Has non-destructive electrical tomographic imaging a role in heritage conservation?

Dr Richard Ogilvy
Team Leader - Geophysical Tomography
Outline of talk

• Electrical imaging technologies under development by BGS
• Void detection (e.g: mineshafts, tunnels)
• Mapping of flow-paths (e.g: leachate, saltwater, contaminant plumes, electro-filtration)
• Remote real-time monitoring of vulnerable sites using wireless telemetry (GSM, GPRS, internet, satellite)
• Implications for the preservation of heritage buildings and sites
Geoelectrical Imaging Technologies

- Electrical Resistivity Tomography (ERT)
- Induced Polarisation Tomography (IPT)
- Complex Resistivity Tomography (CRT)
- Spectral Induced Polarisation Tomography (SIP)
- Capacitive Resistivity Imaging (CRI)
- Automated time-Lapse Electrical Resistivity Tomography (ALERT)
- Self-Potential Tomography (SPT)
- Electromagnetic Tomography (EMT)
- Radar Tomography (RT)
Static 2D and 3D ERT Surveys

Data Collection

Data Inversion

Electrical Image
Capacitive Resistivity Imaging (CRI)

**Cavity Detection**

- Receiver unit and data acquisition
- Transmitter unit
- Dipole length
- Capacitive sensors

**BGS-designed CRI prototype**

- Resistivity data sampled at 10 cm
- 1 m line spacing
- Survey guided by RTKGPS navigation
- Area of 80 m × 25 m covered in 5 hrs
- >100,000 data points captured

(US Patent granted)
Detection of air-fill tunnels (Glasgow) by 3D ERT survey

Resistivity iso-level = 400 ohm.m

Tunnels

Made Ground

Superficial Deposits

Bedrock

© NERC All rights reserved
Cross-hole Resistivity Tomography

Surface Unit

PC

Multi-core cable

Borehole

~25m

Electrode takeouts at regular intervals (eg: 0.5m, 1m, … )

~10-15m

Mine workings

© NERC All rights reserved
Detection of air-filled shaft by cross-hole ERT

Detection was only possible using the new array optimization scheme.

Conventional cross-hole scanning failed to detect this shaft.

Shaft detected by 3D inversion of 8 Panels (A, B, C, D, E, F, G, H)
Commercial landfill: 3D ERT survey to map the volumetric distribution of leachate (opaque blue). Leachate is re-circulated to further enhance the production of landfill gas, and subsequently the generation of electricity for the national grid.

Resistivity iso-level = 4 ohm.m
Electro-filtration in buried mineshaft detected by Self-Potential Tomography (SPT)

Abandoned Pewfall colliery

"...no indication of shaft location, all surveys conducted “blind” on 50m grid"
Dynamic Time-Lapse 2D, 3D ERT surveys (ALERT)

New sensor technology has been developed by BGS for the real-time electrical imaging of sensitive sites “on-demand” using permanent arrays and remote data capture by wireless telemetry (GSM, GPRS, internet, satellite)

- Contaminated land
- Water resources
- Geohazards
- Landfills
- Slope stability
Installation of ALERT system in trenches

ALERT system Mk2

New servers in BGS

DBMS & Control Interface

2D ERT image of saline intrusion, Almeria, Spain
Seasonal changes Jan-Oct 2005

Mediterranean sea
Real-time ALERT imaging of hydraulic tracer

1D

2D

3D (4D)
Landslip monitoring using time-lapse ALERT technology

- BGS-designed ALERT technology has been installed at an active landslide site to predict and track gravitational mass movement.
- Geoelectric property changes can be related to temporal changes in moisture content, infiltration, fluid flow, stress, deformation, or saturation levels and provide early warning of movement.
- The system is providing unprecedented sampling rates that would not be possible by manual repeat surveys.
Implications for heritage conservation

- Electrical imaging technologies are evolving rapidly.
- Rapid changes in climate and human activity are impacting on earth systems, and processes and our survey techniques need to meet this challenge.
- The same aggressive climatic actions and high human loadings (tourism) must be affecting ageing historic structures and sites.
- ALERT and wireless telemetry offers the potential for both automated and volumetric temporal monitoring - thereby eliminating or reducing the need for expensive repeat inspections.
- Could ALERT-CRI technology be used as an early warning system to detect internal deterioration in heritage structures – before such effects become visible?