Uses of Lotem for Indonesian hydrocarbon applications

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www.KMSTechnologies.com

EM for hydrocarbons started 1980s

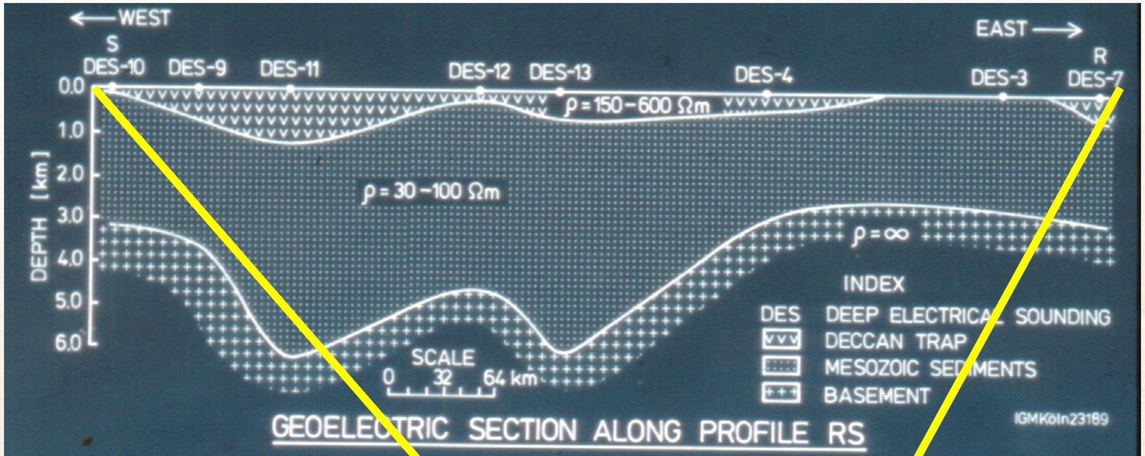
- 1980: extensive programs in EM in USA, Australia, PNG
- Since then: MT is the only workhorse of the industry
- Due to higher technical requirements & success of marine EM → revisit land
- Renewed interest for sub-basalt & carbonates
- Biggest limitation to MT: cultural noise

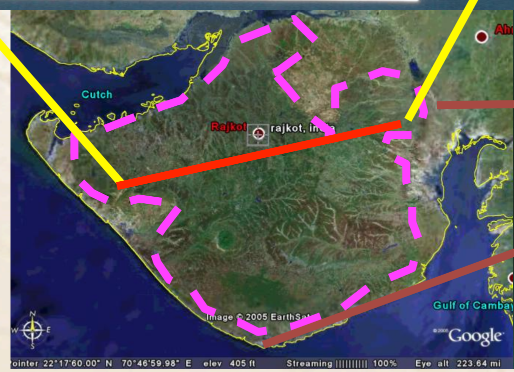
Objectives for CSEM

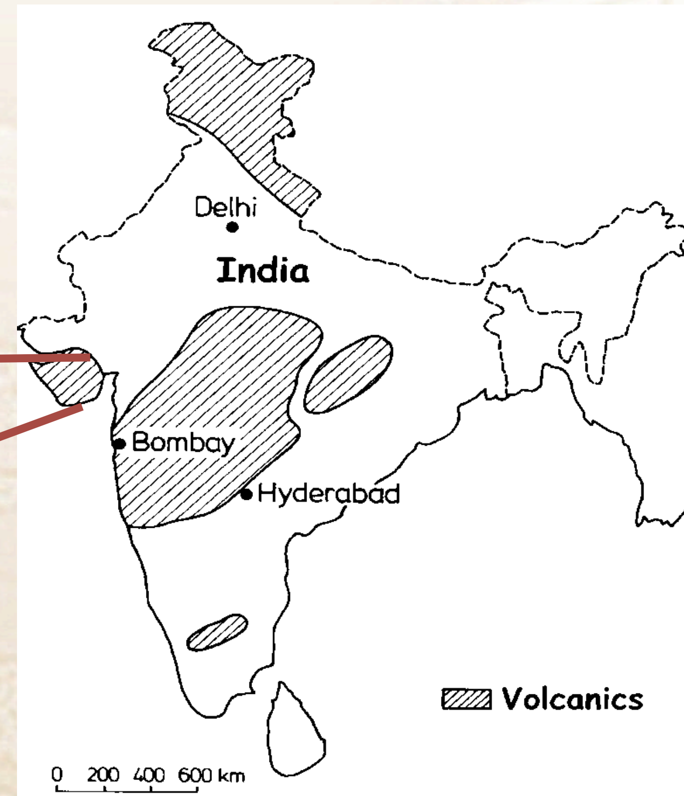
Difficulties in Indonesia:

- Java: only a small % of MT sites give good quality
- Basalt: Seismic is reflected diffusely
  - Past work: USA, Brazil, India, Saudi Arabia
- Carbonate formation – seismic does not work well due to high velocity
  - Past work: Australia, Germany, China
- Will translate to Indonesian condition

Sub-basalt example from India

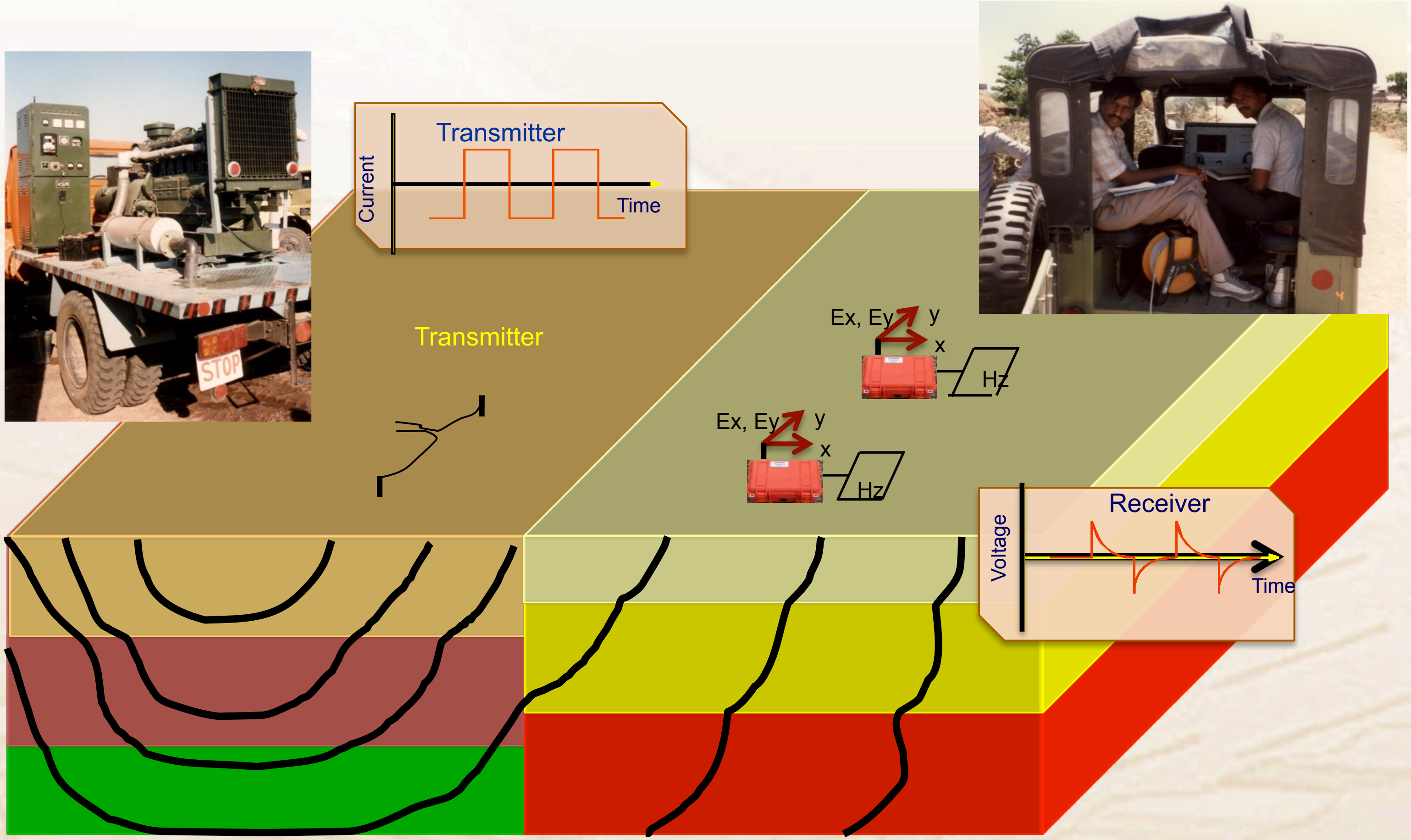




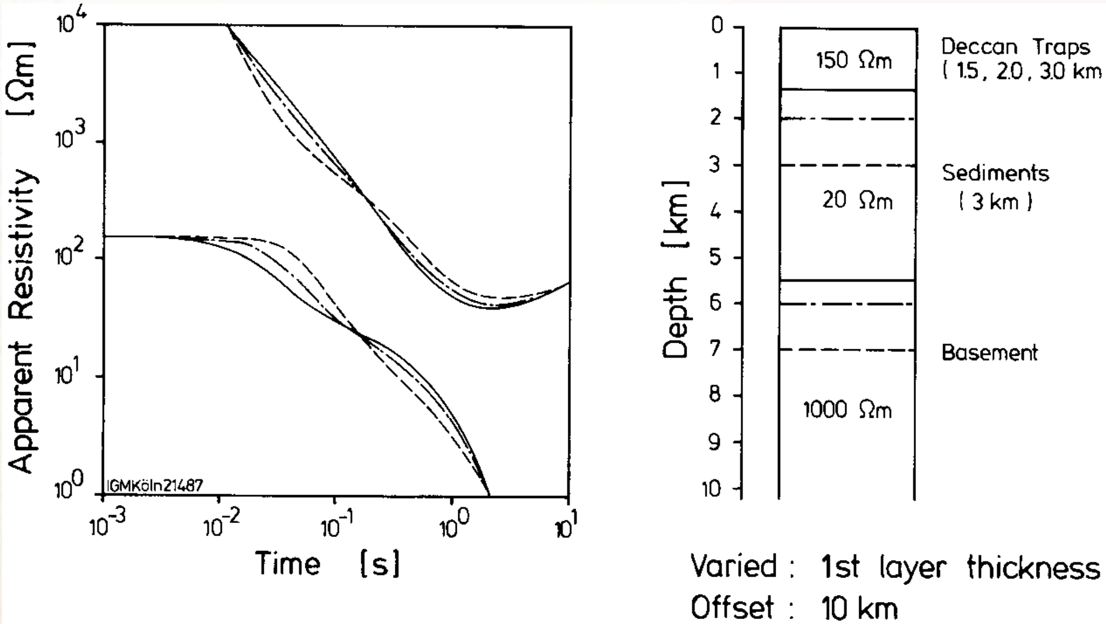


- Complex geology
- Flat lying basalts (Trap basalt)

Sub-basalt example from India



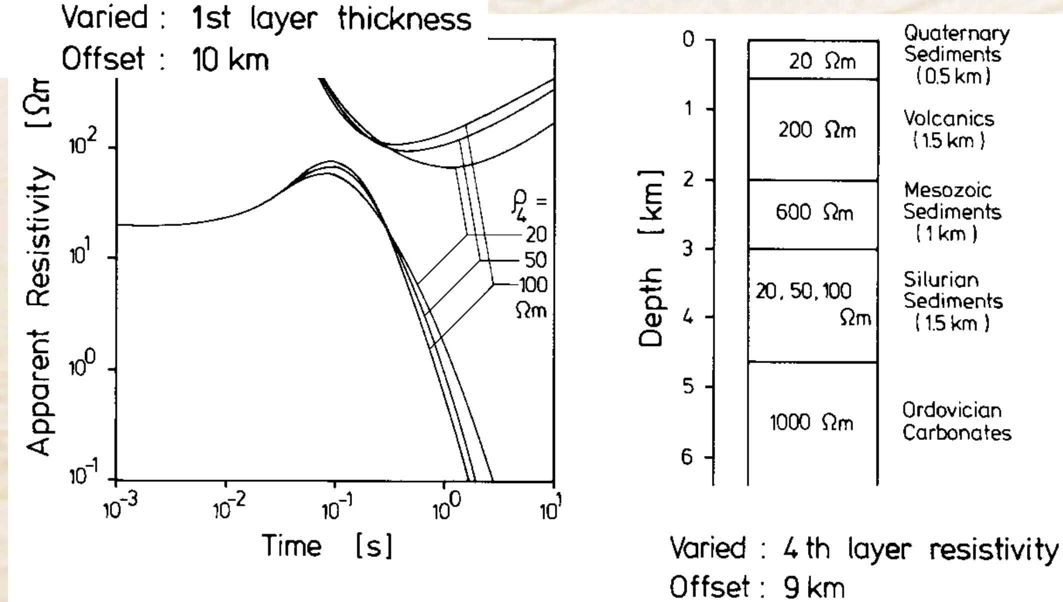
1987 India: Pre-survey synthetics



Trap thickness varied

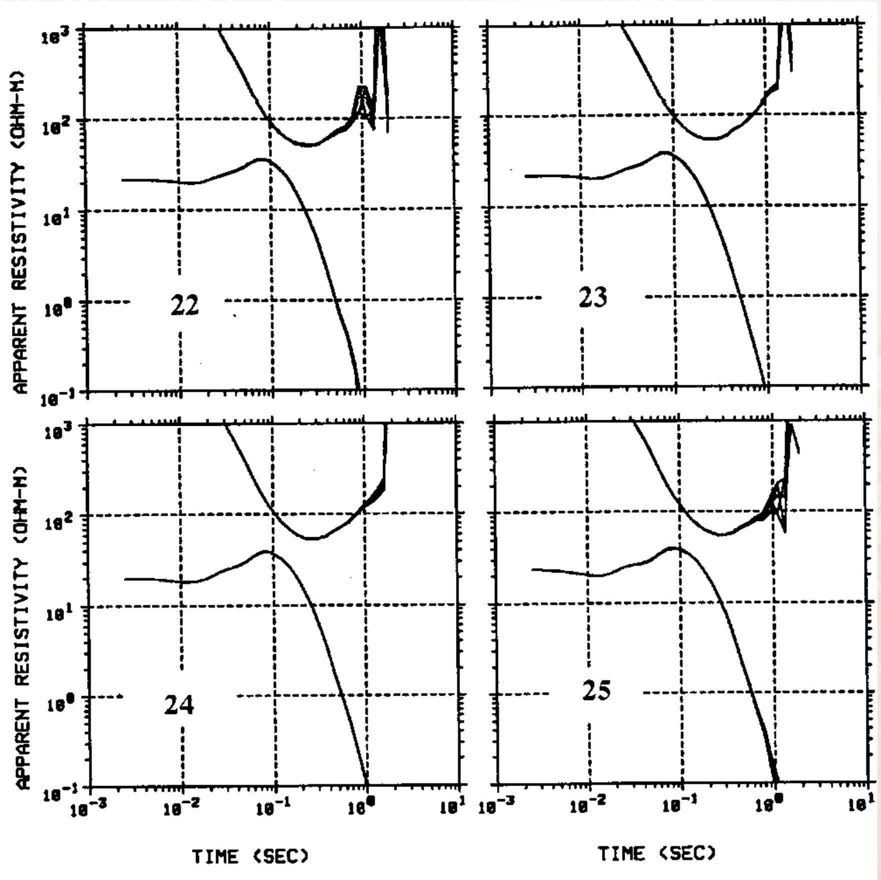
These are 1987 plots
Lost subsequently
Found in archive 2012

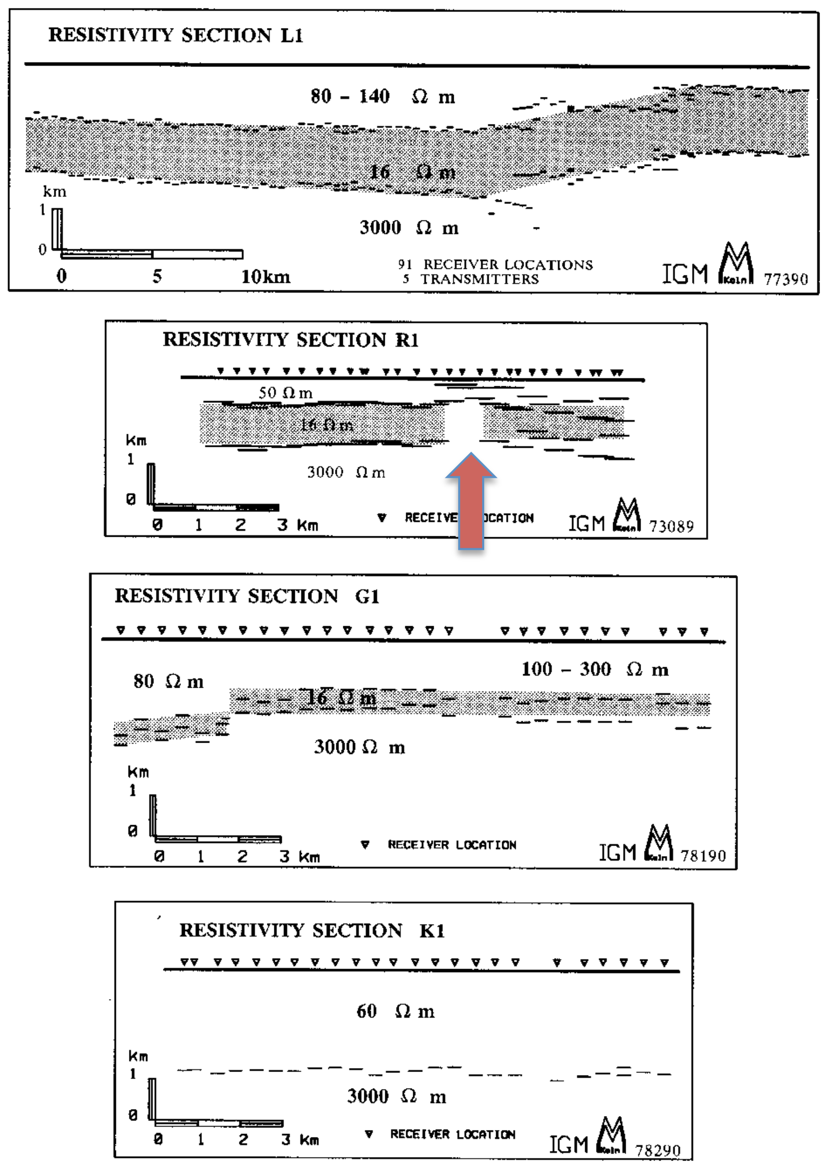
Mesozoics varied



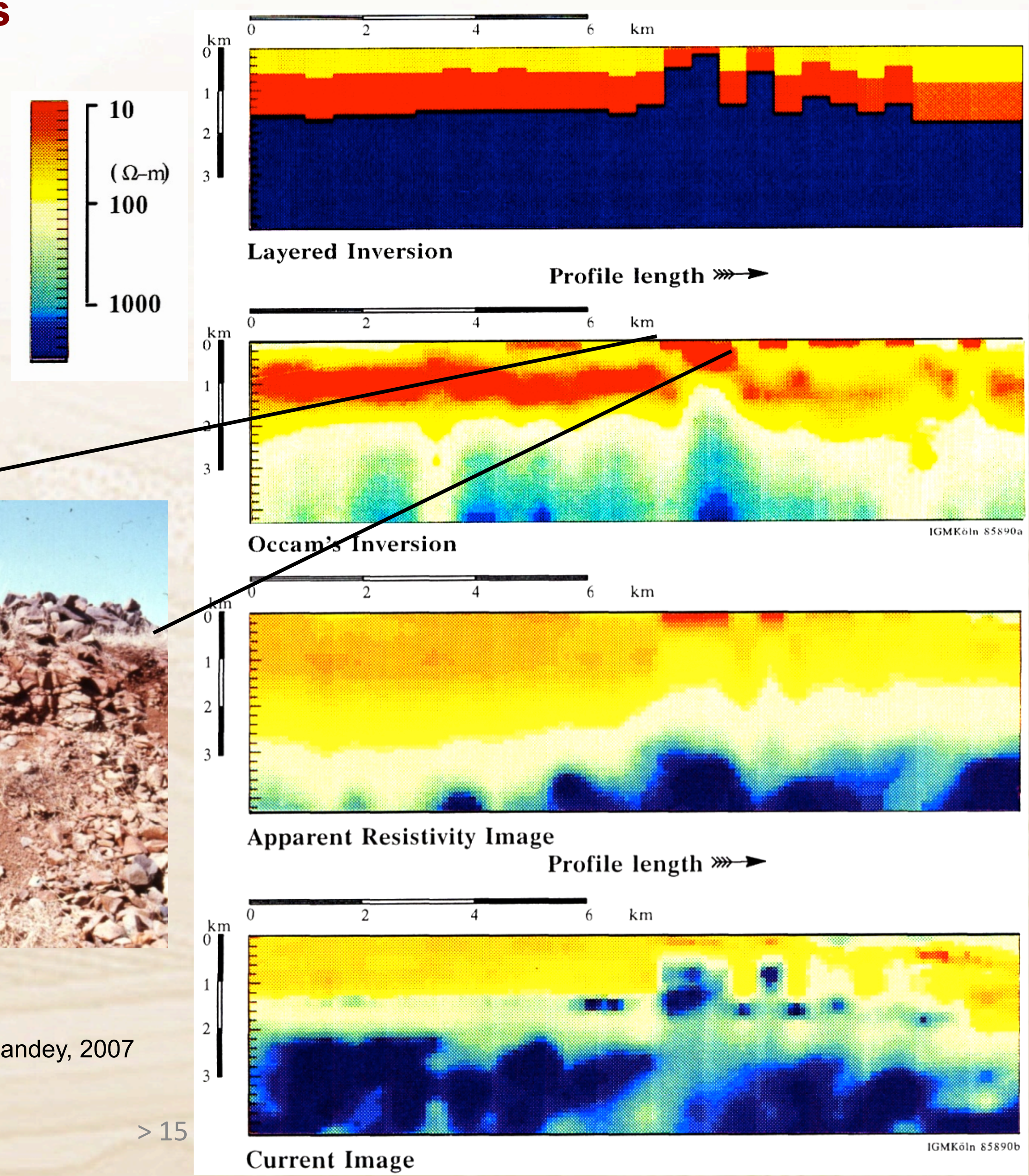
1989 India survey: Data & section compilation

Shape & time of data similar





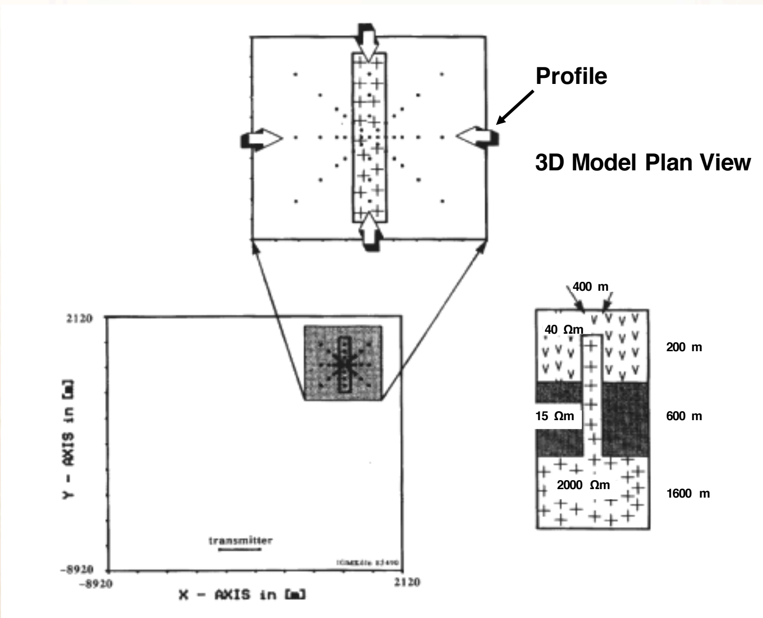
1990: India: Data images

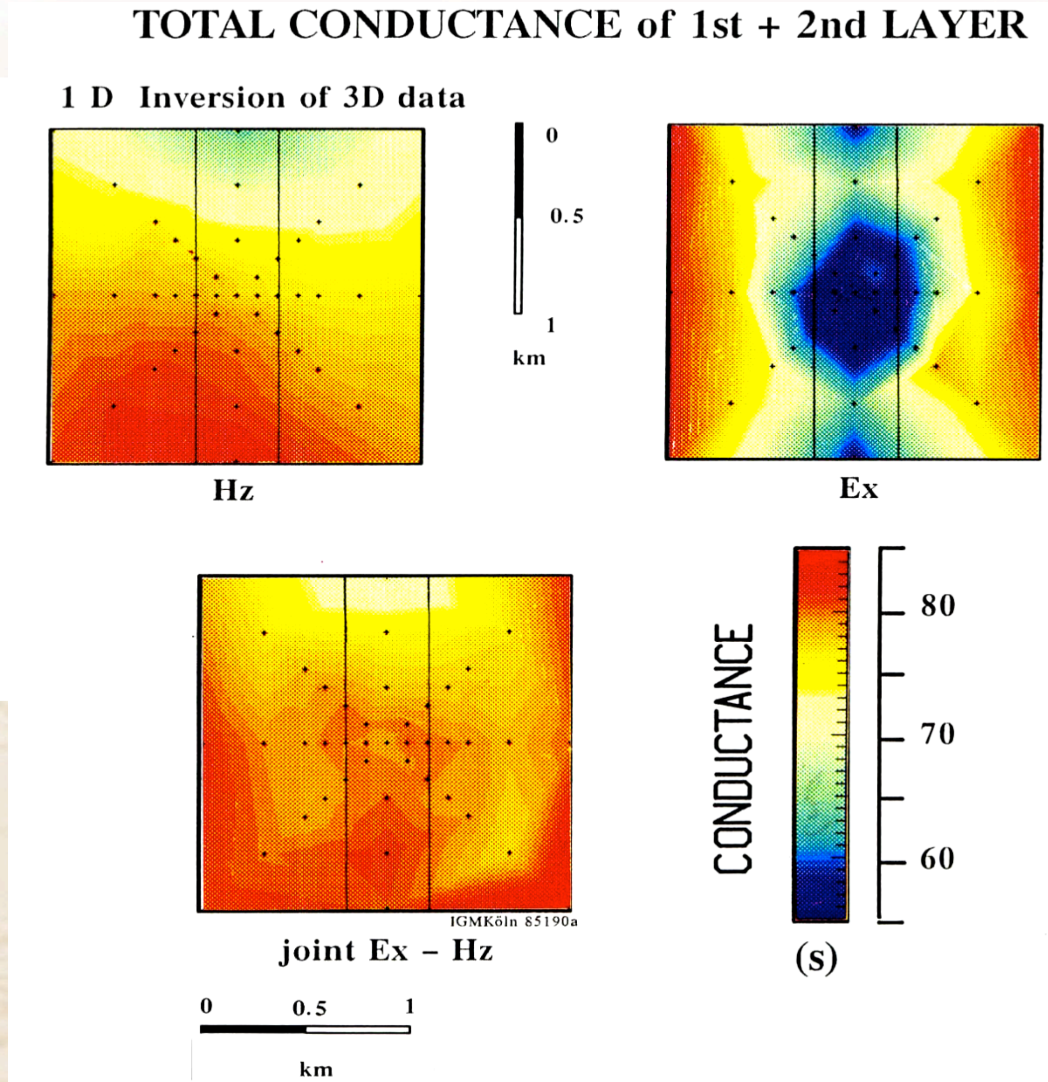


Surface outcrop:

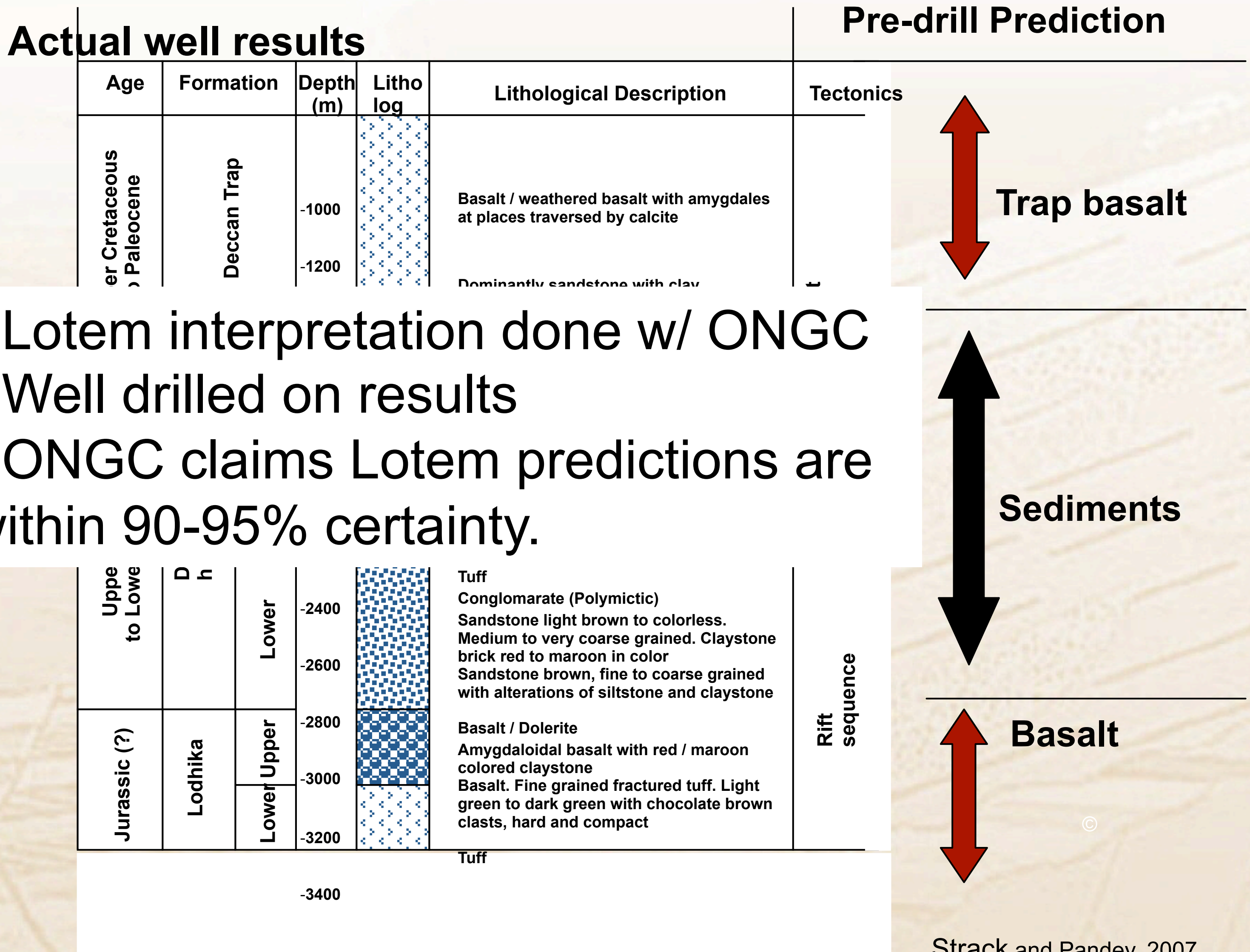
Strack and Pandey, 2007

1990: India: 3D location test





2000 India: Rajkot 1 Well log interpretation



- Lotem interpretation done w/ ONGC
- Well drilled on results
- ONGC claims Lotem predictions are within 90-95% certainty.

Strack and Pandey, 2007

Geology & Geophysics data PNG example - COMPLEX GEOLOGY

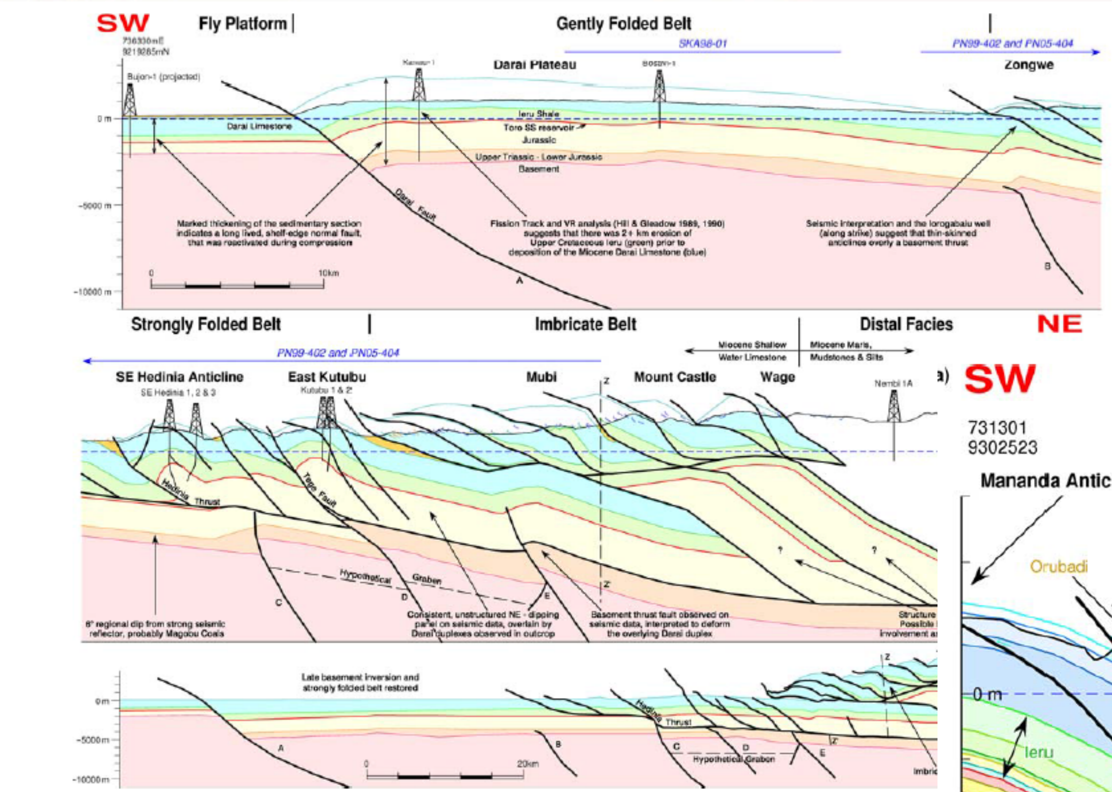
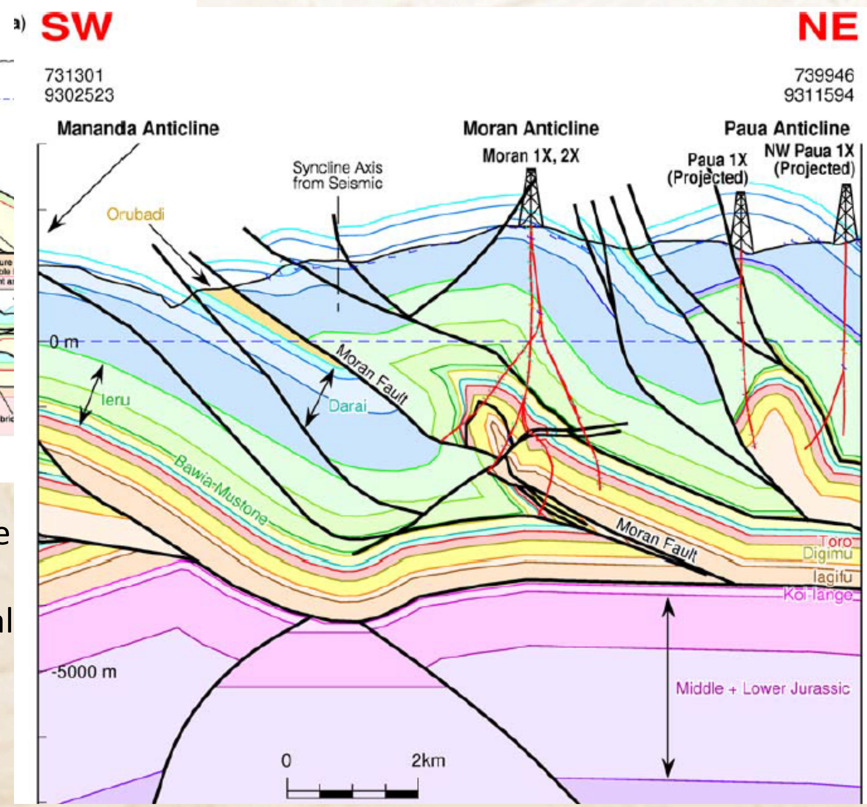


Fig. 3.



- Miocene limestone at surface: typically 1-1.5-km thick
- Underlying Ieru shale, the regional seal: 800 m to 1.5 km thick
- Beneath them: upper Jurassic sandstones which are reservoirs

- By Hill, Lucas and Bradley, 2010: Structural styles in the Papuan Fold Belt, Papua New Guinea: constrains from analogue modelling, Geological Society, London, Special Publications 2010, v. 348, P. 33-55
- Figures 3 & 10

Geology & Geophysics data PNG example – Resistivity section

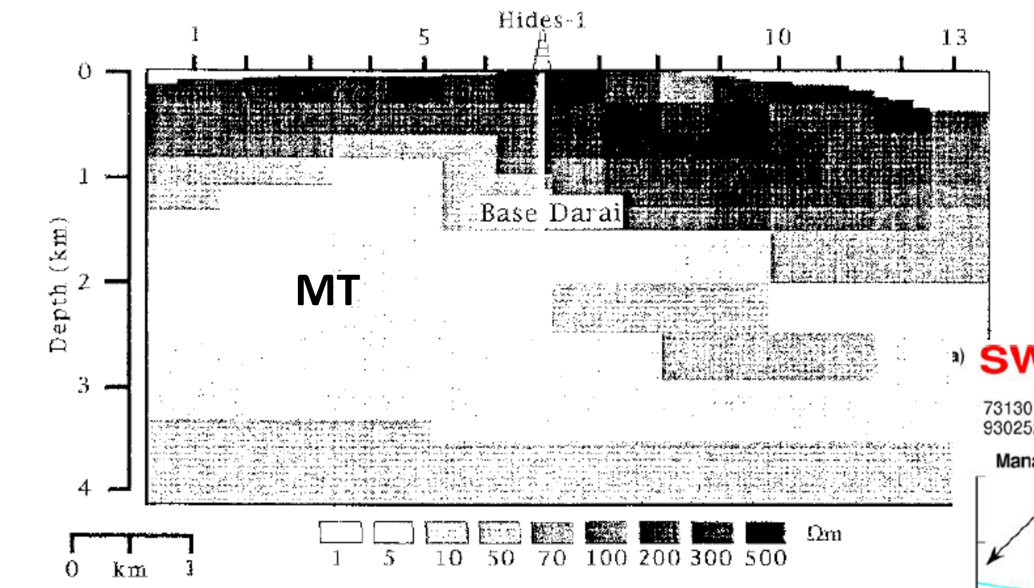


Figure 7. Occam 2D inverse model for Hides MT data. TE and TM apparent resistivity phase data at 13 sites and 12 frequencies (0.004–40 Hz) were fitted in the inversion. Th misfit is 12%.

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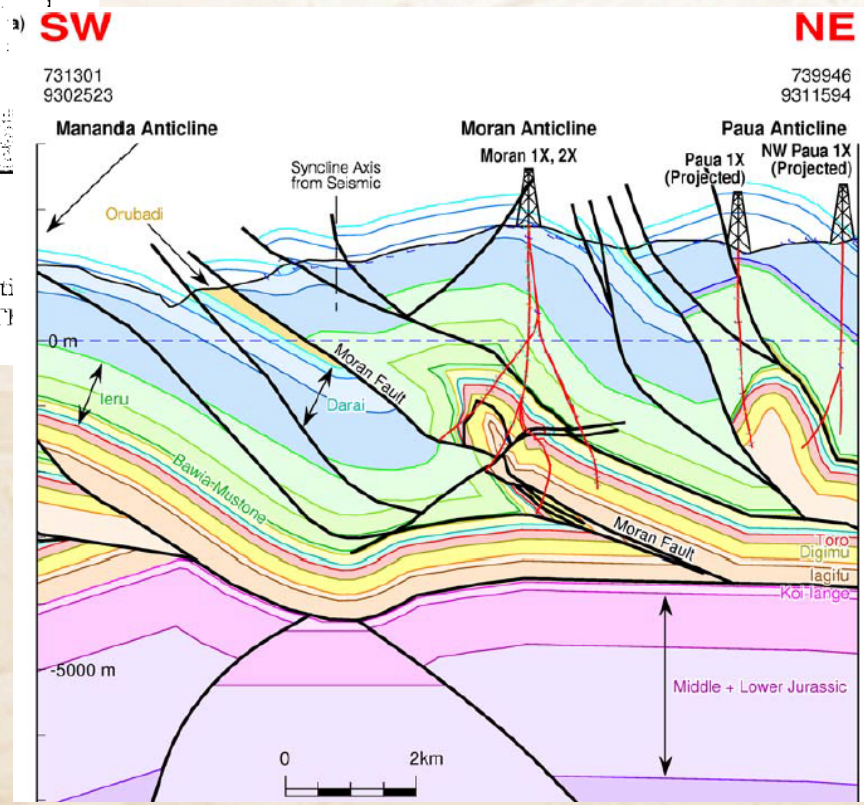

- Hoversten, 1996, Papua New Guinea MT: looking where seismic is blind, Geophysical Prospecting, v. 44, 935-963

Geology & Geophysics data PNG example – example of complexity

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- Underlying Ieru shale, the regional seal: 800 m to 1.5 km thick
- Beneath them: upper Jurassic sandstones

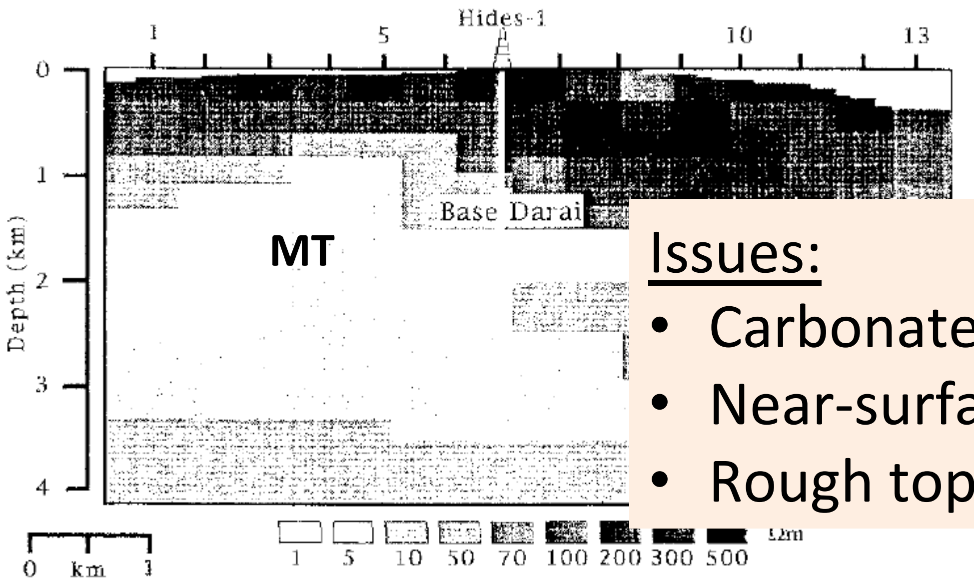


Figure 7. Occam 2D inverse model for Hides MT data. TE and TM apparent resistivities and phase data at 13 sites and 12 frequencies (0.004–40 Hz) were fitted in the inversion. The rms misfit is 12%.

Issues:

- Carbonates – high velocity
- Near-surface inhomogeneities
- Rough topography

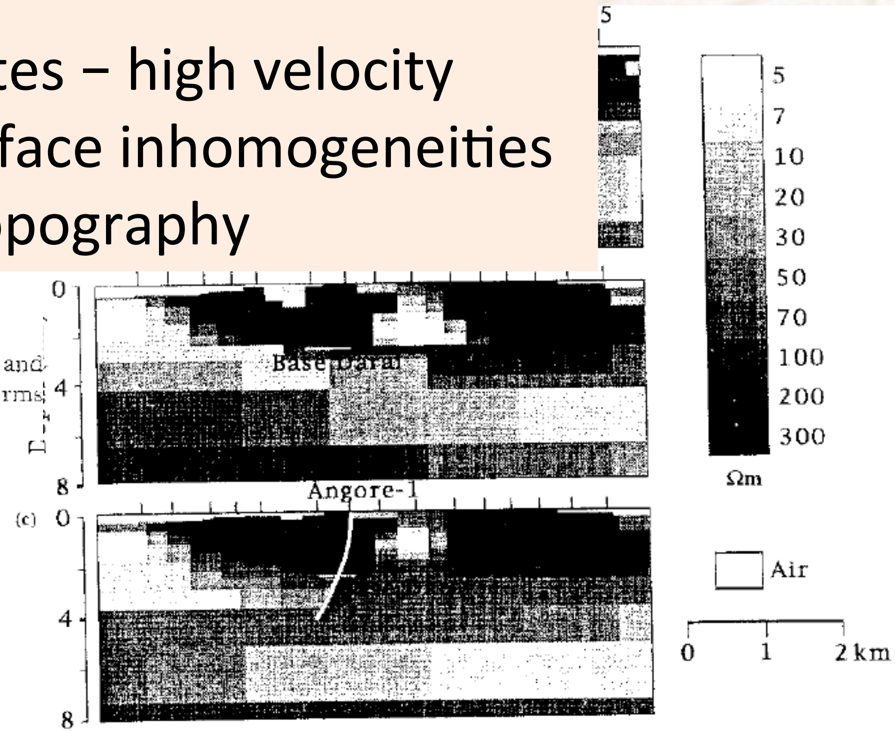
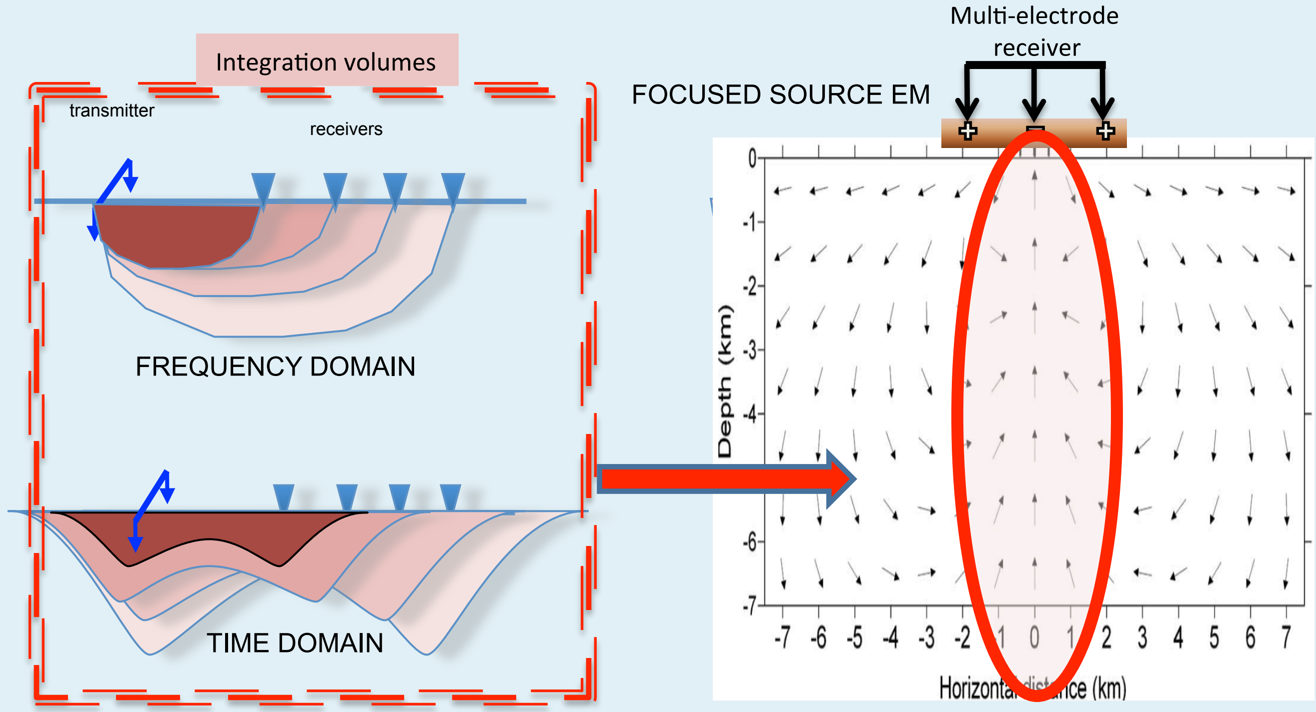


Figure 10. Three models which illustrate the iterative process of fitting measured MT data and static shifts. Thirteen frequencies evenly spaced in log domain between 0.002 and 48 Hz were used. (a) 2D model fit to raw data rotated to geological strike N45°W, with no static

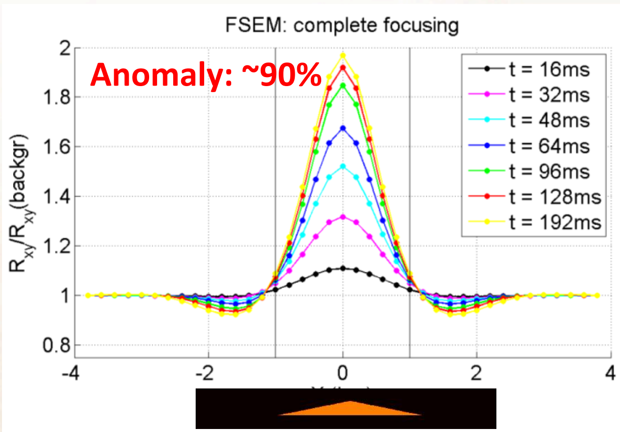
- Hoversten, 1996, Papua New Guinea MT: looking where seismic is blind, Geophysical Prospecting, v. 44, 935-963

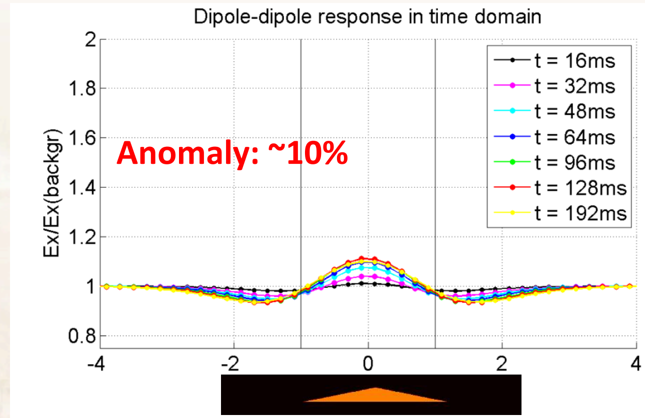
Objective >> Sub-basalt >> Carbonate mapping >> Outlook
Solution: FSEM: Focused source electromagnetics

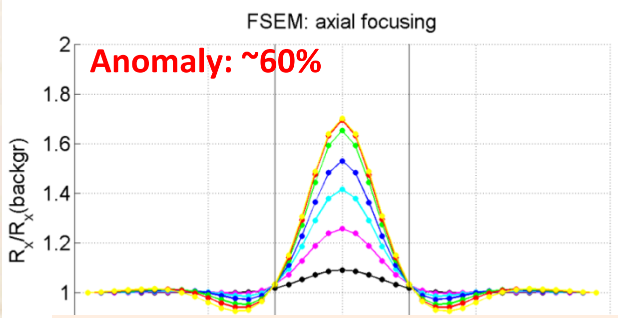


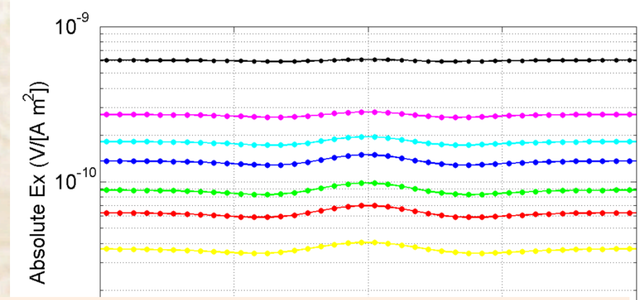
Rykhlinskaya, E., & Davydycheva, S., 2014, U.S. Patent 8,762,062 B2.
Davydycheva, S., 2016, U.S. Patent Application US 2016/0084980 A1.

Solution: FSEM - Modeling results: Offset 1040 m



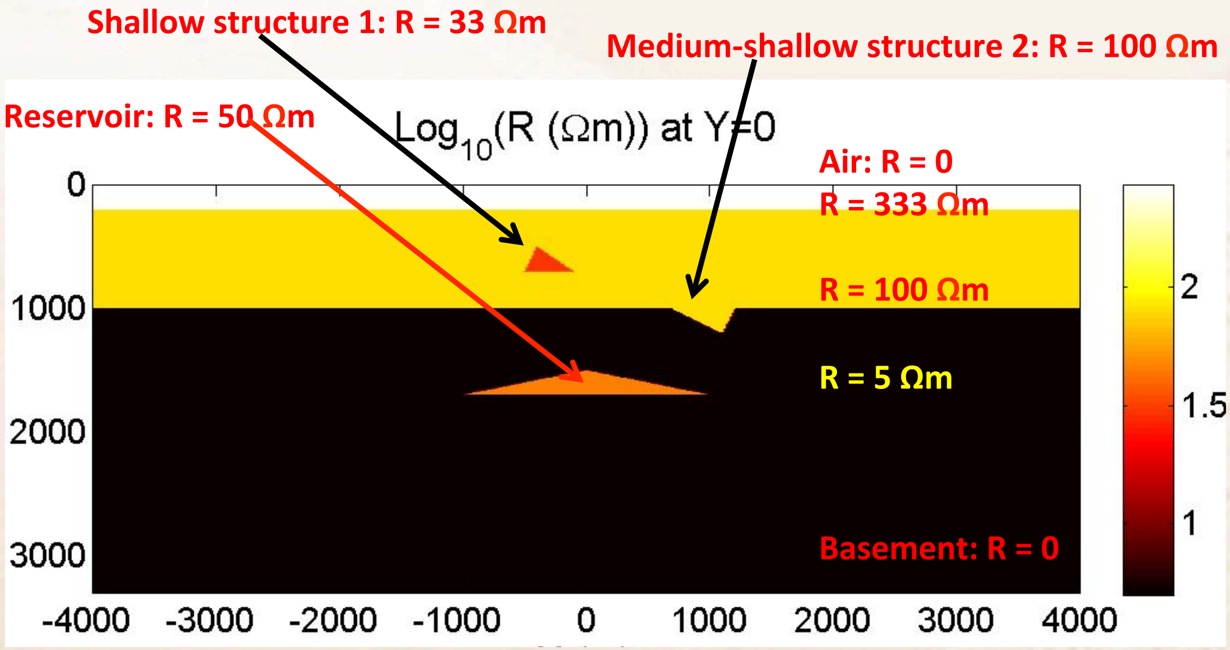






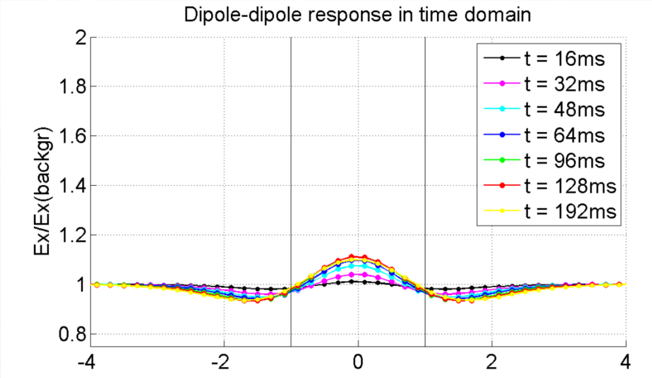
- Best sensitivity to 1.6-km-deep reservoir: at times ~100-200 ms.
- Good enough signal strength at times (after current-off) < 1 s.

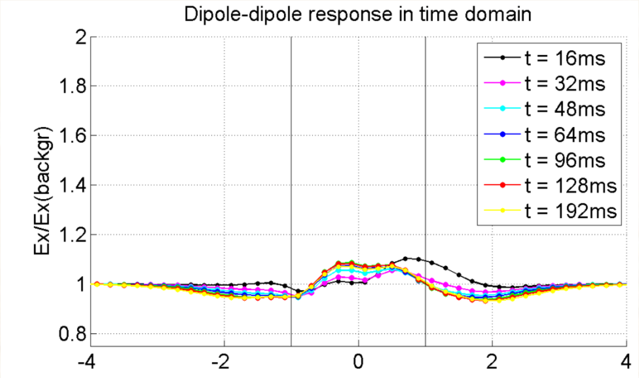
FSEM - Modeling results: Offset 1040 m - model setup



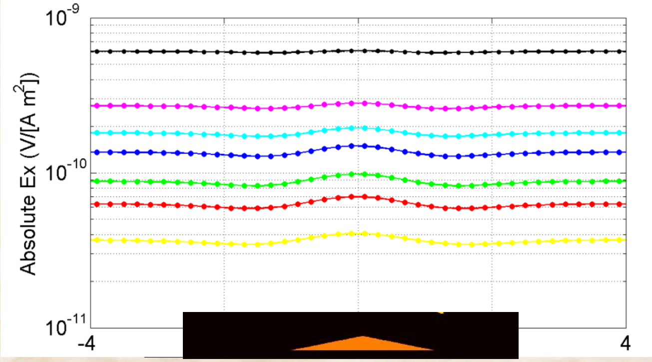
- Good sensitivity to deep reservoir is not enough for success
- Shallow effects may destroy feasibility of this case.
  - All structures are 2D prisms

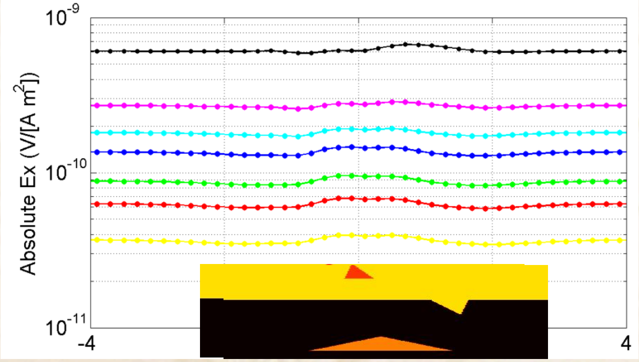
Standard CSEM: Without/With Shallow Structures



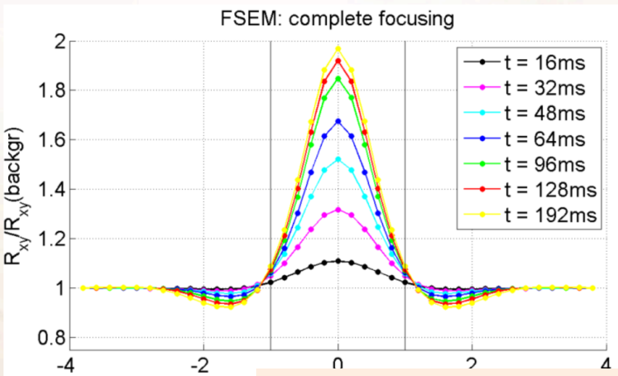


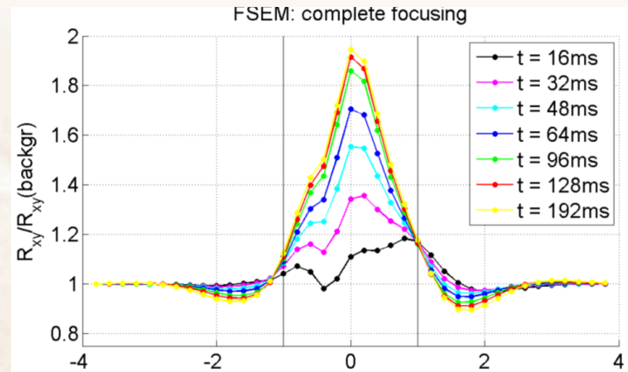
Shallow structures change Ex-Ex response beyond recognition



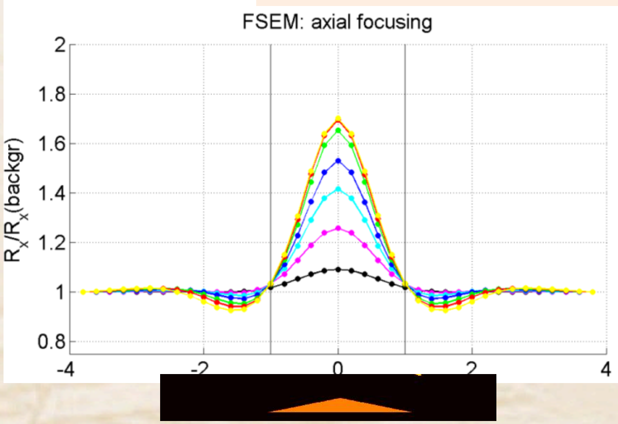


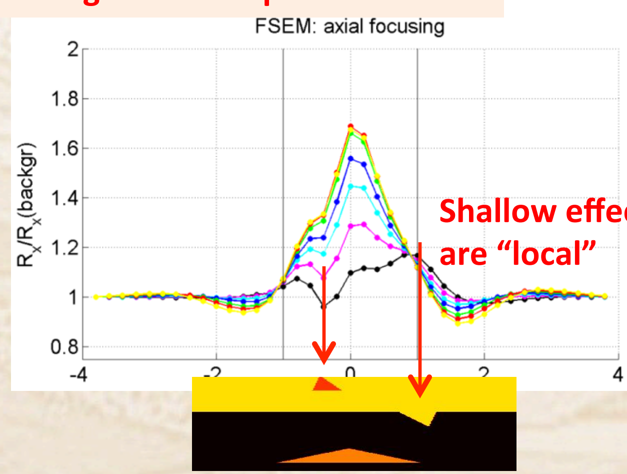
Focused Source EM: Without/With Shallow Structures





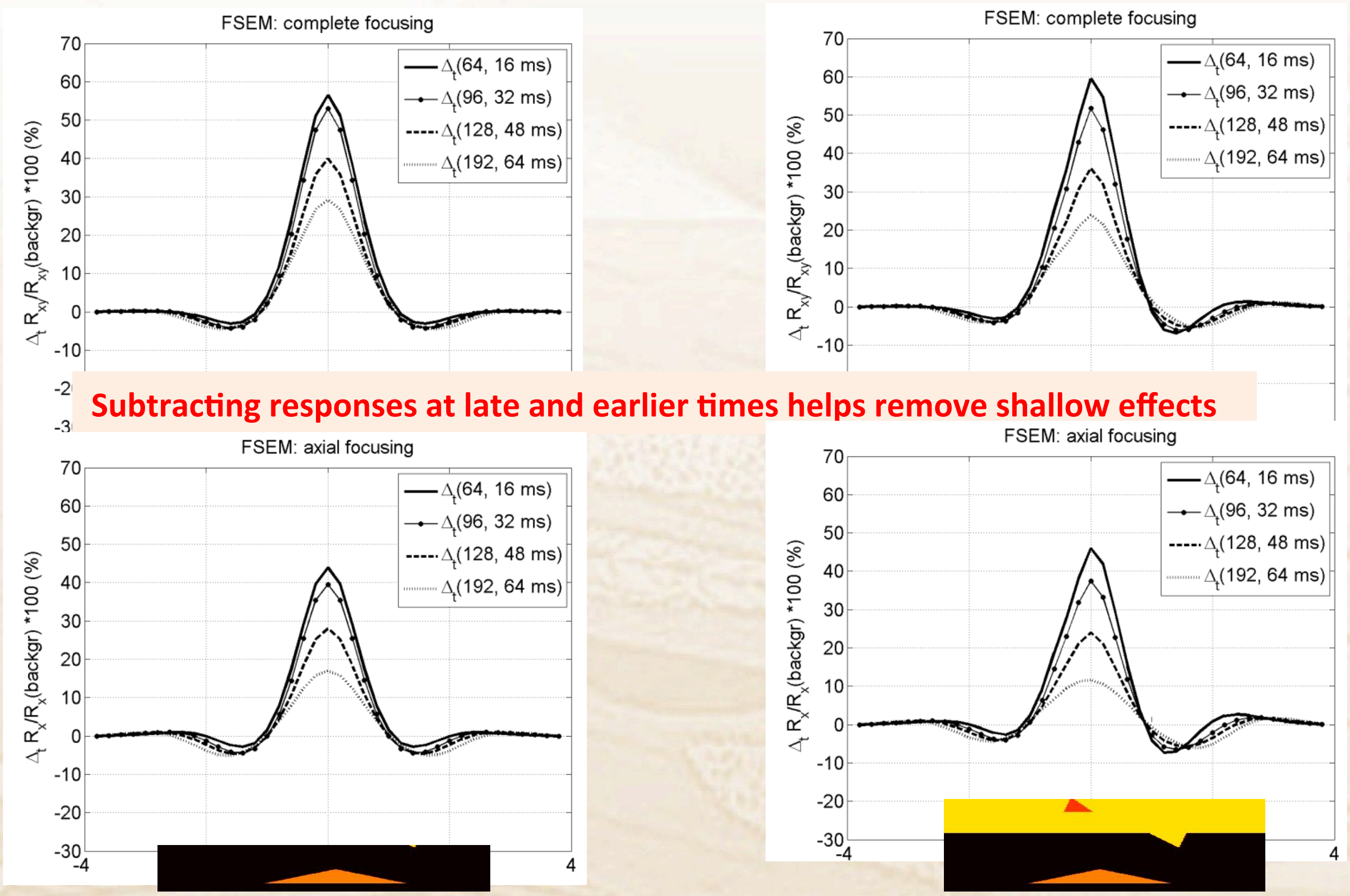
Shallow structures significantly change FSEM response as well





Shallow effects are "local"

Removal of shallow effects through time differentiation



Subtracting responses at late and earlier times helps remove shallow effects

For Indonesian condition

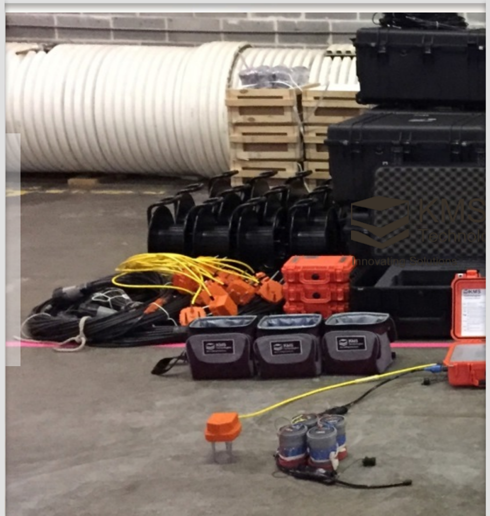
- EM is standard in Indonesia
  - Need to justify business value
  - Demonstrate in pilots
- Combined seismic/EM acquisition
  - Same crew = > 50% saving
  - Same instruments record microseismic/EM
- Interpretation/integration
  - CSEM: 3D anisotropic model available
  - Integrated interpretation

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)



Colorado 2015 CSEM transmitter test

- 100 KVA transmitter up-scalable
- Flexible input. (DC to 3 phase AC)
- Array system integrated