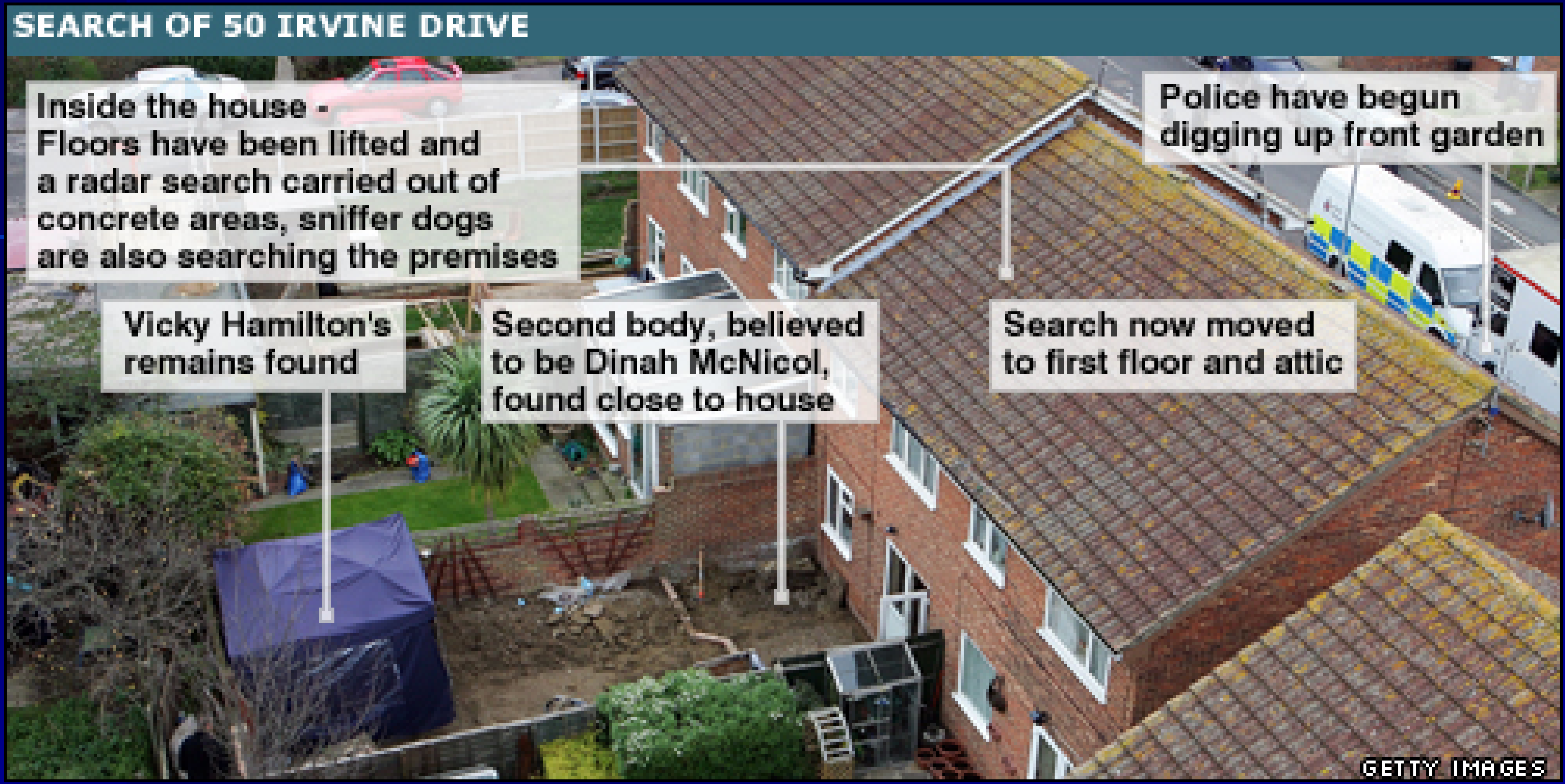

KEELE UNIVERSITY

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STATS GEOPHYSICAL

EPSRC

Updates and Advances in the location of Clandestine burials

Jamie Pringle [1] and John Cassella [2]

Burial Research Group

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Staffordshire University

Grateful thanks to

John Jervis and to Stats Limited, St. Albans, UK

Current situation

- What's new
  - Very little in terms of archaeology *per se*
  - Standardised protocols/SOP's in body recovery re FSS, NPIA
  - Forensic pathology ??
- Search and recovery
  - A move from semiqualitative perspective (with probes etc) to quantitative modern technology
    - Remote sensing, geomorphology, steam sampling
    - Probable areas for search
    - Dogs and others (insects)
    - Methane probes
- Geophysics techniques NOT yet in Police search handbooks

Typical Geophysical Targets

- **Evidence of human ‘interaction’ with subsurface:**
  - **Clandestine Graves** (single or mass)
    - Old (years?) or new (days), shallow (<1m) or deep (m’s)
  - **Buried Weapons or other items** (inc. money, stolen goods)
    - Generally small, but how deep and where?
  - **Lost Vehicles**
    - Often dumped and buried (easy to find?)
  - **Disturbed ground**
    - Evidence of excavation or other interference (e.g., soil disturbance)
  - **Occupation**
    - Evidence of human presence/occupation at a site (e.g., vehicle use)
- **Clandestine Graves highest profile**
  - Ongoing collaborative research concentrating on

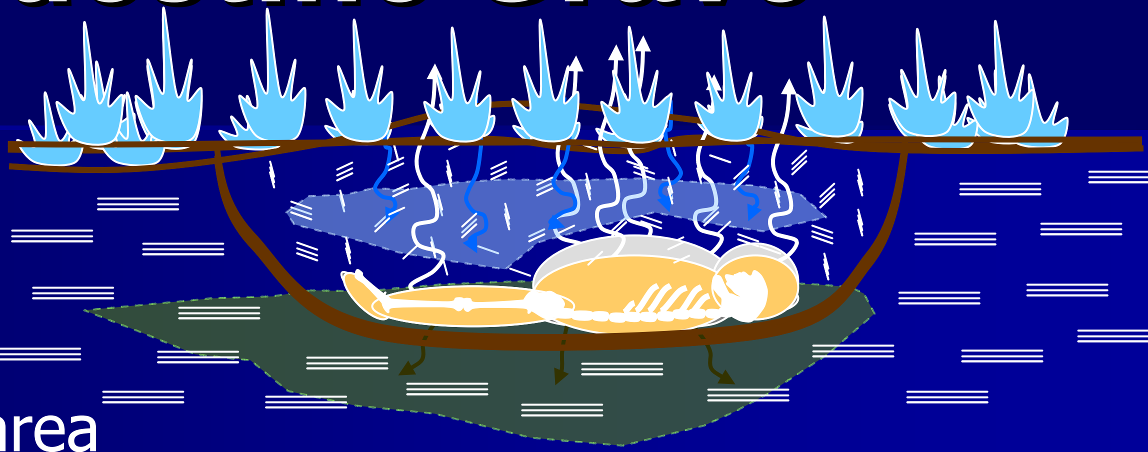
But…

Geophysics is not the first choice for grave location…

- Aerial surveys and/or photographs & remote sensing
- Site walking
  - Anthropologists & archaeologists
- Cadaver Dogs
- Entomology
- Methane probes
- Compaction probes
- Ecology/botany
- And as a last resort
  - mass excavation…

Courtesy of N. Cassidy

If a Clandestine Grave



- Scale of Survey area
- Surface environment
  - Urban, rural, vegetation, topography, location, etc.
- Time scale & estimated date/time of burial
- Integrity of crime scene
- Manpower & funding
- Politics
- Plus the burial itself…
  - Depth, orientation, age, size, distribution, condition
  - Nature of subsurface materials
  - Deliberate concealment, enclosure, etc.

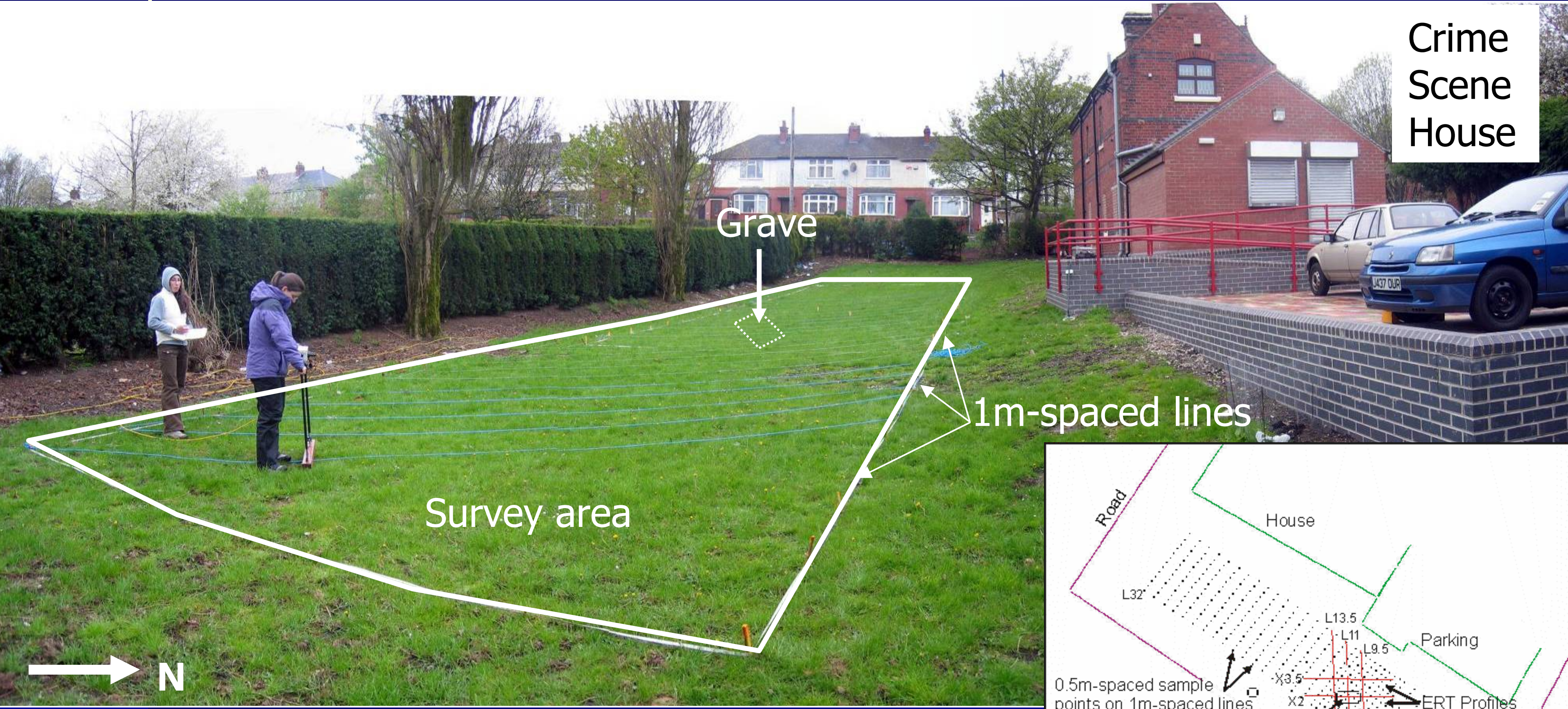
Complications

- Decay process very temperature, & therefore depth, dependent
  - Body buried 0.5m bgl will skeletonise in ~ year
  - Body buried 2m bgl can remain intact for ~ year & take 5-10 years to skeletonise
- Environmental conditions
  - high acidity (peat), very cold/arid conditions ‘mummify’
- Ambient temperature
  - **Putrefaction** process occurs ~40-50˚C)
  - Otherwise body fluids not broken down in same manner
    - increased decay times & reduced fluid discharge

Geophysical Basics

- Active & passive methods
  - **Active** uses technology to send induced signal into ground & measures return
  - **Passive** measures local variations in field
- Variety of techniques, equipment & difficulty, depending upon local ground conditions, likely target size, depth below ground level, orientation, etc.

Simulated clandestine grave



Pringle *et al.*, (2008)

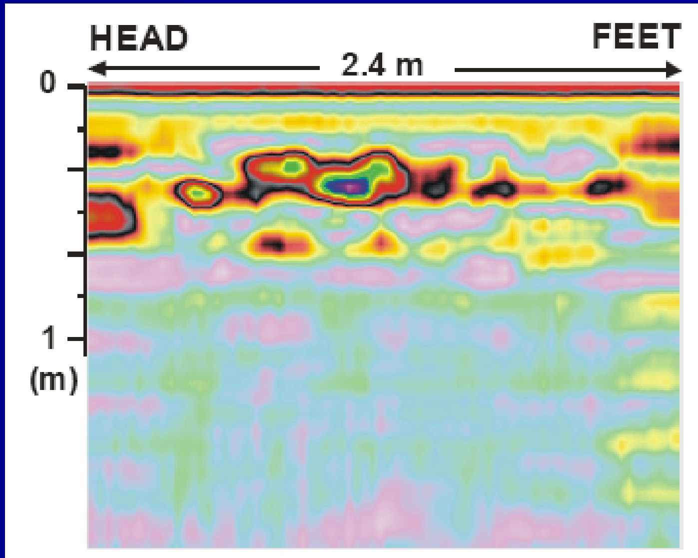
'Sid' burial

- Cause of 'death' – ice-axe in skull
- Clothed (resin) plastic skeleton buried (0.6m bgl) with animal tissues & saline water
- Remains recovered 5 months later by Staffs 2nd yr F.S. UG's

Ground Penetrating Radar (or GPR)

- **Active** field method
- The most commonly used geophysical technique for forensic purposes (not always a good thing!)
- Developed in the 1970's
  - Mainly for landmine detection
- Now used in many applications as it resolves features at depth
  - Pipe line leakage, civil engineering etc.
  - Geology & **Forensic**
- Does not perform well in high conductivity (clay, salt water)
- Penetration & resolution depends on antenna frequency & site

Corpse buried beneath concrete (Freeland, 2003)



GPR (2): The System

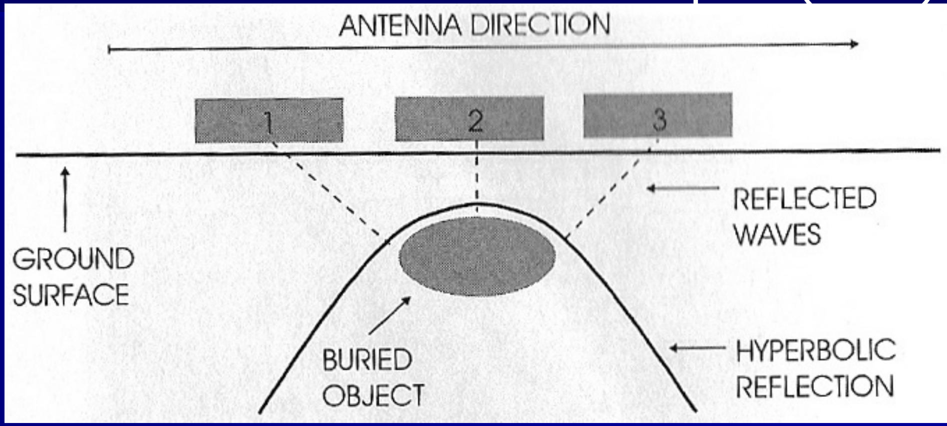
Consists of – Source generator (pulse), transmitter antenna (dipole), matched receiver antenna, fast analogue to digital converter (ADC) and computer to record and display data. The antennas are mounted on a carrier or cart and separated by a small distance. *Many different types…*

© Cassidy (2005)

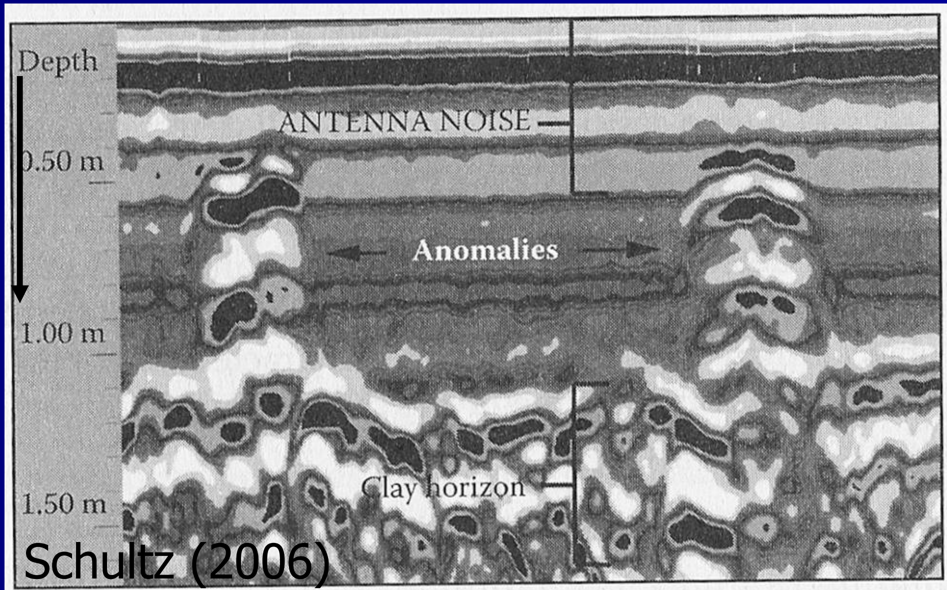
GPR (3): The Theory

- Set central frequency
- Transmitter/Receiver antennae take 1-D recording
- Sequentially moved to record 2D line
- Targets will be ½ hyperbolae

Dupras (2006)



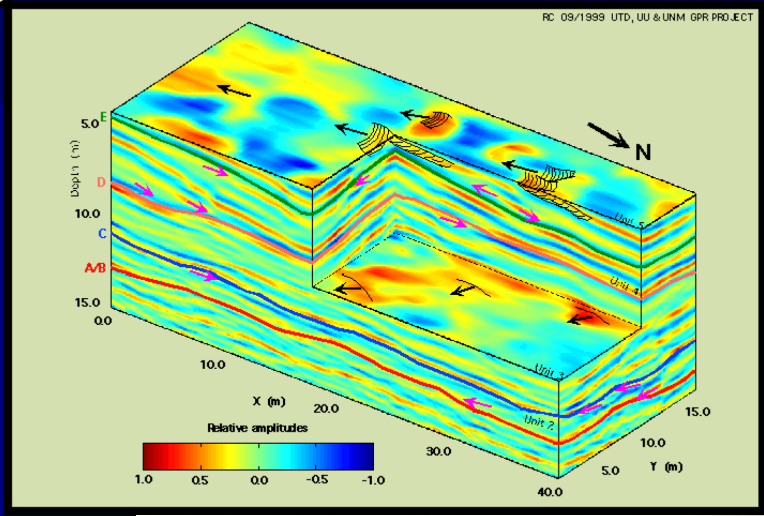
Distance (m)

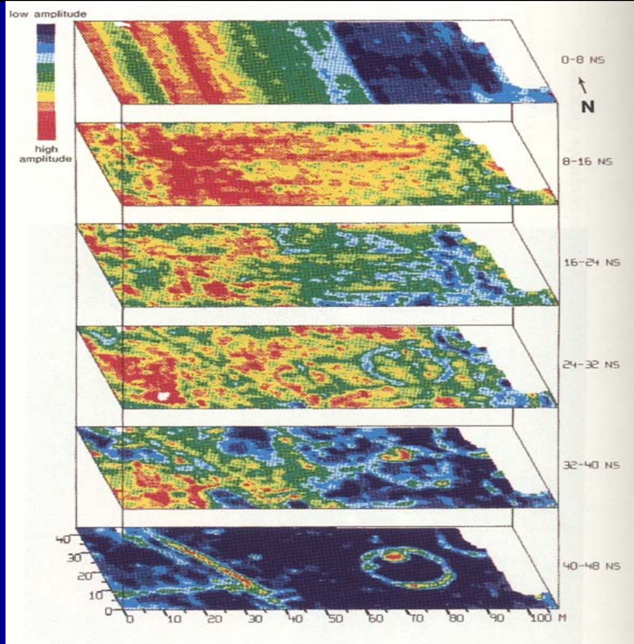


Schultz (2006)

GPR (4): Survey Grids

- Successive 2D profiles can create a 3D grid
- Using standard processing software, creates '3-D' datacubes
- Horizontal 'time-slices' can also be created
  - Can image deeper events that may be masked by shallow objects





GPR (5): Fred West… A GPR Success?


© Gloucester Echo

February 24, 1994 –

- **25 Cromwell St, Gloucester.**
- 9 Bodies under house and garden
- 3 others at second address and in a field
- Victims include two of their daughters!


© Gloucester Echo

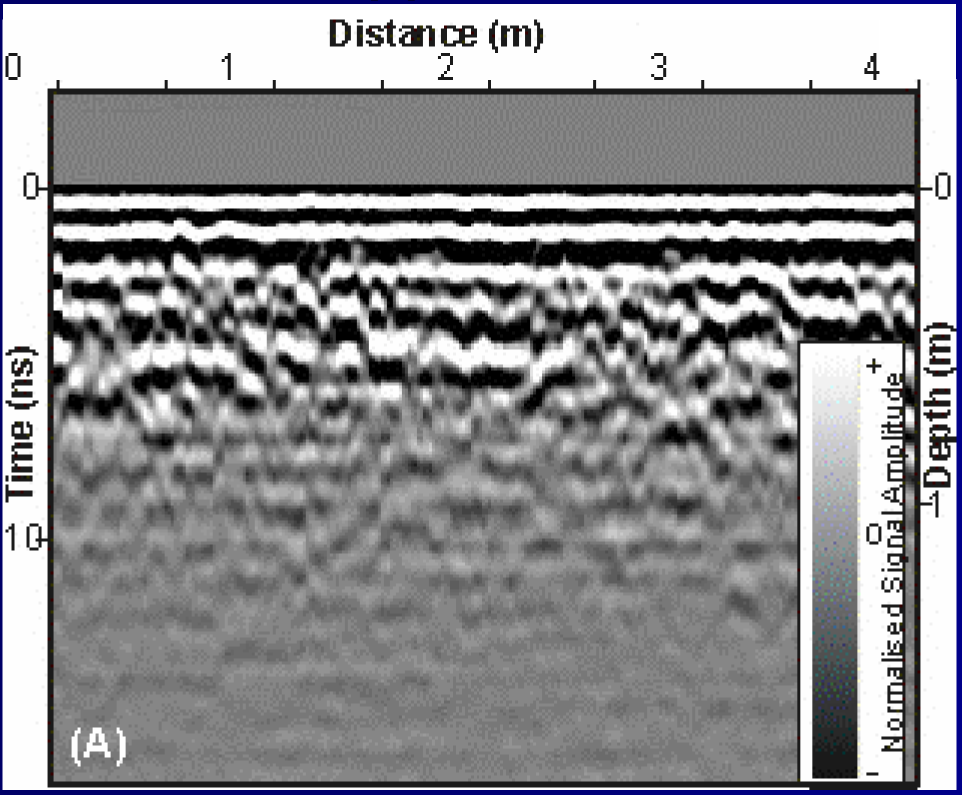
First real public exposure of GPR for forensics

ERA technologies (U. K.)

Successful?….

GPR (10): 'Sid' Results

- 1month profile L12.5
- control profile L12.5

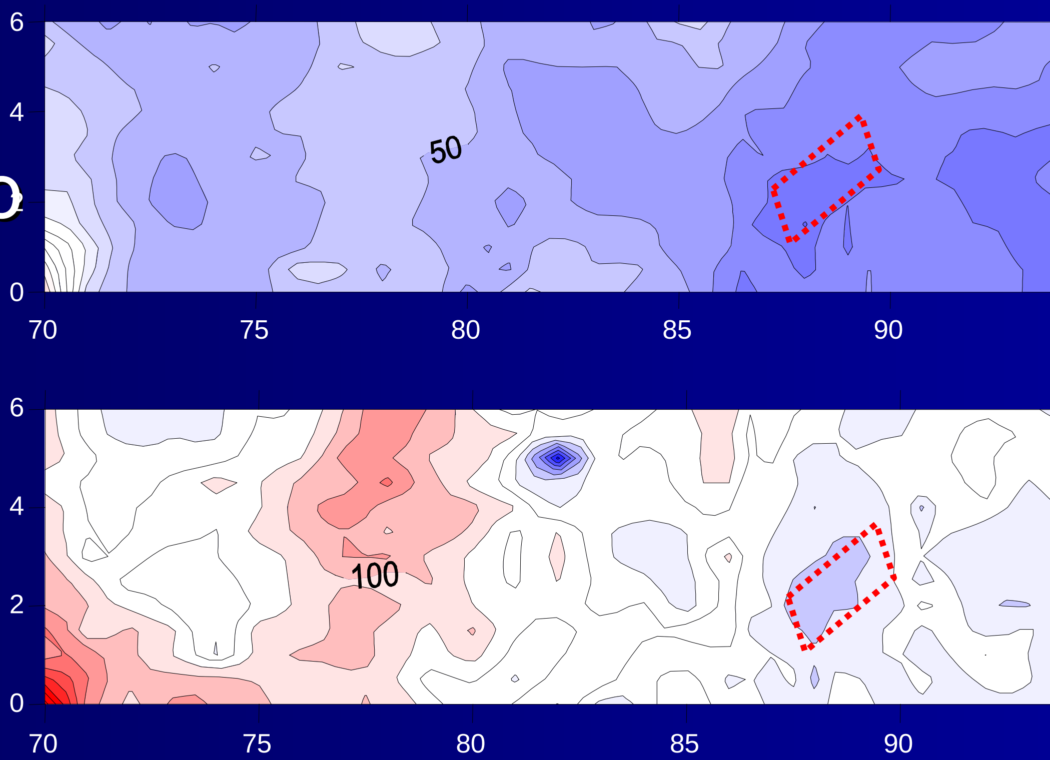


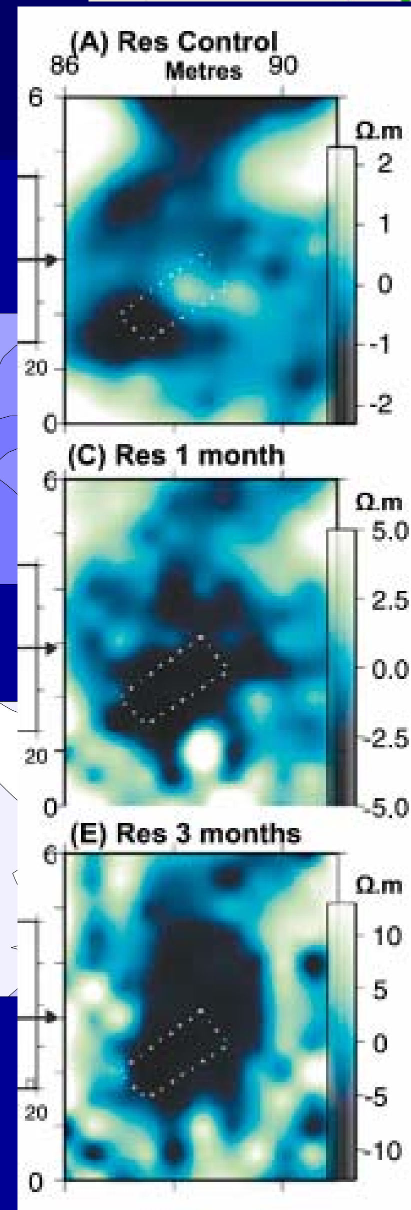
- Whole garden profiled 3x
  - Control
  - 1mth &
  - 3mths post-burial
- The same profile shown here
- Not a strong target!

Resistivity
CSH Case Study

- Di-Di results
- Sensitive to <0.5m bgl variations
- Expecting low values
- Good results

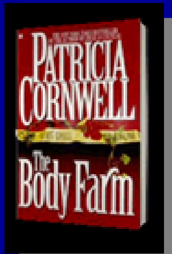
1mth Dipole-dipole despiked





Resistivity
Pigs in Grave (PIG) Project

- Undertook research into geophysical (and forensic) response of decaying, buried bodies
- Called Pigs in Graves project (or PIG project)
- Inspired by 1986 (so far unsolved) triple murder in US.
- Range of conditions simulated
  - Over 25 Pigs in blankets, tarpaulins, fully clothed, in plastic etc. in different environments plus range of injuries



- On-going but restricted research. Seldom published but inspiration for Patricia Cornwell's book, The Body Farm

Locating graves with resistivity surveys

- Twin probe array has been used in a number of criminal investigations in the UK (Cheetham, 2005), including the moors murders (Scott and Hunter, 2004).
- Two electrodes on mobile frame and two remote probes gives high lateral resolution.
- Graves commonly appear as areas of low resistivity (e.g. Lynam, 1970; Cheetham, 2005).

Changes in grave resistivity

Two possible causes have been suggested for the reduced resistivity of graves (Cheetham, 2005, p.72);

1. **The 'disturbed' grave soil is more porous than the surrounding soil. Supported by the observation of low resistivity over both empty pits as well as buried pig cadavers (Lynam, 1970).**

2. **Decomposing remains are known to result in a localised increase in fluid ion concentrations (Vass *et al*., 1992; Hopkins *et al*., 2000), which would result in increased groundwater conductivity in the vicinity of the grave.**

Pig1 Project aims

Using pig cadavers buried in the garden of Staffordshire University's 'Crime Scene House' as human proxies for 'shallow' graves, this study has two major aims:

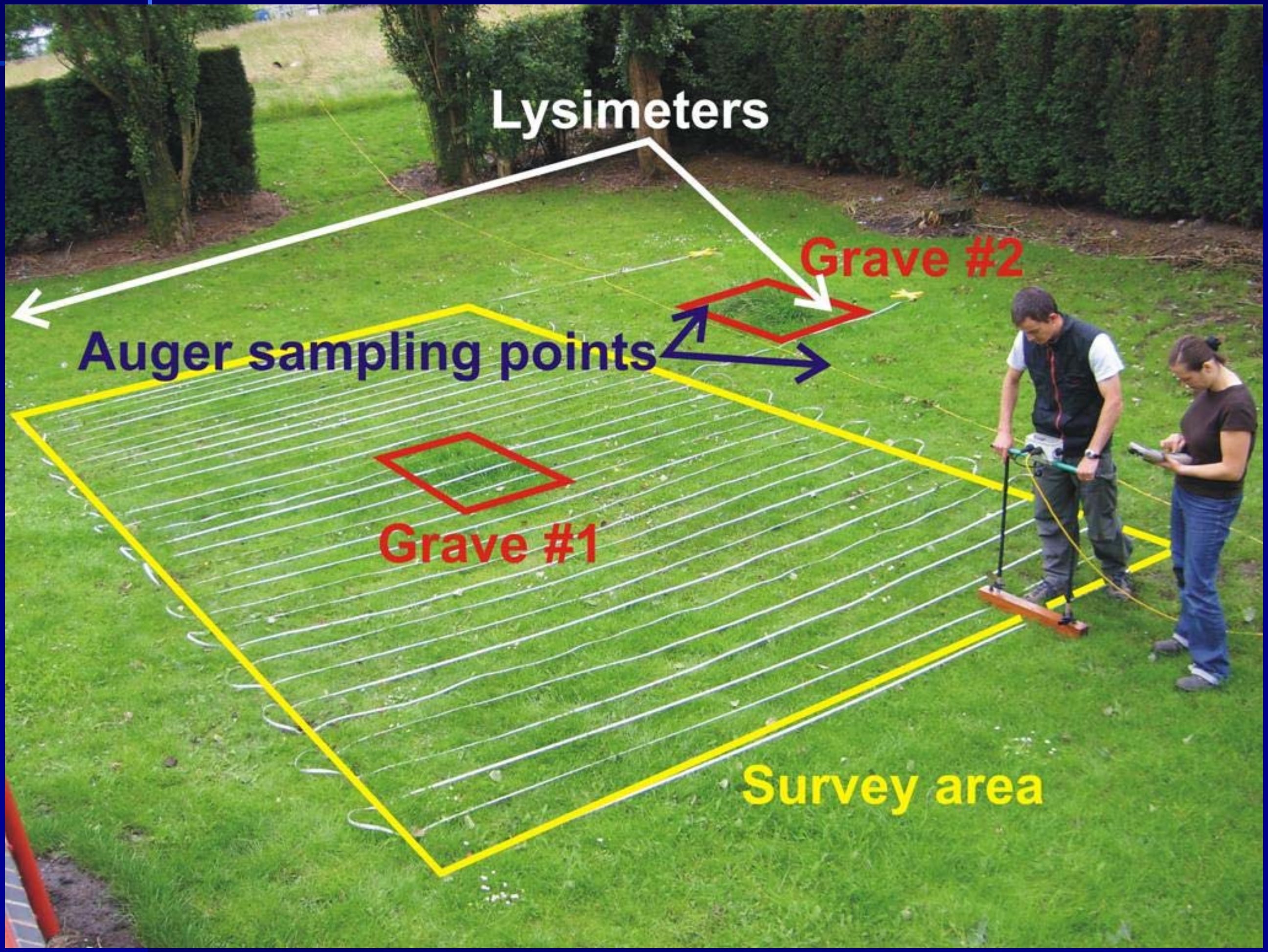
1. To determine the relative importance of disturbed soil and cadaver decomposition to the resistivity response of the grave.

2. To investigate how this resistivity response changes with time.

Pig burials and study site – March 07

Two eviscerated pig cadavers buried in graves 0.6m deep. Soil was ‘made ground’, with sand layer at ~0.5m depth.

Survey plan

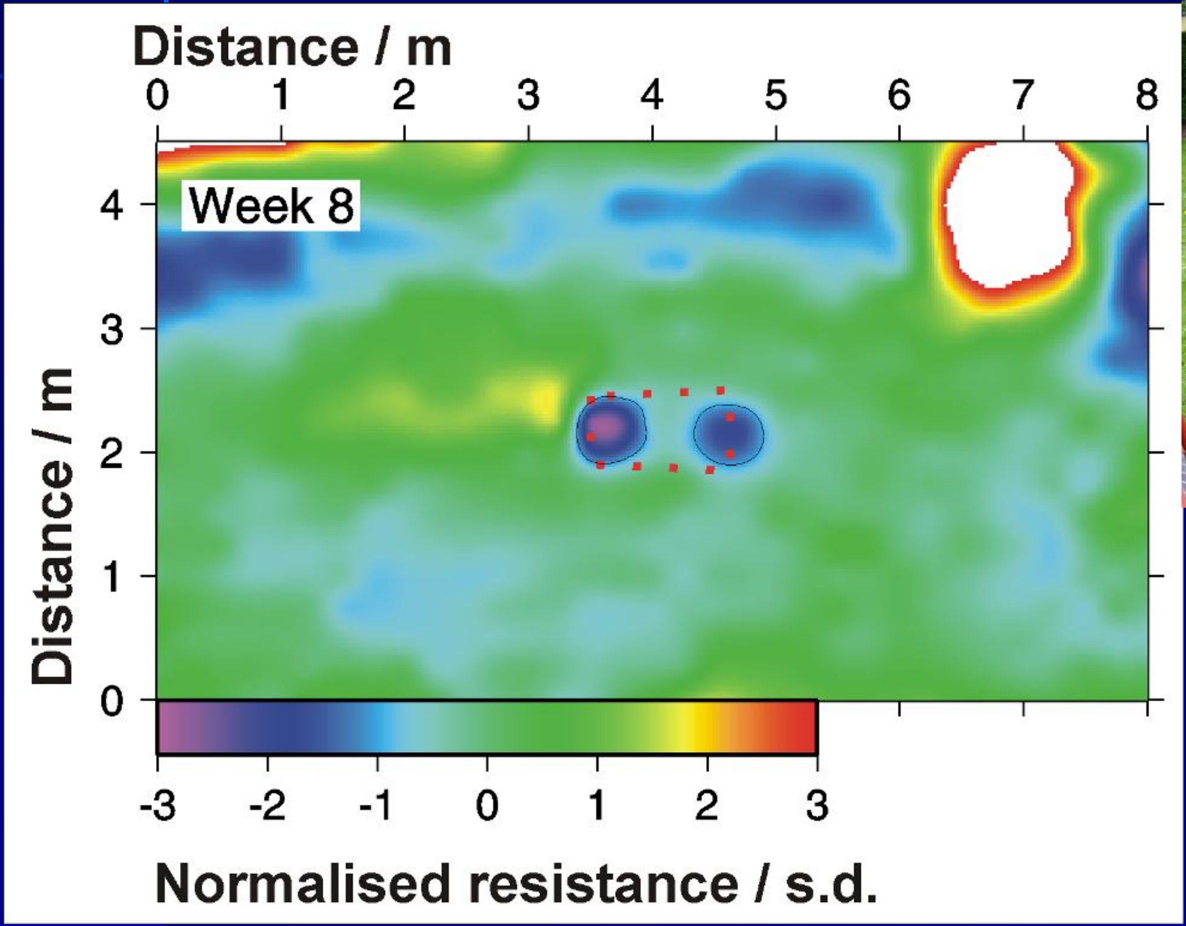


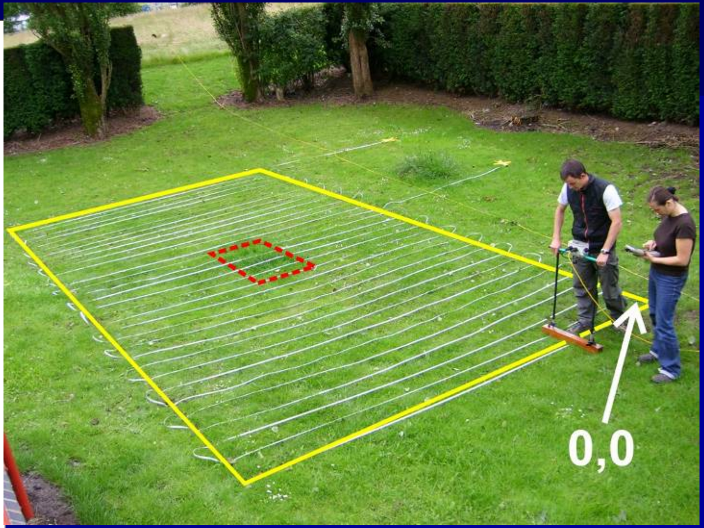
Area surveyed every two weeks for six months & once a month thereafter.

Readings at 0.25 m XY intervals.

Soil & water samples obtained from second grave & control locations

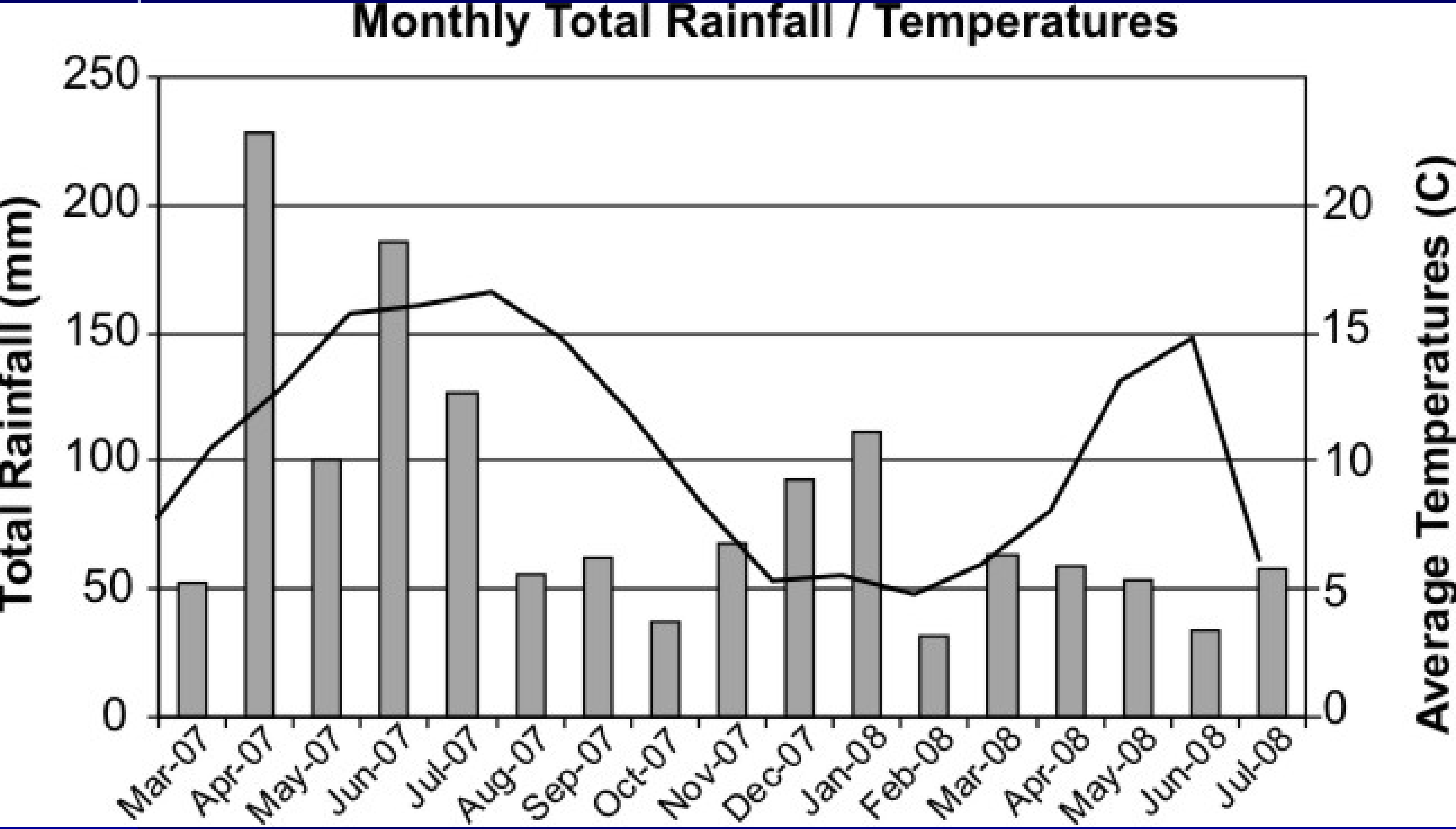
Resistivity survey data





Processing: raw data were median filtered, interpolated, trends were removed & then values normalised. Data: Jervis *et al.* (In press).

Site rainfall / temperature

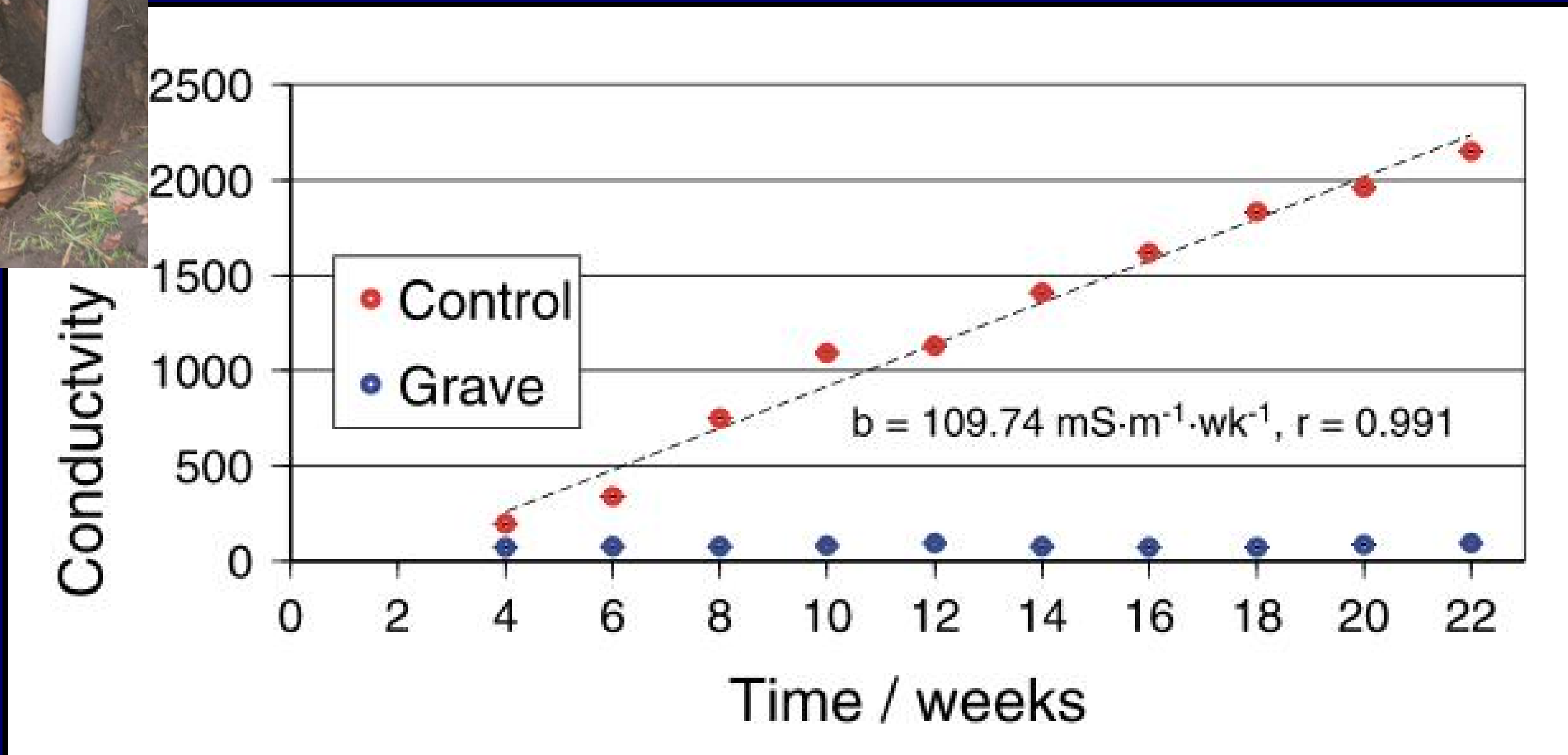


Soil and groundwater sampling

Soil samples collected using augers (right image) & oven dried to allow porosity & saturation to be estimated.

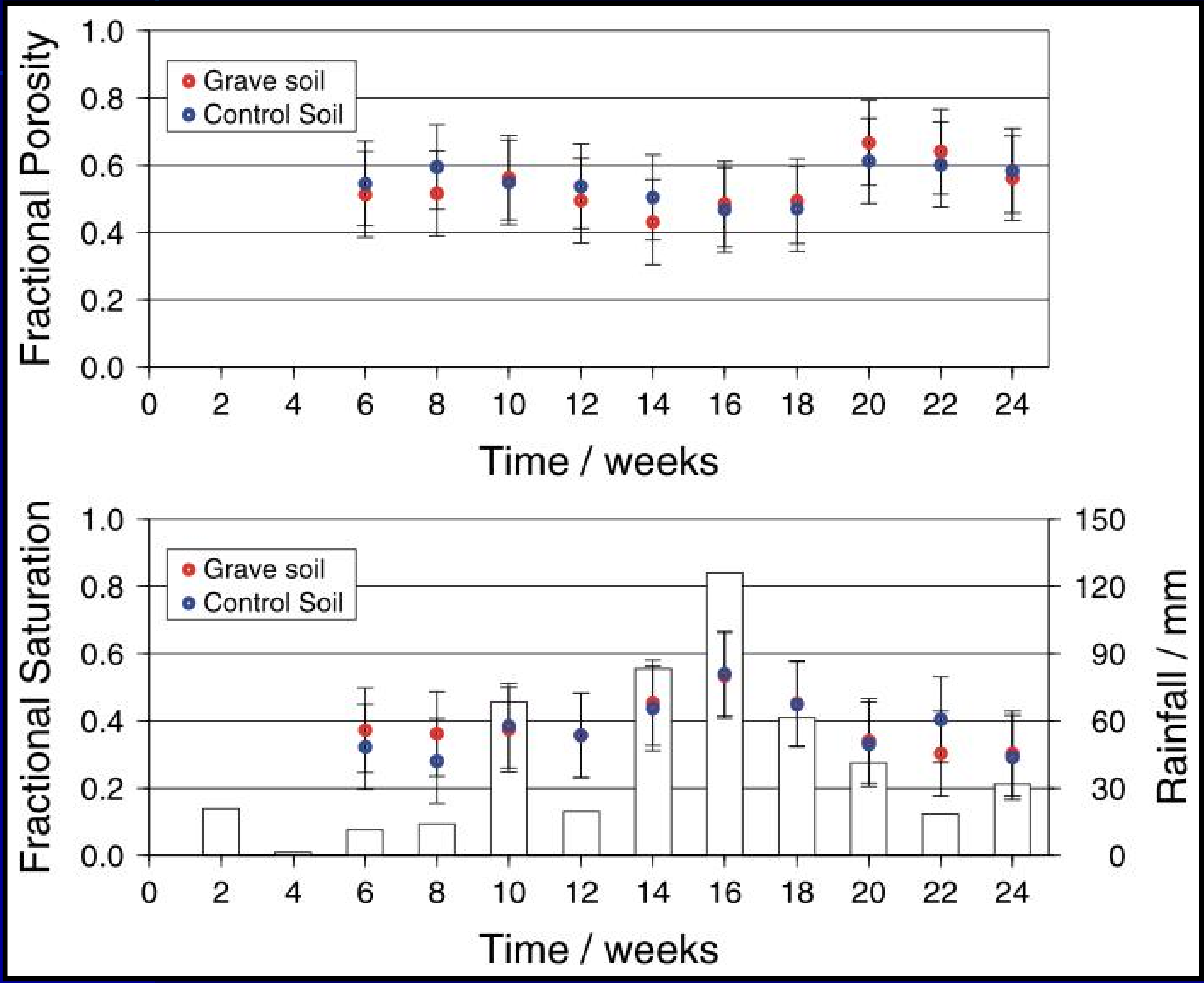
Groundwater conductivity measured for samples collected from lysimeters (left).

Fluid Conductivity data



Grave fluid conductivity increases by ~110 mS·m^{-1}·wk^{-1}. Control fluid conductivity is roughly constant, with μ_σ=79.6 mS·m^{-1} and s_σ=8.6. Data: Jervis *et al.* (In press)

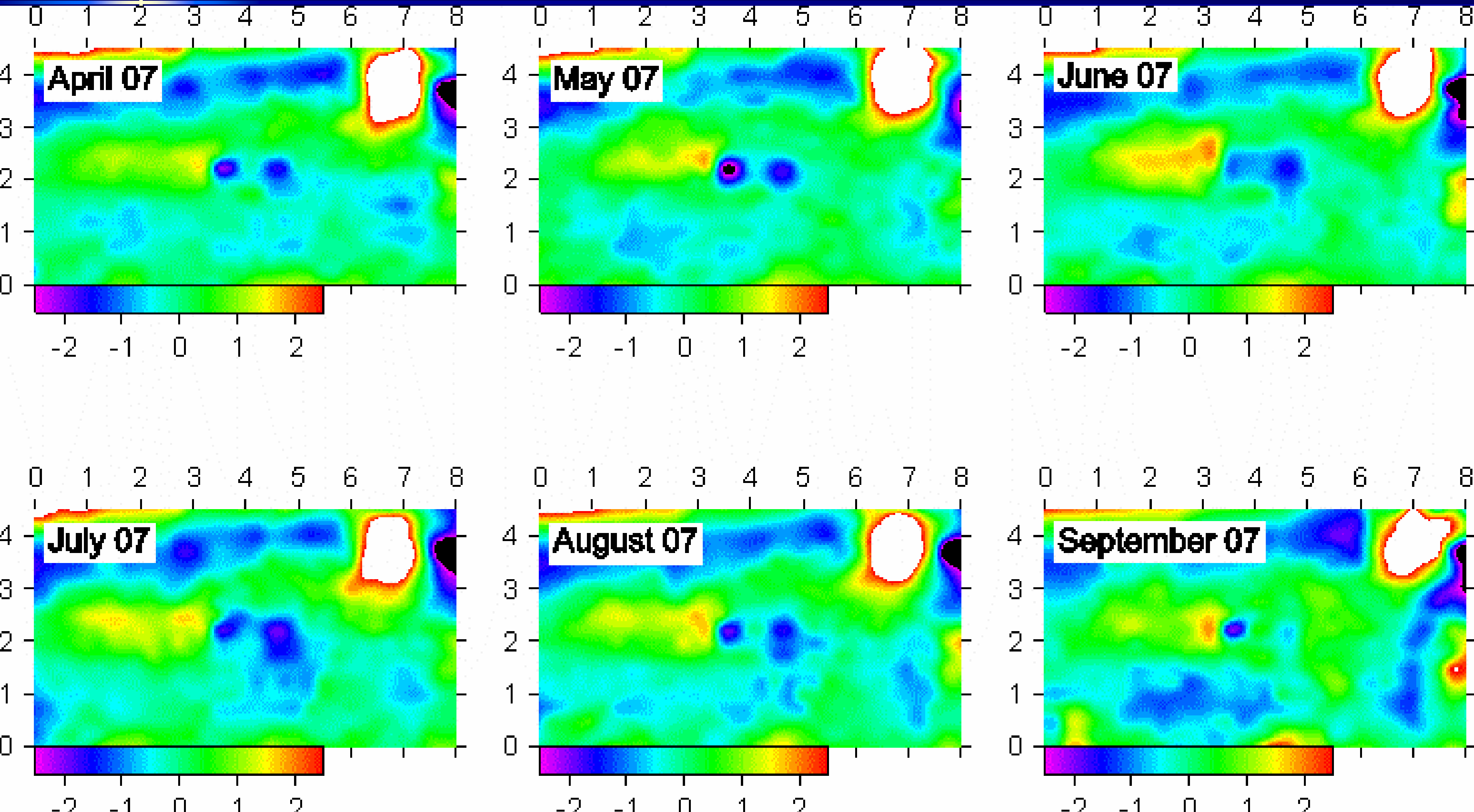
Soil porosity and saturation data



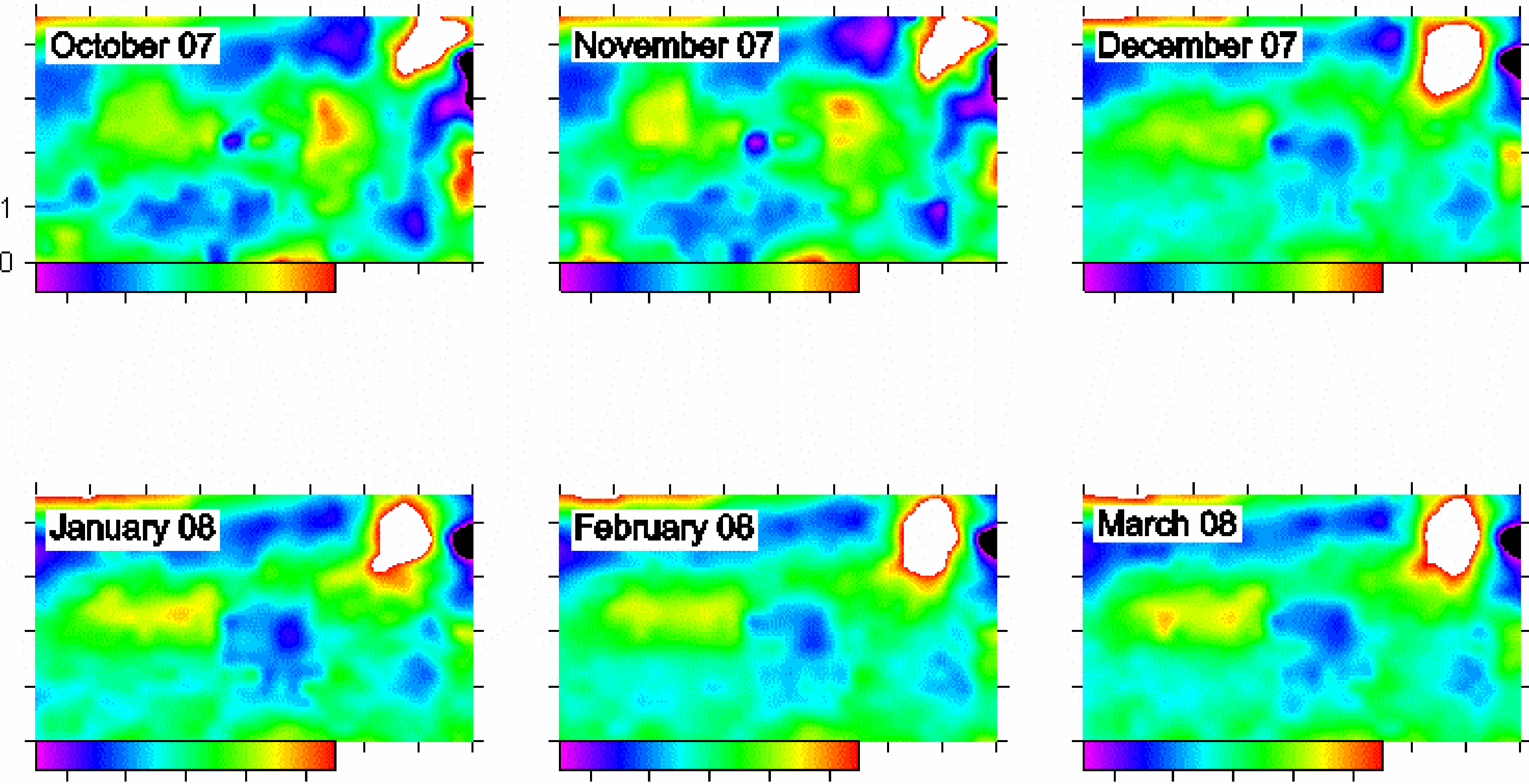
Soil properties measured during the first 24 weeks of the project.

Statistical tests inconclusive as to whether there is any significant change in porosity or saturation in grave samples relative to control. Data: Jervis *et al.* (In press)

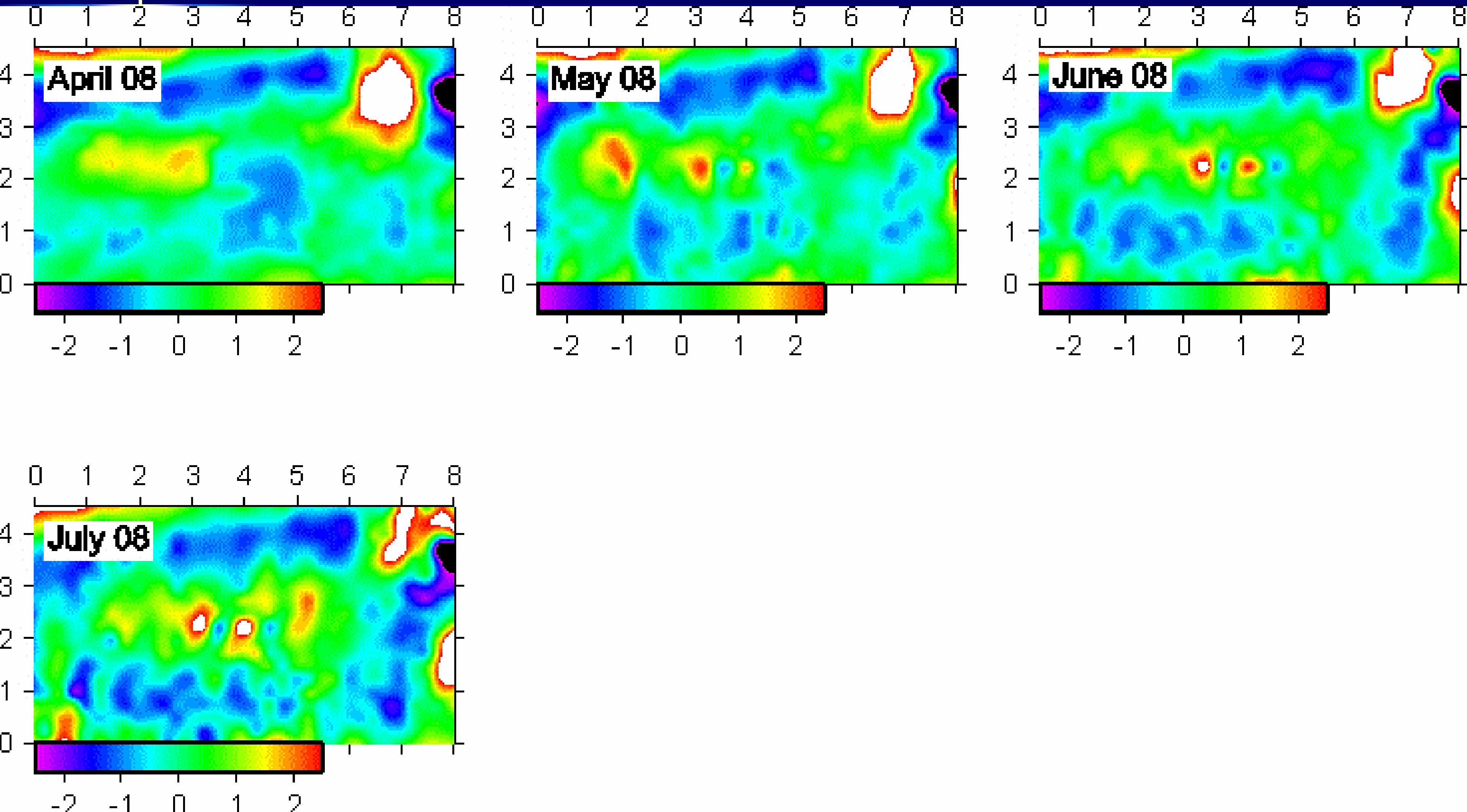
Survey data: 0 – 6 months



Survey data: 6 – 12 months



Survey data: 12 – 18 months



Pig1 Project Results

- Strong grave anomaly 3 – 6 months post-burial
- Most probably due to increasingly conductive leachate fluids released from decomposing cadaver
- Anomaly varies in size & amplitude throughout the study. Certain times of the year may be offer a better chance of grave detection than others.
- Contribution of altered porosity and/or saturation remains unknown: need empty pits as well

Pig Project 2 aims

Using pig cadavers buried in the walled garden of Keele University as human proxies for ‘shallow’ graves, this study has three major aims:

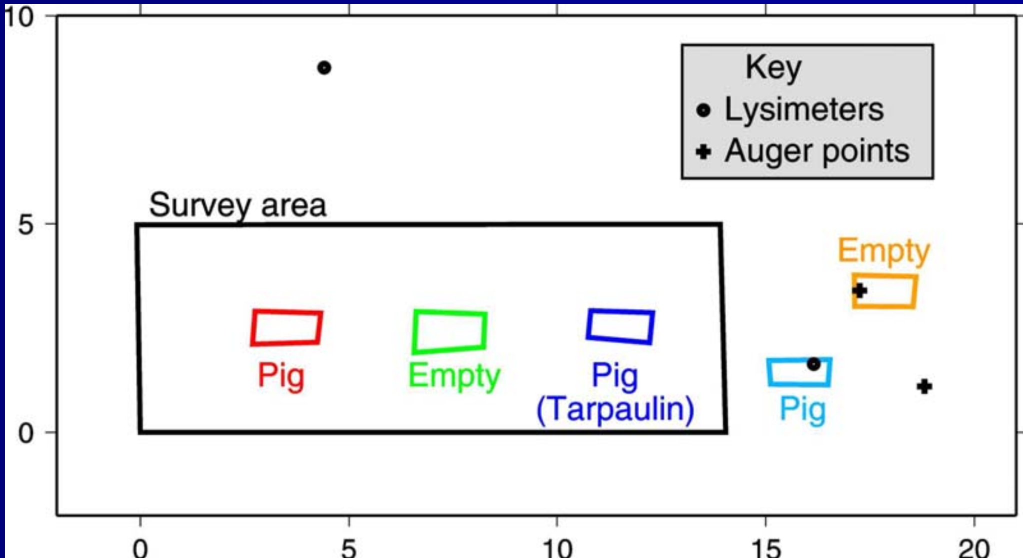
1. To determine if body clothing/wrapping has a significant affect on geophysical detection.

2. To investigate how this resistivity response changes with time.

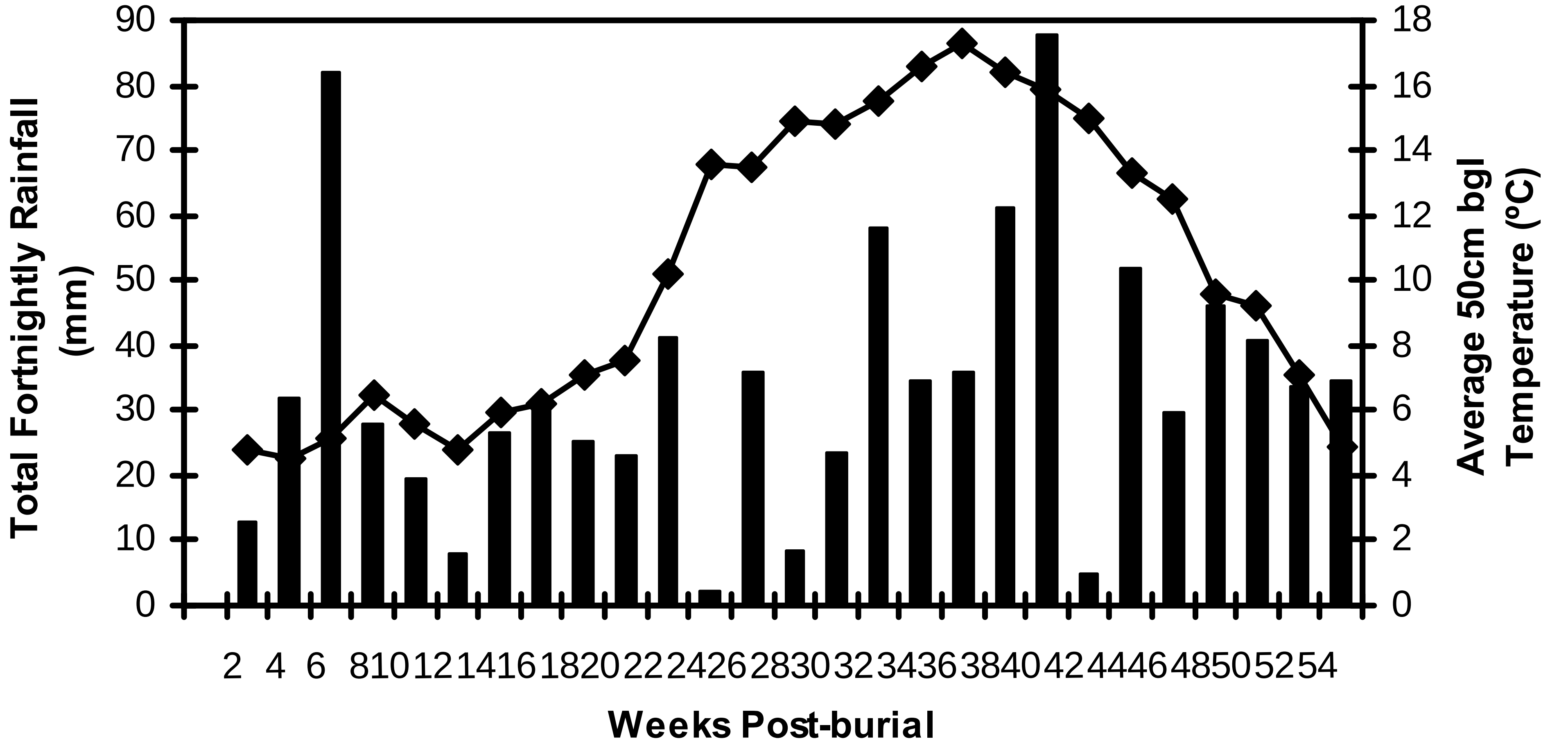
3. Check results with the empty ‘grave’.

Targets – December 2007

- Two buried pigs (one wrapped in tarpaulin)
- One empty pit
- Further pig & empty pit to collect soil samples
- Surveyed every 14/28 days



Site rainfall / temperature



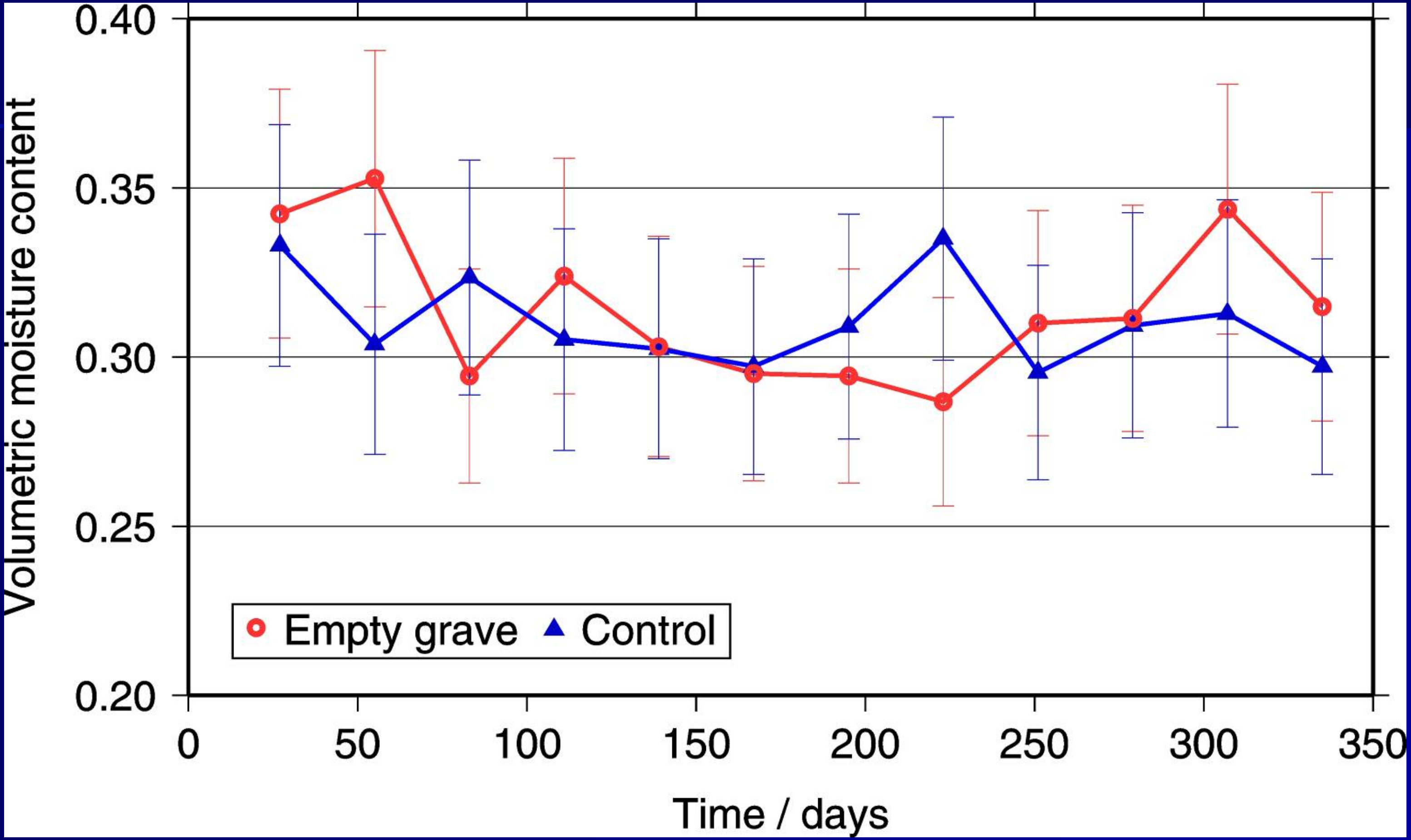
Soil sampling

Soil cores collected from empty grave & a control point using augers.

Samples extracted from 0.2 to 0.6 m & oven dried at 105 °C to obtain estimates of porosity & moisture content.

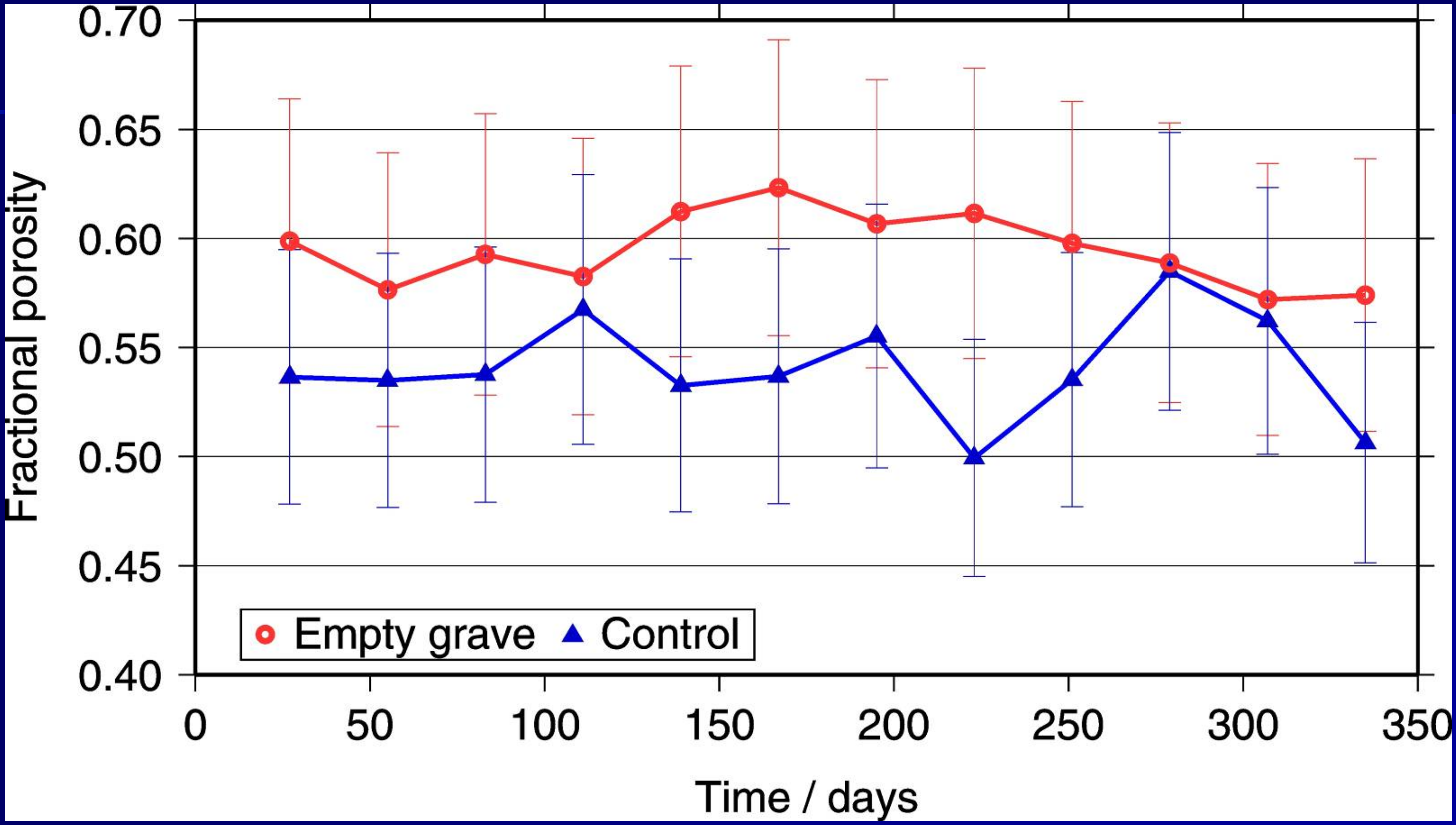
Site soil profile: made ground (slightly clayey, slightly gravelly sand) over sandstone bedrock at 2 to 5 m depth.

Soil moisture content data



A paired values T-test suggests that there is no significant difference in moisture content between the grave and control soils (P=0.73, μ_d=0.003).

Soil porosity data



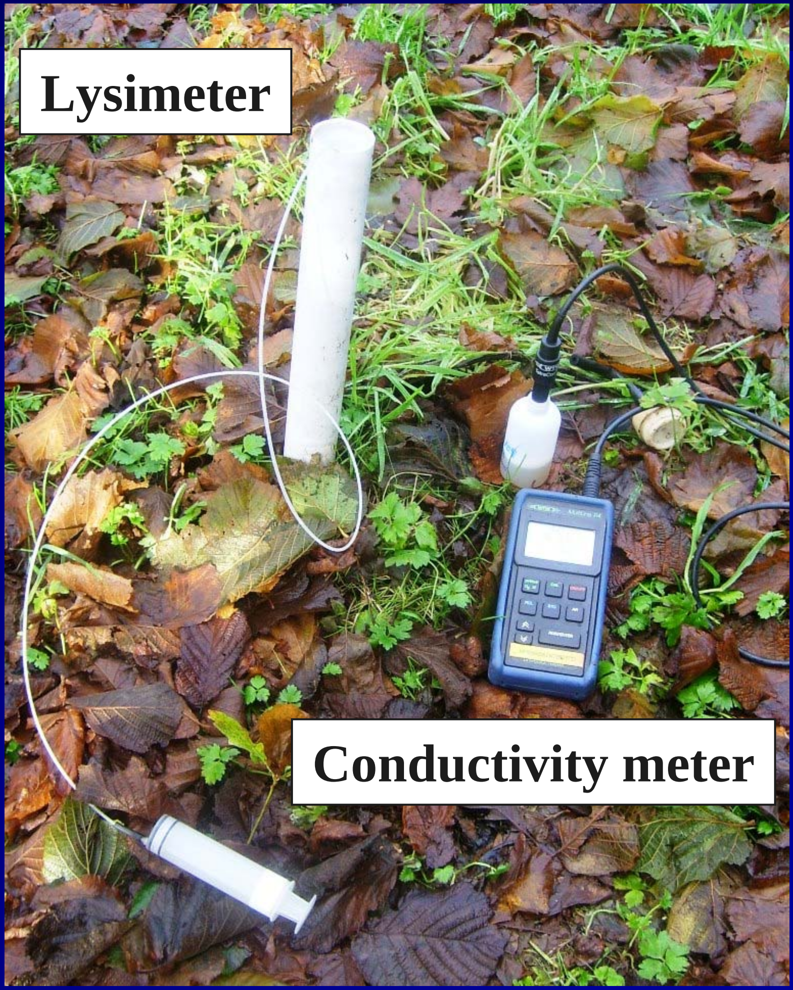
Grave soil samples are more porous ($P<0.001$, $\mu_d=0.05$) than control samples. However, porosity not always used in soil conductivity formulae (e.g. Amente et al., 2000).

Groundwater sampling

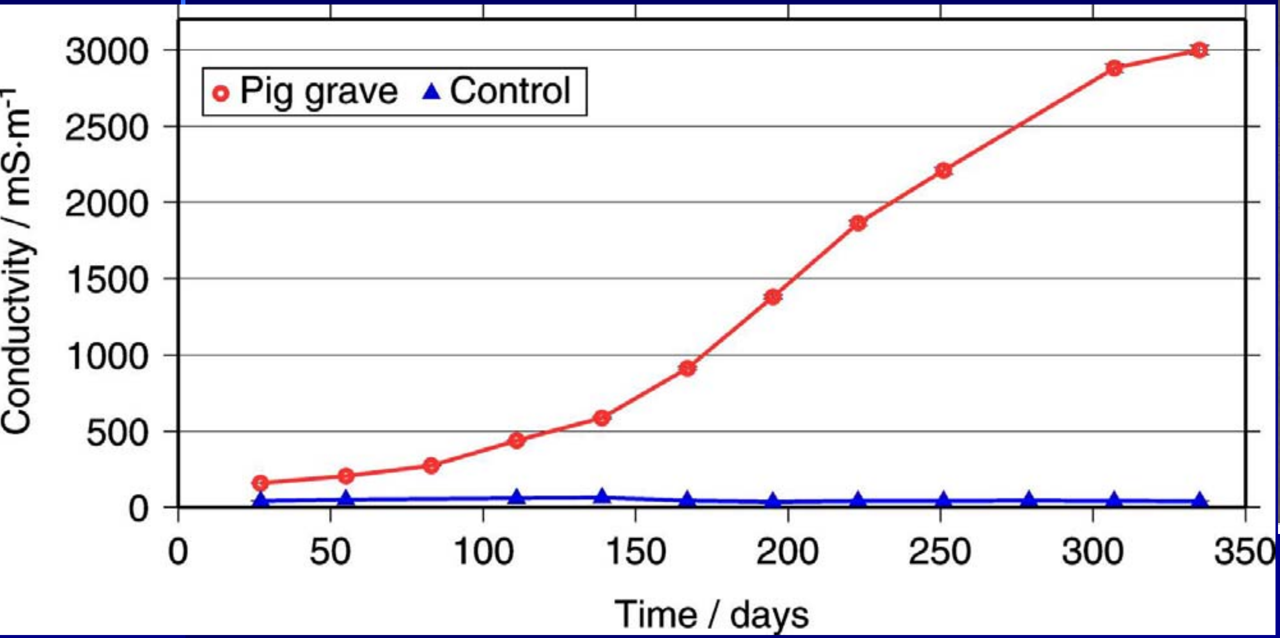
Lysimeters emptied and pressurised two days before sample collection.

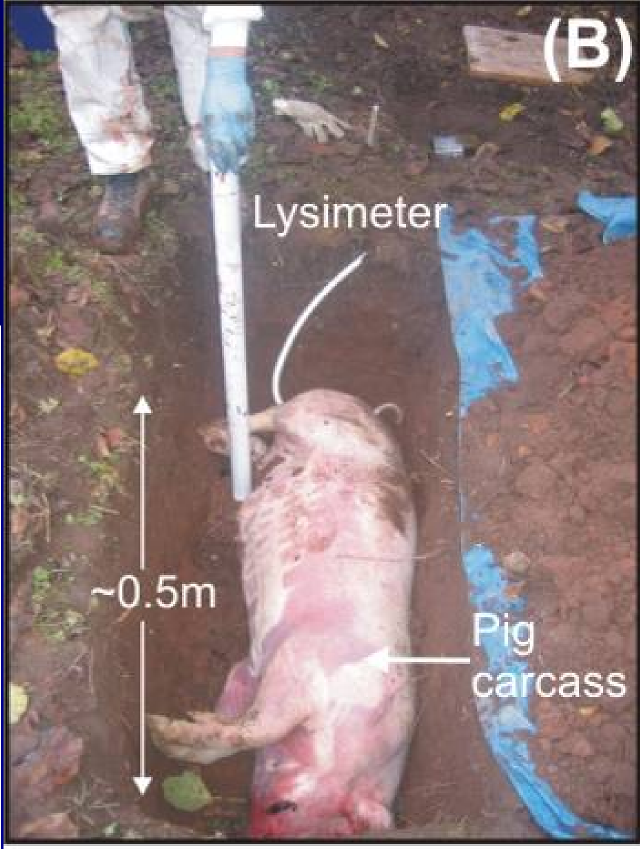
One pig grave sample and one control sample collected the day before each survey.

Conductivity of each sample measured in the field immediately after collection.



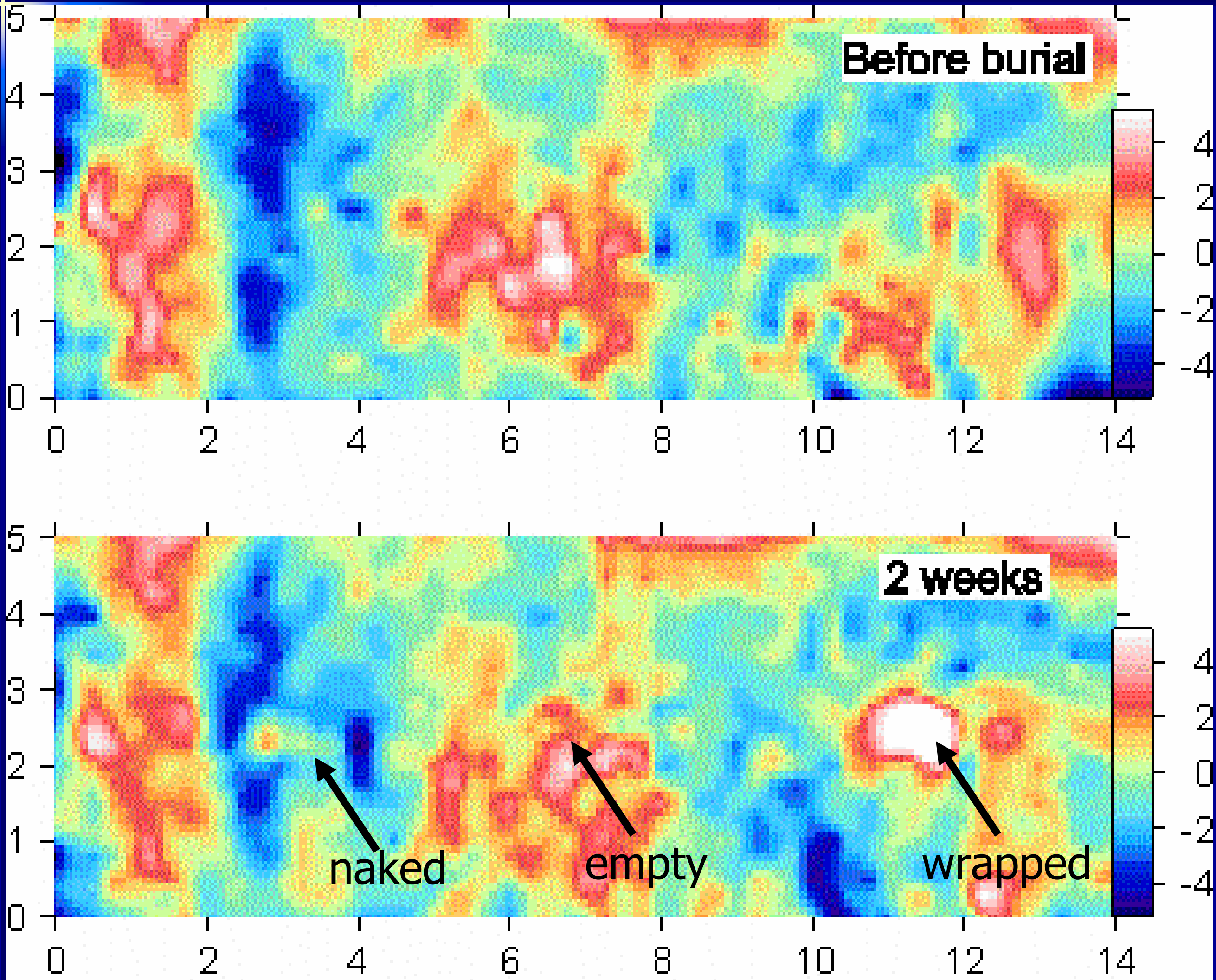
Groundwater & leachate



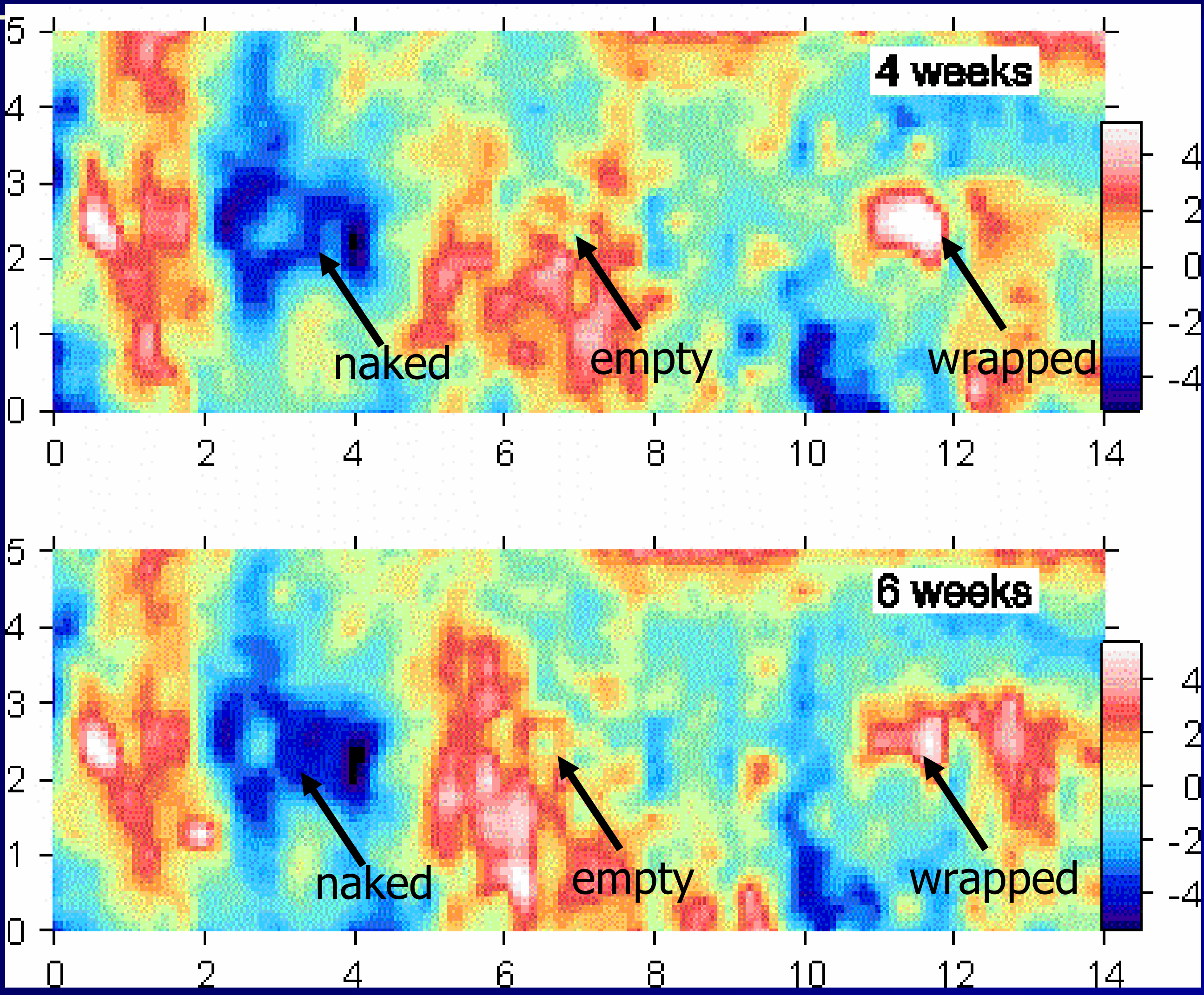


Low resistance anomaly associated with the pig grave appears to be due to conductive fluid released by the cadaver –hence, the difference in response between wrapped and unwrapped pigs.

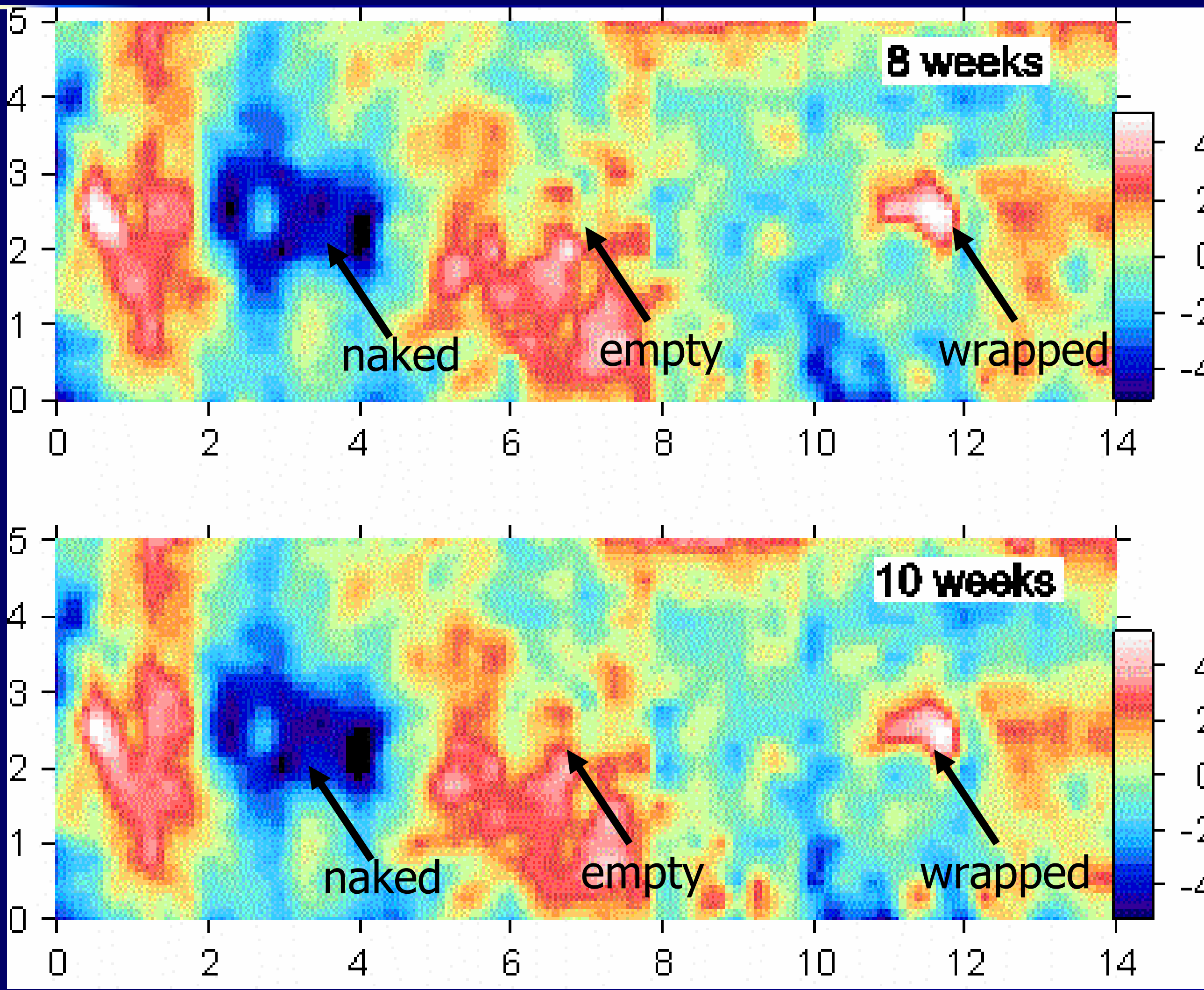
Electrical resistivity data



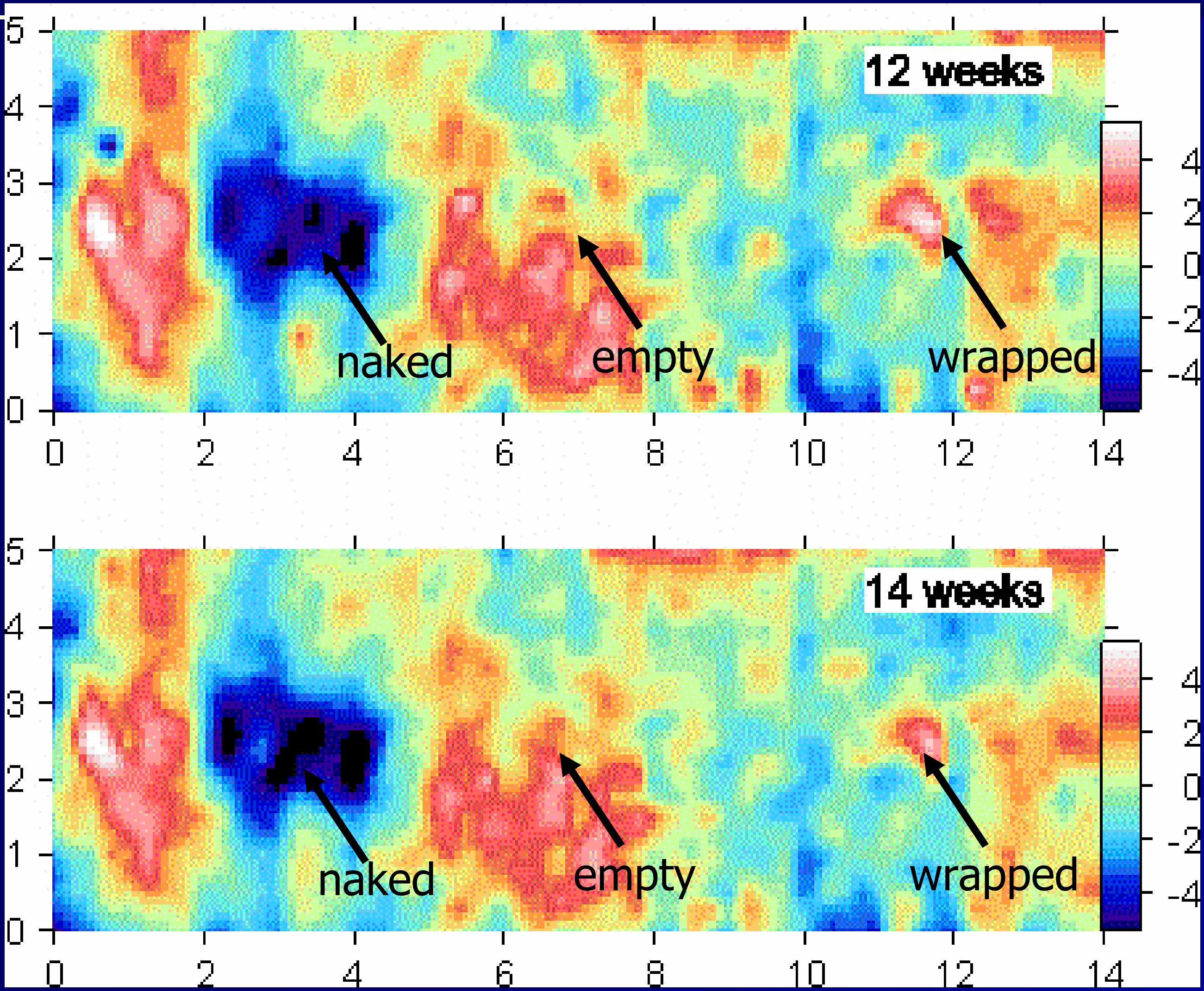
Electrical resistivity data



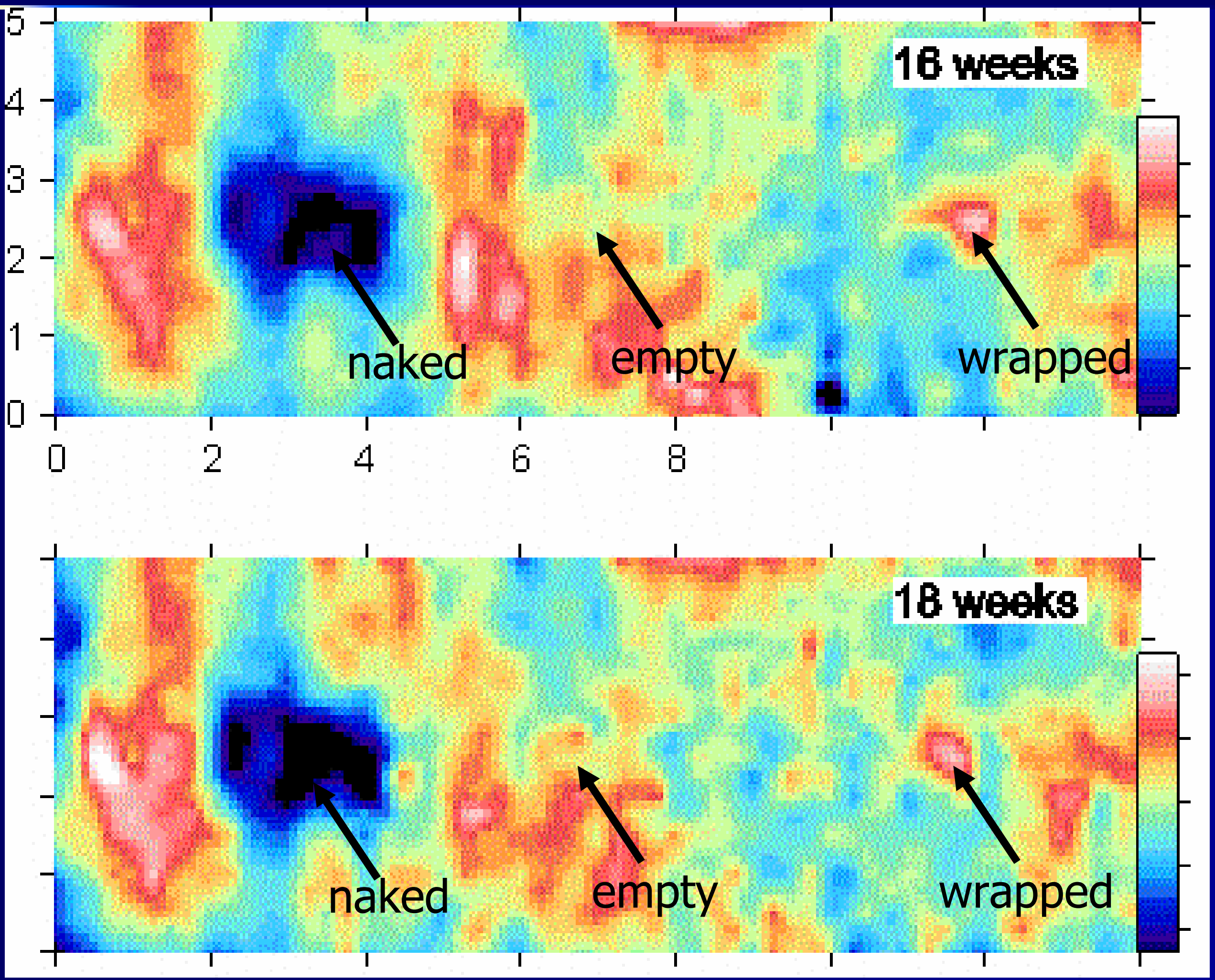
Electrical resistivity data



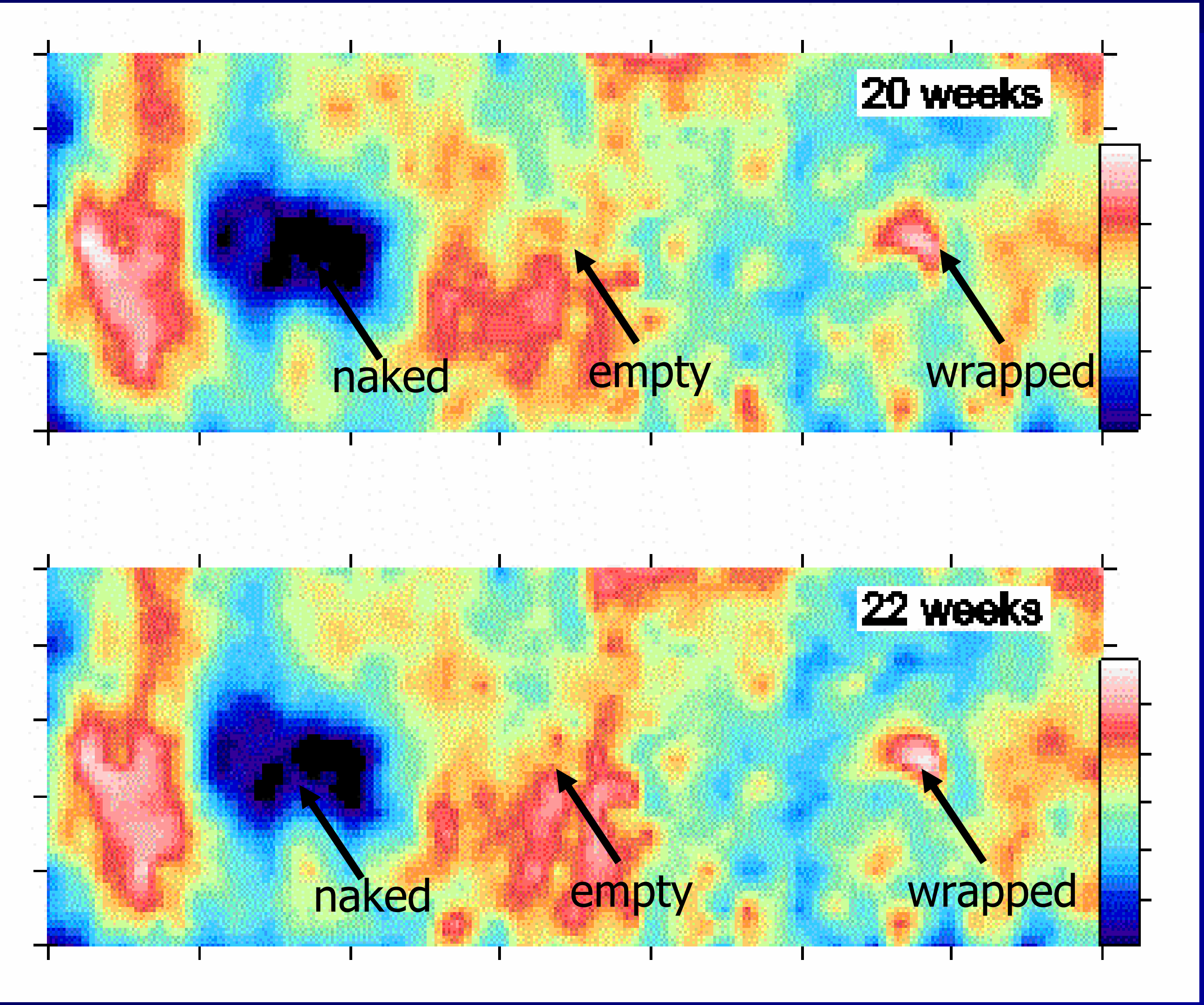
Electrical resistivity data



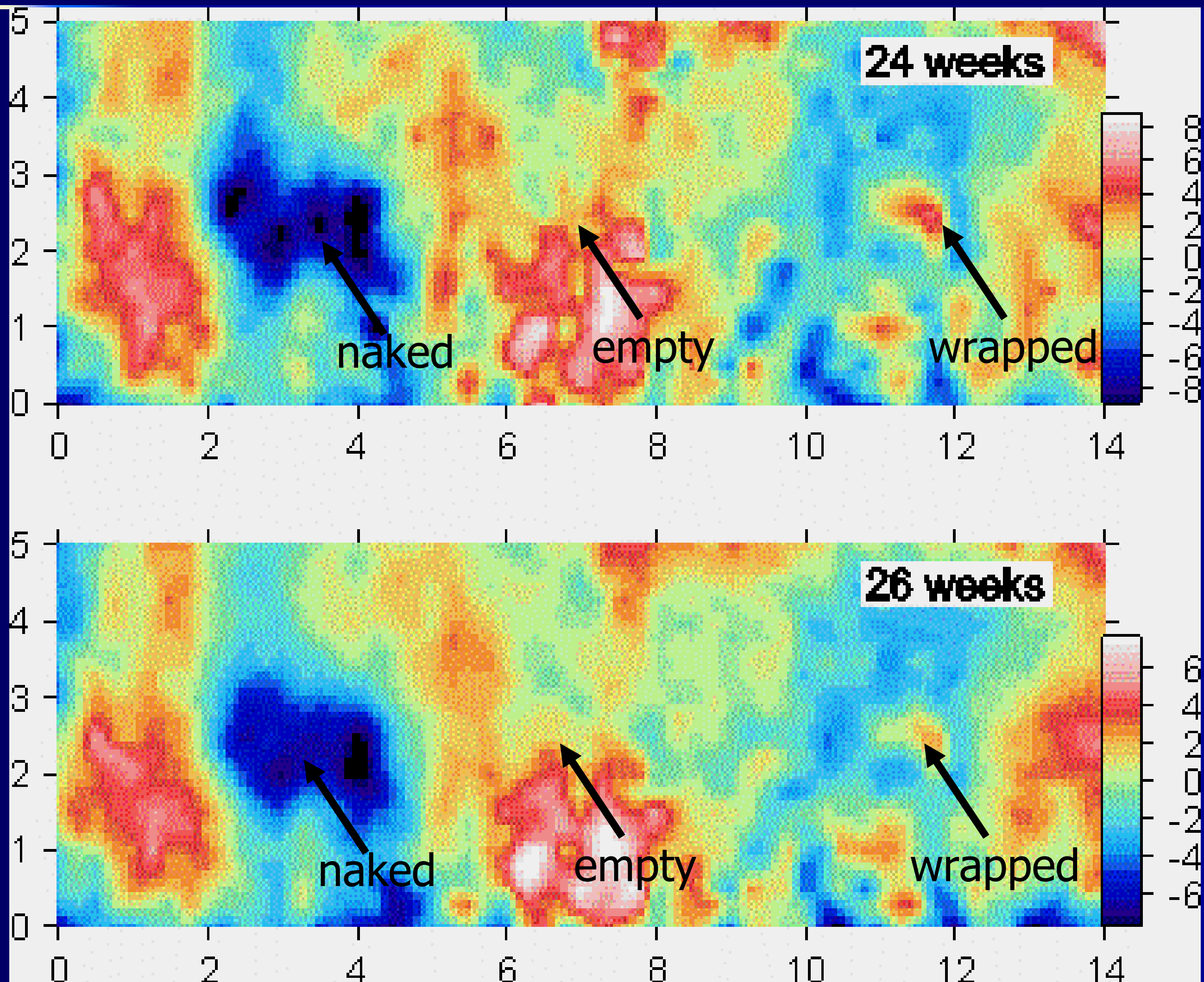
Electrical resistivity data



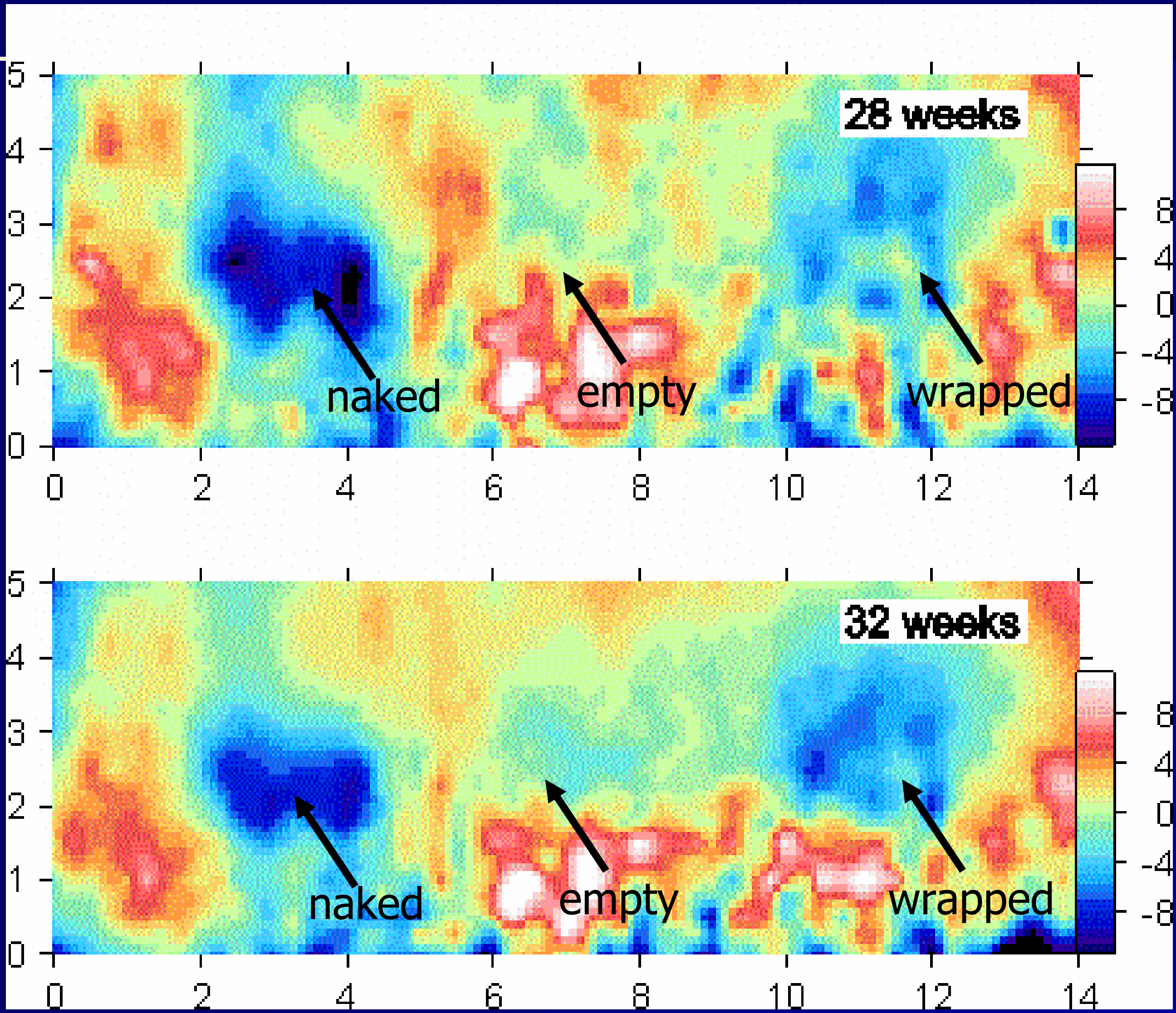
Electrical resistivity data



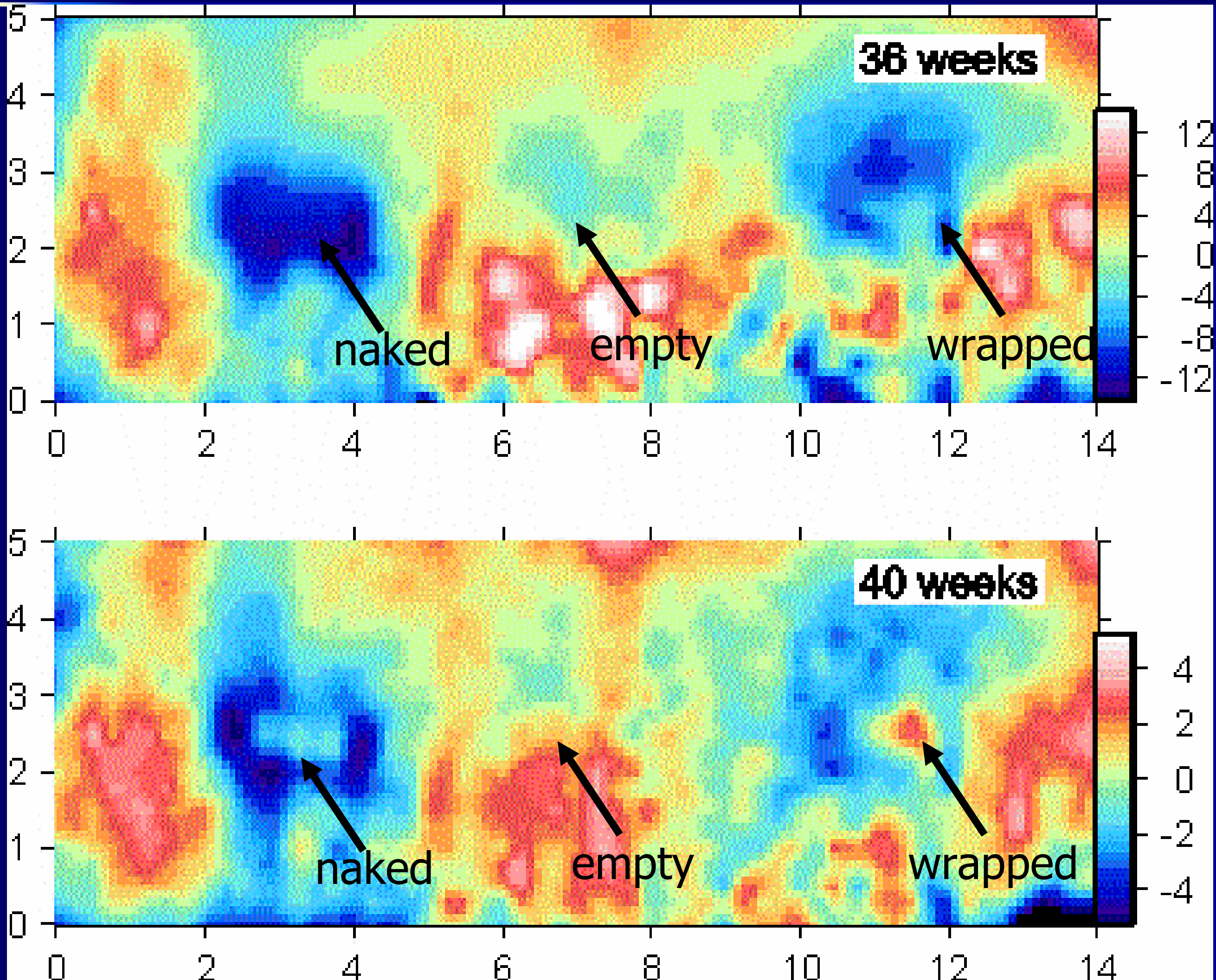
Electrical resistivity data



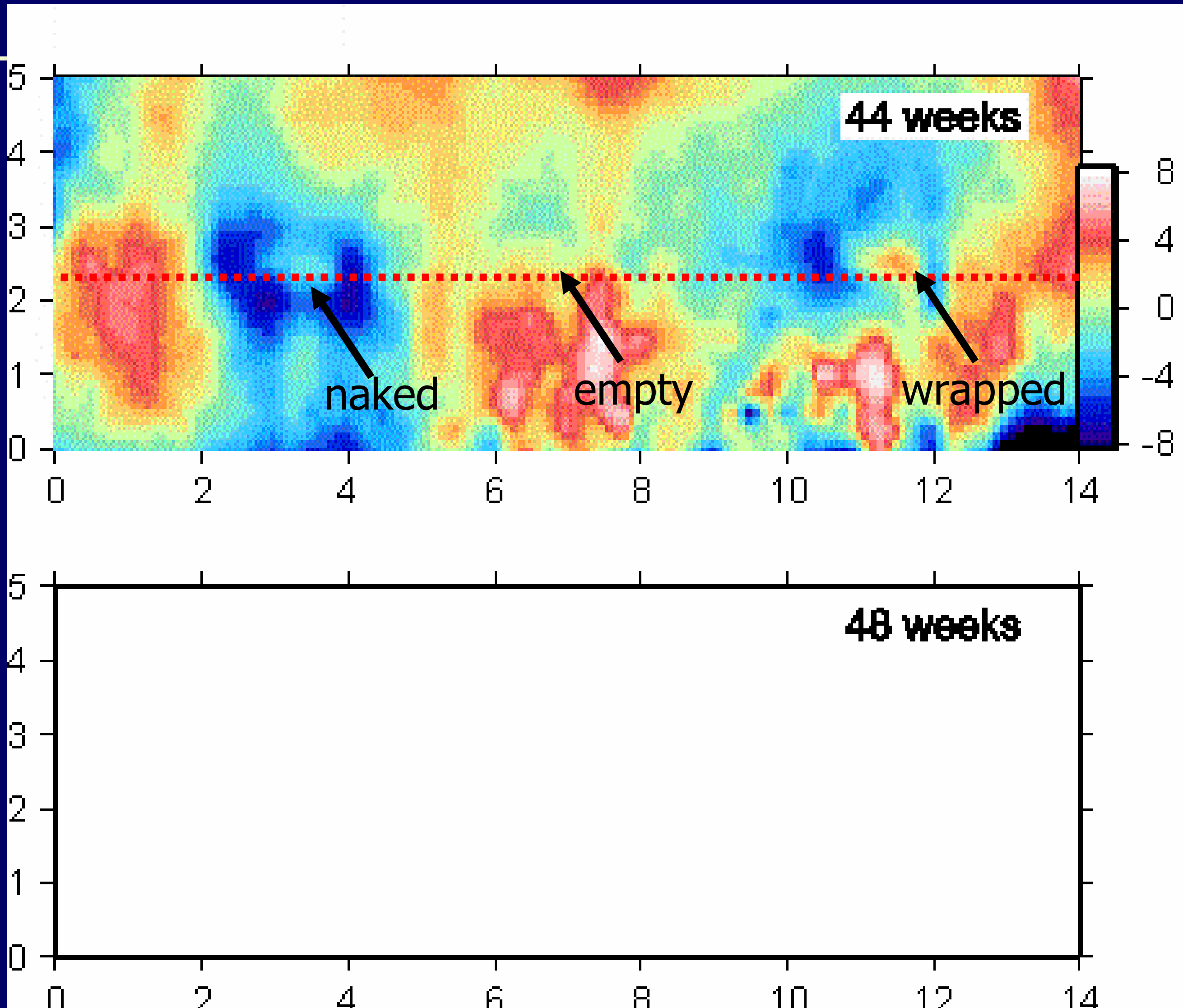
Electrical resistivity data



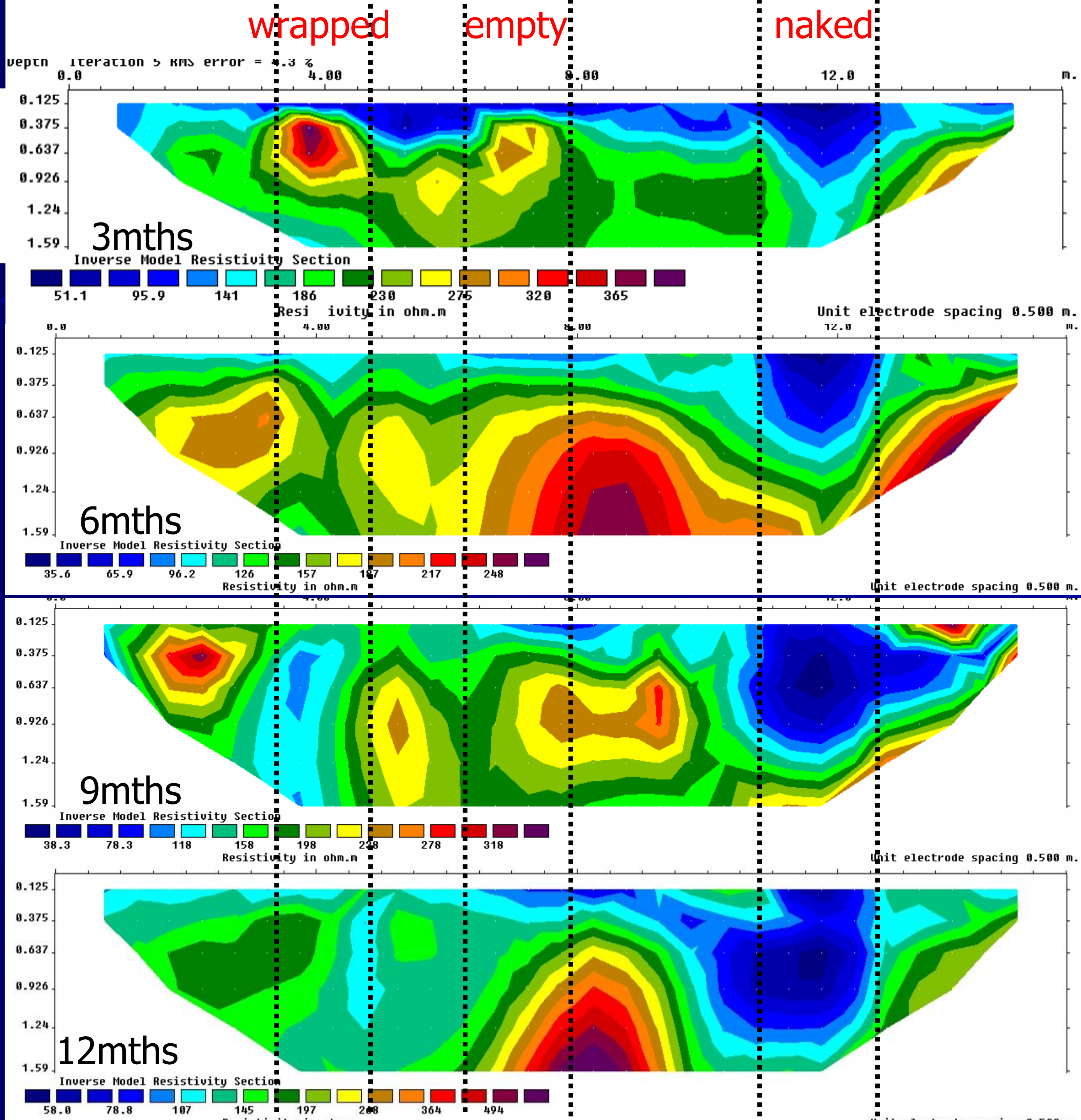
Electrical resistivity data



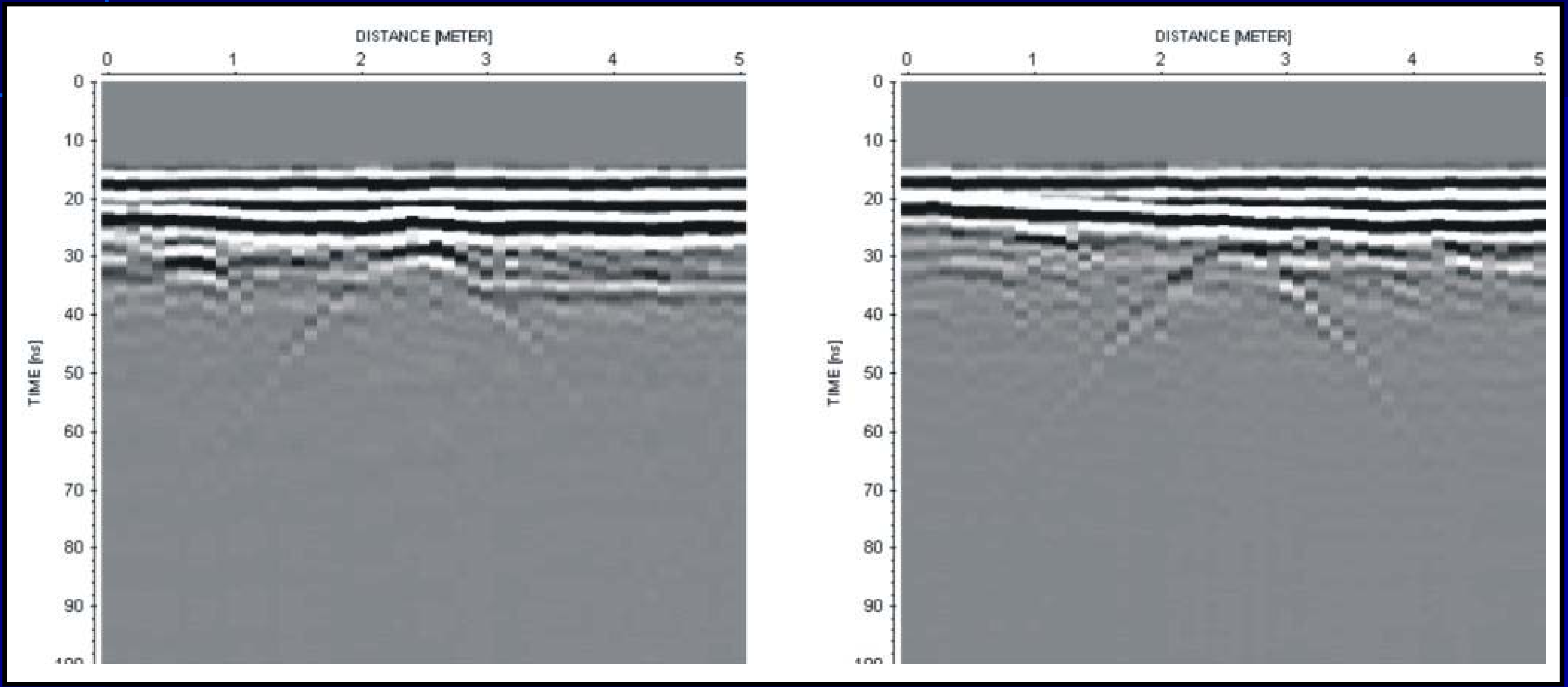
Electrical resistivity data



Repeat ERT Profiles

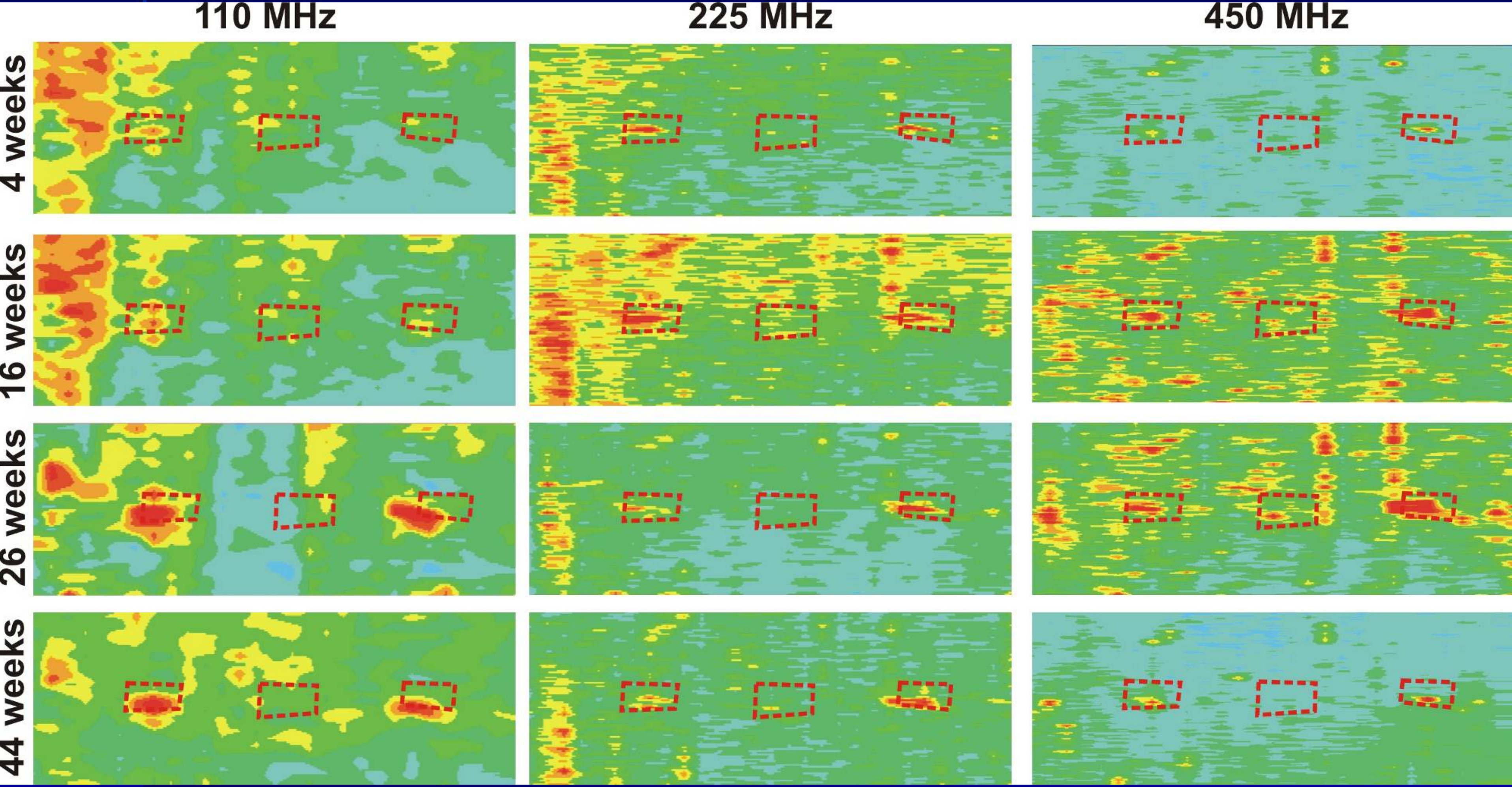


GPR 2D Profiles



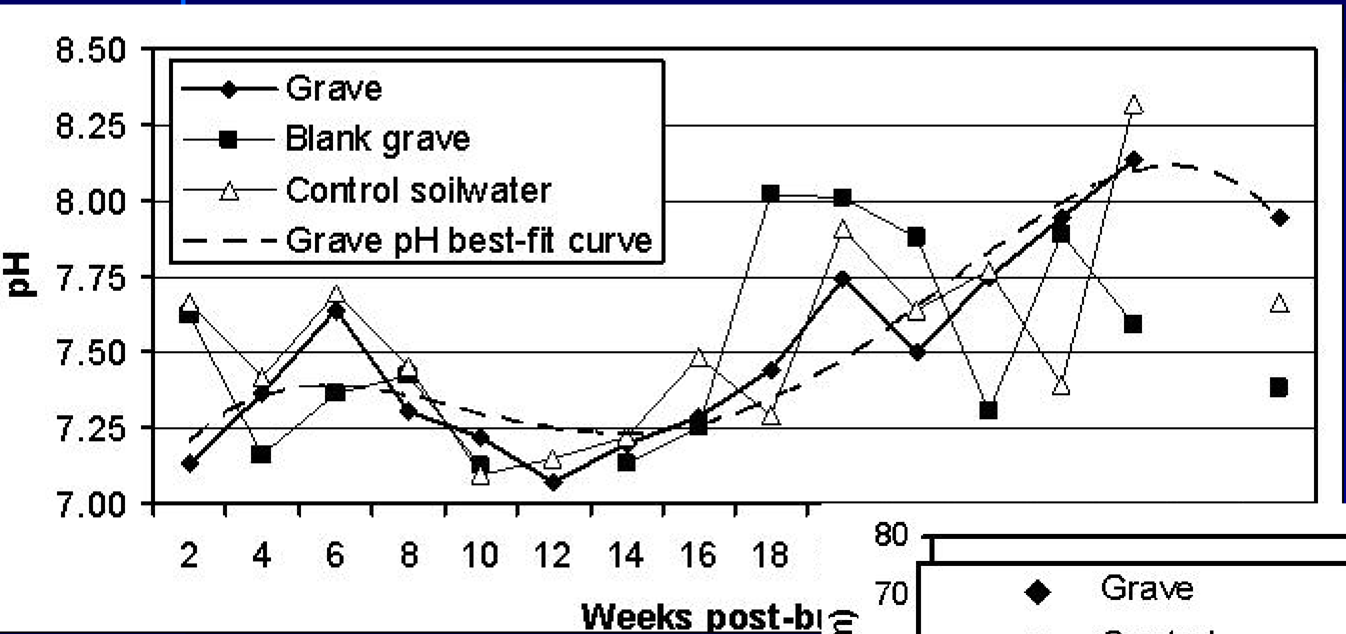
Both burials visible in GPR data (here after 3 months of burial). Wrapped pig is on the right.

GPR 3D Time-slices



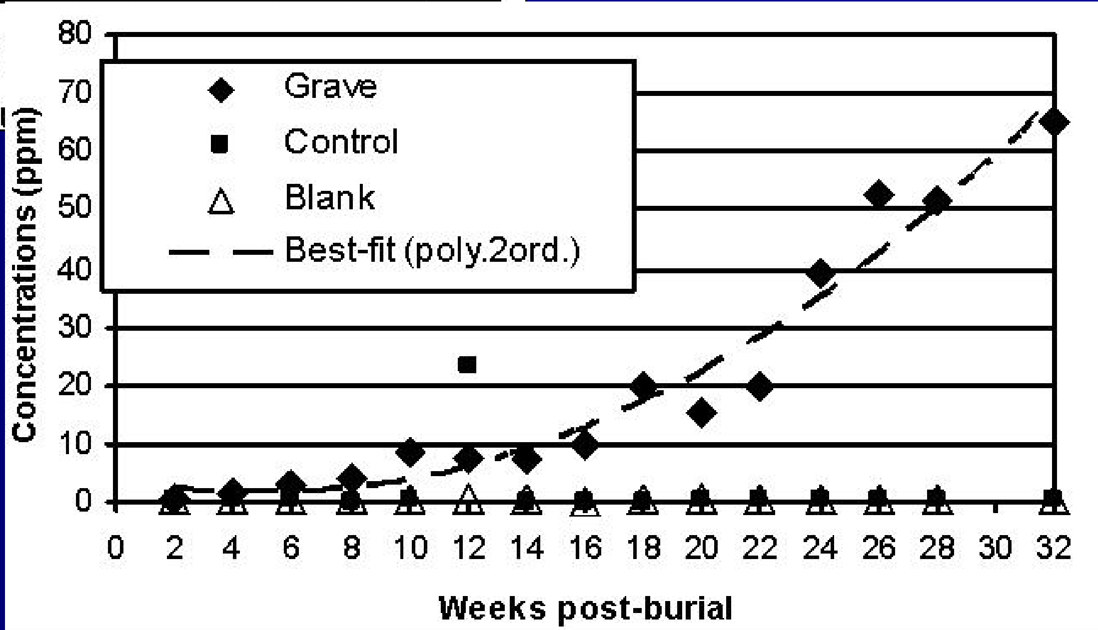
Left to right squares: naked, empty & wrapped

Pig Leachate analysis

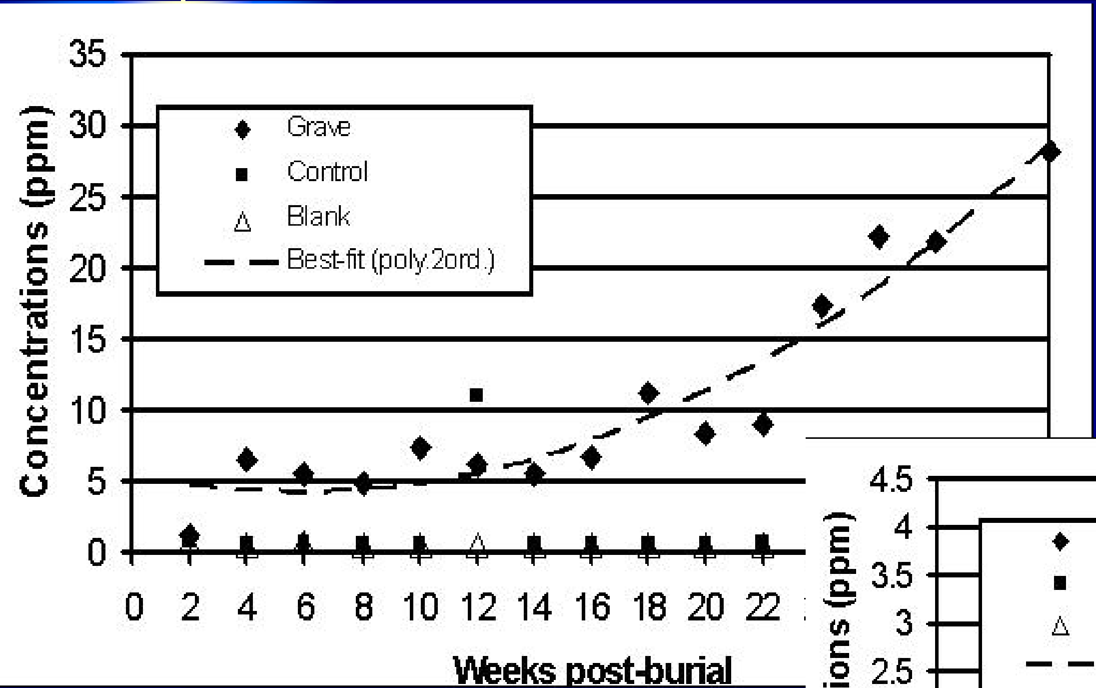


pH

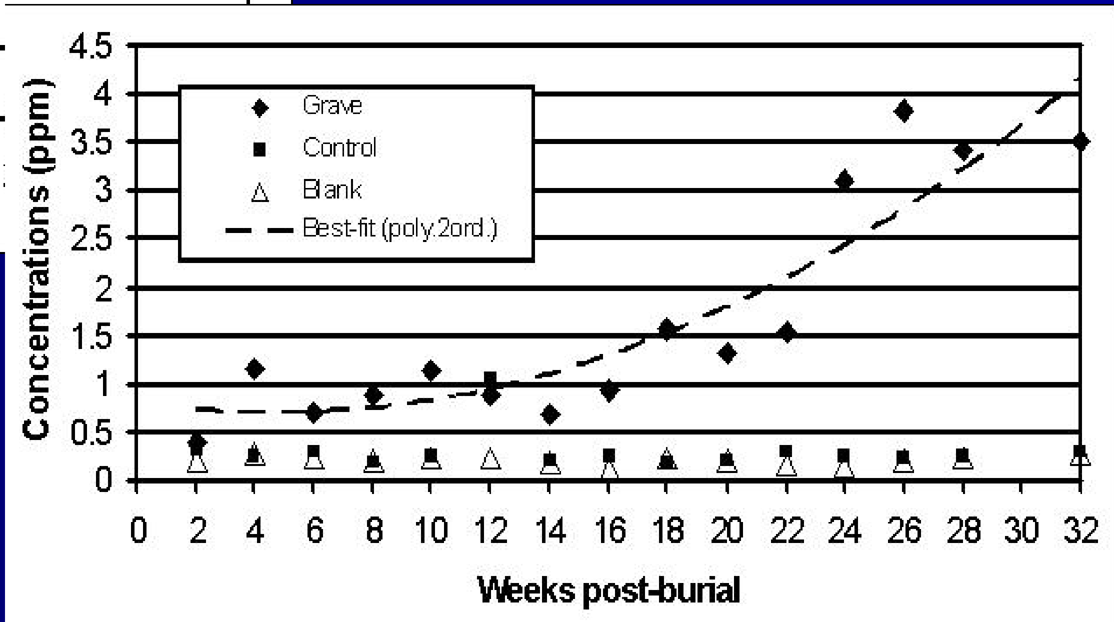
K



Pig Leachate analysis



Na



Mg

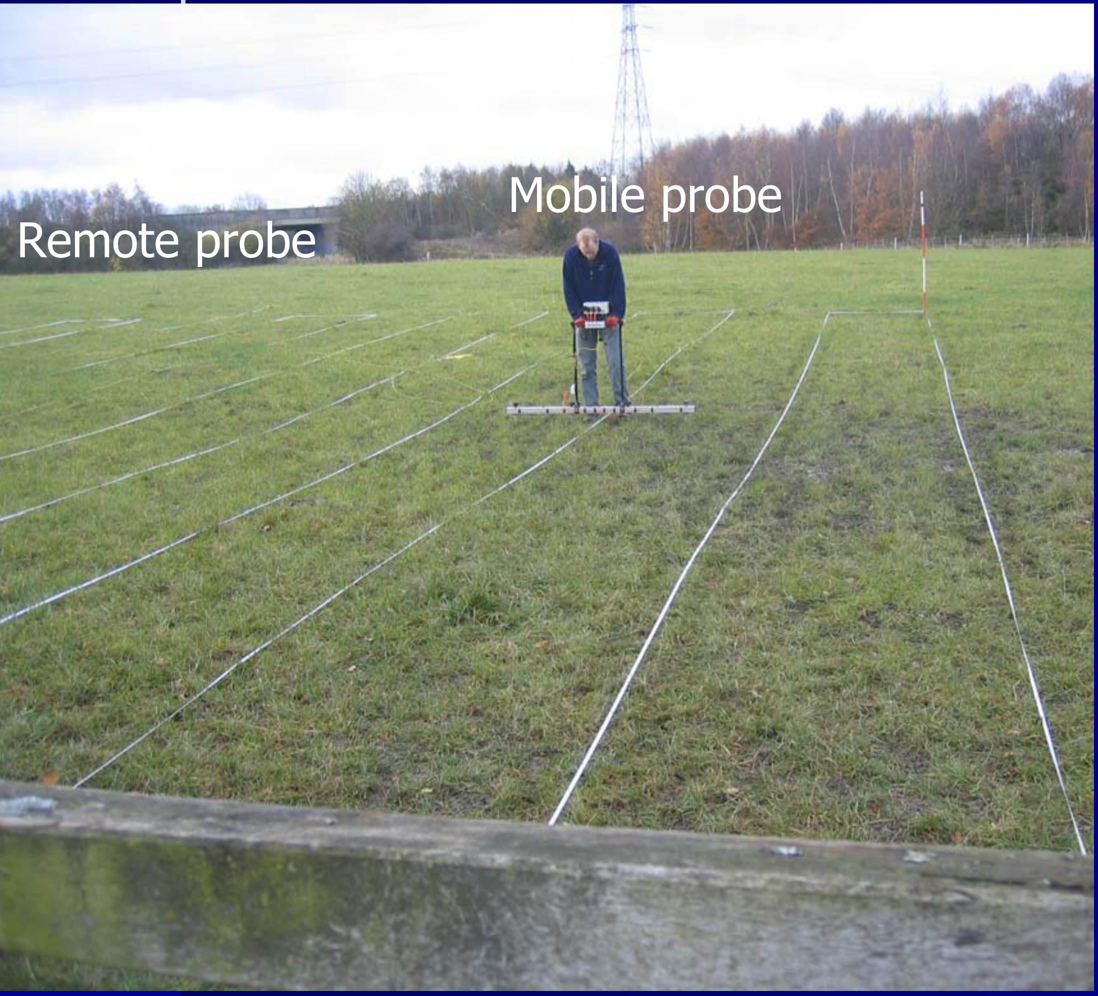
Pig2 Project Results

- More complicated than pig1 results
- Naked pig again resistivity low
- Wrapped pig initially a resistivity high but changes
    - Potentially due to tarpaulin being eaten away?
- Empty grave similar response so not porosity/disturbed soil cause
- Ongoing

Burial Search Case Study: Resistivity

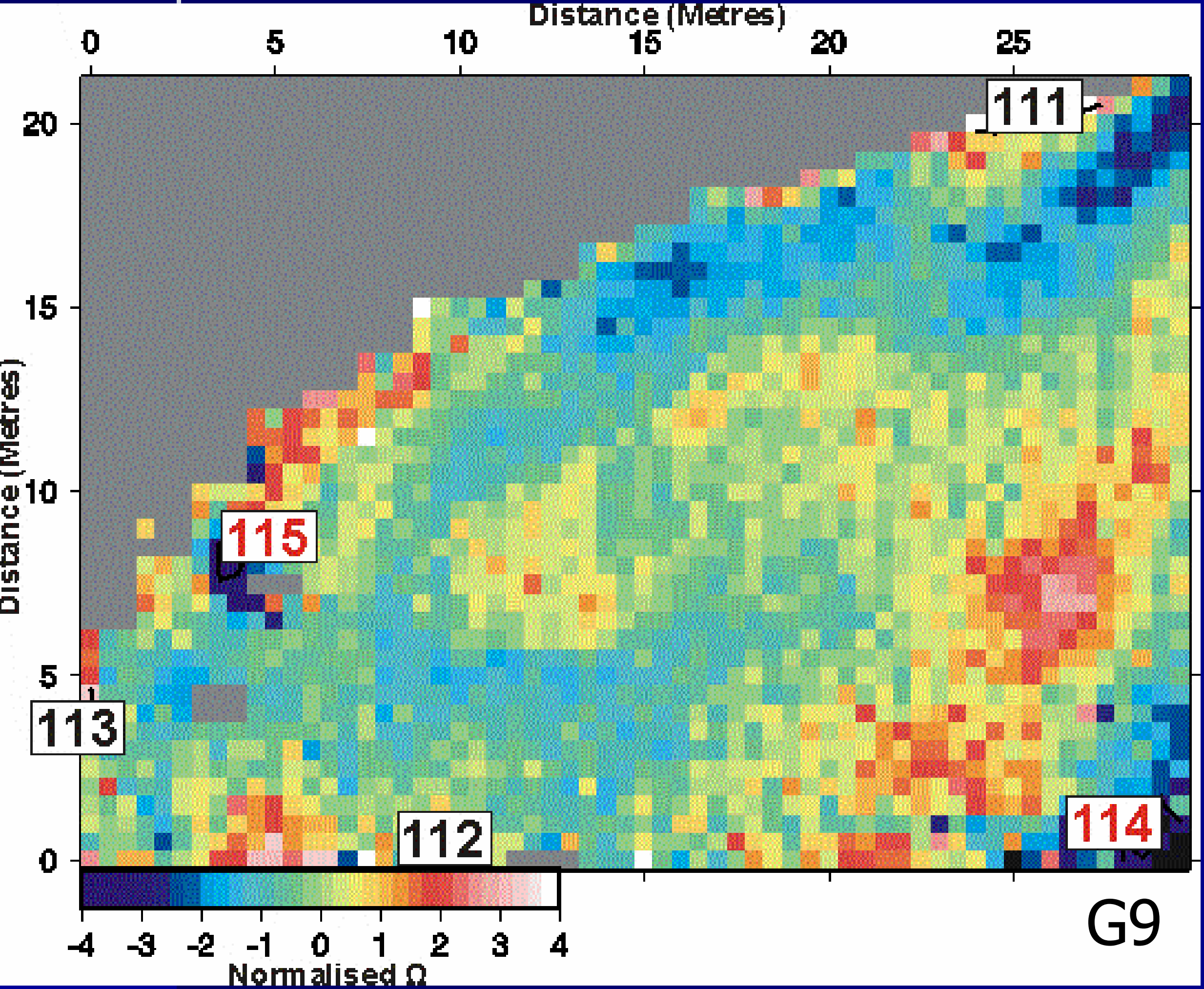
- Keele has been asked to locate a suspected murder victim that has been shallowly buried in a rural area
- Adult victim is relatively small & may be wrapped/in suitcase
- Probably buried a year ago
- Ground condition inspection show soils have relict coal mine material & very clay rich
  - Precludes GPR
- Can match likely resistivity response of target with simulated burials of similar ages
  - Thus main technique utilised
- Requested survey area 200m either side of entrance & 20m into field
  - Based on discovered burial statistics

Burial Search Case Study: Resistivity (2)

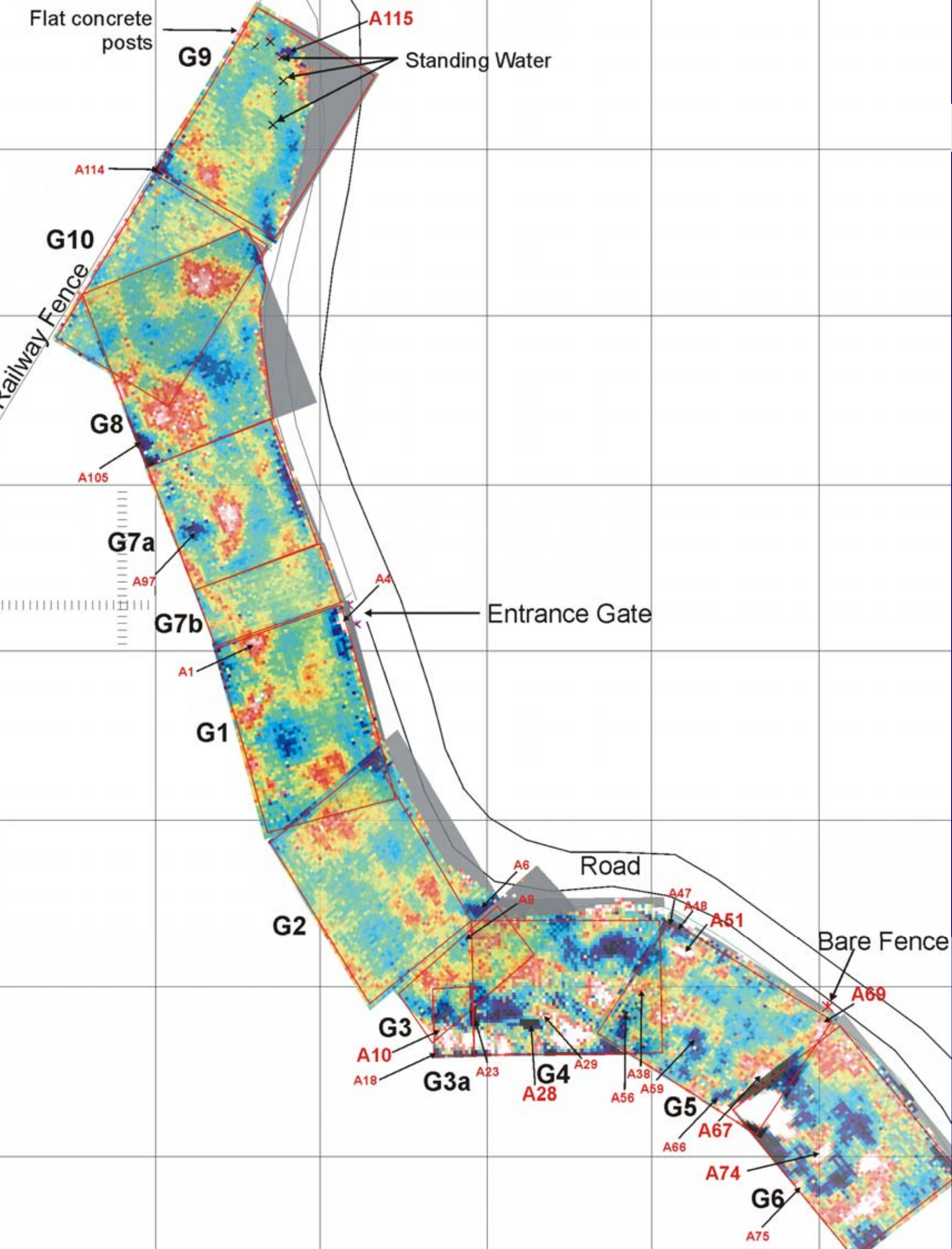


- Modern equipment allows 3 adjacent sample positions to be sequentially acquired
- Covered 400m x 20m area in 3 days using 0.5m x 0.5m sample spacing
  - 32,000 points

Burial Search Case Study: Resistivity (3)



- Data has to be collected on grid format
- Necessitated rotating grid squares & significant overlap to avoid any data gaps
- Prioritised & numbered ~3Ω anomalies from background



Case Study:

- Merging grids significantly reduced anomaly numbers
- **Priorities:**
- (A) Likely grave targets
  - High priority
    - Right strength & size (7)
  - Low priority
    - Right strength (17)
- (B) Likely geology
  - Right strength but too big
- (C) Grid edge affects
  - As it says

Summary

	Metal Detector	Magnetics	Electro-magnetics	Ground Penetrating Radar	Comments
Shell Casings	●				
Bullets	●				
Unexploded ordnance	○	●			
Grave (shallow)		○	◍	●	Two-box metal detector
Grave (under concrete)				●	
Body underwater				○	Depends on reinforcing mesh
Property in water	◍	◍		○	Consider Fathometer
55 gallon drum 5–10 feet deep		●	◍	○	GRP in freshwater only

● Most Applicable ◍ Applicable ○ May Work

Pye (2003)

- For clandestine graves:
  - Simple, recent burials:
    - Conventional methods successful
  - Complex, clandestine or old sites:
    - Geophysics may work
    - Site specific
  - May be picking up disturbance rather than target
- Remote explosions:
  - Forensic seismology used to identify causes
    - Kursk submarine disaster example
- More case studies, further research & quantitative site comparisons needed
  - Geophysics will then become mainstream

Suggested Reading

- Research Articles:

  - Bevan, B.W. (1991) The search for graves. *Geophysics*, **56**(*9*), 1310-1319.
  - Davenport, G.C., Griffin, T.J., *et al.,* (1990) Geoscientists & law enforcement professionals work together in Colorado. *Geotimes*, **35**, 13-15.
  - Davis, J.L., Heginbottom, J.A. *et al.,* (2000) Ground penetrating radar surveys to locate 1918 Spanish flu victims in permafrost. *Journal of Forensic Sciences*, **45**(*1*), 68-76.
  - Fenning, P.J. & Donnelly, L.J. (2003) Geophysical techniques for forensic investigation. *In:* Pye, K. & Croft. D.J. Forensic Geoscience: Principles, Techniques & Applications. *Geological Society of London Special Publication*, **232**, 11-20. [2 in library]
  - France, D.L. *et al.* (1992) A multi-disciplinary approach to the detection of clandestine graves. *Journal of Forensic Sciences*, **37**(*6*), 1445-1458.
    - http://www.terraplus.ca/case-histories/dave1.htm
  - Freeland, R.S., Miller, M.L. *et al.,* (2003) Forensic application of FM-CW & pulse radar. *Journal of Environmental Geophysics*, **8**(*2*), 97-103.
  - Jervis, J.R., Pringle, J.K., Cassella, J.P. & Tuckwell, G.T. 2008. Using soil and groundwater to understand resistivity surveys over a simulated clandestine grave. In: Ritz K, Dawson L, Miller D, (editors), Criminal and environmental soil forensics. Springer Publishing, Dortrecht, The Netherlands, 271-284.
  - Koppenjan, S.K., Schultz., *et al.,* (2003) The application of GPR in Florida for detecting forensic burials. In: Proceedings of the Symposium on the application of geophysics to engineering & environmental problems (SAGEEP 2003), San Antonio, Texas, USA.

Suggested Reading

- Research Articles:

  - Matias M.J.S., Silva M.M. da, *et al.* (2004) An investigation into the use of geophysical methods in the study of aquifer contamination by graveyards. *Near Surface Geophysics,* **3**, 131-6.
  - Nobes, D.C. (2000) The Search for "Yvonne": A Case Example of the Delineation of a Grave Using Near-Surface Geophysical Methods. *Journal of Forensic Sciences*, **45**, 715–721.
  - Powell, K. (2004) Detecting human remains using near-surface geophysical instruments. *Exploration Geophysics*, **35**, 88-92.
  - Pringle, J.K., Jervis, J., Cassella, J.P. & Cassidy, N.J. (2008) Time-lapse geophysical investigations to create composite probability maps over a simulated urban clandestine grave site. *Journal of Forensic Sciences,* **53**(*6*), 1405-1417.
  - Ruffell, A. (2005) Searching for the IRA "disappeared": Ground Penetrating radar investigation of a churchyard burial site. *Journal of Forensic Sciences*, **50**, 1430-35.
  - Ruffell, A. & McKinley, J. (2008) Geoforensics, Wiley-Blackwell, Chichester, UK, 332pp.
  - Schultz, J.J., Collins, M.E. & Falsetti, A.B. (2006) Sequential monitoring of burials containing large pig cadavers using GPR. *Journal of Forensic Sciences*, **51**(*3*), 607-615.
  - Witten, A., Brooks, R. (2001) The Tulsa Race Riot of 1921: a geophysical study to locate a mass grave. *The Leading Edge*, **20**(*6*), 655-660.

Forensic Biology

- Location using breakdown products
  - Proteins to aa’s ?? Human specific
  - Carter → Ninhydrin studies
  - Vass → patented body hoover
  - Wilson and Bradford

Modelling the buried human body environment in upland climes using three contrasting field sites <u>Wilson et al</u>, *Forensic Science International* 169 (2007) 6–18

"The importance of conducting taphonomic experiments specific to different geoclimatic conditions is highlighted by forensic case studies in which the prevailing environmental conditions have influenced factors such as search and recovery, time since death investigation [and issues of taphonomic preservation and bias. The impact of macroclimate is important. Yet forensic casework in the United Kingdom with its maritime climate continues to make direct reference to experimental studies conducted largely in the continental United States."

Available online at www.sciencedirect.com

SCIENCE DIRECT

Forensic Science International 154 (2005) 24–34

Forensic Science International

www.elsevier.com/locate/forsciint

The effect of the burial environment on adipocere formation

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Available online 10 November 2004

Review of human decomposition processes in soil

Dent et al

Environmental Geology (2004) 45:576–585

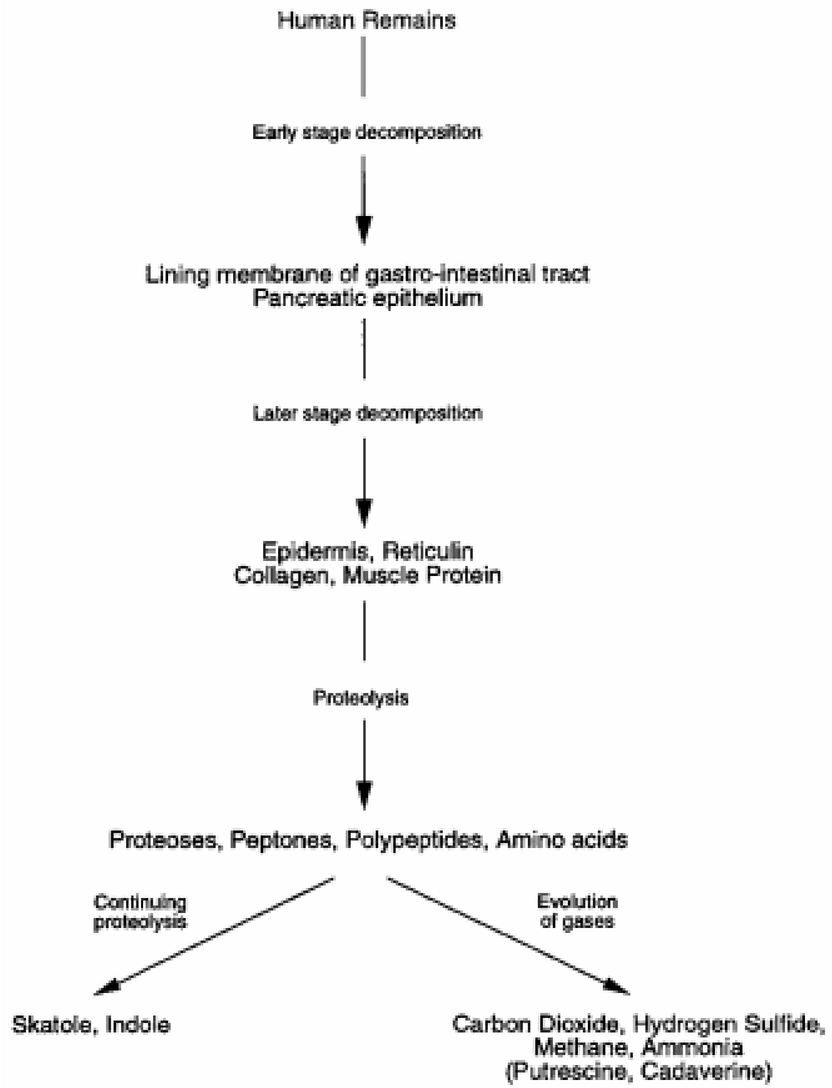

Fig. 3
Changes to protein during decomposition

Automated Clandestine Grave Detector

Ads by Google

Patents > 2008-02-07 > SECTION G PHYSICS > MEASURING; TESTING > INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES

Clandestine grave detector

Abstract

An apparatus and a method for detecting a burial site of human remains are disclosed. An air stream is drawn through an air intake conduit from locations near potential burial sites of human remains. The air stream is monitored by one or more chemical sensors to determine whether the air stream includes one or more indicator compounds selected from halogenated compounds, hydrocarbons, nitrogen-containing compounds, sulfur-containing compounds, acid/ester compounds, oxygen-containing compounds, and naphthalene-containing compounds. When it is determined that an indicator compound is present in the air stream, this indicates that a burial site of human remains is below or nearby. Each sensor may be in electrical communication with an indicator that signals when the sensor has detected the presence of the indicator compound in the air stream. In one form, the indicator compound is a halogenated compound and/or a hydrocarbon, and the presence of the halogenated compound and/or the hydrocarbon in the air stream indicates that a burial site of human remains is below or nearby.

Filed on: 2006-08-03; Application Number: 11498705

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QUARLES BRADY LLP

Quantifying the actions of individuals and groups engaged in body deposition #1

- Quantifying the actions of individuals and groups engaged in body deposition (we tend to plan our searches around a number of basic assumptions - movement downhill, close to a wooded border, out of plain sight, etc).
- In giving a number of subjects a scenario of body deposition, tracking their movements via GPS, and debriefing them as to why they did what they did, it might be enlightening and highly applicable to body search scenes.

Quantifying the actions of individuals and groups engaged in body deposition #2

- **Quantifiable elements**
  - Total distance travelled by offender.
  - Furthest distance from road reached by offender.
  - Change in elevation preferred by offender.
  - Distance from road of body deposition site.
  - Maximum distance betweeen offender and body during deposition.
  - Duration of deposition.
  - Dimensions of burial.
  - Depth of burial.
  - Volume of soil moved.
- **Non-quantifiable elements would perhaps be:**
  - Prefence of liminal deposition site?
  - Degree of vegetation disturbance.
  - Navigation by horizon markers (winthrop).
  - Number, depth and location of dep. site toolmarks.

Quantifying the actions of individuals and groups engaged in body deposition #3

- specifically psychological elements:
- Response to proximity of decomposing remains.
- Requirement to wrap bodies: pragmatism *vs* psychological distance?
- Group dynamics within the deposition scenario.

McCauley Institute - Geoforensics and Information Management for crime Investigation

GIMI #1

- The GIMI network aims to find ways in which new technologies can help in the forensic investigations of crime scenes, such as locating the graves of murder victims, uncovering buried items of evidence and helping to narrow down areas of search for the police.

- The network draws together the expertise of over 40 scientists and forensic professionals from five countries, who will review and evaluate the potential for using non-invasive methods in forensic investigations. Their assessments will lead the way for interdisciplinary research and development work which will provide innovative solutions to the challenges in this field.

Reduction of Search Areas GIMI #2

- Based upon the matching of soil properties from case evidence, with soil maps and spatial databases, potential target areas for search can be identified.
- The onus is then on the soil forensic research team to obtain the crucial link between the legal investigation area and the geo-morphological evidence.
- Non-invasive soil property monitoring, such as through airborne or terrestrial remote sensing, allows a potentially rapid search of areas of interest.
- Linking descriptions of soil characteristics from analytical and non-invasive sources with existing Geographic Information
- Systems (GIS) and associated databases of soils and vegetation enables areas of search to be geographically targeted. This can be done, for example, by identifying sites with a combination of soil and vegetation characteristics derived from analysis of evidence.
- Other geographic datasets (e.g. data on transport routes and population centres) can then be used in combination with those of soils and vegetation to explore hypotheses regarding worthwhile areas of search.

Key Messages

- Research still conducted by still isolated workers – *no* national network fully formed
- Most appropriate techniques/models
- Most appropriate time for clandestine grave location


PATH

ile