SEARCH OF 50 IRVINE DRIVE

Inside the house - Floors have been lifted and a radar search carried out of concrete areas, sniffer dogs are also searching the premises

Vicky Hamilton’s remains found

Second body, believed to be Dinah McNicol, found close to house

Police have begun digging up front garden

Search now moved to first floor and attic
Updates and Advances in the location of Clandestine burials

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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...
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.
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

Survey area

1m-spaced lines

Grave

N

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…
GPR (3): The Theory

- Set central frequency
- Transmitter/Receiver antennae take 1-D recording
- Sequentially moved to record 2D line
- Targets will be $\frac{1}{2}$ hyperbolae
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
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!

First real public exposure of GPR for forensics

ERA technologies (U. K.)
Successful?....
GPR (10): ‘Sid’ Results

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

Monthly Total Rainfall / Temperatures

Total Rainfall (mm)

Average Temperatures (°C)
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).
Grave fluid conductivity increases by \( \sim 110 \, \text{mS} \cdot \text{m}^{-1} \cdot \text{wk}^{-1} \). Control fluid conductivity is roughly constant, with \( \mu_\sigma = 79.6 \, \text{mS} \cdot \text{m}^{-1} \) and \( s_\sigma = 8.6 \). Data: Jervis et al. (In press)
Soil porosity and saturation data 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

Jervis, Pringle, Tuckwell & Casella (2008) Resistivity surveys over simulated 'shallow' grave. EIGG Postgraduate Symposium, Keyworth
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
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.
A paired values T-test suggests that there is no significant difference in moisture content between the grave and control soils ($P=0.73$, $\mu_d=0.003$).
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

Before burial

2 weeks

naked  empty  wrapped
Electrical resistivity data

4 weeks
- naked
- empty
- wrapped

6 weeks
- naked
- empty
- wrapped
Electrical resistivity data
Electrical resistivity data
Electrical resistivity data

16 weeks

naked
empty
wrapped

18 weeks

naked
empty
wrapped
Electrical resistivity data

- 20 weeks
  - naked
  - empty
  - wrapped

- 22 weeks
  - naked
  - empty
  - wrapped
Electrical resistivity data

24 weeks

naked
empty
wrapped

26 weeks

naked
empty
wrapped
Electrical resistivity data

28 weeks

naked
empty
wrapped

32 weeks

naked
empty
wrapped
Electrical resistivity data

36 weeks

naked  empty  wrapped

40 weeks

naked  empty  wrapped
Electrical resistivity data

- 44 weeks
  - naked
  - empty
  - wrapped

- 48 weeks
Repeat ERT Profiles

- 3mths
- 6mths
- 9mths
- 12mths

Profiles for different time periods showing changes in resistivity sections.
Both burials visible in GPR data (here after 3 months of burial). Wrapped pig is on the right.
GPR 3D Time-slices

110 MHz  225 MHz  450 MHz

4 weeks

16 weeks

26 weeks

44 weeks

Left to right squares: naked, empty & wrapped
Pig Leachate analysis

pH

Weeks post-burial

Concentrations (ppm)

Best-fit (poly.2ord.)
Pig Leachate analysis

Diagram showing concentrations of Na and Mg over weeks post-burial.
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 $\sim 3\Omega$ 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

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

Pye (2003)
Suggested Reading

Research Articles:

  - [http://www.terraplus.ca/case-histories/dave1.htm](http://www.terraplus.ca/case-histories/dave1.htm)
Suggested Reading

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


"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."
The effect of the burial environment on adipocere formation

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Review of human decomposition processes in soil
Dent et al

![Diagram of human decomposition processes in soil]

- Human Remains
- Early stage decomposition
  - Lining membrane of gastro-intestinal tract
    - Pancreatic epithelium
- Later stage decomposition
  - Epidermis, Reticulin Collagen, Muscle Protein
    - Proteolysis
      - Proteases, Peptones, Polypeptides, Amino acids
        - Continuing proteolysis
        - Evolution of gases
          - Skatole, Indole
          - Carbon Dioxide, Hydrogen Sulfide, Methane, Ammonia (Putrescine, Cadaverine)

Fig. 3
Changes to protein during decomposition
Automated 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: 11495705
Quantifying the actions of individuals and groups engaged in body deposition

- 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 between offender and body during deposition.
  - Duration of deposition.
  - Dimensions of burial.
  - Depth of burial.
  - Volume of soil moved.

- **Non-quantifiable elements would perhaps be:**
  - Preference 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.
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**

- 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