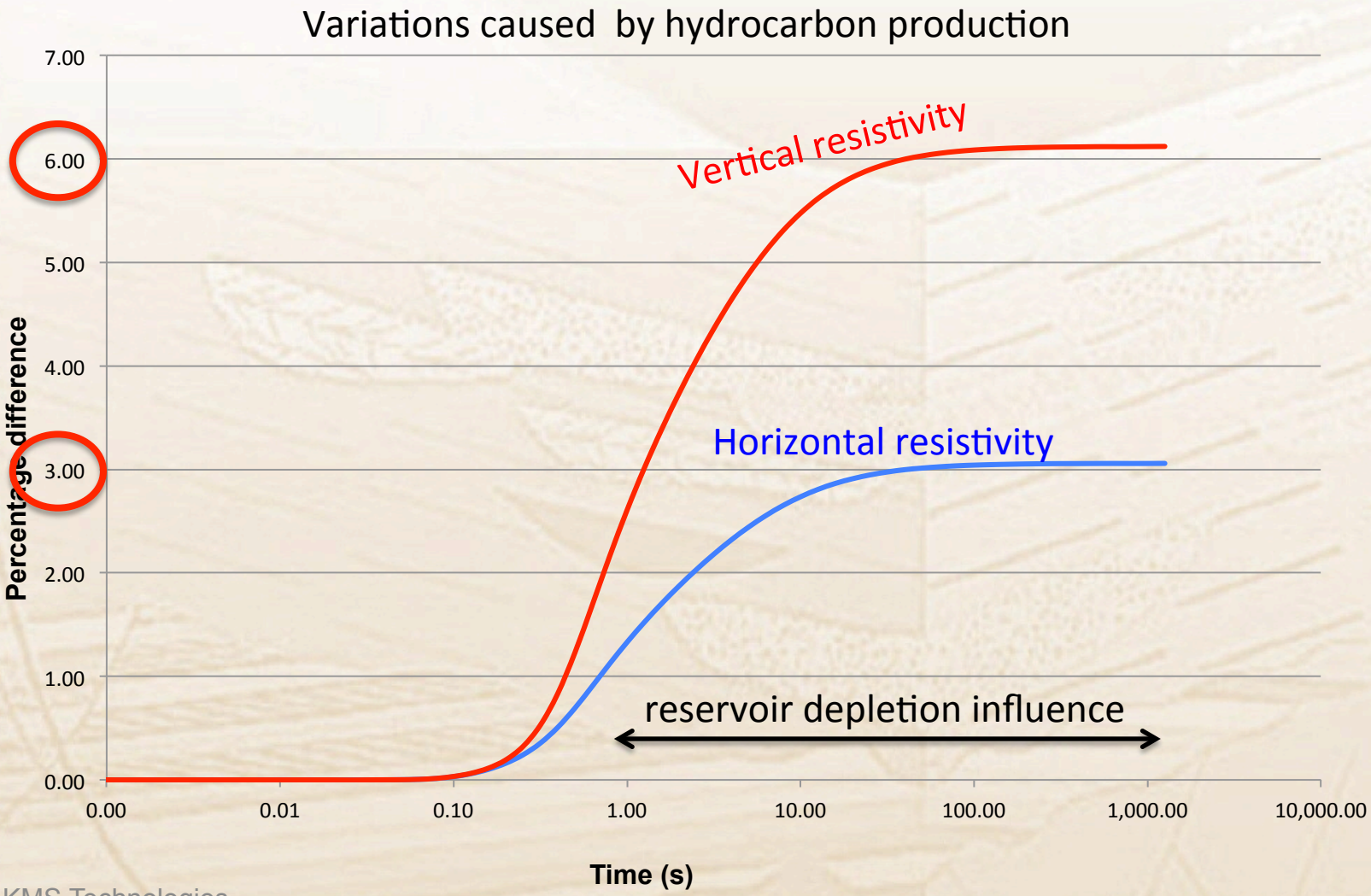
- Shale gas/oil
  - Oil/gas is inside shales – **Resistor in a conductor**
  - Reservoirs are thin – **Thin resistive layer effect – DHI for surface data, 3D induction log for well**
  - Low porosity/perm. → fracturing **Larger volume**
  - Drilling → horizontal / highly deviated wells - **geosteering**
  - Fractures → anisotropy – **3D EM anisotropy**
- Geothermal
  - Heat source & reservoir **- conductors**

Future: Shale resources: From a log to an anisotropic model

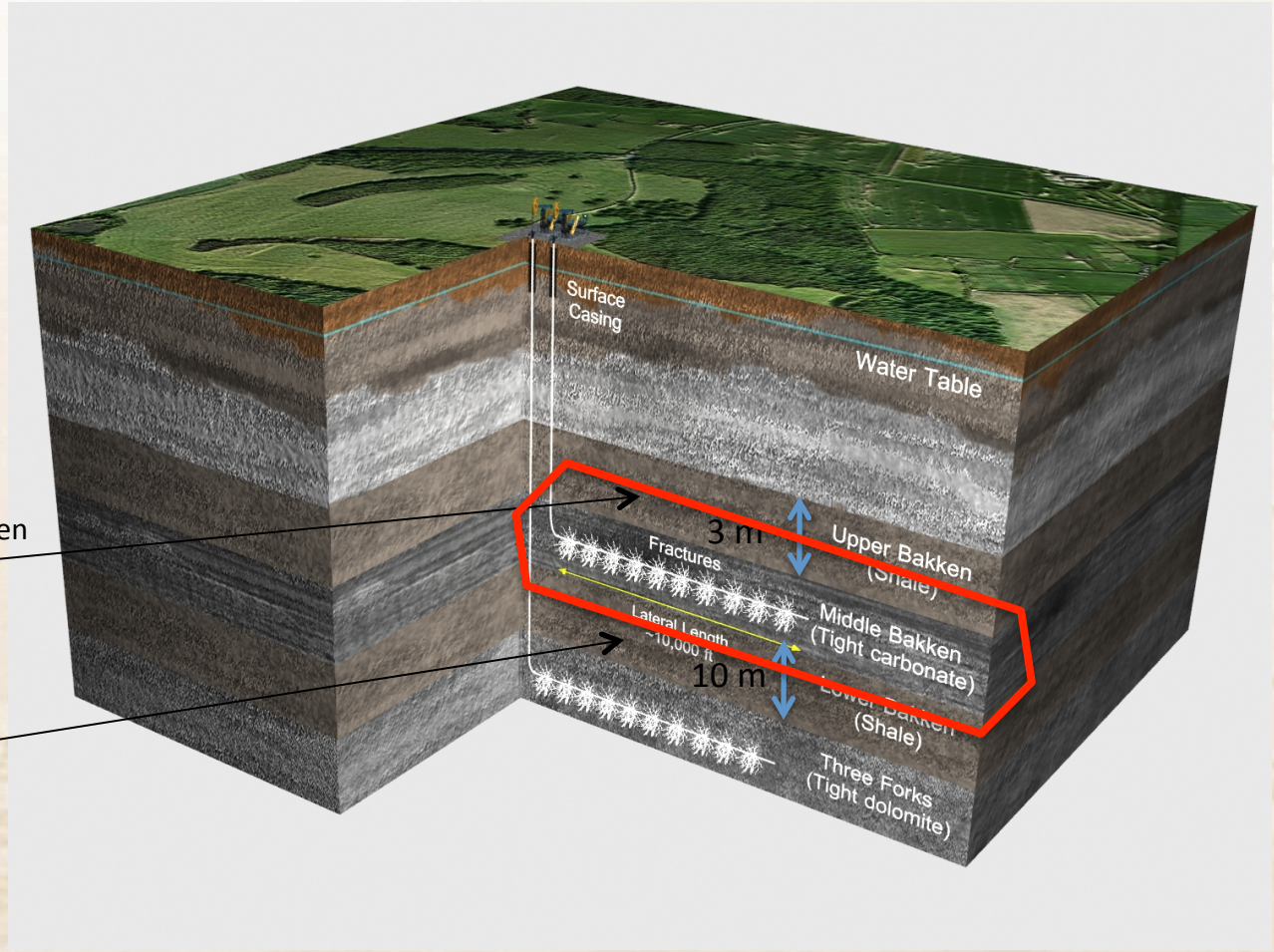
Log data courtesy of Microseismics Inc.



Future: Shale resources: CSEM time lapse: before & after production

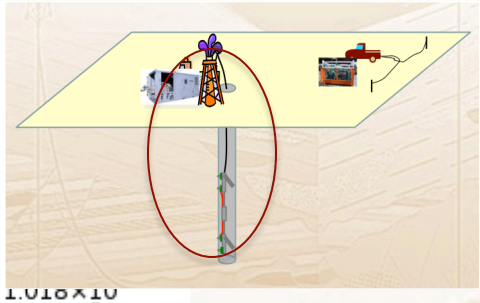


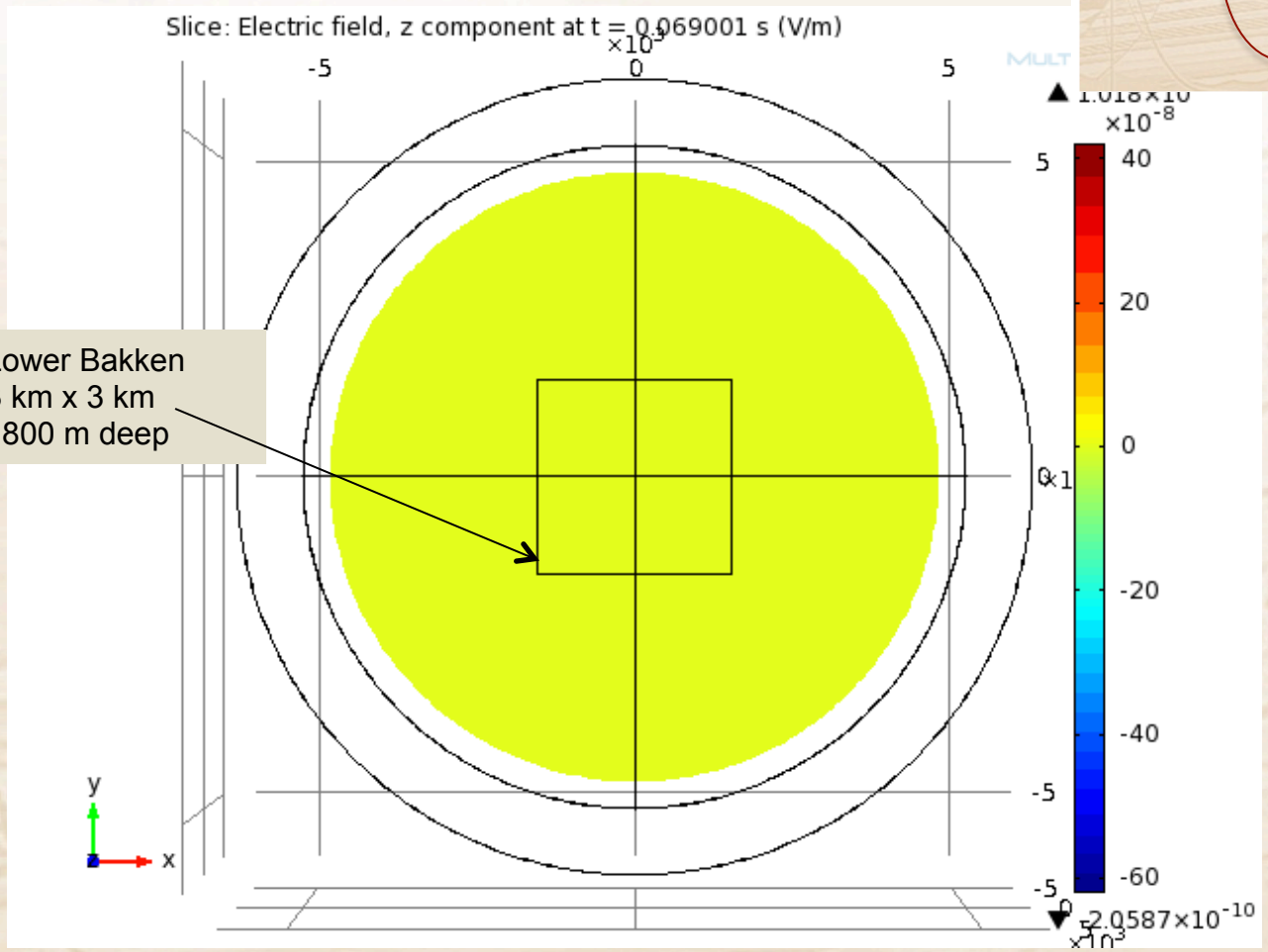
Future: Shale resources: Bakken simulating FRACTURE monitoring



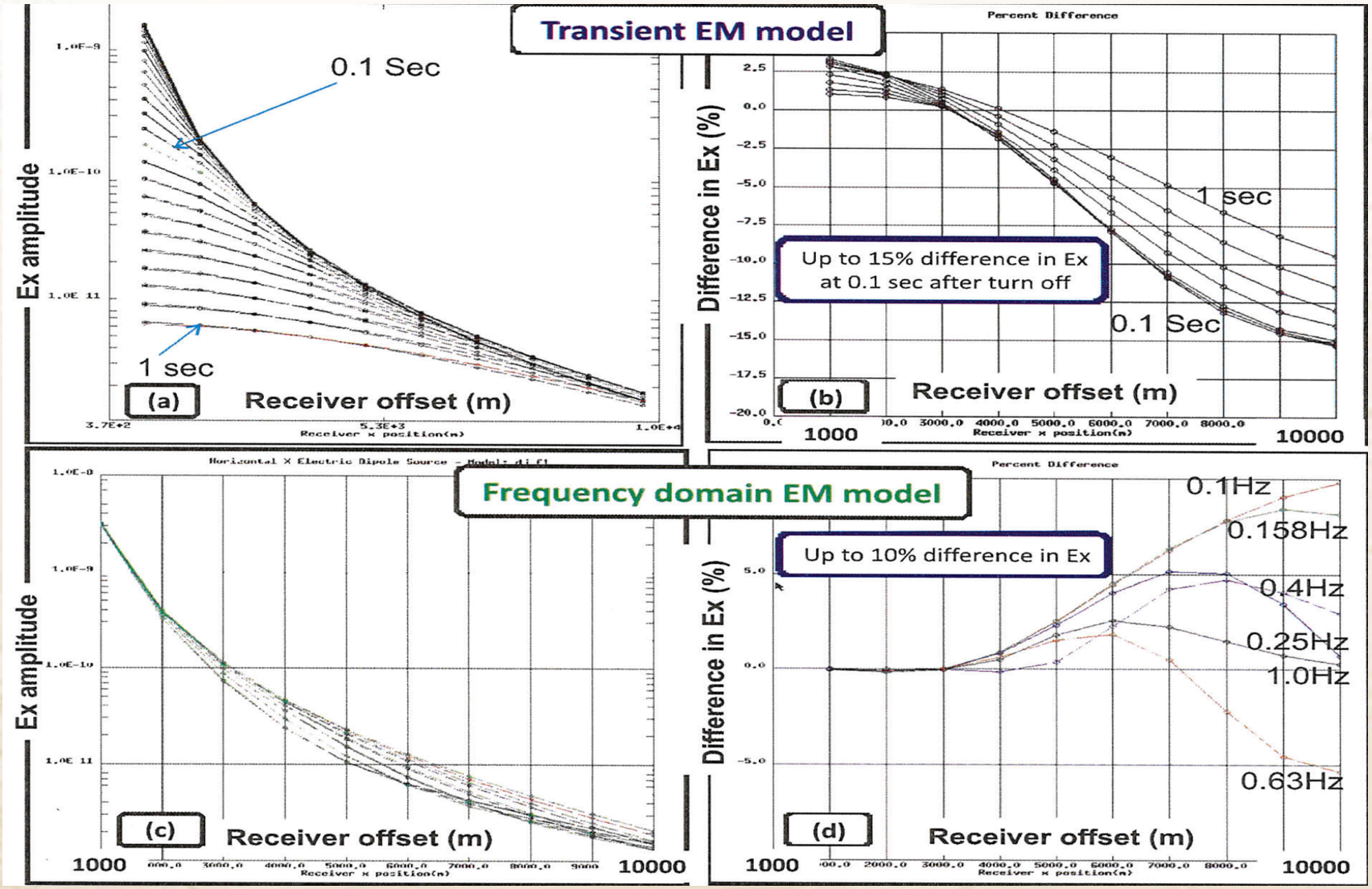
http://www.statoil.com/en/NewsAndMedia/News/2011/Pages/XXX16Oct2011.aspx

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



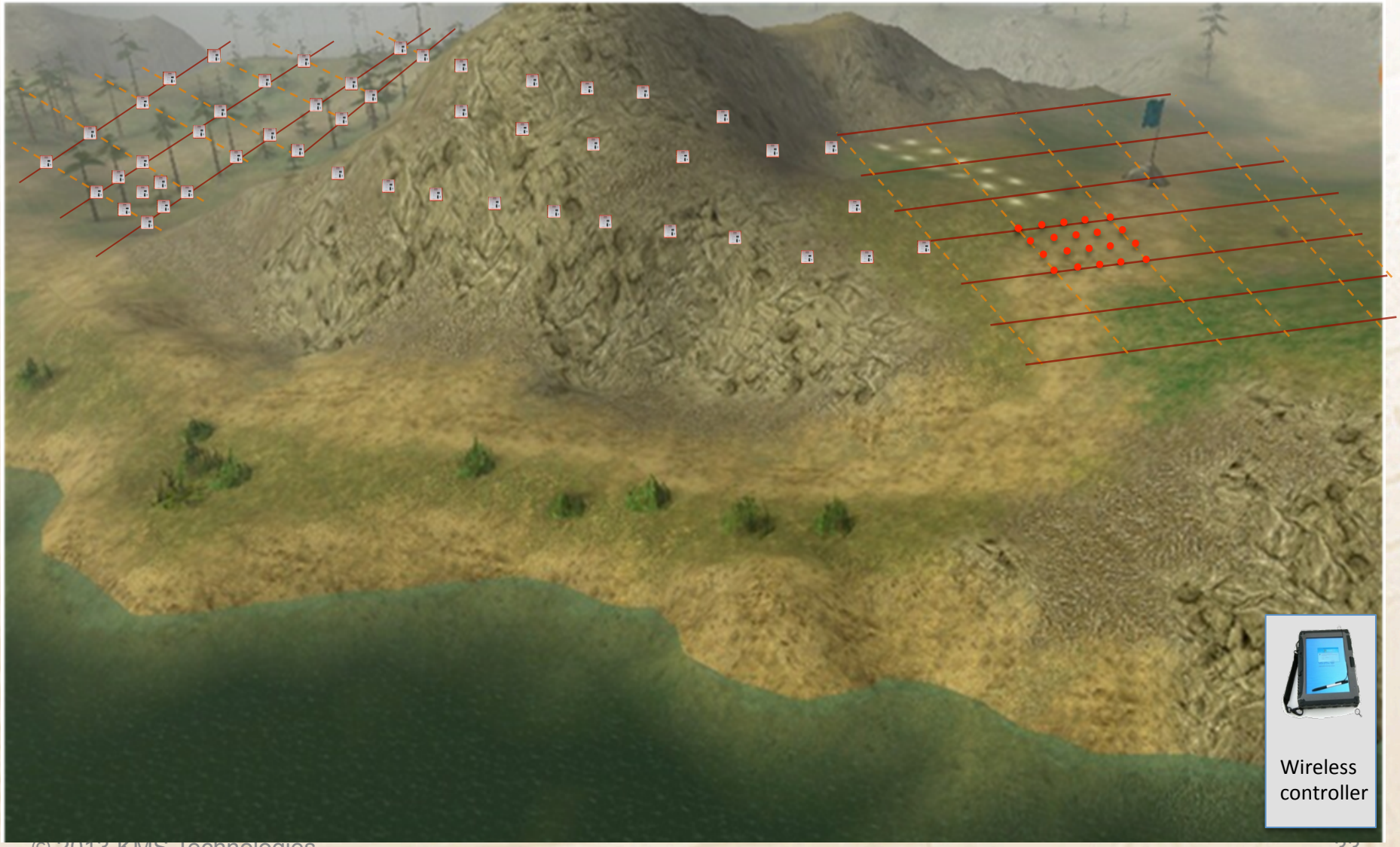


Future: Shale resources: Chevron Haynesville study



(after Kumar & Hovesten, 2012)

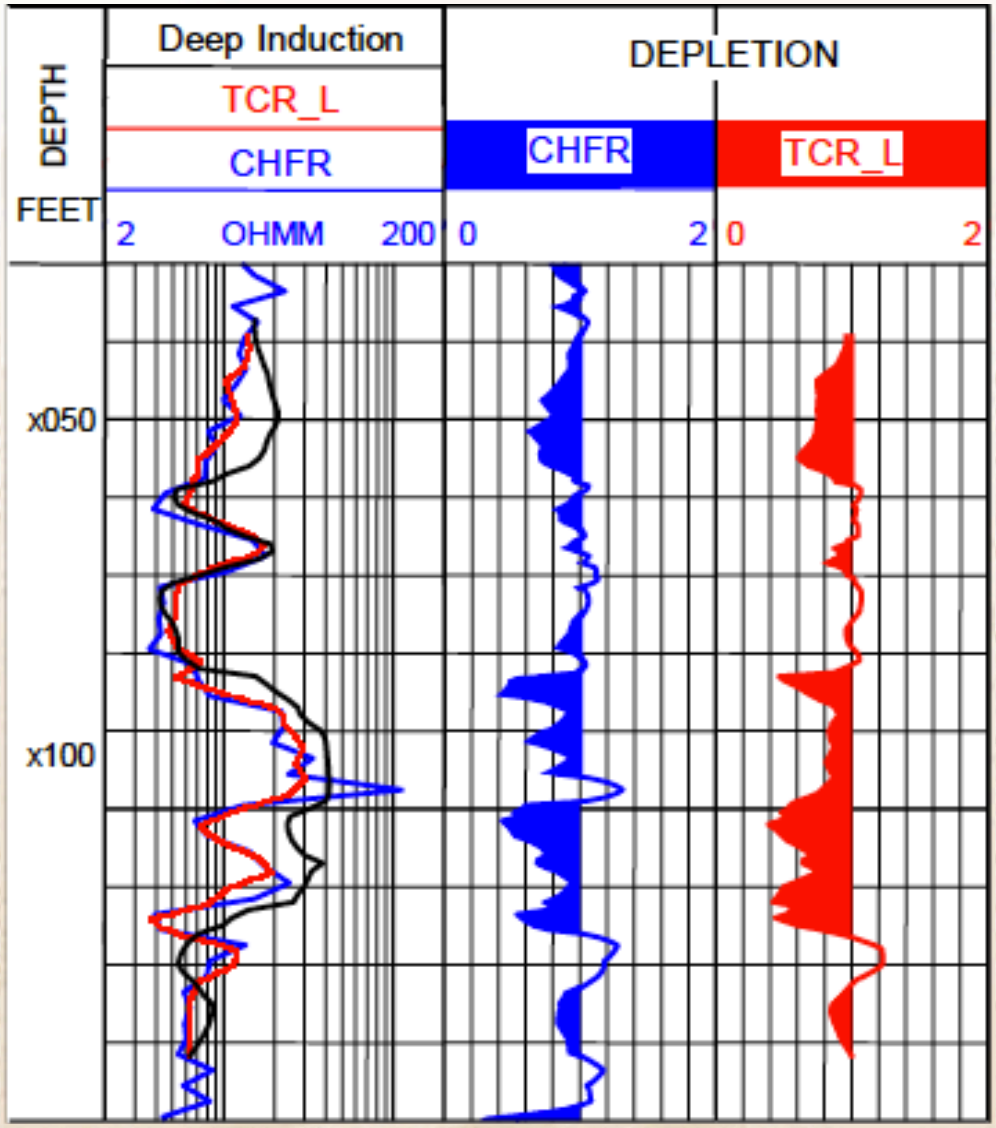
Future: Shale resources: New ARRAY acquisition → better images



Future: Shale resources: New ARRAY acquisition → better images

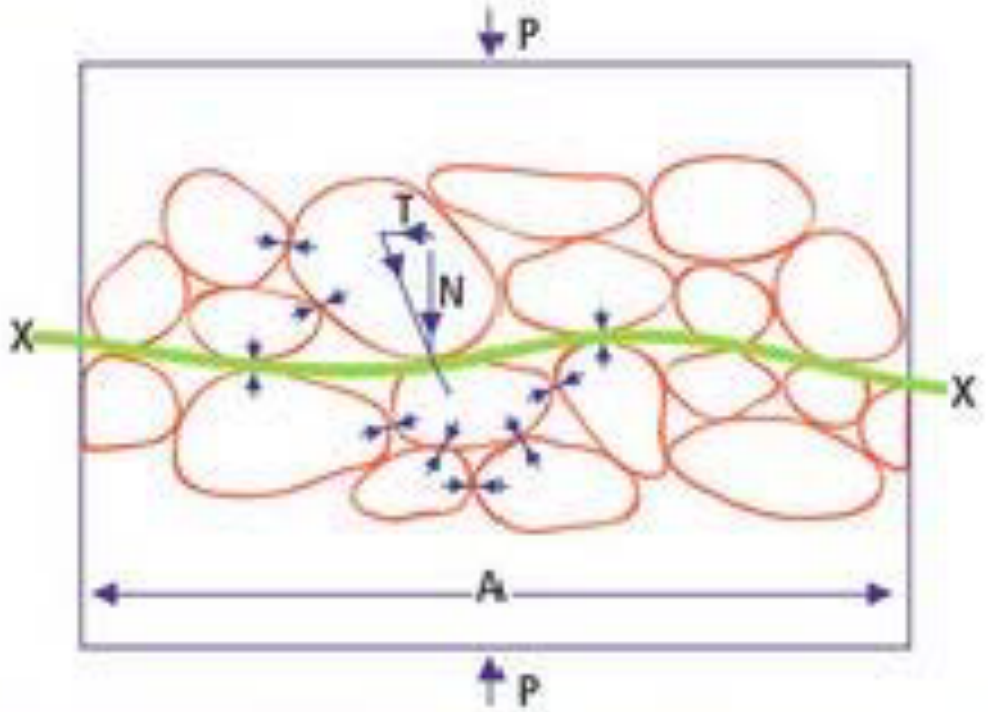
- Wireless
- True array system
- Large dynamic range
- High bandwidth

Future: Monitoring: DO WE HAVE RESISTIVITY CHANGES



Zhou et al., 2002)

Reservoir monitoring: Seal integrity: EM & microseismic



- Overburden & fluid stress in balance
- When fluid pressure too high →quick sand
- Seal BRITTLE → porosity reduction → resistivity increase
- Seal FRACTURE →porosity increase→ resistivity increase
- Microseismic signature from fracturing
- EM responds to fluid movements →
- EM signature from brittle & fracturing

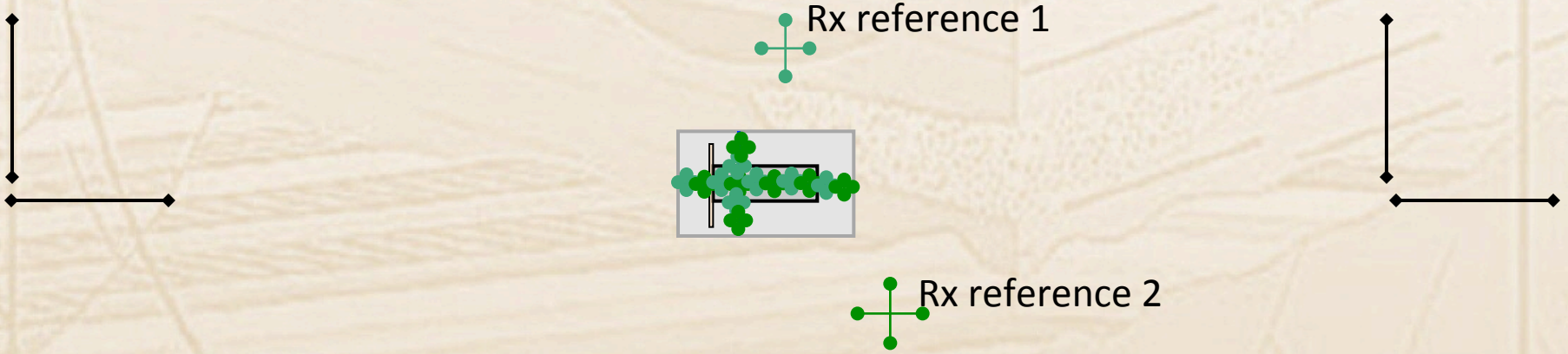
After Carlson, 2013

MONITORING survey layout: transmitter & receivers

- Transmitters only for baseline
- Consecutive survey may use subset transmitters

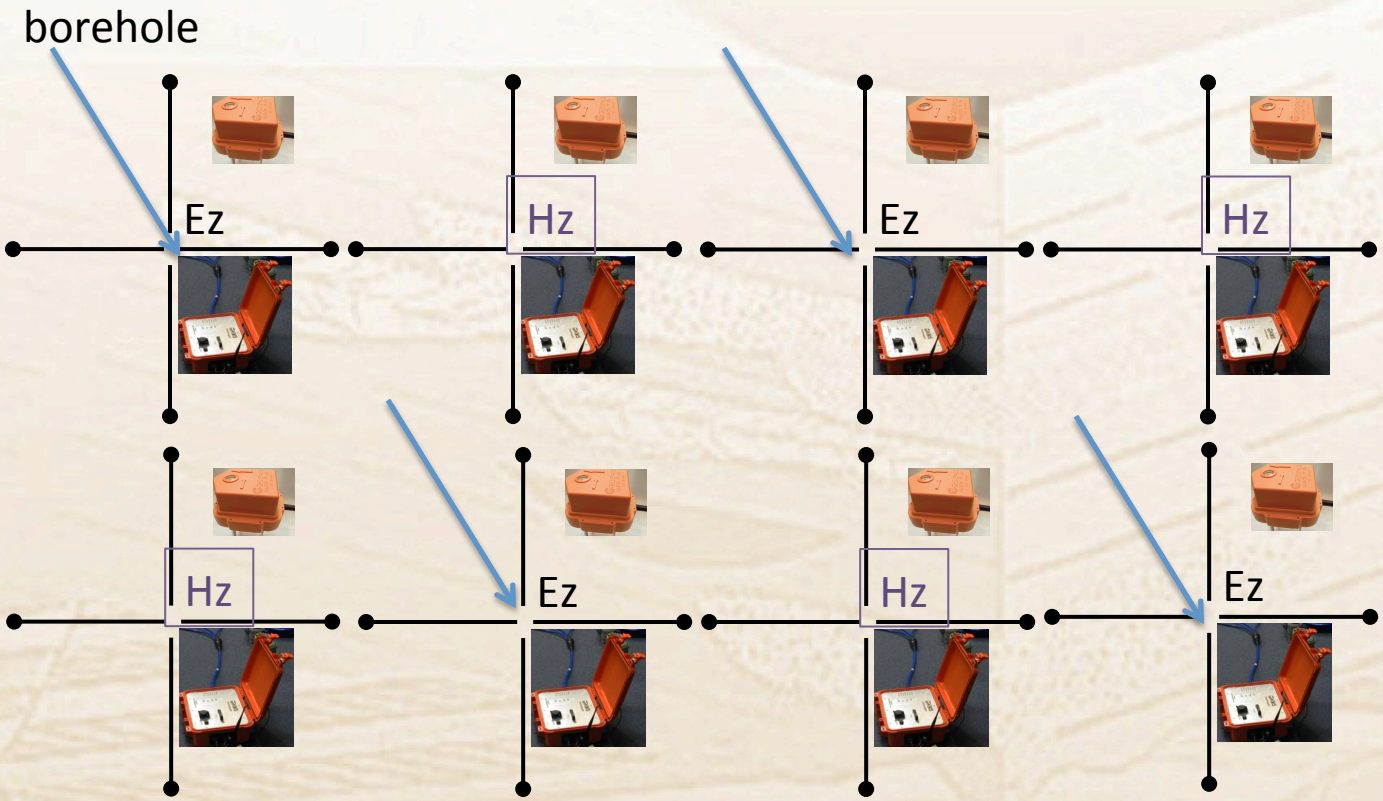
Tx length 500 m

offset 2400 m

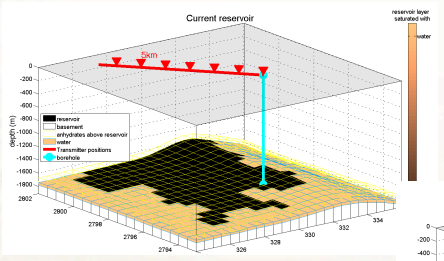


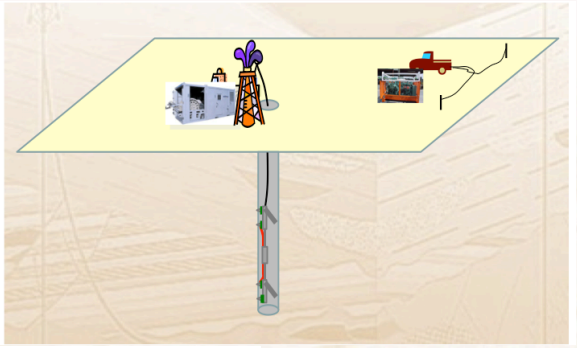
PTTEP PILOT layout for KMS820 receivers

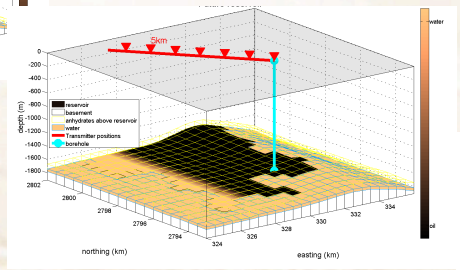
2 electric fields Ex,Ey; alternate Ez in shallow borehole or Hz; 3c geophone/microseismic every site.

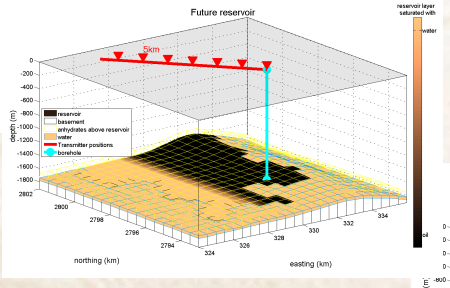


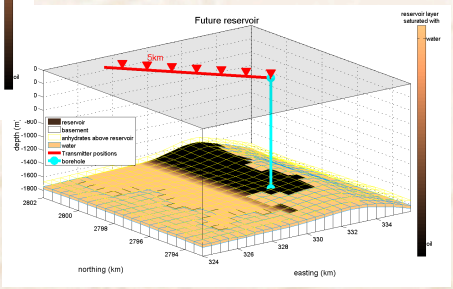
Future: Monitoring: Ghawar field: ADD BOREHOLE: Integration!

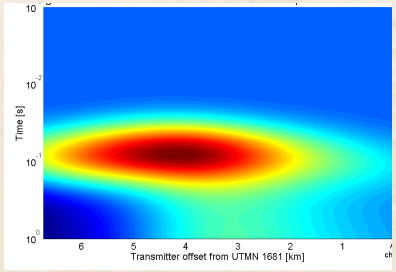


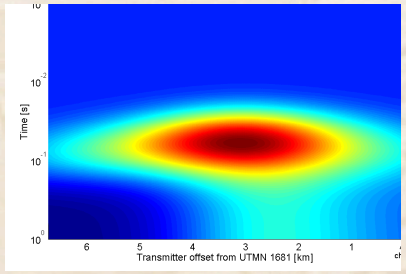


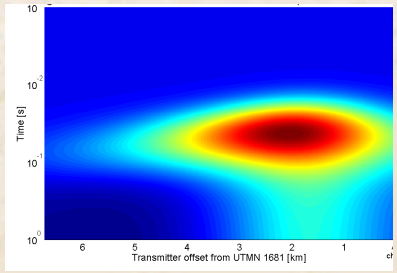


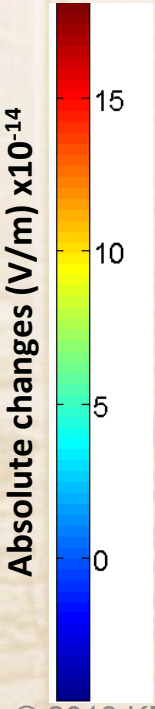












Period of 5 years

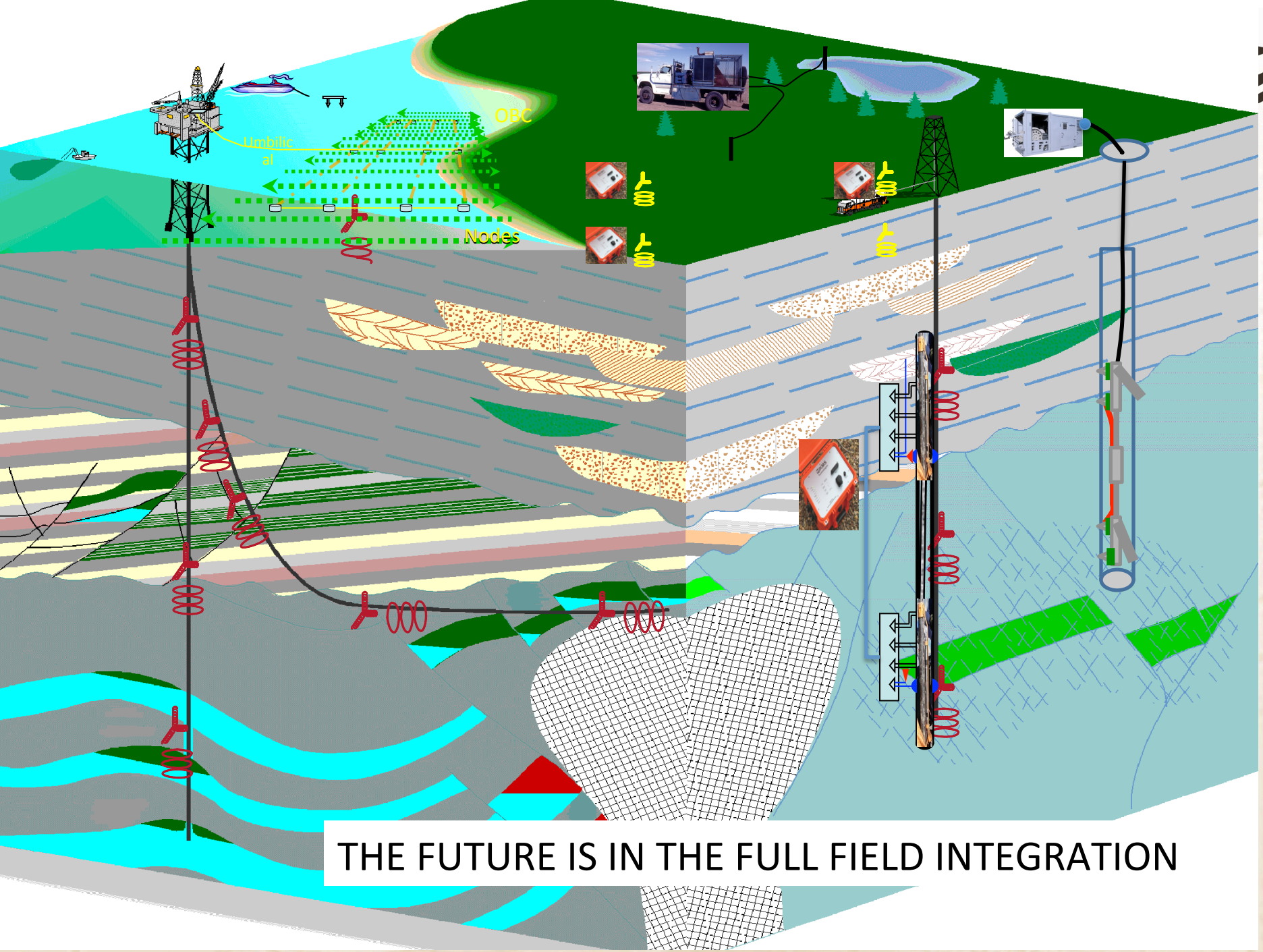
After Colombo et al. 2010

- We can make TENSOR measurements
  - Borehole
  - Surface and surface-to-borehole
- 3D inductions is available from all logging contractors.
- Marine EM success has confirmed EM use.
- Lower cost novel hardware is becoming available

Summary

- 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 studies are needed!**



THE FUTURE IS IN THE FULL FIELD INTEGRATION

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