Traditional EM & onshore hydrocarbon exploration

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Non-Seismic Methods Workshop  Bahrain, 13 Oct. 2008
EM / resistivity methods and the Oil patch

Fundamentals

- Frequency domain EM
- Time domain EM

**Diffusive wave propagation !!**

- Electric fields
- Magnetic fields
- Natural sources
- Transmitter based systems
The model

- **Reservoir**
  - 2 by 2 km, 200 m thick
  - 200 Ωm @ 500 m depth
- **Background**
  - 30 Ωm sedimentary basin
- **Fault**
  - 10 km long, 5 Ωm
  - Extending from 25 to 225 m depth
- **Clay lense**
  - 800 by 200 m, 10 m thick
  - 0.04 Ωm @ 100 m depth
Reviewed methods

• Magnetotellurics
• Controlled source audiomagnetotellurics
• Long offset transient electromagnetics
• Fixed loop transient EM
• Dipole-dipole arrays as…
  – Direct current
  – Frequency domain induced polarization
  – Time domain induced polarization
Modelling tool used

- 3D integral equation multi-method modelling package

Magnetotellurics (MT)

MT survey layout & impedance (Zxy) plot

Frequency (0.01 – 10k Hz)

MT Apparent resistivity
Zxy depth slices, reservoir & fault
Zxy depth slices, reservoir & lens
MT impedance response

- Very small response
- Near surface distortion

Frequency 0.1 Hz

Line 1000N
MT Tipper response

- Tipper below resolution
- Also heavily distorted
Controlled Source Audio-MT (CSAMT)

- Tx 10 km wire, 6 km away
- Rx as in MT
- Frequency 0.1 – 100 Hz
CSAMT impedance & electric field

Zxy background

Ex background

Zxy reservoir

Ex reservoir
Traditional CSAMT configuration

- Sensitivity small
- Source effects dominate
- Big distortion from near surface
Long Offset Transient EM (LOTEM)

- Tx 10 km wire, 6 km away
- Rx dipoles Ex & Ey
- Step response 0.1 - 60 ms

LOTEM decay for two models
LOTEM Ex maps

- Near surface anomaly beats reservoir in magnitude
- Reservoir footprint still indicative

Timeslice 2ms background

Timeslice 2ms reservoir

Timeslice 2ms reservoir & NS lens
LOTEM Ex sections

- Need to be far enough away from near surface features

Pseudo section background

Pseudo section reservoir

Pseudo section reservoir & NS lens
Fixed loop TEM

- 2x2 km loop transmitter
- Step response 0.1 - 60 ms
- 300m dipole receivers

Fixed loop TEM decay
Loop source response

Line zero sections

Background

Reservoir

Reservoir & lens

10 ms maps

Position of section or map on map or section respectively
Loop source sensitivity

- Same issues as other methods
- Removal of source field possible
- Slightly less near surface distortion due to loop source

Scattered E-field sections for reservoir and reservoir & NS lens
Interim resume

- Near surface inhomogeneities distort anomaly, especially electric field

- No fundamental difference between frequency and time domain
Dipole – dipole configurations

- electric resistivity tomography
- Induced Polarization
- MTEM, FTEM, etc..
DC apparent resistivity pseudo sections

- Good sensitivity to resistivity contrast

Results shown at 0.01 Hz frequency domain IP
IP response

Pseudo sections of IP phase [mrad] @ 0.1 Hz, Cole-Cole parameter: c=0.5, m=0.3, T=1s
Near surface inhomogeneities

- Also very strong distortion

Reservoir @ 500m depth

Reservoir & overburden lens
Electrode spacing

- Size matters!

Reservoir @ 500m depth

Reservoir & clay lens with 500 m bipole size

Reservoir & clay lens with 300 m bipole size
So is there a winner?

- target resolution ~ inhomogeneities
- Frequency domain <> Time domain
- Survey geometry crucial
Where is the real challenge?

• Processing / inversion / interpretation
• Integration with seismic et al. crucial

• Further approaches not considered here e.g.
  – Borehole surveys
  – AEM for proxies