KMS Technologies

Upscaling/Calibrating Resistivities from borehole-to-surface

K. Strack and S. Davydycheva

2018

SEG Summer research workshop , Galveston

FOR SELF STUDY ONLY

>20 years of excellence in electromagnetic R&D

Upscaling/calibrating Resistivities from Borehole-to-Surface

'The need for more geophysics tool'

SEG RC

K. Strack & S. Davydycheva

KMS Technologies, USA, info@KMSTechnologies.com

August 2018

www.KMSTechnologies.com

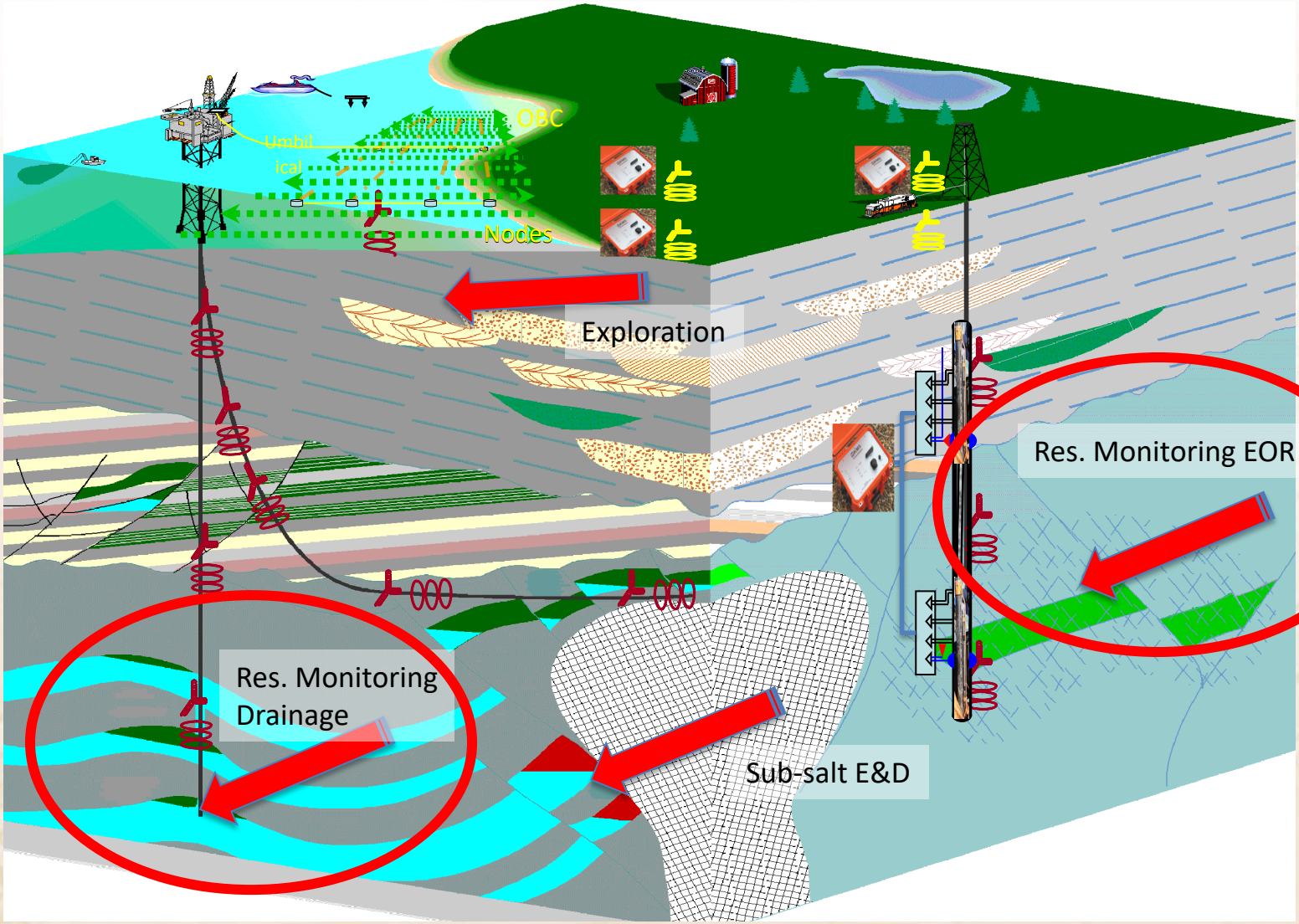
Upscaling → Emerging EM Imaging opportunity
Some thoughts…

- Resistivity/induction logs often used for 4D correlation
  - WHY? – deep depth of penetration
- STANDARD Resistivity logs read APPARENT resistivities (except for 3D induction)
- Electrical measurements best for fluid imaging
- Surface EM adds value but not enough to grow market!
- Borehole EM essential for reserve estimates

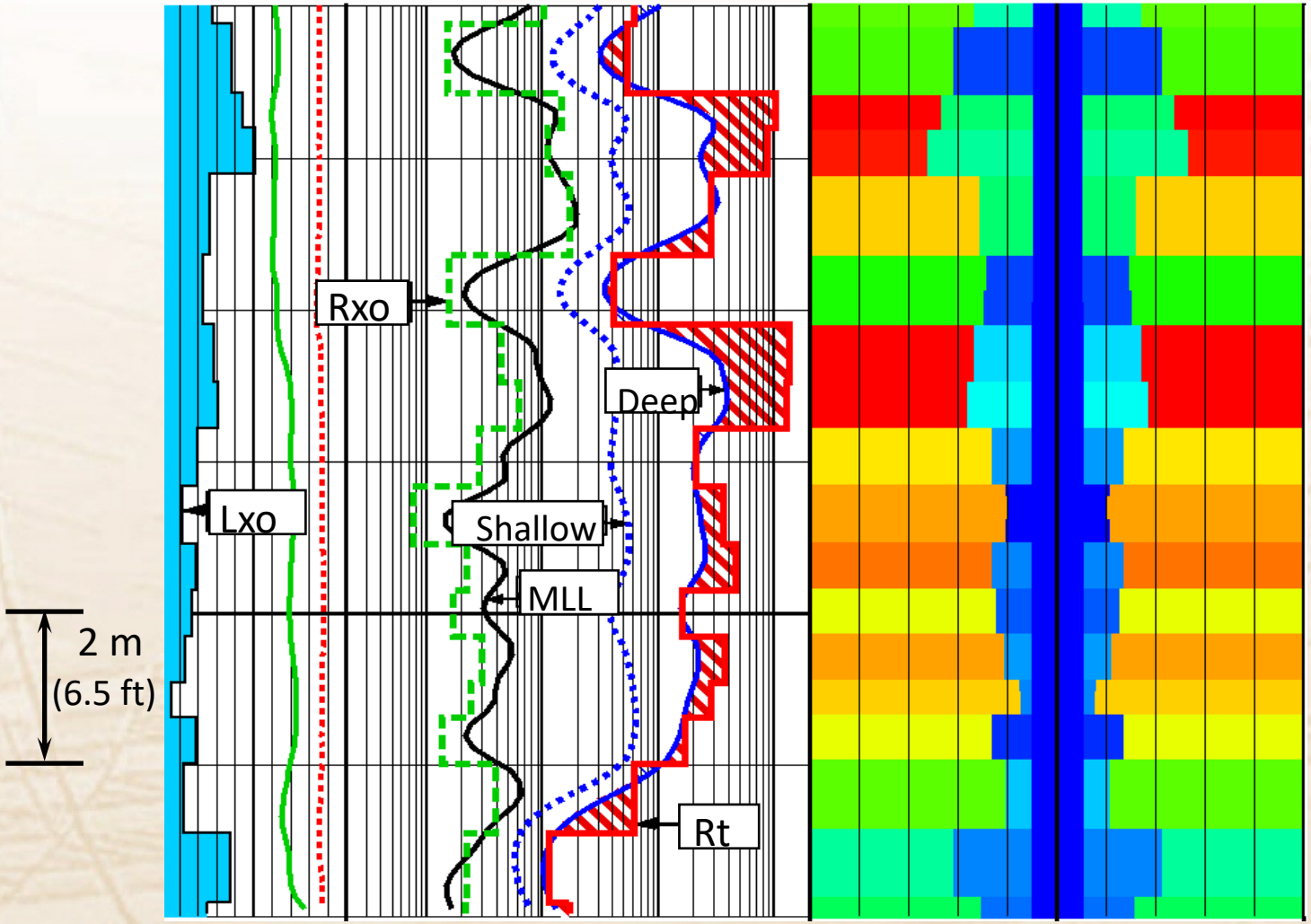
Upscaling → Emerging EM Imaging opportunity
What are the issues

- Surface measurements MUST be calibrated against logs (mostly only 'eyeballed')
- Model MUST be backed by 3D & full anisotropy
- Errors MUST be understood
- →→ justify acquiring more data; better fluid imaging, better reserve estimate

Background >>> Borehole >>> Calibration >>> Example
High value APPLICATIONS – LOW to HIGH – TECHNICAL driven

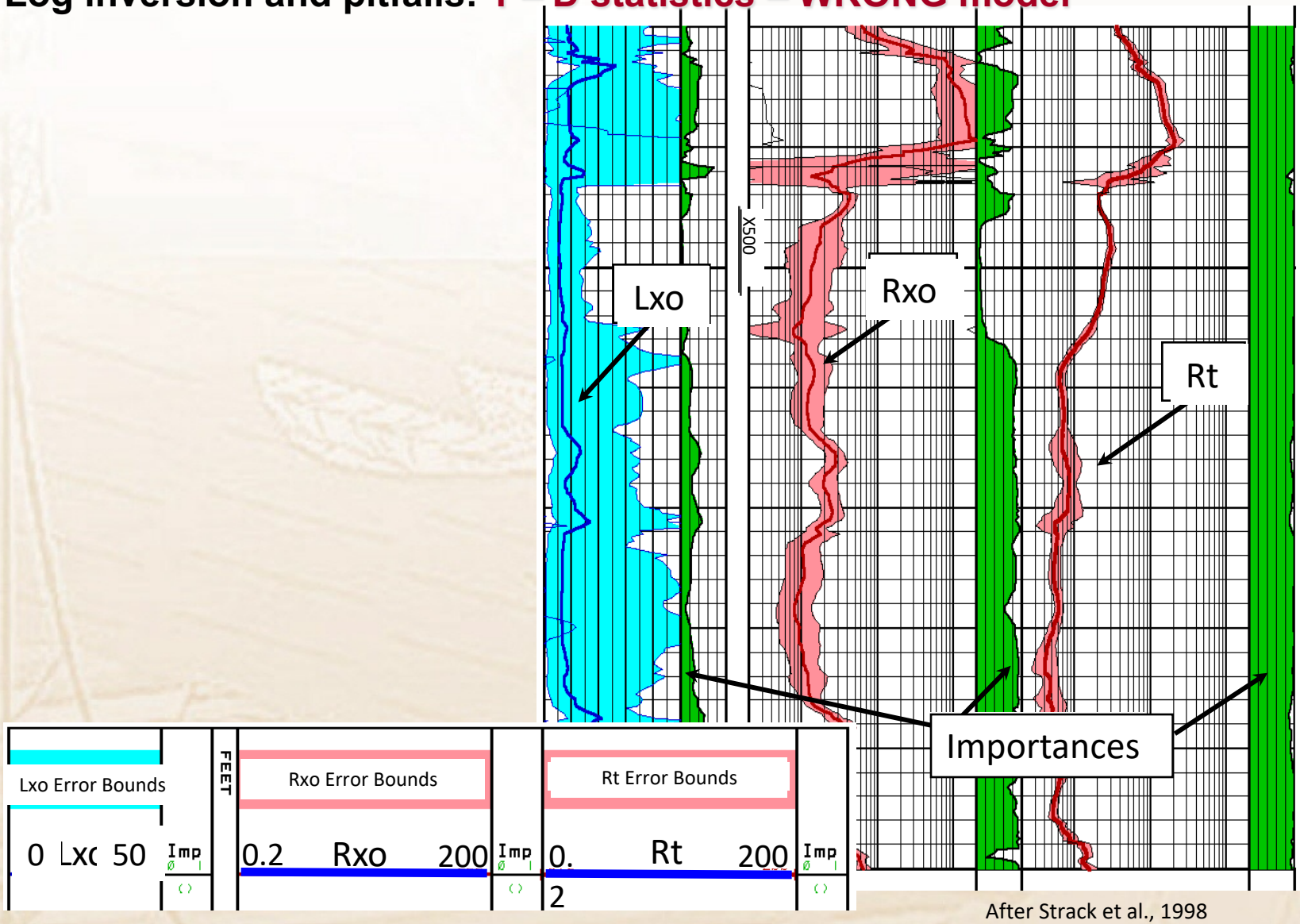


Log inversion and pitfalls: underestimating oil reserves



After Strack et al., 1998

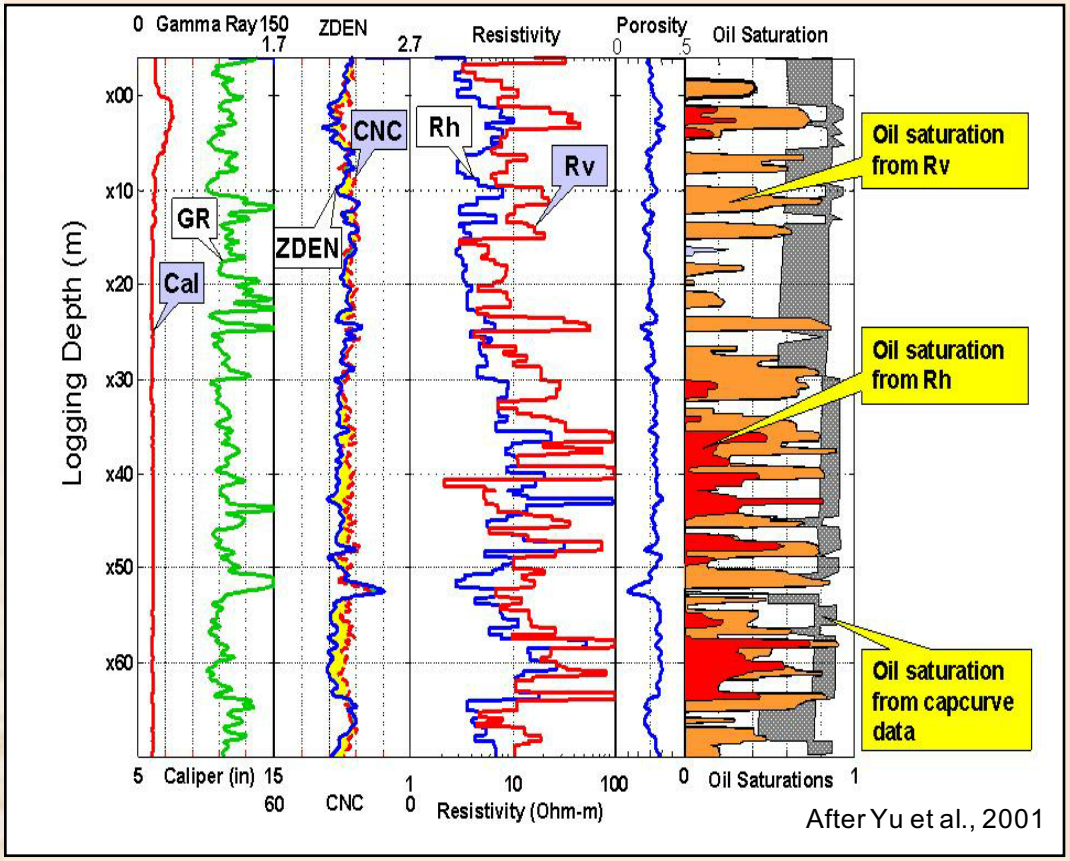
Log inversion and pitfalls: 1 – D statistics – WRONG model

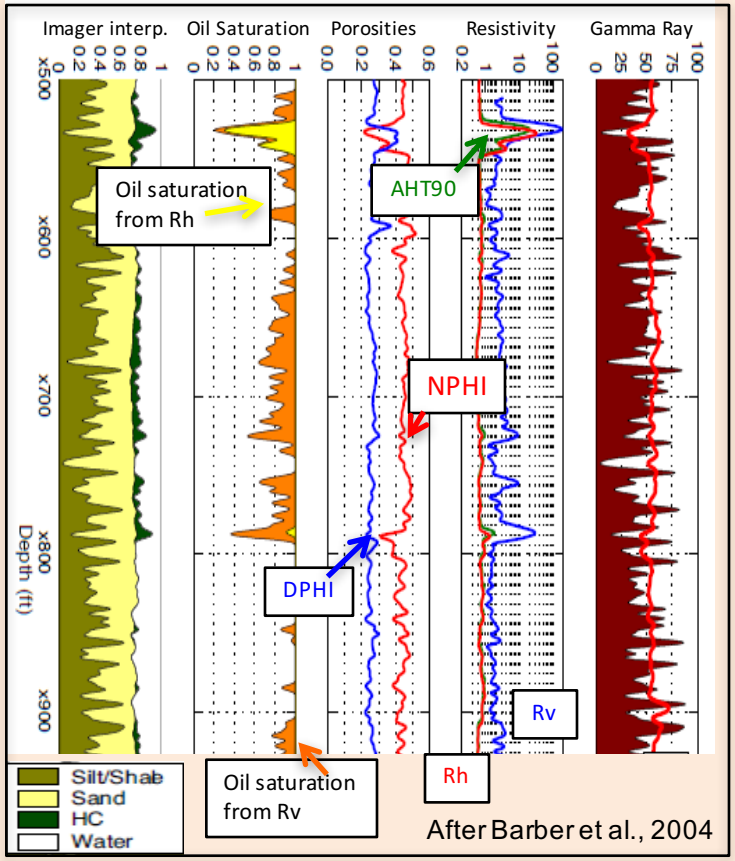


After Strack et al., 1998

Key issues limiting success I – how much error can we see

Anisotropy - > 40% improved Oil-in-place (OIP)



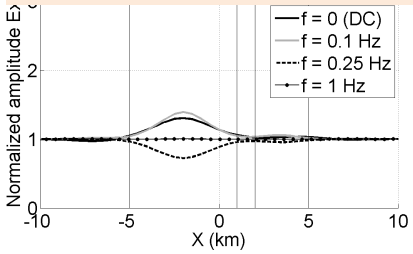


Courtesy Baker Atlas

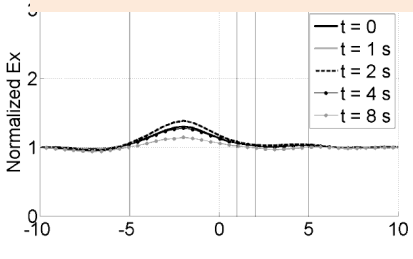
Limits in calibration & solution

CSEM versus Focused Source

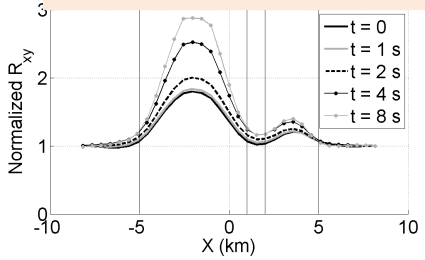
Frequency domain CSEM



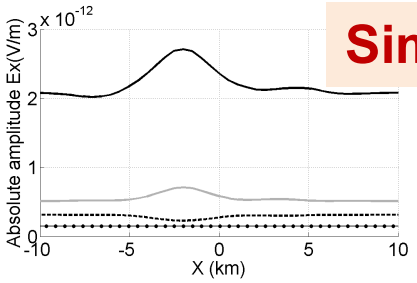
Time domain CSEM

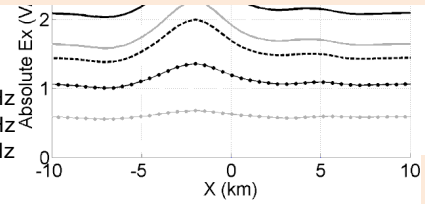


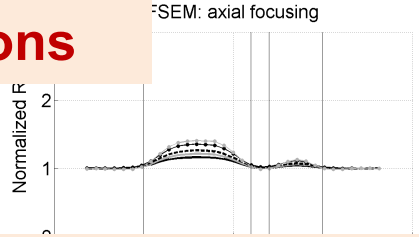
Focused Source EM

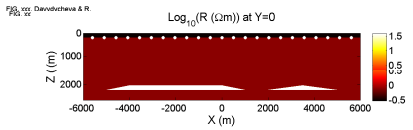


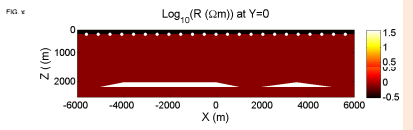
Similar to our observations











- Smaller reservoir can be detected
- Higher spatial resolution
- Shallow structure removable
- Shallow structure removable

fCSEM & tCSEM: Anomaly: 40% - 10%

FSEM: Anomaly: 200% - 40%

Rykhlinskaya, E., & Davydycheva, S., 2014, U.S. Patent 8,762,062 B2.
Davydycheva, S., 2016, U.S. Patent Application US 2016/0084980 A1.

Overall Workflow leading to design of specific reservoir

Deliverables & objectives

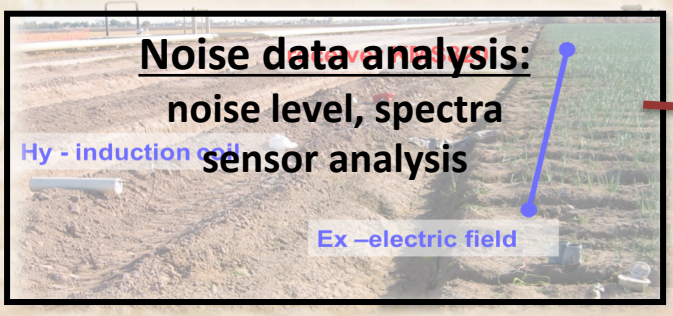
3D Feasibility & noise test

Input data:
well log data
geologic information
seismic horizons
noise measurements

Verification 3D modeling benchmarks

Define target variations

Resolution study

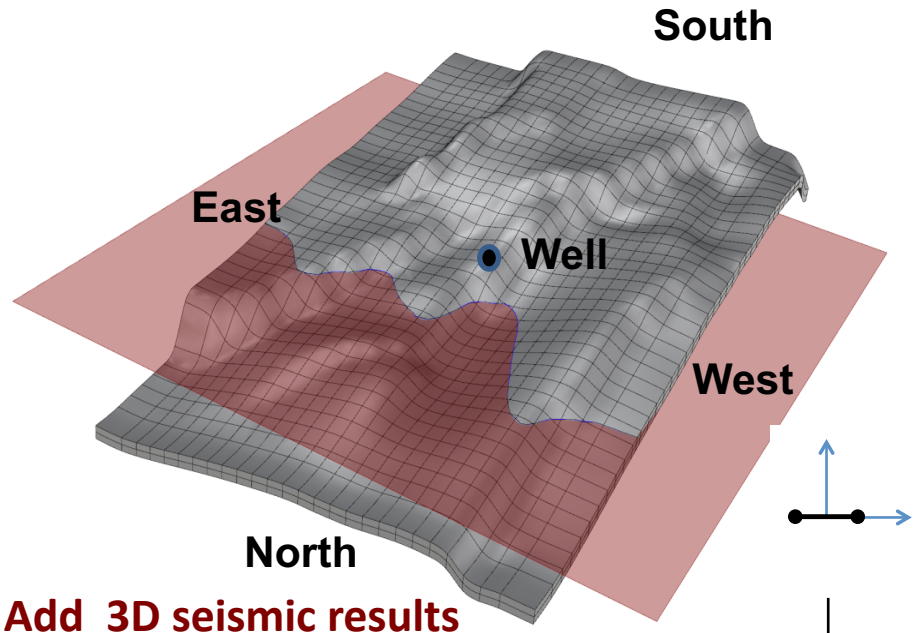


Pilot design:

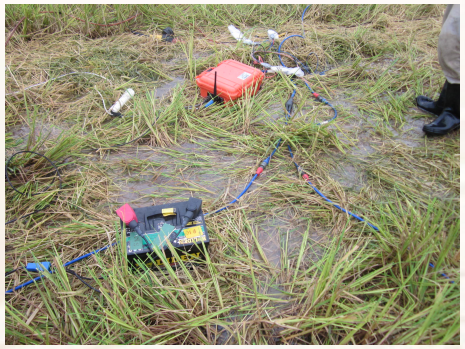
Sensors & methods

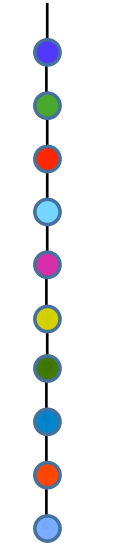
SYSTEM DESIGN

Example Asian oil field: 3D reservoir Feasibility

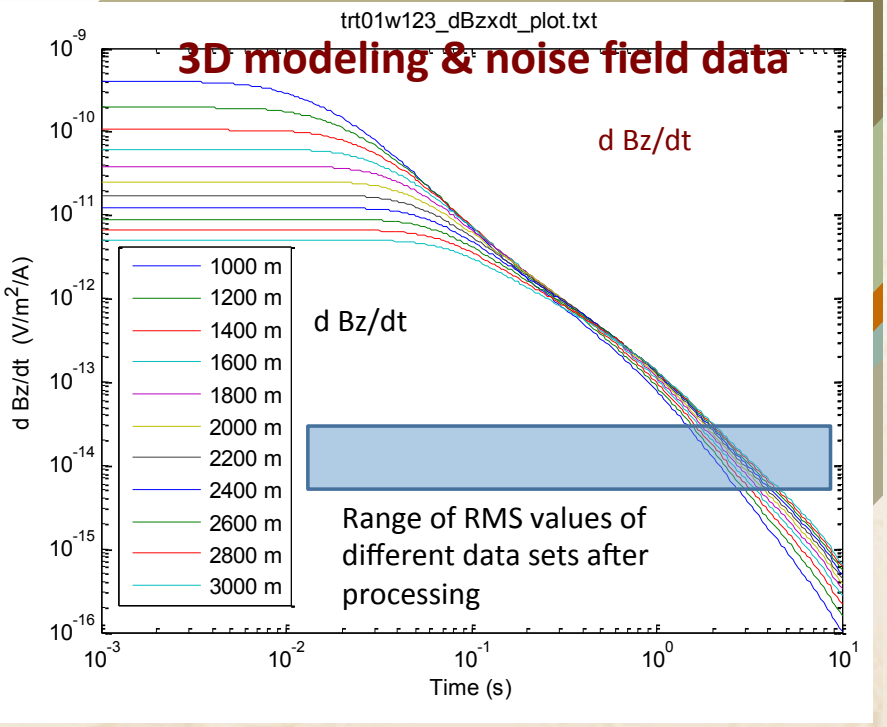


Add 3D seismic results

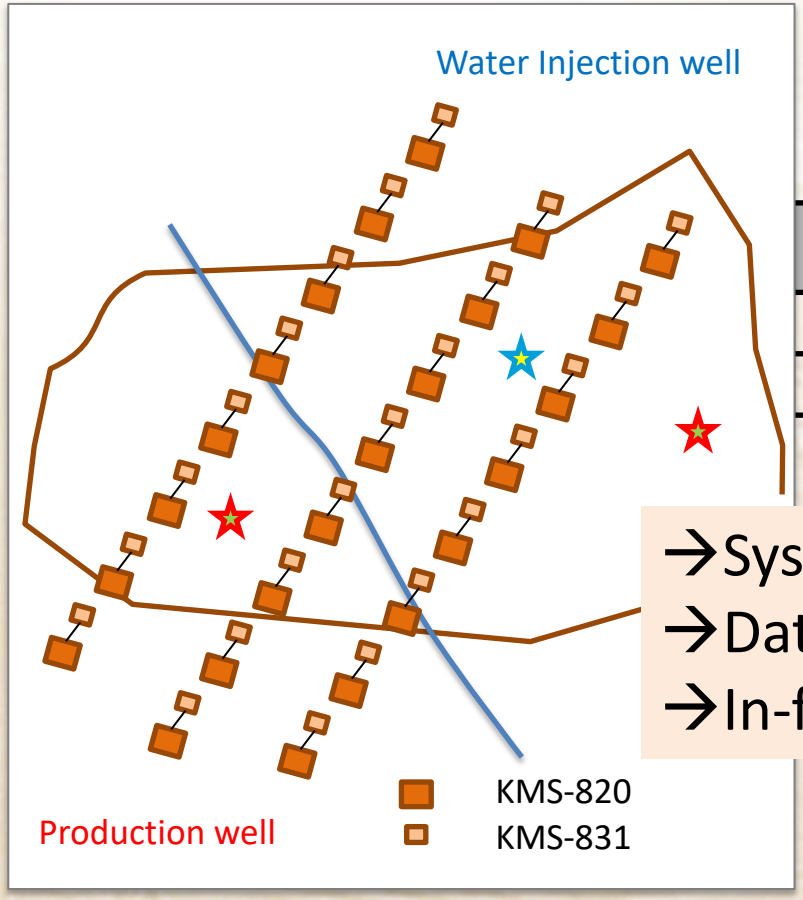




3D modeling & noise field data



Example layout



Microseismic sensors

Site	KMS instrument	Ex & Ey	Hz	3C fluxgate H	3C geophone	SH borehole
■	820	x	x	x	x	X
▪	831	x			x	

→System hardware
→Data storage/telemetry
→In-field processing design (QA)

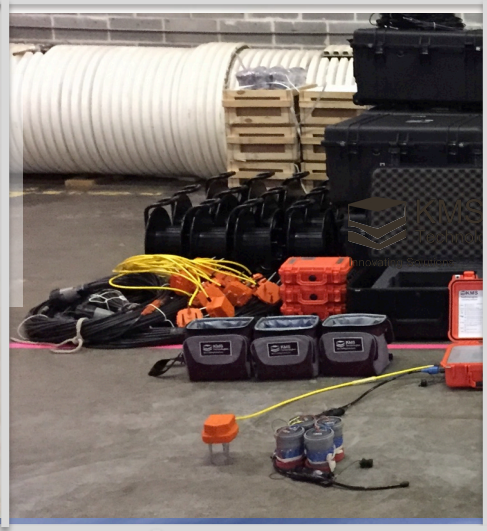
ensors

195 channel monitoring system

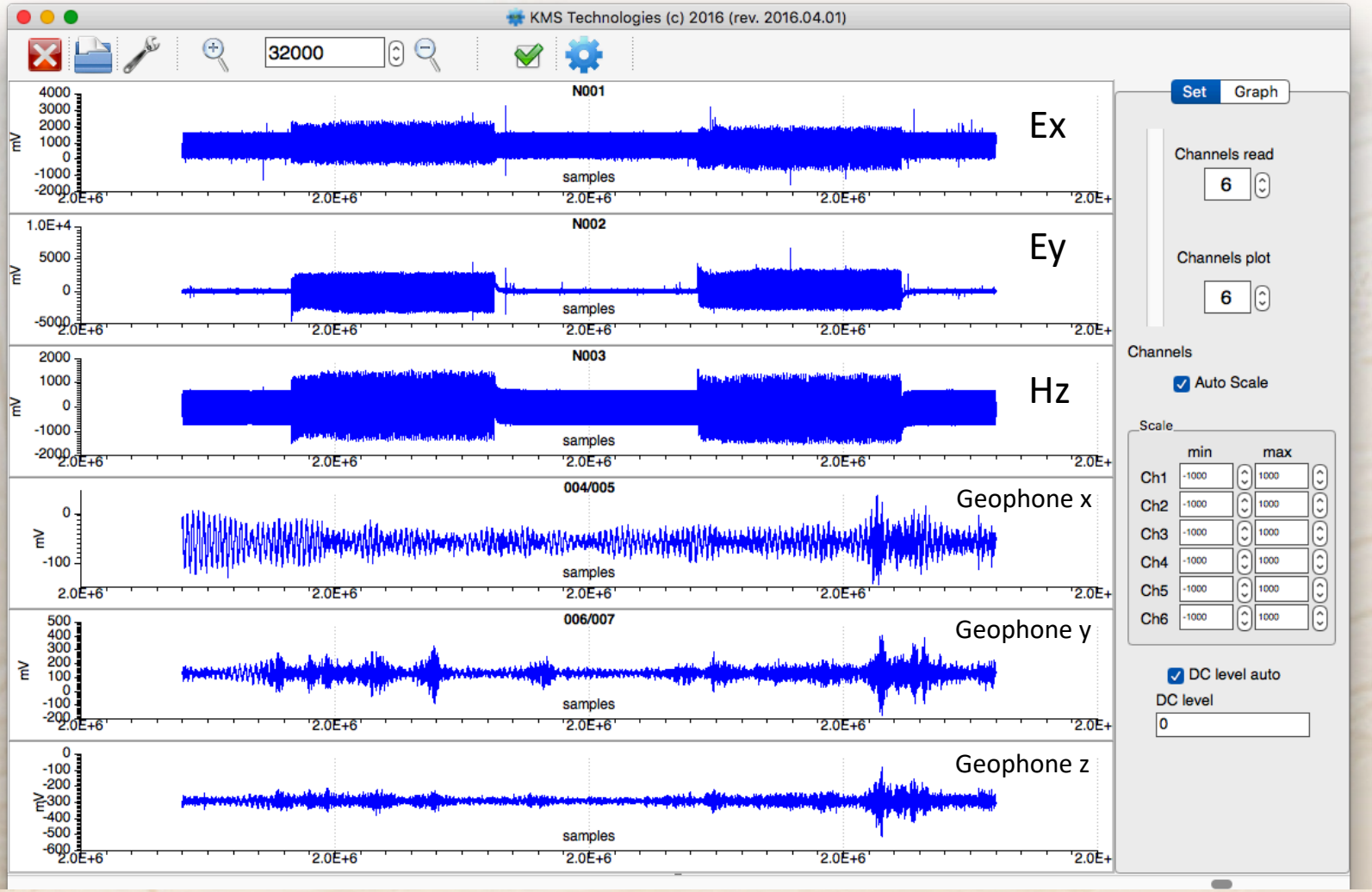
RESERVOIR MONITORING

ARRAY Electromagnetics

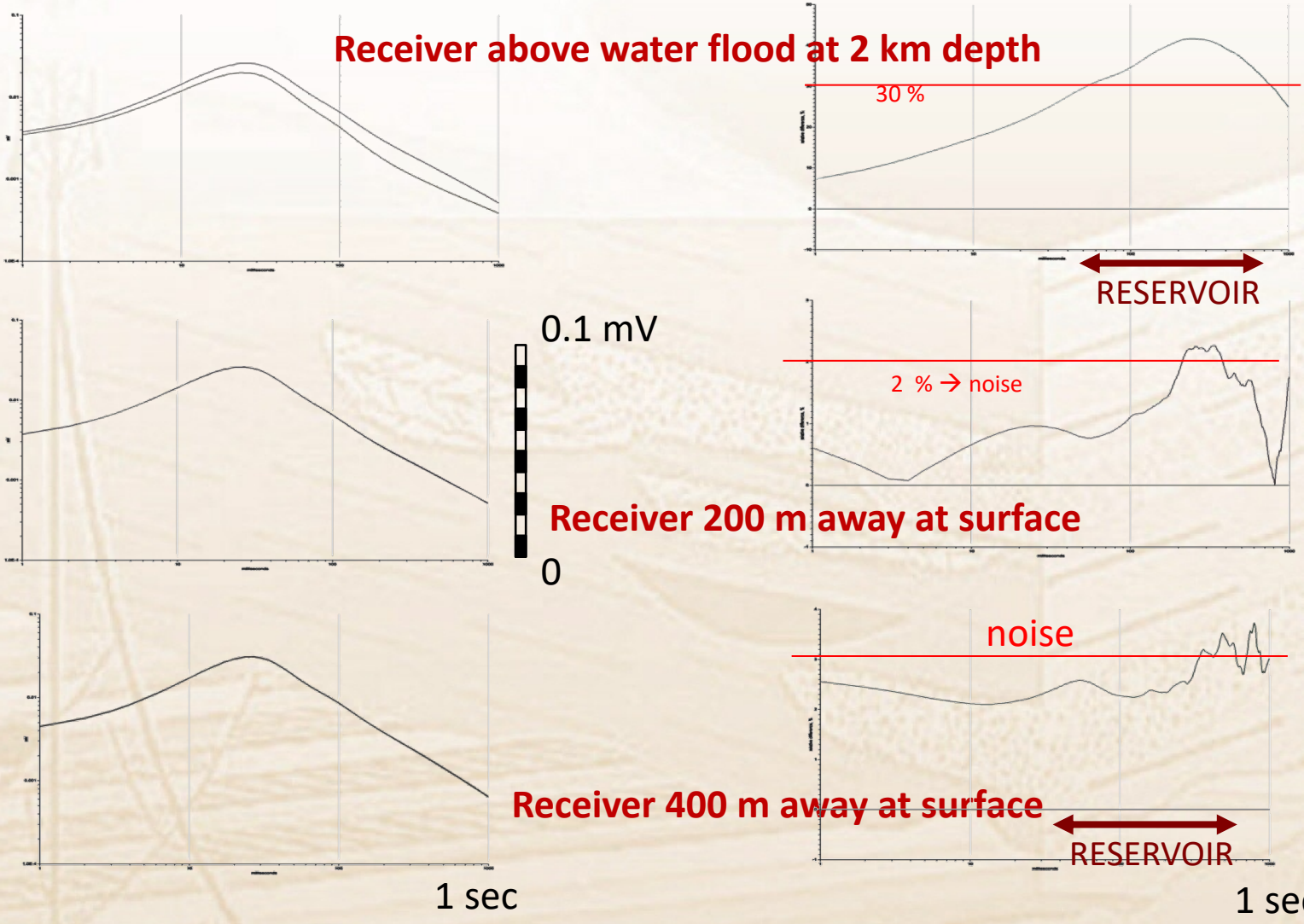
- 195 channels, wifi, wireless or LAN
- 3C magnetic field (DC to 40 kHz)
- 3C microseismic
- 2C electric fields
- Shallow borehole (microseismic/EM)



Reservoir Monitoring: Raw data example: microseismic/EM monitoring



Magnetic field sees water flood - 2 DAYS time lapse

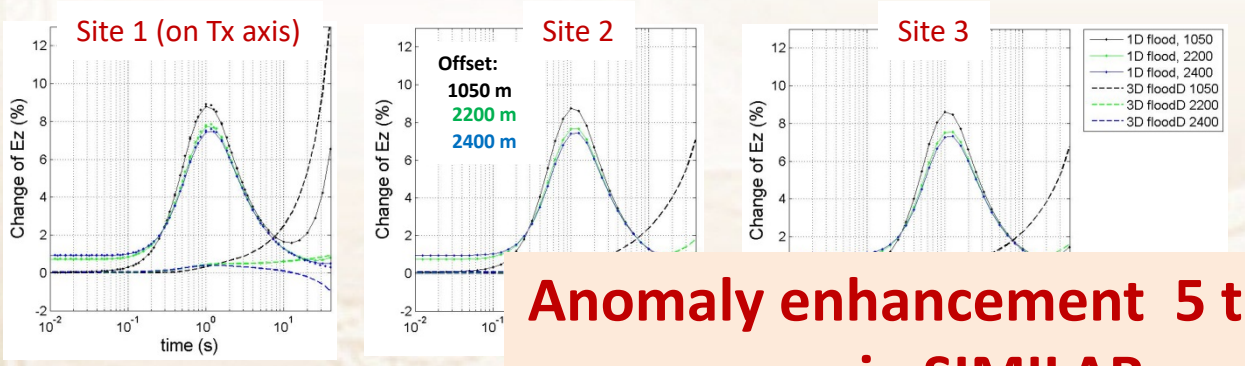


Reasons for discrepancy

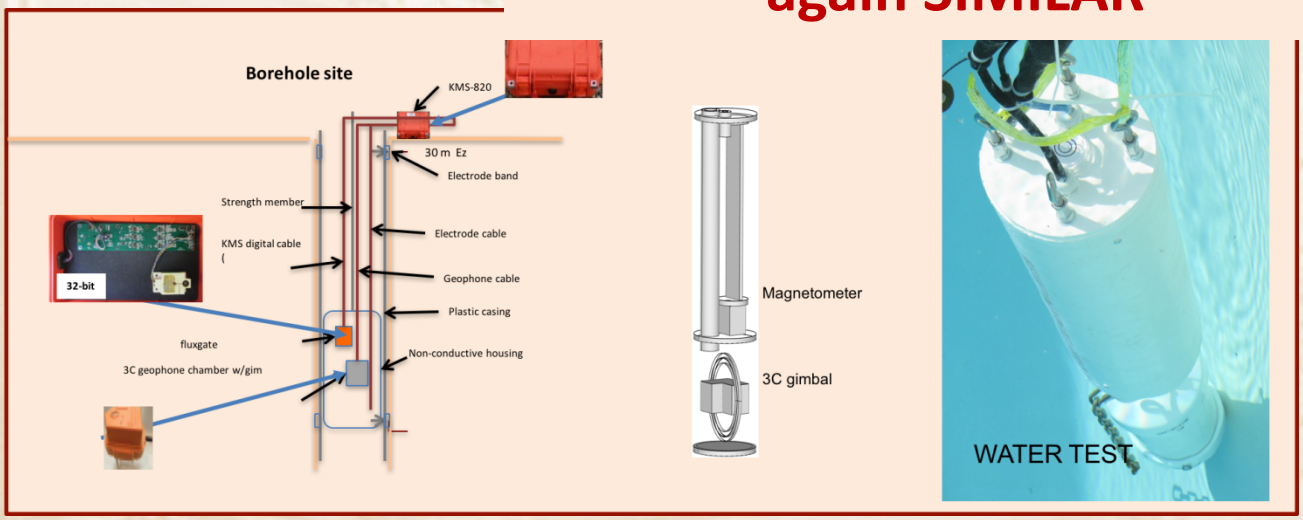
- MANY underground well (highly deviated)
  - 3D modeling → casing effect unlikely (?)
- Image focus
  - Remedy 1: FSEM
  - Remedy 2: Ez in shallow borehole

Alternative: Shallow borehole tool – Ez 3D response

Ez at z = 10 m



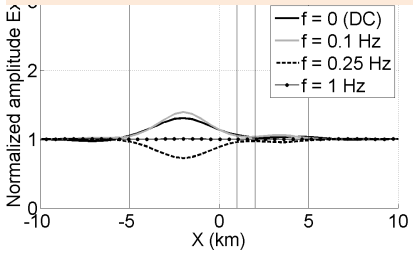
Anomaly enhancement 5 times again SIMILAR



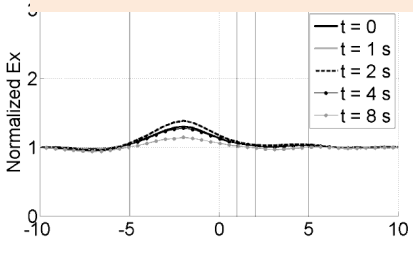
FSEM: Focused source solution to volume imaging

CSEM versus Focused Source

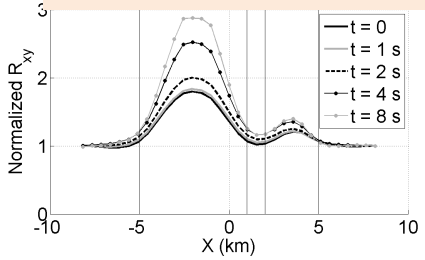
Frequency domain CSEM



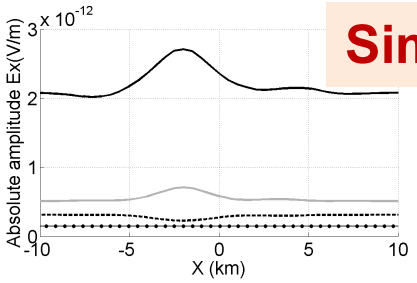
Time domain CSEM

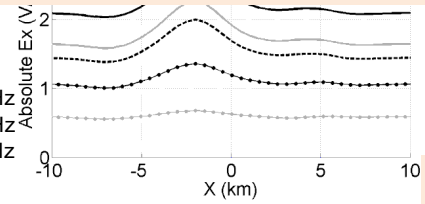


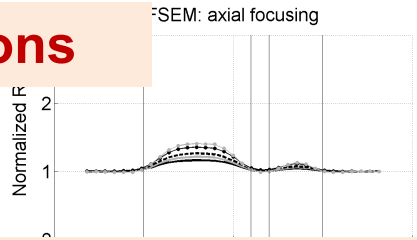
Focused Source EM

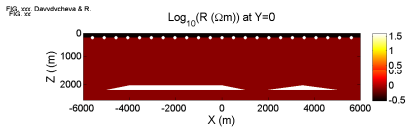


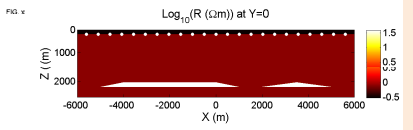
Similar to our observations











- Smaller reservoir can be detected
- Higher spatial resolution
- Shallow structure removable
- Shallow structure removable

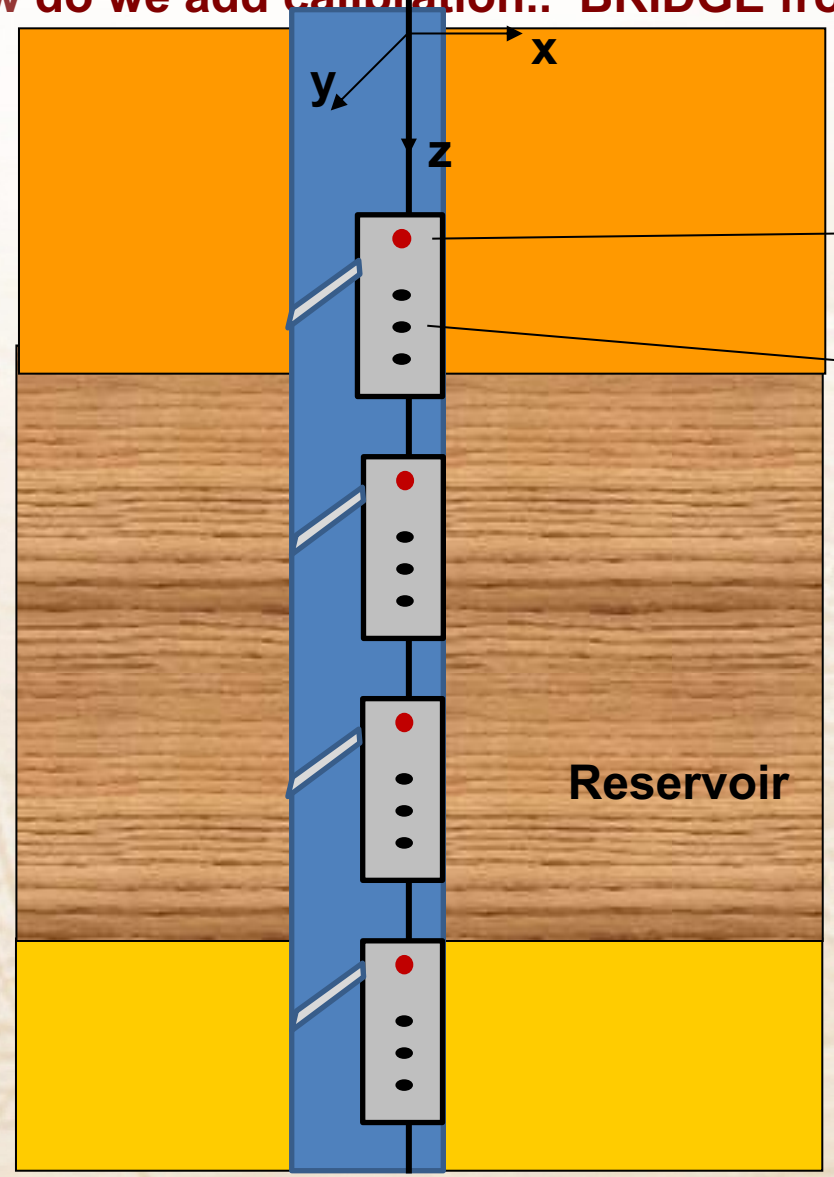
fCSEM & tCSEM: Anomaly: 40% - 10%

FSEM: Anomaly: 200% - 40%

How do we add calibration.. BRIDGE from log to surface scale I

- NEED log scale data (2 sample/foot)
- NEED surface scale data
- Sensitive to resistors & conductors (→ E&H)
- KNOWN image focus
- Open hole & Through Casing
- Integration → multi-scale

How do we add calibration.. BRIDGE from log to surface scale II

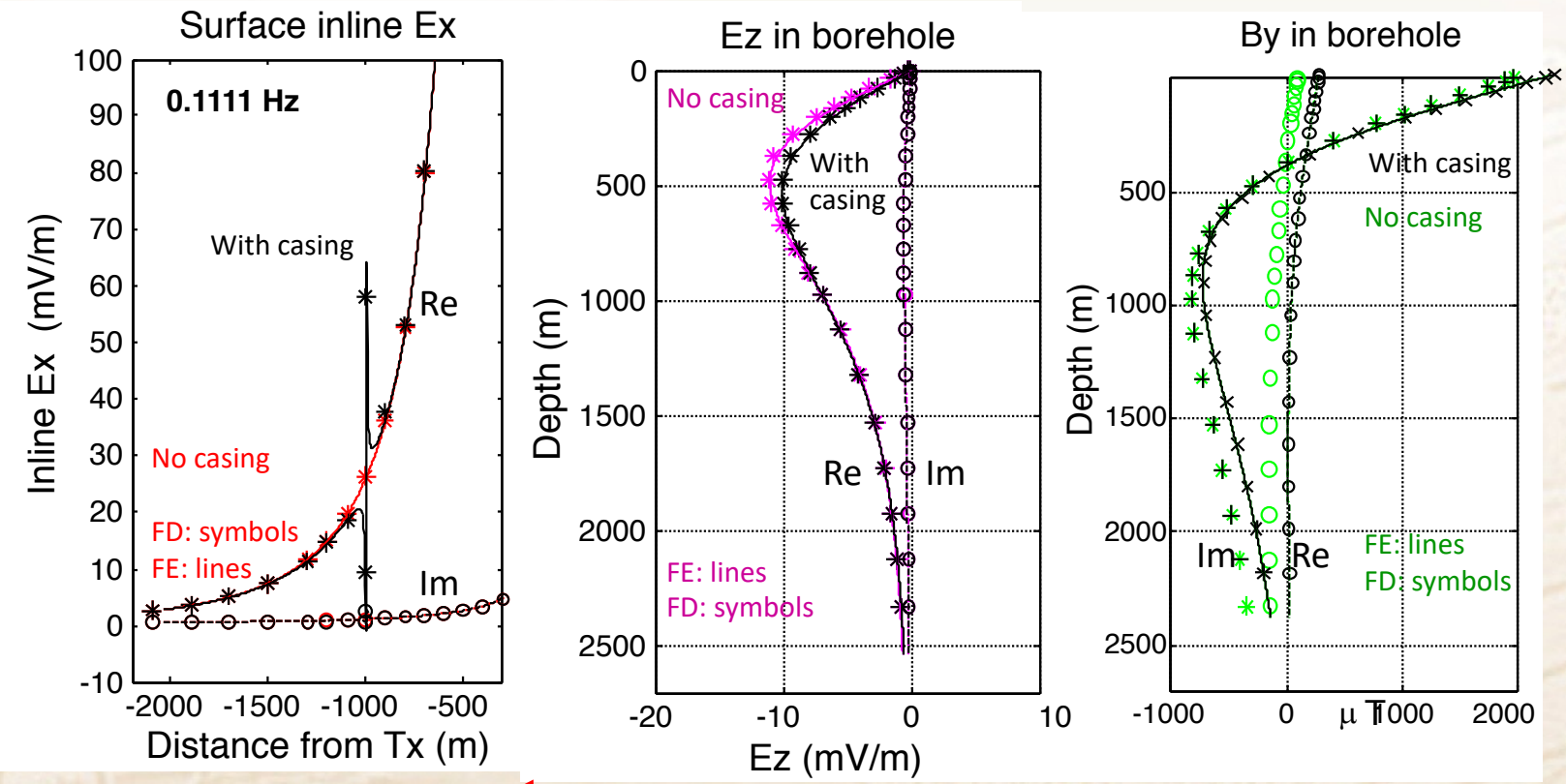


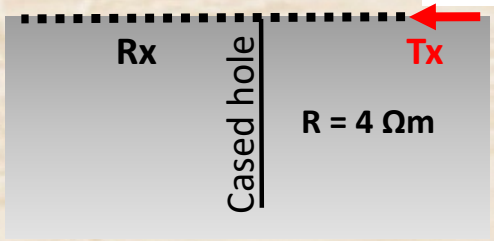
Through casing measurement tool with multiple shuttles

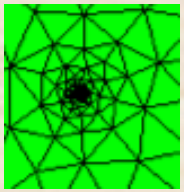
Functions:

- Use only receivers when surface source is used.
- TCR logging (1 source in Shuttle 1 and receivers everywhere).
- Dipole-dipole mapping (use one shuttle as dipole rest as receiver THEN rotate between shuttles).

How do we add calibration.. BRIDGE from log to surface scale III







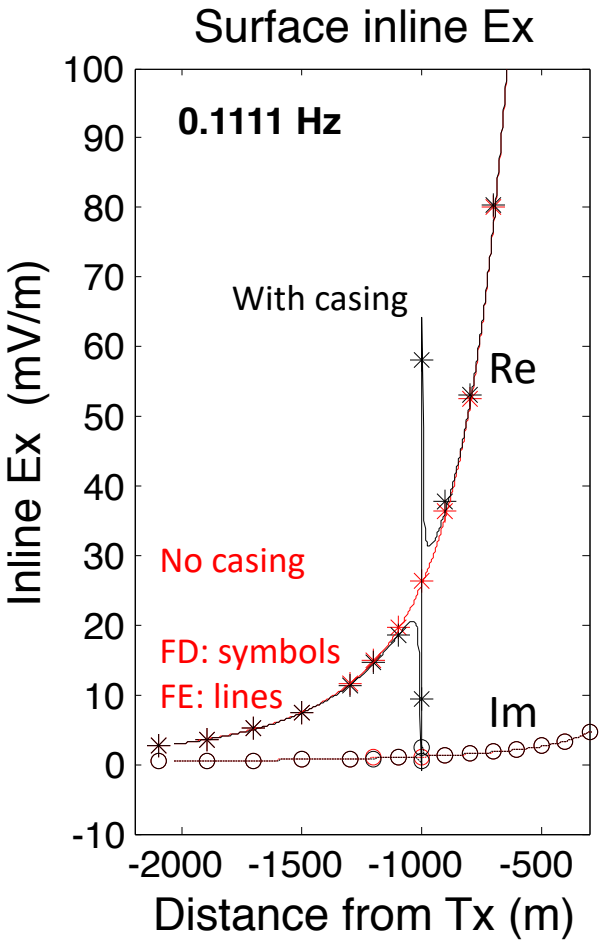
FE mesh at steel casing plan view

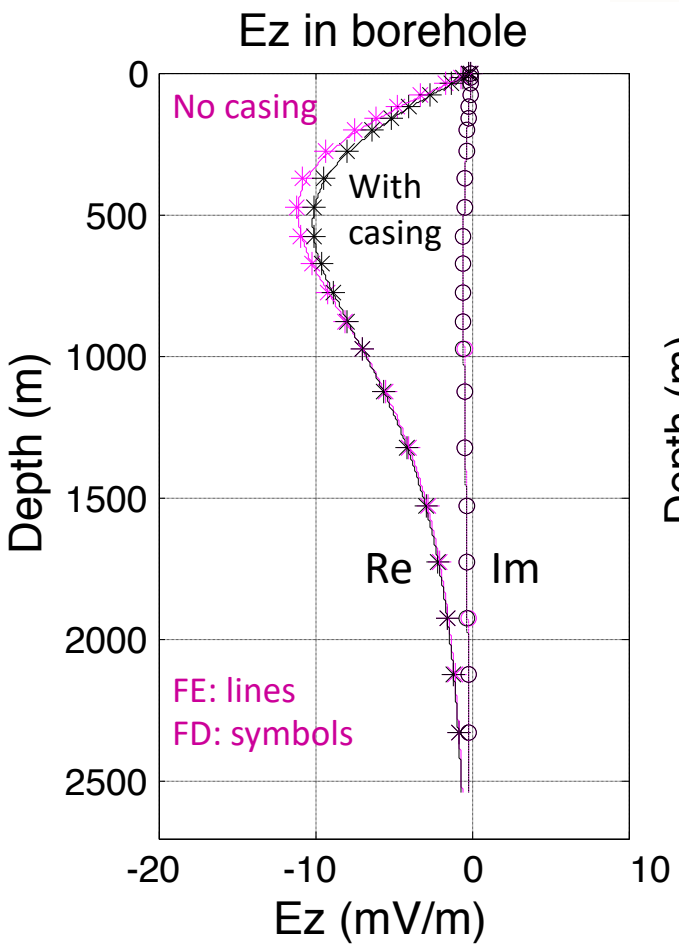
Suggested equipment

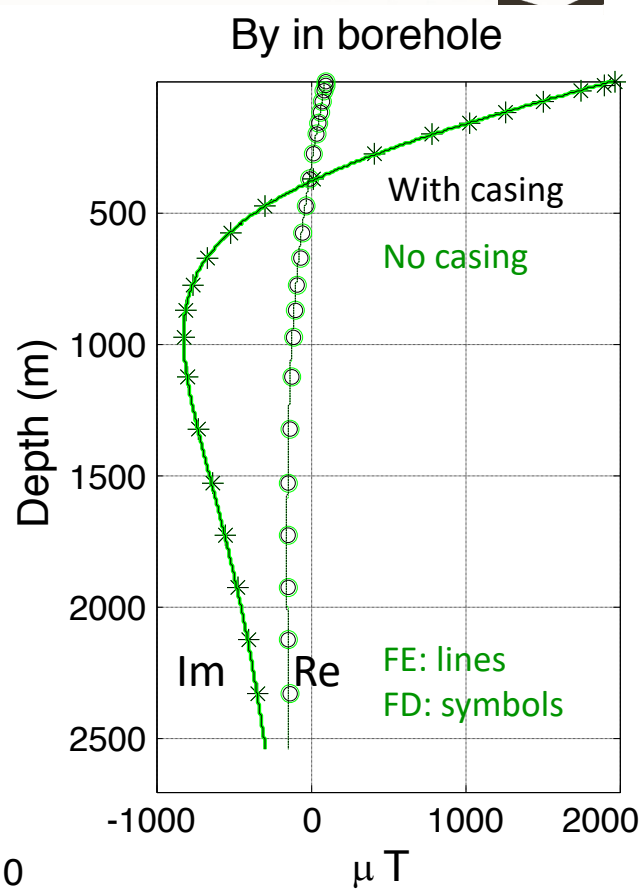
Conclusion… focus on tool development

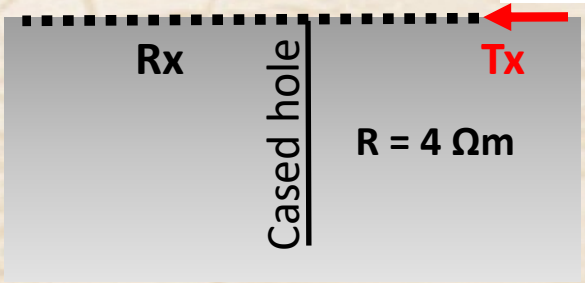
- We have finished part of a full field monitoring system
- Integration of borehole is MUST
- What limits us in success in reservoir monitoring?
  - Check against production & well data
  - → need high accuracy, log integration
  - Fast turn-around → hardware & acquisition
- NEXT: Build a deep borehole tool

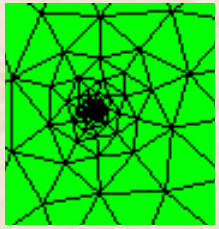
THANK YOU







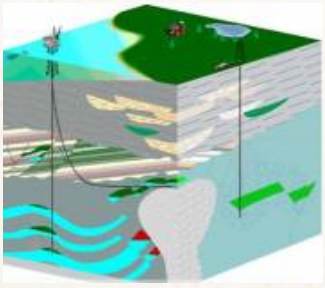




FE mesh at steel casing
plan view

KMS Technologies – KJT Enterprises Inc.
11999 Katy Freeway, Suite 160
Houston, Texas 77079
USA

info@KMSTechnologies.com



www.KMSTechnologies.com