# National Geophysical Survey Science Opportunities

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# Outline

- Brief biography
- Science opportunities
- High resolution 3-D seismic surveys
- Why should we be interested in EM?
- Controlled-source electromagnetics (CSEM)
- Magnetotellurics
- Interpretation of EM data
- Conclusions and applications

# Biography

1976-80 Headquarters Geophysicist, National Coal Board

1980-82 Consultant to British National Oil Corporation

1982-92 Professor of Applied Geophysics, Delft

1992- Professor of Petroleum Geoscience, Edinburgh

2004-07 Technical Director, MTEM Limited

2007-10 Chief Scientist, Geoscience and Engineering, PGS

Present: Professor of Petroleum Geoscience, Edinburgh

# Science Opportunities

- Acquisition of high resolution 3-D seismic data
- Determination of natural fracture direction
- Likelihood of hydrocarbons before drilling
- Combined seismic and EM data for better characterisation of reservoirs and source rocks
- Location of underground hot water for geothermal applications

# Scotland's Primary energy usage (rest of UK is probably similar)

- 55% of Scotland's primary energy usage is for heating.
- 78% of Scottish households use gas for heating – to raise the temperature by ~ 20°C.
- Much more carbon dioxide is generated by domestic boilers than by power stations.
- We need to think about geothermal energy for heating. Why is so little being done?

# High resolution 3D seismic surveys

- Since 2007 the bandwidth of marine seismic reflection data has greatly improved through
  - multi-component receivers
  - removal of the sea surface reflection
  - source signature measurement and deconvolution
- For land surveys we can also use
  - multi-component receivers
  - source signature measurement and deconvolution

# Multi-component receivers

- Three-component receivers are now in common use and are essential for measuring shear waves.
- Shear waves are sensitive to fractures:
  - S-waves travel faster parallel to fractures
  - S-waves travel slower perpendicular to fractures
- Processing of shear-wave data is not as routine as P-wave processing – there is plenty of scope for developments.

# Seismic sources

- Measurement of marine air-gun signatures is now routine.
- On land we use Vibroseis and dynamite.
- Vibroseis ground force measurement is routine.
- The dynamite source signature is not measured – but there are possibilities using two charges per shot-hole.
- Tying dynamite and Vibroseis data is an issue.

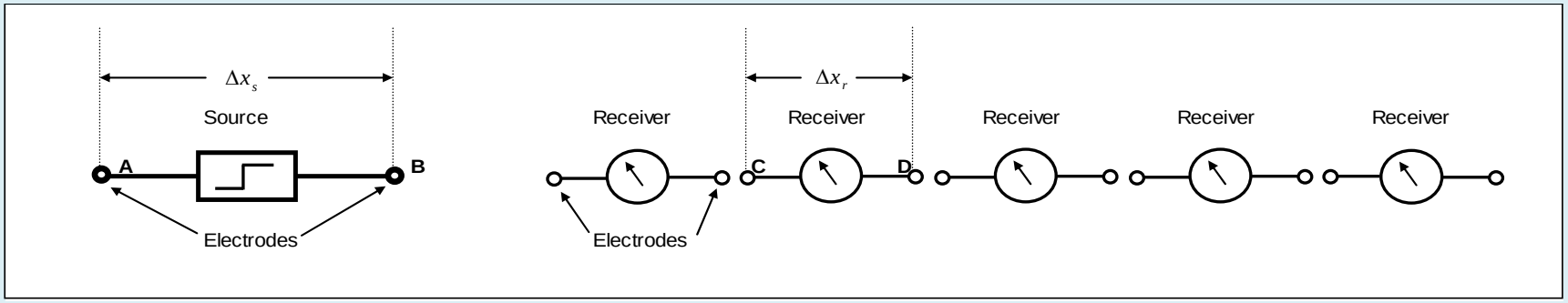
# Summary: seismic surveys

- 2-D regional survey lines and 3-D more focused surveys are crucial for understanding the structural geology and potential resources of the UK.
- They can also define areas where other geophysical surveys, may be required to indicate fluid content – e.g. in conventional reservoirs, shales, hot rocks.

# Why be interested in EM?

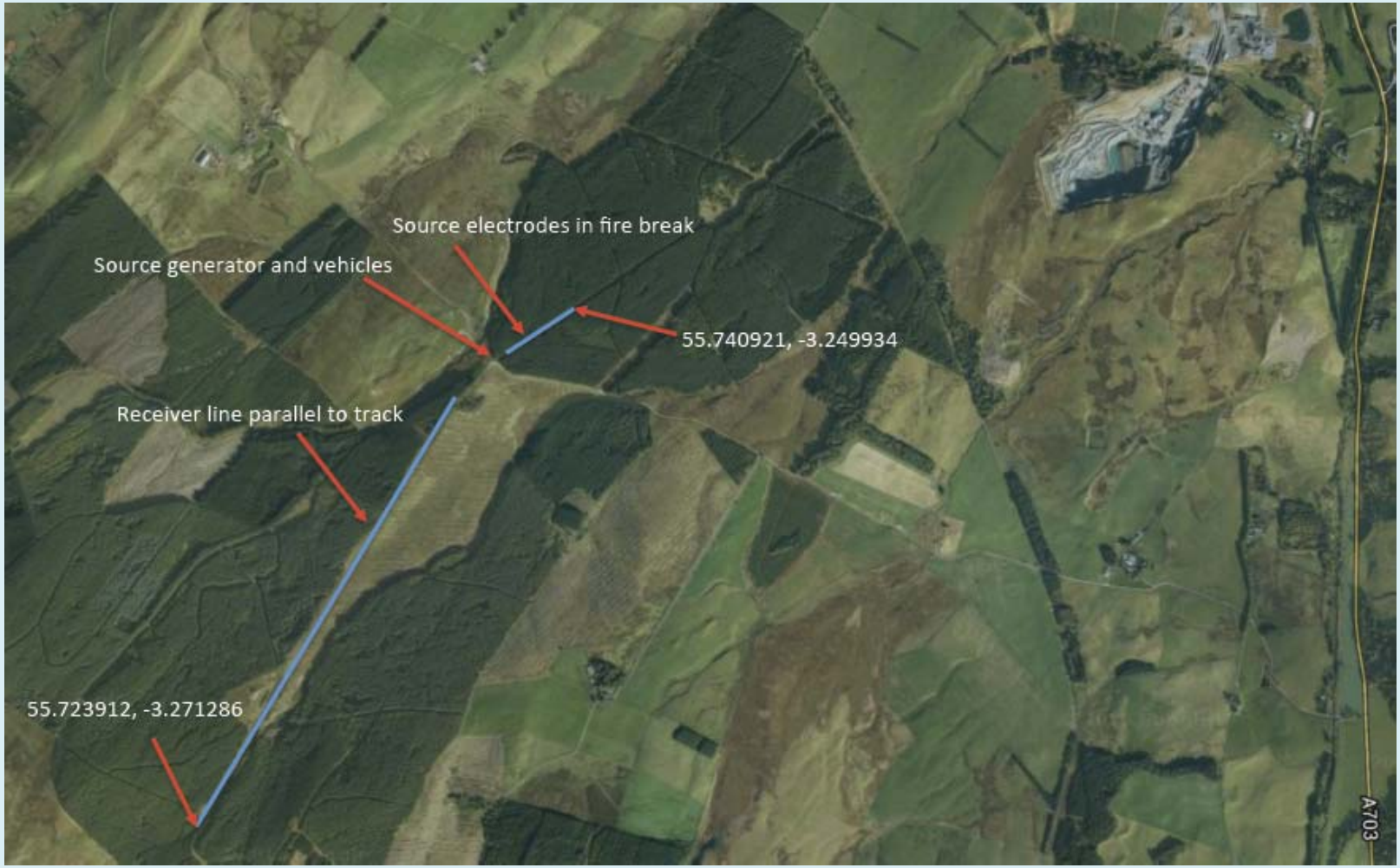
- Resistivity is much more sensitive to brine saturation than P-wave velocity.

# CSEM -The MTEM method




- Layout similar to 2-D seismic surveying
- Total spread length typically 4-8 km
- Source-receiver spacing of 4 times target depth to fully resolve target.
- Source and receivers synchronised by GPS timing.

# Full System Test: Cloich Forest



# Source truck and generator

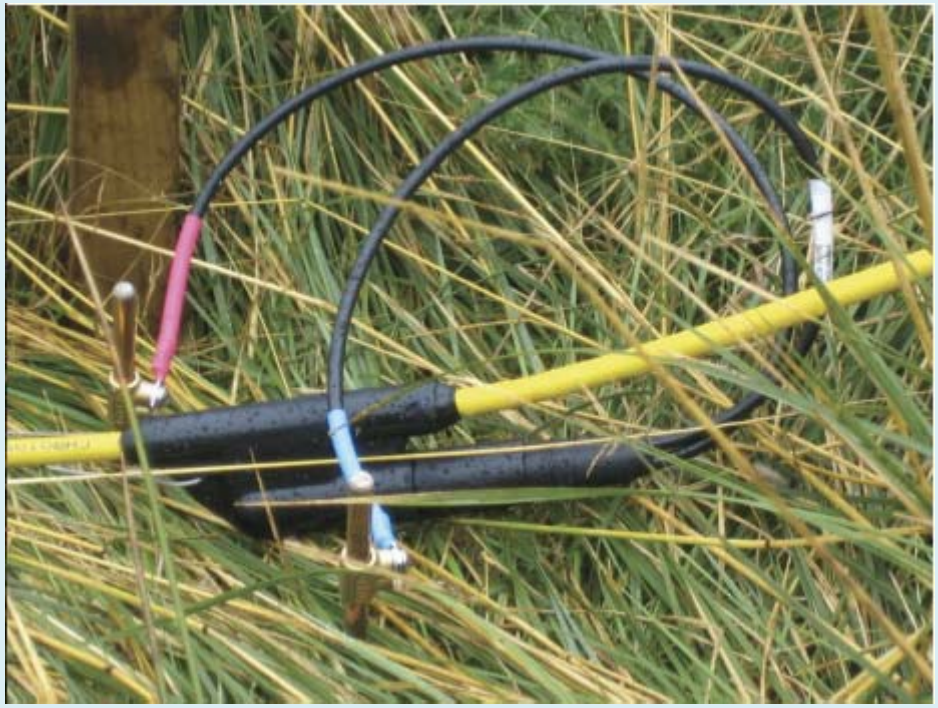

# Source electrodes

Source electrodes at 100m separation

# Receiver

Receiver box


Receiver electrodes



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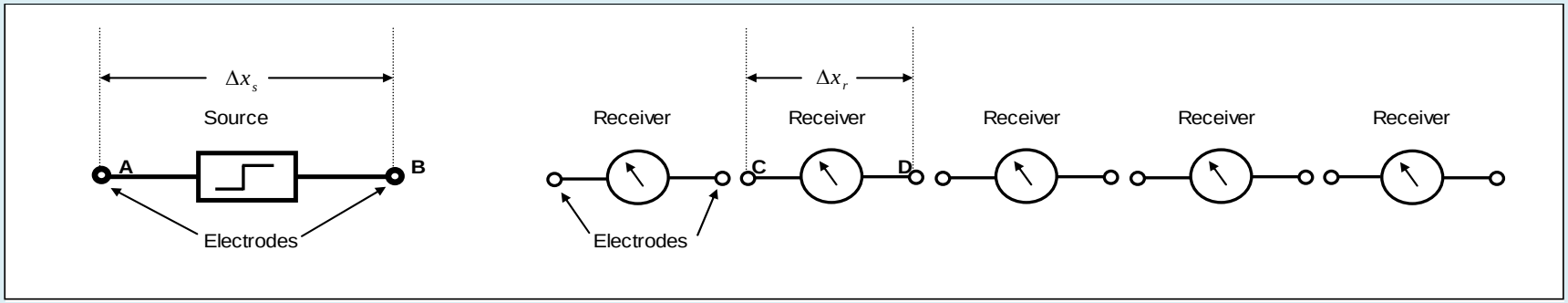
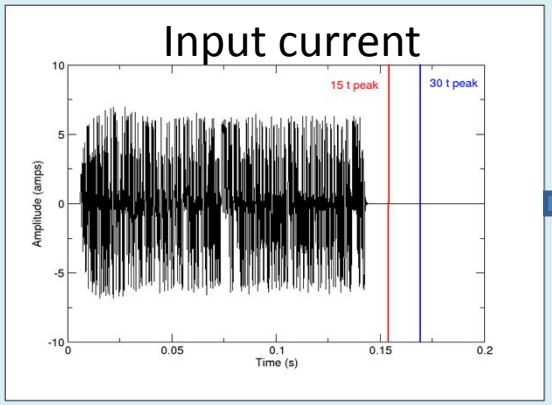
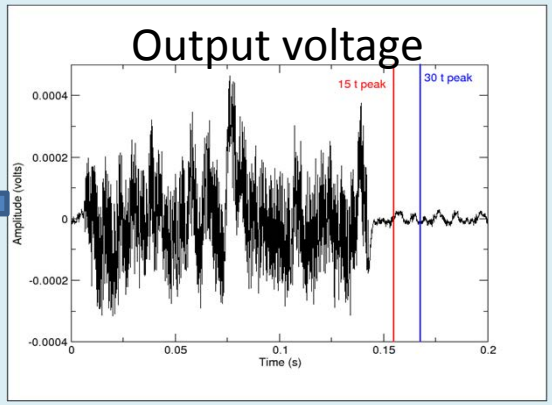
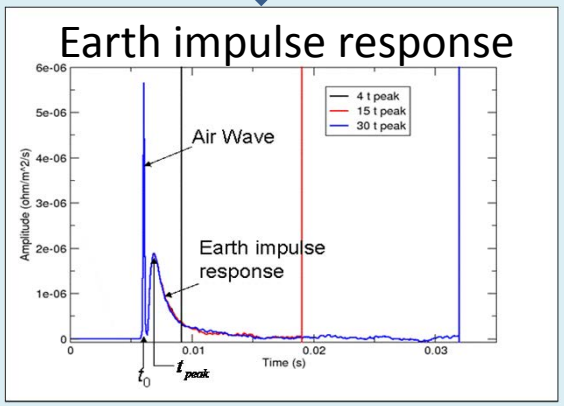


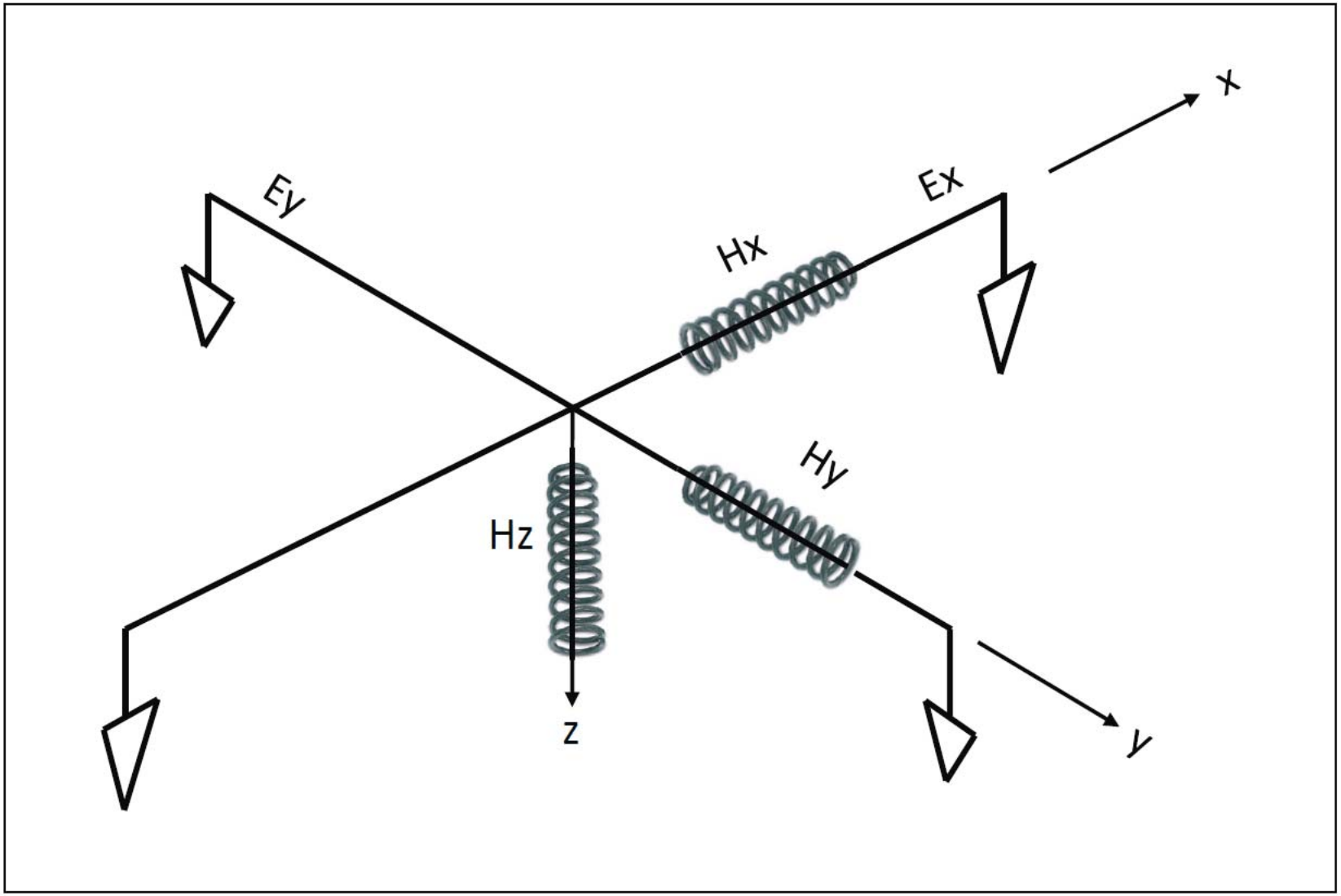




Deconvolution



# Magnetotelluric Receiver



# Why use magnetotellurics?

- CSEM with a dipole current source is good at finding resistors.
- Magnetotellurics is good at finding conductors.
- Hot water in the ground contains dissolved salts and is very conductive.
- We can use magnetotellurics to find hot water at depth.
- It is important for geothermal applications.

# Interpretation of EM data

- Interpretation of EM data is like interpretation of gravity and magnetic data: you find a model to fit the data. This is called inversion.
- The model must not contradict other data.
- We can use other data, e.g. seismic data and well logs, to constrain the model.
- With known seismic velocities and lithology, a background resistivity model can be obtained.

# Conclusions

- The National Geophysical Survey is a tremendous opportunity for exploration science and determination of national resources.
- 3-D seismic surveys can determine structure and (with multi-component receivers) natural fracture density and direction.
- Electromagnetic surveys can complement seismic surveys and provide information on fluid content.
- Seismic data lead to background resistivity models for interpretation of EM data.

# Applications

- CSEM surveys complement seismic surveys by determining reservoir resistivity – hence hydrocarbon saturation - thus reducing the risk of drilling dry wells.
- Shallow CSEM surveys could find sink holes.
- Magnetotelluric surveys could be very useful for finding hot water for geothermal applications.