Foreword

David Miller, Lorna Dawson, Karl Ritz

The 2nd International Workshop on Criminal and Environmental Forensics focuses on novel approaches in soil forensics and their use in casework. Internationally, the issues of security and environmental health are high on political and public agendas, leading to needs for effective mechanisms for responses to threats to our quality of life and safety. The European Security Research Advisory Board (2006)[1], in their report on the European Security Research Agenda, called for improved forensic technologies and analysis capabilities for both digital and physical crime scene investigation. In 2007, the European Commission's Directive on Environmental Liability[2] was due for implementation, under which perpetrators of activities causing damage to habitats, waters or contamination which puts at risk human health, are financially liable. Nationally, the Scottish Government's strategic objectives include a Safer Scotland and a Greener Scotland. The achievement of each objective requires robust and scientifically supported means of providing intelligence and evidence for use in prosecution where required.

The conference follows on from the 1st meeting, held in Perth, Australia, in March 2006, organised by the Centre of Australian Forensic Soil Science, updating on the methods and breadth of experiences in different countries and conditions. Conscious of the importance of raising public awareness and understanding of science, the conference has also been designed to broaden interest across a range of audiences by featuring:

(i) a public lecture by Dr James Robertson, of the Forensic Laboratories of the Australian Federal Police, Australia, on the importance of soil forensics in criminal investigation;

(ii) the invitation to a soiree with a range of authors of fictional crime novels to attend, in recognition of the great popularity of this genre of writing and its role in communicating messages about the public importance of forensic science;

(iii) a careers-awareness event for undergraduate and post-graduate students, attracting students from Scottish universities;

(iv) career development potential, with formal accreditation for Continuing Professional Development (CPD) by the Bar Standards Board and the Chartered Institute of Waste Management;

(v) the publication of an associated book based upon many of the contributions to the conference.

It is planned that environmental and criminal soil forensics will be the topic of a further such conference, proposed for 2008/09, with the prospect of a series of such conferences developing over coming years.

The organisers wish to express their thanks to the considerable number of people and organisations which have helped enable the conference through their sponsorship, participation and time.

References

[1] http://ec.europa.eu/enterprise/security/doc/esrab_report_en.pdf
[2] http://ec.europa.eu/environment/liability/white_paper.htm

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Detailed programme

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08.30 - 9.00	Registration
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10.45 - 11.05	**Refreshments**
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12.05 - 13.45	**Lunch and Press Conference** **Poster session**
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14.25 - 14.45 14.45 - 15.05 15.05 - 15.25	Mark Raven, CSIRO Land and Water "Overview of X-ray diffraction techniques with application to criminal and environmental forensic cases" Duncan Pirrie, Matthew R Power, Patricia EJ Wiltshire, Gavyn K Rollinson, Julia Newberry and Holly E Campbell, University of Exeter "Critical evaluation of the application of automated SEM-EDS (QEMSCAN) mineral analysis in criminal and environmental soil forensics" Brad Lee, Tanja Williamson, and Robert Graham, Purdue University, "Identification of stolen rare palm trees by soil morphological and mineralogical properties"

15.25 - 15.45	**Refreshments and posters**
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16.05 - 16.25	Olga Gradusova and Ekaterina Michalovana, Russian Federal Center of Forensic Science “Technogenetics minerals as indicators of the scene of a crime”
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20.30	Delegates free to choose own dinner arrangements

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09.45 - 10.20	**Keynote Speaker** Ms Patricia Wiltshire, University of Aberdeen, "The answer lies (but not always) in the soil"
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12.35 - 13.30	**Lunch and poster session**
Session 4	**Geostatistics and Geographical Information Systems** Chair Ms Pat Bellamy (Session organisers: Ms Pat Bellamy and Dr Mark Brewer)
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14.05 - 14.40	**Keynote Speaker** Professor Colin Aitken, University of Edinburgh "Some thoughts on the role of statistics and probabilistic reasoning in the evaluation of evidence"
14.40 - 15.00	**Refreshments and poster session**
15.00 - 15.20 15.20 - 15.40	Patricia Menchaca, Robert Graham and Marianne Stam, University of California, "Update on the development of a searchable forensic soil database (SQUID) in California, USA" Heather Kerrigan and Jennifer McKinley, Queens University Belfast

15.40 - 16.00	"High-resolution spatial variability of materials in forensic investigations" Andrew Morrisson, Sue McColl, Lorna Dawson and Sue Cocks, Lynne Macdonald and Bob Mayes, Robert Gordon University, The Macaulay Institute and John Moores University, "The soil forensic university network - SoilFUN: results from North West England"
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16.20 - 16.30	**Comfort Break**
	What, How, Where, Who? Chair: Professor Richard Aspinall
16.30 - 16.50	Bob Mayes, Lorna Dawson, Carol Smith, Andrew Morrisson, Jasime Ross and Sarah Milton, The Macaulay Institute "Using gas chromatographic information from plant wax compounds and similar substances for forensic matching of urban garden soils"
16.50 - 17.10	Stuart Walker, Flinders University "A critical comparison of conventional, classic, spectroscopic and elemental analytical methods for forensic and environmental soil investigations"
17.10 - 17.30	Anna Williams and Tracey Temple, Cranfield University "Forensic and environmental responses to pandemics through an applied taphonomic approach"
17.30 - 17.50	Wolfram Meier-Augenstein, Queen's University Belfast "Stable isotope composition of human tissue can aid victim identification"
19.00 19.30/20:00 - 00.00	Coach **Conference Dinner**: "Murder, Mystery and Microscopes" Dinner and Ceilidh, Our Dynamic Earth, Edinburgh

Day 3	Thursday 1 November
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Session 6	**Forensic Taphonomy** Chair: Professor David Miller (Session organisers: Dr Mark Tibbett and Dr Shari Forbes)
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12.45 - 13.45	**Lunch and poster session**
Session 7	**Communications and Advocacy** Chair: Professor Rob Fitzpatrick (Session organisers: Ms Joanne Ashworth and Mr Derek Auchie)
13.45 - 14.20	**Keynote Speaker** Ms Jo Ashworth, Head of Physical Evidence, National Police Improvement Agency "A multi-disciplinary approach to soil forensics and crime investigation - the road to the courtroom"
14.20 - 14.40	Clive Alcock, Chief Executive Cumbria Police Authority "March of the gladiators – scientists entering the arena of lawyers"
14.40 - 15.00	Derek Auchie, The Robert Gordon University "Expert scientific evidence and the law: some important pitfalls"
15.00 - 15.20	Julie Bond and Stuart Bell, Forensic Science Service "Mud sticks"
15.20 - 16.00	**Refreshments and poster session**
Session 8	**Public Lecture: The Global Way Forward** Chair: Professor Richard Aspinall
16.00 - 16.45	**Public Lecture** Dr James Robertson, Forensic Laboratories of the Australian Federal Police "Digging for clues: How soil is helping to solve crimes."
16.45 - 17.00	Questions
17.00 - 17.15	Closing remarks: Dr Lorna Dawson, Professor David Miller, Professor Karl Ritz

Paper abstracts

Session 1 Environmental Soil Forensics

Soil and sediment environmental forensics – what do we know?

Stephen M. Mudge
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One of the key factors that influence the distribution, transport and subsequent stability of materials in the environment is water solubility; those chemicals that are hydrophilic tend to disperse and are less intensively studied as a consequence. In contrast, those compounds that have low water solubility tend to accumulate in soils, sediments and biota, making their analysis a little easier. In the reconstruction of environmental histories, these hydrophobic chemicals can tell us a lot. There are gross scale changes that are apparent from the use of chemicals by man, with soot being one of the most visually obvious for industrialisation and the environmental concentration of lead increasing several times in response to man's activities. Vertical core profiles can indicate these changes and key 'breakpoint' dates can be seen. These profiles may have a particular significance when the EU Environmental Liabilities Directive comes into force (draft legislation now due in autumn 2007). There is a requirement to remediate, reimburse or replace contaminated sites and one of the potentially contentious aspects will be determining background or baseline conditions when these were not available at the time of development.

The more water soluble chemicals tend to leave less of a trace in the environmental media although, with some lateral thinking, they may be traced by the way they affect the media. An example of this was a spill of detergent that leaked into a waterway leaving no residual traces in the soil. However, the nature of the detergent washed out organic matter from the soil leaving a negative track rather than a positive one. Effluent from domestic sewage treatment plants contains a wide range of residual chemicals including Triclosan, an antibacterial agent used in such formulations as toothpaste. The chemistry of this compound is such that it dramatically changes its solubility at environmental pH values and may associate with the soil/sediment phase under normal conditions but become water soluble when rainfall is greater. Reconstructing environmental discharges on the basis of this chemical may be fraught with difficulty.

Spatial provenance modelling for food and other natural products

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Due to the globalisation of legal (and illegal) trade and the limits of paper/electronic mandatory or voluntary traceability systems, there is an increasing demand for techniques which can verify and/or validate the geographical origin of food commodities. Not only is this relevant for consumer confidence but, in almost every case where the origin and/or quality is questioned, there is interest in having an independent analytical method able to verify the claimed origin. Geographic profiling is particularly useful for the provenancing of raw food products like mineral water, vegetables and fruits and processed products like honey, wine, olive oil, as these items have a strong geochemical relation with the host rock and/or soil and precipitation. As certain rock and soil types have a limited spatial distribution on earth, the chemical signature that the products inherit from their geochemical and/or bio-climatic environment, may enable geographical sourcing. The bio-geo-chemical isotopic and elemental signatures consist of elemental and isotopic profiles related to regional climate (H and O isotopes), bio-environment (C and N isotopes) and geology (elements and S, Sr, Nd, Pb and other isotope systems). Against this background, the EU has funded a €19M research project, TRACE, to develop geo-bio-climatical analytical specifications of origin to be combined in a general traceability system. The project investigates whether geo-bio-climatic profiles from a set of food commodities with different grades of complexity, such as mineral water, wheat, olive oil, honey and lamb meat, taken from 26 different 10x10km test sites in Europe and Argentina, can be linked to the geo-bio-climatic environment at these sites. The gathered data is combined with GIS-based traceability data in a spatial traceability knowledge system.

At the meeting, we will present the project concepts, the progress on spatial traceability knowledge systems for mineral water and honey, and the extension of the methodology to forensic non-food items.

Provenancing archaeological objects using traces of soil

Stephen Hillier[1], Lorna Dawson[1], Jean Robertson[1], Evelyne Delbos[1], Jenny Shiels[2], Stuart Campbell[2], Bob Mayes[1], Jasmine Ross[1]
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The provenance of archaeological objects may be unknown or questioned for a variety of reasons. Traces of soil are commonly present on many objects and we have examined the potential of using modern soil mineralogical and chemical methods as an aid to establishing provenance. These include X-ray powder diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), alkane analysis using gas chromatography, and colour using spectrophotometry. The advantages and disadvantages of some of the different techniques in determining the provenance of traces of soil will be discussed and illustrated by their application to some objects ranging from Roman to Medieval age from Scotland and Wales.

The potential use of a novel heavy metal sensor and novel taggants in environmental forensic investigations

Patricia Pollard, Morgan Adams, Simon Officer, Radhakrishna Prabhu, Catherine Hunter, Andrew Morrisson.
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This paper discusses the potential use of a novel heavy metal sensor and novel taggants in environmental forensic investigations. The novel voltammetric heavy metal sensor has recently been developed to allow rapid in-situ quantitative measurement of a range of heavy metals during brownfield site environmental land assessments. The data acquired provides a metals fingerprint that could be input into the forensic soil database. This paper also discusses the potential use of novel fluorescent taggants in environmental forensic investigations.

Molecular chemistry and isotopes: what are the limits of their forensic application?

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There is a well established history of using molecular chemistry for environmental forensics, and there is a growing use of stable and radio isotope techniques to further elucidate forensics questions. However, an increasing number of applications have seen limitations for these techniques. This presentation will present details of case studies and provide the limitations for molecular chemical techniques.

The causes of deterioration of concrete from a forensic point of view

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The deterioration of concrete was already recognised back in the early 1900s and was at the time considered a natural consequence of ageing. Since then, a great number of different mechanisms have been identified, invariably resulting in deterioration and damage of concrete (binder, aggregate or both), compromising performance and reducing service life. Through careful selection of suitable materials and construction methods, deterioration can, in most cases, be effectively prevented. However, choice of improper materials, inappropriate design, and other-than-designed-for use and/or exposure may negatively affect a structure's longevity, or degrade its aesthetic appearance. Proper identification of primary and secondary causes of deterioration is essential to determine the correct rehabilitation strategy, as well as to prevent future damage in similar structures. Reduced concrete performance can be confirmed by a multitude of standard methods, including compressive/tensile strength, water infiltration depth, total porosity, chloride content, etc. Though widely accepted and certainly useful, these methods typically apply to bulk concrete.

However, to identify the *cause* of concrete deterioration for a given structure, assessment methods originally stemming from geology, including petrography and geochemistry among others. Petrography can be applied on plane sections from extracted drill cores, as well as on 20µm thin sections in transmitted light under the optical petrographic microscope. Polished sections can be used for analysis by microprobe (EMPA) including element mapping. Specially prepared thin sections impregnated with a fluorescent dye enable identification *and* assessment of spatial distribution of micro-structural features, including capillary porosity. Petrographic data on modal content of coarse and fine constituents, and rock types and minerals present is essential for correct interpretation of geochemical assessment, for instance on bulk concrete using XRF, or after partial digestion by ICP. Many issues that pose tough problems for civil engineers using conventional bulk testing methods can be resolved rather easily using (a combination of) geological methods. The capability of geological methods for the assessment of concrete and building materials in general will be demonstrated by a number of case studies actually using such methods.

Session 2 Criminal Soil Forensics

Forensic soil science: current research and case work activities in Australia

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Recently in Australia there has been an increase in usage, awareness, relevance and importance of soil materials in forensic science. The Centre for Australian Forensic Soil Science (CAFSS) has been actively involved in specialised soil forensic work for a wide range of clients. Activities include assisting police forces, government agencies and non-government organisations with the search, location and recovery of soil and mineral samples from: (i) murder, cold murder and cover-up murder cases; (ii) counter-terrorism cases, (ii) assault, rape and kidnapping cases; (iii) armed robbery and theft cases; (iv) environmental contaminant cases (dust and toxic metals in the environment) and (v) forensic archaeology cases in Australia and overseas, including diverse projects such as stolen dinosaur eggs and ferns from national parks. Most cases were overwhelmingly complex, and the challenges of associating relevant information from one source with another, often required the development of new sophisticated field and laboratory methods.

Experience gained conducting over 50 case studies, and focused ongoing research by CAFSS, has led to the development of a draft Soil Forensic Investigation User Manual, describing best practice for both field (identifying and collecting soil samples) and laboratory techniques, which requires consistent and correct use of terms. This approach has enabled soil properties to be successfully used to discriminate between, or match, soils for critical evidence in forensic cases. The manual contains guidelines in the use of the following: (i) Terrain models, interfacing with soil databases and maps from State governments and the Australian Soil Resource Information System, which are used for soil-landscape fingerprinting; (ii) Soil sampling, description and mapping, with emphasis on the use of standard procedures and terms for describing and sampling soils (e.g. methodology for describing soil colour, consistence, texture and horizons developed by soil scientists over 100 years); (iii) Petrographic microscope descriptions, incorporating selected soil micromorphology methods; (iv) Soil preparation methods depending on specific soil type (e.g. sieving to < 50 micron to obtain small size fractions and heavy mineral separations) for X-ray diffraction (XRD) mid infrared (FTIR) analyses; (v) Geophysics (magnetic susceptibility, electromagnetics and ground penetrating radar); (vi) Electron microscopy (SEM and TEM); (vii) Chemistry (ICP-MS, X-ray fluorescence, multi-element and isotopic signatures); (viii) Soil biology (diatoms, pollen, DNA); (ix) Investigative practice and requirements for presentation of soil evidence in law courts and tribunals based on recent experiences.

Overview of X-ray diffraction techniques with application to criminal and environmental forensic cases

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The application of sophisticated analytical methods to forensic investigations is gaining increased importance due to advances in instrumentation and sampling techniques. Whilst X-ray diffraction (XRD) is a reasonably mature technique, it is still of great importance because of its non-destructive nature, often allowing further investigations of the original intact specimens. The major strength of XRD is its ability to identify and interpret crystalline components 'directly'. XRD can be used to analyse all manner of crystalline materials from crime scenes such as explosive residues, soil materials, paint chips, adhesive tapes, building materials, minerals, alloys, ceramics, gemstones and drugs. Various sample preparation techniques are employed depending on the quality and quantity of evidence available. Materials can either be analysed undisturbed on the carrier object or removed and analysed separately. Mounting the specimen in the instrument is also dependent on the size and shape of the items being investigated.

Several case studies will be presented outlining aspects of XRD analysis applied to both criminal and environmental forensics. Emphasis will be placed on case investigations where new approaches have been applied to analyse extremely small samples from shoes and clothing, and preparation procedures to obtain representative samples. These case studies will include pinpointing the location of buried bodies, identifying the source of industrial dust, analysis of bone fragments, and matching soil material from clothing to crime scenes.

Critical evaluation of the application of automated SEM-EDS (QEMSCAN) mineral analysis in criminal and environmental soil forensics

Duncan Pirrie[1], Matthew R Power[2], Patricia EJ Wiltshire[3], Gavyn K Rollinson[4], Julia Newberry[5], Holly E Campbell[1]

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The complex mix of organic and inorganic components present in urban and rural soils and sediments potentially enable them to provide highly distinctive trace evidence in both criminal and environmental forensic investigations. Organic components might include macro or microscopic plants and animals, pollen, spores, marker molecules etc. The inorganic components are naturally derived minerals, mineralloids and man made materials which may also have been manufactures from mineral components. Ideally in any forensic investigation there is a need to gather as much data as possible from a sample, but this will be constrained by a range of factors, commonly the most significant of which is sample size. Indeed, there are a very wide range of analytical approaches possible and a range of parameters that can be measured in the examination of the inorganic components present in a soil or sediment. These may include bulk colour, particle size distribution, pH, bulk chemistry, mineralogy, mineral chemistry, isotope geochemistry, micropalaeontology, mineral surface texture amongst a host of others. Whilst it would be prudent to utilise as many parameters as possible, the forensic significance of the resultant data should be carefully considered. In particular, many parameters that could be measured (such as particle size distribution, pH and colour) may be affected by the nature of the sample, may vary temporally or in response to sample storage conditions and hence may provide misleading results .

The inorganic components of soil and sediment are typically relatively inert and therefore potentially one of the most valuable parameters to measure. To this end, we have utilised an automatedscanning electron microscope with linked energy dispersive X-ray spectrometers (QEMSCAN) in numerous criminal forensic investigations. The system is fully automated and operator independent and enables even small samples to be fully mineralogically characterised. QEMSCAN analysis provides quantitative information on not only the modal mineralogy but also mineral grain size and shape and also the relationship between the individual minerals. In this paper, we present the results of a detailed analysis of the reproducibility and variability of mineralogical data derived through the repeated automated analysis of soil samples collected as part of a larger study into the variability of soil mineralogy and palynology in the forensic context. The aim of the paper is to test and critically evaluate the use of automated SEM-EDS analysis.

Identification of stolen rare palm trees by soil morphological and mineralogical properties

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The San Diego County District Attorney's office requested our help to investigate the theft of palm trees from a private collection of exotic plants. Circumstantial evidence led investigators to the suspect's residence where 33 palm trees were found planted in the lawn. Because the victim raised all palms from seed in the same potting mix, we compared morphologic and mineralogic properties of soil samples collected from the root balls of palms that were at the victim's and suspect's residences. Analyses of soil colour, reaction with dilute hydrochloric acid, particle size, heavy:light mineral ratios, and mineral speciation of the > 2.86 g cm^{-3} fine sand fraction, indicated that 25 of the 33 soil samples collected from palm trees at the suspect's residence were very similar to soil samples from palm trees at the victim's residence. After a pre-trial hearing at which the soil evidence was presented, the suspect changed his innocent plea to guilty.

Meeting the user requirement – a case history

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Soil analysis in the UK has traditionally been supplied by individual researchers to answer specific evidential issues within their own specialty and, as a bespoke service, cost inevitably restricted its use to the most serious crimes. Lack of knowledge of the overall circumstances inevitably tended to limit the breadth of conclusions, especially since the soil results were often regarded as entirely separate from other forensic results. Further, the benefits were poorly understood by investigators and so many opportunities to provide crucial physical intelligence and evidence were being missed. Although a large number of individual specialised scientific techniques were available, there was no recommended suite of techniques, the advantages, limitations and significance of the various techniques in forensic circumstances were largely unknown, and it was impossible to know what would be the best method of analysis in any particular context, or for a particular type of soil.

NCOF on behalf of ACPO Homicide Working Group devised a user requirement for forensic soil analysis and EPSRC provided £300k of funding over three years for the project, now in its second year and known as 'SoilFit', led by Lorna Dawson of Macaulay Institute. Subsequently, further funding to establish the associated GIMI network was obtained. It is already clear that substantial benefits to investigators across the UK will be produced.

This paper considers one particular aspect of the project implementation - the need to satisfy the full range of cases in which soil analysis could be of benefit, rather than just relying on success in serious crime to spread the word of mouth to less serious cases. A brief overview of the UK investigative process is given in order to help define the opportunities to provide soil intelligence. A case example is presented in which soil analysis appeared to be of only marginal importance but was able to resolve whether the case involved accident, murder, or rather less serious offences against the HSAW Act!

Technogenetics minerals as indicators of the scene of a crime

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Integrated study has been used for many years in forensic soil examination in our laboratory. In particular, it is used more in cases, when trace-forming material is only present in small quantities (less then 30 mg) and represents a mechanical mixture of soil microaggregates and (or) small parts of natural and (or) technogenetics materials. In these cases, comparative research of soil microaggregates morphology in combination with microscope and instrumental methods in small parts investigation is very successful.

During investigation in a case of rape of one teenage boy by another, the shoes of the suspect and comparative samples from the scene of crime, which was the basement of a house with a central heating system, were presented for forensic soil examination. There was a wet place under rusty water-pipes. Comparative sample was grey-brown soil (10 YR 5/2), which included hydroxide Fe (III), glass fibre fragments from pipe heat insulator and aerosol ferromagnetic balls, small parts of bones and vivianite globules.

Vivianite mineral formation had been identified by means of traditional mineralogical methods and instrumental method (Micro X-ray Fluorescence Spectrometer and microprobe energy dispersive analysis). The possibility of vivianite formation in the buildings was confirmed by expert practice. There were some soil microaggregates (0,5 mm in size) on the accused person's shoes, of the same colour and texture as the soil component of the comparative samples, and the same small parts of hydroxide Fe (III), glass fibre, aerosol balls and single vivianite globule. Accordingly, integrated research methods of the mechanical mixture (soil aggregates and small parts of different nature) allow us to obtain more objective information about trace-forming material. Local technogenetics forming process of hydroxide Fe (III) and vivianite mineral let us establish, with a high degree of certainty, the presence of the accused person at the scene of a crime.

The Soham murder enquiry – the nature of evidence and its context

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The geological aspects of the Soham murder enquiry represented a rare example in which abundant geological material could be set clearly into an established context using well-proven techniques. Field evidence was combined with biostratigraphy to characterise deposits found under Ian Huntley's car and place them within the narrow age range of chalk also found at the body deposition site. It was possible to present a case which allowed the Jury to understand and assess for themselves not only the similarity between case-related samples, but also the range and extent of innocent locations from which the car might have acquired deposits containing chalk of an identical age and lithology.

If technical evidence is to be presented in court, it should be based on well-established principles and agreed by all parties or it should be capable of full evaluation by a Jury. It is rare for this counsel of perfection to be achieved and the expert witness must be aware of the dangers inherent in the act of presenting 'evidence' that cannot be set fully in context. The question of how similar two samples need to be in order for the Jury to conclude that they came from a common source cannot be answered without a minimum of control sampling. Where that minimum lies will depend on the details of the case but it is not sufficient to rely simply on the fact that the degree of similarity or the particular feature on which the case is based has never before been encountered by the expert witness concerned. Other areas of forensic science use scales of probability to illustrate the strength of similarities; this presentation will explore the applicability of these scales to forensic geology.

Sourcing geological materials left at crime scenes: an isotope approach

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Identifying, sourcing and tracking elements have been the goal of many branches of scientific research over the past few decades. The methods employed are numerous and range from tracking particulate matter in the atmosphere to identifying sources of sediments in river catchments. However, this methodological approach can be extremely useful in forensic science by providing additional trace evidence that, until recently, has been otherwise ignored. In addition, the ability to be able to trace not only materials but potentially individuals to foreign localities where intelligence or evidence is lacking could be extremely valuable to the security services. Methods currently applied in the support of law enforcement agencies and immigration control are also rather limited when it comes to establishing the actual country of origin of a person, or materials left at crime scenes, or to check on the veracity of statements made about geographical origin and recent geographical movements of humans and materials. Data will be presented from a number of cases illustrating the nature and form of the approach using both stable and radiogenic isotopes involving environmental and human materials. Illustrations from a number of successful cases involving sourcing will be illustrated and how these can be used to potentially help law enforcement in the future.

The geoforensic analysis of soils from footwear

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Using experimental and case work examples, this study demonstrates the spatial mixing of different soil layers which have been introduced onto soles of footwear pre-, syn- and post-forensic event. The persistence of sediments introduced onto footwear (both uppers and soles) is identified, highlighting appropriate methods of collecting them from both outer and inner parts of the footwear. Experimental studies support the practical observations of sample collection in real criminal case scenarios but highlight pitfalls which can result in false-positive and negative conclusions during the analysis and interpretation of recovered samples.

Experimental studies using three layers of Plasticine of different colours identify that time is more important in the explanation of the spatial distribution of materials on the soles of footwear, although selective pressure caused by gait has a contributory effect. The introduction of three soil layers, each containing specific physical and chemical markers, supports the experimental proxy work undertaken with Plasticine. Complementary chemical analysis of the soils using XRF confirmed the complex mixing patterns over time. We conclude that care must be taken when sampling footwear for forensic comparison, often more so than is presently exercised. The persistence of sediments on and in footwear is identified in four criminal case work studies utilising surface texture analysis of quartz grains and palynomorph identification using both binocular and scanning electron microscopy. These studies also provide provenance indicators of the materials from both real case and experimental studies. These persistence and provenance identifications are tested and confirmed under experimental conditions.

Session 3 Geoforensics

New observations on the interactions between evidence and the upper horizons of the soil

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In many cases, evidence or a body left lying on a natural ground surface will start to disperse and be hidden from view in a relatively quick time period. Observations from experiments into scavenging effects on bodies, and from experiments on the bioturbative influences on small objects in the soil, reveal some interesting general effects that can assist in decisions on search and locations strategies. Using deer cadavers as an analogue for humans to observe body part dispersal, some interesting trends in initial decomposition provide data on how rapidly small objects can disappear from view, and how the influences on a decomposing body before the intervention of vertebrate scavengers can potentially mislead interpretation.

Further experiments monitoring earthworm activity within the upper soil horizons show the effects in the forensic short to medium term on objects placed on the surface, demonstrating careful consideration needs to be given to location and recovery methods. Case studies illustrate the potential impact of these observations on crime scene recovery.

Forensic geology

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Earth science is a broad-spectrum discipline that covers all of the mechanisms involved in the study of the land, sea and air. In our day-to-day activities, we must travel in one of those mediums. What we do in the medium and how we cross the boundaries affects the type of evidence that could be collected at a scene. A forensic geological examination may not just entail a routine study of soil evidence. Depending on the type of incident involved, a multidisciplinary examination may be warranted.

The main use of the science is to assist law enforcement in placing persons at scenes of crime. It can also be used to track pathways of serial killers, terrorists and international thieves. We live in a highly mobile society that has many cross-border criminal activities. These activities include drug shipments, smuggling, commercial theft, fraud and terrorist actions. Where a drug shipment has truly originated or passed through is just as critical as knowing where a terrorist’s vehicle was loaded and its path to the target. A forensic geological examination may be able to provide those answers. Forensic geological analysis is based on the premise that every soil or mineral exhibit has provenance. Provenance is determined by the ability of the investigator to establish that the exhibits are site specific. The degree of individuality and nature of the specific mineralogical elements is the key in pronouncing the significance of that provenance within the confines of the incident. Localised site-specific determinations can be made by shape, textural and contamination features found within the confines of each exhibit. The ability to establish the regional provenance of a mineralogical exhibit will have more significance in an international case than a local incident.

The power and value of a forensic geological examination can only be fully appreciated once past uses are detailed in case studies. Enlightened investigators will then see how this type of examination can assist in developing other facets of an investigation that may otherwise be lost. Every criminal investigation deserves to have all potential avenues of examination explored and utilised if appropriate.

Rapid, non-destructive screening of adhered rock and crystalline material for criminal investigations

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The criminal mind is becoming increasingly familiar with clean-up procedures at the scene of a crime and following criminal activity. Police officers and forensic scientists are being faced with smaller and smaller amounts of trace evidence to analyze therefore the techniques which are carried out upon what remains are crucial – as the amount of material available for investigation is diminishing. This project aims to test the combined scientific, cost- and time-effectiveness of using non-destructive analysis of soil, rock dust and other crystalline materials adhered to fabric and other materials associated with crime suspects as a rapid screening method for further forensic-based scientific analysis. The amount of evidence obtained can be used to establish alibi veracity and thus the implications of this type of investigative research can clearly be seen. Investigative research into the analysis of trace mud splashes on different substrate material attempts to utilise the amount of information which can be obtained at this micro scale. The nature of soil formation is very complex and is reliant upon a number of varying factors from bedrock to climate for a given area; it is this complexity which makes analysis of soil at a micro level important for establishing criminal movement and provides an individual soil signature for different locations around the world. Analysis of these splashes become increasingly more important when a multi-proxy approach can be applied using a number of analytical techniques to establish their origin. Non-destructive techniques are therefore a top priority in this type of investigative research. Fieldwork has provided a temporal aspect to this study. Samples taken at specific time intervals allow any variation in the mineralogical compositions of the field sites to be monitored. The implications for this aspect of the study in relation to criminal investigations can be seen with regards to the time in which articles may be seized from a crime and compared to the crime scene location; variation in scene of any kind would have implications for the time span in which samples may be analysed using analytical techniques.

The answer lies (not always) in the soil

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Soil is often a source of biological particles and fragments that may be useful in criminal investigation. The biological evidence may include pollen grains, seeds, plant fragments, diatoms, other algae, various kinds of invertebrate as well as fungal spores, and lichen propagules. These can be transferred to both offenders and victims and have, in many court cases, provided evidence of contact between people, objects and places, times, and location of clandestine burial and concealment. The crime scene must be viewed in its entirety and not only in terms of exposed soils and sediment, since these have often proved not to be the source of the critical evidence.

The major constraint in using biological trace data to their full potential is not just the issue of appropriate sampling and accurate identification, though these present serious hurdles, but a deep understanding of the ecology and environments in which the organisms occur. This is not something that can be easily taught or acquired quickly. Case histories will be presented to illustrate the advantages and specificity that biological trace evidence can provide.

The coordinated approach of multidisciplinary teams to locate concealed victims of homicide, developing the role of forensic landscape investigation

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Police searches for the graves of victims of homicide have historically been undertaken by the use of large numbers of Police, military and public volunteers, conducting visual or manual probe line searches covering formalised grided sectored areas. The speculative digging of large sectors has also been employed with variable success. More recently, the search for homicide graves has involved teams of multi-disciplinary experts such as geologists, anthropologists, botanists, victim recovery dogs (VRDs), remote sensing aerial assets, behavioural profilers, clinical psychologists and the military geophysics. These are co-ordinated and managed by a police search specialist.

Mineral exploration geologists, engineering geologists and geohazard specialists investigate the ground using a range of methods and techniques. Before a physical ground investigation is undertaken, a conceptual geological model of the ground is developed. This provides information on the tectonic setting, stratigraphy, hydrogeology, hydrology, groundwater, hydrochemistry, superficial deposits, principal soil types, depth to bedrock, nature of bedrock interface, engineering and physical properties of the ground, geomorphological processes, mining, past land use, current land use, geological hazards and man's influence. Similarly, the properties of the target (body and associated buried objects) are also determined and how in particular they have influenced the geology. This provides estimates of the target's age, size, and geometry, expected depth of burial, time and duration of burial, physical, chemical, hydro-geological and geotechnical variations compared to the surrounding ground. An understating of the undisturbed and disturbed geology and the target properties are crucial before the correct search strategy and choice of instrumentation may be decided, and the optimum method of deployment identified. These may include the use of geophysics, geochemistry, satellite imagery, air photo interpretation, invasive site investigation methods (drilling, trial pitting, trenching) or ground monitoring. Geological investigative techniques are applicable to police searches, since the underlying search philosophy, concepts and principles are similar, i.e. there is a buried 'object' or 'target' to be found.

One of the most important services a geologist can give a law enforcement investigator is the production of a geological model of a potential grave site, an understanding of the geological and geomorphological processes, the characterisation and understanding of the origin, source and properties of the soils, rocks and target, and a choice of investigative methods. For the geologist (and other subject matter experts) to be effectively incorporated into a search team, he/she must be an effective communicator of complex geological (scientific) jargon, recognise the limitations of his/her skills and capabilities and be aware of the boundaries and interface with other subject matter forensic experts. The objectives of this paper are to outline how the combined skills and expertise of police and geological search specialists enable the ground in the vicinity of homicide graves, to be better understood and more professionally and effectively searched, and to draw attention to the complexities involved during the search for a homicide grave that involve multi-disciplinary teams of subject matter experts.

The heavy mineral component of soils: its use in civil and criminal investigations

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Soils, classically, consist of organic, gas, and mineral phases. The latter typically include the clay mineral species present and the minerals that comprise the silt, sand, and gravel fraction. With respect to these, the relative abundance of major mineral phases (quartz, feldspar, calcite, iron oxides etc.) has been widely used to characterise soils from a given location. Often overlooked, however, is a ubiquitous mineral component that may serve as a diagnostic 'fingerprint' for the soil. This component consists of trace quantities (usually <1 percent) of a wide variety of minerals whose specific gravities exceed that of bromoform (S.G. 2.85) and which have been termed 'heavy minerals'. Whereas a weathered soil may consist essentially of quartz (and possibly one or two clay mineral phases), examination of the heavy mineral fraction of the soil may reveal a rich suite that includes ilmenite, leucoxene, rutile, kyanite, staurolite, tourmaline, garnet, epidote, hornblende etc. in quantities that may be diagnostic for the unit's identification. A further advantage of heavy minerals lies in the fact that, while two soils from a local area may be indistinguishable based on their major mineral content (e.g. 'quartz plus kaolinite'), they may be quite distinguishable, even if they contain the same heavy mineral suite. This arises from the fact that if the sediments on which the soils have developed were deposited by different river systems or formed at different times (i.e., are separated stratigraphically by even a diastem), then it is unlikely that they will contain the *same relative proportions* of identical heavy minerals. For this reason, ratios of certain heavy minerals (e.g., Zircon + Tourmaline/Rutile, the classic 'ZTR Index', or the Ilmenite:Leucoxene ratio) can often be used to distinguish samples from two sites.

Examples are provided where heavy mineral information provided critical evidence in identifying the source of contaminants that caused premature 'burn out' of aircraft engines manufactured by a local firm, a vandalism case involving destruction of an expensive bulldozer engine used at the Alabama State Docks, and a case filed against the State of Alabama where improper road building practices resulted in the destruction of a lake on private land.

Assessment of aggregate sizes and phosphorus distribution in terms of landscape positions along Northing tramline

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The transfer of P from agricultural soils to watercourses can be a serious problem in many agricultural areas. It is well documented that erosion by overland flow is the dominant process by which soil components are detached, transferred and deposited within and out of cultivated fields. It depends on, and varies with, many complex factors, which affect not only susceptibility for erosion and runoff to occur but also the potential for soil P release to runoff water. The distribution of P compounds between aggregate size fractions is an important property with regard to P transfer in runoff, because of the different susceptibilities of aggregate fractions to release P to soil solutions through a sequence of disaggregation and desorption reactions. Owing to increasing P affinity with decreasing particle/aggregate size, P content of soil particles or aggregates often increases with decreasing particle/aggregate size.

The quantity of the sediment P delivered to the field edge is a function of soil erosion rate, amount of sediment deposition within the field, and the quantity of P selectively adsorbed to the eroding soil particles or aggregates. Current research is concerned with evaluating the potential for vertical P transfers from sediment deposition zones within erodible, cultivated fields. Spatial patterns of soil aggregates distribution and soil P concentration in a small, gently sloping, silty clay loam, cultivated field were investigated through the analysis of aggregate size fractions, TP concentration at 0-1cm depths from regions that represented less eroded, eroded, and depositional areas along Northing tramline (T6). Samples were taken from inside the tramline.

Results were illustrated the preferential losses of finer sized aggregate fractions as a result of the size selective nature of erosion processes. Consequently, the higher accumulation of clay and finer silt fractions were found within the finer aggregate fractions (< 53 µm) in depositional region, compared with larger aggregate fractions (> 53 µm) in the same position. Those were also coupled with the highest concentration of P (TP) which may be associated with those soil components.

Localisation of a mass grave from the Nazi era

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In 1944/45, 34 diseased Jewish concentration camp prisoners were buried in a mass grave in a municipal forest area close to Stuttgart (Germany). The grave was opened after the end of WWII in order to bury the corpses in a dignified manner in a graveyard. The precise location of the mass grave, which had not been maintained and the area had become overgrown, was to be reconstructed through pedological investigation.

An aerial photograph from the time when the mass grave was dug indicates that the grave was dug somewhere within a 5 hectare area. In order to determine the precise position, the area was mapped in a defined pattern (5x5 m), recording detailed, geo-referenced information of the microrelief and soil cores (including intrusion resistance). This led to the identification of two adjacent areas (~ 32 m^2) that revealed significant differences. A ditch (depth: 1 m; width: 60 cm; length: 9m) was dug to study the area in greater detail. A clear anthropogenic influence was found, as indicated by the detection of numerous, strongly corroded iron finds, from the pH, C_{org} and P-depth functions along the ditch. The final proof of the grave's location was gained when a pivot tooth was found in the central area of the area being investigated at a depth of 60 cm. The pivot crown was of the kind known as a Richmond crown (characterised by the numerous solder joints, inhomogeneous composition and low-grade materials), which was used in Germany up until 1950.

Towards an understanding of the geophysical response of shallow graves

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The use of geophysics in the search for shallow graves usually relies on locating secondary indicators of burials (such as disturbed ground or decay products) rather than the direct detection of a corpse. As the electrical and magnetic properties of these secondary features are poorly understood, geophysical techniques are often used in (both real and simulated) forensic situations without prior knowledge of how, or indeed whether, they will be successful in finding a grave. A fuller understanding of the bulk electrical and magnetic properties of a clandestine grave in various locations and circumstances is crucial in selecting the best geophysical technique to use on a case-by-case basis.

In this study, two pig cadavers buried in Staffordshire University's 'Crime Scene House' garden are used as a proxy for human graves. Lateral Wenner array, bulk ground resistivity surveys have been performed over one pig grave every 14 days since April 2007. Soil and groundwater samples (also obtained every 14 days) from the second grave are acquired alongside local weather records in an attempt to understand the evolution of resistivity datasets during the course of the project.

The results show that the conductivity of the fluid within the grave rose sharply after burial and this is attributed to the decomposition of the organic matter in the ground. The available evidence suggests that this is perhaps the most important factor that allows a grave to be detectable using electrical methods. This means that conditions and circumstances that inhibit or promote the decomposition of a cadaver have a direct bearing on the chance of an electrical-method geophysical survey being successful. The effects of different soil types, burial styles and climatic conditions on the outcome of a resistivity survey are considered in light of the presented results.

Session 4 Geostatistics, Databases and Geographical Information Systems

Geostatistics and uncertainty in spatial variables in relation to forensic investigations

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In geostatistical methods, a set of spatially variable observations is treated as a realisation of a spatially correlated random function. Subject to certain assumptions about the properties of the field, this allows us to make inferences about values of the variable at unsampled sites. In this paper, we shall present an outline of existing geostatistical methodology, highlighting those features which are pertinent to forensic problems. We shall show how non-linear geostatistics can be used to make inferences about the provenance of soil samples within a region on the basis of their geochemical composition. We shall discuss the principal difficulties for the application of geostatistics to forensic problems

Some thoughts on the role of statistics and probabilistic reasoning in the evaluation of evidence

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There is an increasing awareness amongst those involved in the administration of justice of the importance of the ideas that the proper evaluation of evidence requires consideration under two propositions, those of the prosecution and of the defence, and that probability, as a measure of uncertainty, has a role in this consideration. The evaluation of evidence provides a factor which converts the prior odds in favour of the prosecution proposition to posterior odds in favour of the prosecution proposition. The implications of the application of this idea to soil forensics and the difficulties in its implementation will be discussed. (This is joint work with Dr. Tereza Neocleous).

Update on the development of a searchable forensic soil database (SQUID) in California, USA

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This presentation discusses progress in the development of the Soil Query Information Database (SQUID), a searchable forensic soil database. Sample collection, statistical considerations, the GIS-based database, and the preliminary evaluation of the different soil characteristics that may be the most useful as discriminatory tools will be presented. Currently, at least 300 soil samples have been collected within the 36 square mile study area. Seventy-five of these were collected from a 10 square mile swath of the southwest corner of the study area, and approximately fifty were collected from a 6 square mile area in the northeast part of the study region. The 90 to 180 micron and the less than 90 micron fractions of the southwest samples have been evaluated for their colour, and the whole samples for their magnetic susceptibility. Preliminary examinations of the data suggest that these two easily obtainable features may be important for the discrimination of soil samples in this area. The northeast section of the study area contains multiple alluvial units derived from differing parent material. Because of the high variability within these units, attributes such as magnetic susceptibility and colour may not be suitable for discriminating between them. Consequently, the samples collected here will also be examined for their heavy mineral content and the ability of these minerals to distinguish between the different alluvial soils.

Discriminant analysis is being applied to the soil colour, magnetic susceptibility, and trace mineral data to differentiate the geologic and soil units. A GIS map database is currently under construction to exhibit spatial variability. It is comprised of multiple layers including the geologic map units and their attributes. Attributes such as colour, trace minerals, magnetic susceptibility, particle size, and heavy mineral separations will contribute individual GIS layers. This study will serve as a pilot project that can guide the development of a greater statewide or regional system.

High-resolution spatial variability of soil and sediment content

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The strategy of large-scale (km) sampling has been questioned by geomorphologists and forensic scientists alike as being unrepresentative, with the suspicion being that variation within the km grid could be significant. Studies assessing smaller-scale (metre) variation are however, very limited, with notable lack of a comprehensive analysis of such variation. Two major studies that make use of larger-scale sampling are currently underway: the joint GSNI/DETI TELLUS project and the Macaulay SoilFit project. This research builds on the premise of these studies, but focuses on variation at the smaller scale. A case study utilising potential forensic evidence collected on a spatial sampling scheme is presented. The application of Geographical Information Systems (GIS) and geostatistics to the analysis and integration of different spatial evidence is also described. The case study involves a potential entry and/or exit route for a crime scene over open ground. GPS-referenced data provide a digital elevation model (DEM) on which layers of spatial evidence are superimposed. The GIS-based terrain analysis approach provides information on the geomorphological and hydrological partitioning of the landscape. Sampling was carried out on a grid of 45m x 45m. A total of 200 samples were taken, comprising a deep (20cm) and surface sample for each point. Samples were analysed using NIRS and although results are preliminary at this stage, geostatistics carried out on the data indicate variation at the scale sampled, as well as at a finer scale than that sampled. These initial findings emphasise the need for investigation of soil variability at a metre scale resolution. On-going analyses by particle size analysis, XRD, FTIR and colour, will provide further insight into the spatial variability of the soil and sediment content. GIS and geostatistics form the basis for analysing the data, with GIS particularly providing novel and enlightening methods of identifying variation in samples. Links and spatial relationships between spatial evidence are explored through spatial analysis techniques in the investigation of this potential crime scene.

The Soil Forensic University Network (SoilFUN) – a collaborative project

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SoilFUN, which was founded in 2006, is a Network of Universities with a common interest in generating a UK-wide forensic database of urban soil data. Data is generated through student projects and is made freely available to all partner Universities. The database resides at the Macaulay Institute. Individuals or teams of students at different universities undertake soil sampling at a number of locations in their own cities. The sampling sites chosen typically represent different land-use vegetation (LUV) types. Sampling sites include deciduous urban woodland, park flower beds, road laybys and other typical areas where a crime might have been committed or a weapon/body/cache concealed. Replicate sampling at each site, and the selection of replicate LUVs within cities, allows comparisons to be made between similar and differing LUVs. Ultimately, between-city comparisons will be possible as the database becomes populated. Typically four different sampling areas of each LUV type and four replicates within close proximity at each site are taken.

Protocols are available to all members of the SoilFUN network; these include sampling, storage , sample handling, colour analysis, gas chromatography of soil alkanes and Fourier Transform infrared spectroscopy of mineral and organic components. Reference samples are available for QC purposes and members may also wish to undertake additional analyses e.g. heavy metals, nutrients, minerals etc. The network is in its initial phase and has nine members from around the UK. Membership of SoilFUN is open to all who wish to contribute to the database. Training on the analytical methods employed can be arranged.

Microbial community DNA profiling: sample similarity and geographic proximity in a large database

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The forensic utility of microbial community DNA profiling as a tool for the analysis of soil evidence depends on its capacity to correctly link soil samples that may have originated from a common source and its capacity to differentiate samples that originate from unrelated sites. We have investigated the relationship of profile similarity to geographical proximity in a database of 1348 community DNA profiles of ascomycete fungi derived from samples collected according to a spatially structured sampling grid at 24 distinct sites from an arid region of New South Wales, Australia. Distances between samples ranged from 1 m to over 100 km. Profiles were compared using three statistical approaches: (a) pairwise sample similarity measures using the Sorensen and Morisita-Horn indices, (b) hierarchical cluster analysis using Pearson correlation statistics, and (c) principal components analysis.

We have found that none of the statistical approaches reliably differentiated geographically proximal (1 m sq. plots) from geographically unrelated sites ($d > 250$ m). Samples from unrelated sites were found to have highly similar profiles, indicating a substantial risk of false positive source attribution. Conversely, some samples from geographically proximal sites had quite dissimilar profiles, indicating that profile dissimilarity was not a reliable indicator of source exclusion. These findings indicate that more foundational research is needed before microbial community DNA profiling is embraced or rejected as a tool for forensic soil analysis. Several directions for future research are suggested. First, the sample profiles characterised here were ‘species poor’ with relatively few OTUs per profile. Species richness may need to exceed some minimum threshold to achieve forensically reliable profiles. Second, it is possible that the ascomycete fungi were a poor species group on which to base geographic similarity comparisons. Differences in sample discrimination potential for different microbial species groups deserve investigation. Third, the lack of consistency between the results provided by the different statistical approaches, though likely a consequence of the limited species diversity in the profiles, calls into question the choice among different methods of statistical analysis to be used for profile comparisons.

Using gas chromatographic information from plant wax compounds and similar substances for forensic matching of urban garden soils

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The waxy surfaces of plants consist of complex mixtures of discrete aliphatic lipid compounds, including long-chain hydrocarbons, long chain fatty alcohols and fatty acids, which can be analysed by GC or GC-MS. These compounds are relatively inert and long lived, and commonly become incorporated into the soil. Different plants have different characteristic patterns of plant wax compounds; the patterns of these compounds found in soil can be expected to reflect both present and past vegetation in that soil. Soil from gardens may be a source of forensic information in cases where suspects may use the garden as a means of entry or escape from a domestic crime scene, e.g. burglary. The wax signatures of soil may have potential as biomarkers to match soil samples from a suspect with soils from a domestic garden associated with a scene of crime. The wide range of garden plants grown suggest that the soil wax marker patterns varies greatly between gardens; such variation can also be enhanced by the degree of cultivation and the incorporation of a range of different composts, manures and organic mulches.

This study examined the potential of using information from plant wax compound analysis to compare soil samples taken from within flowerbeds between different urban domestic gardens, to establish whether such information could be used as a soil 'fingerprint' for comparison. Replicate samples of surface soil from flowerbeds were sampled from urban domestic gardens in the Aberdeen area. The samples were freeze-dried and milled before being analysed for hydrocarbons, fatty alcohols and fatty acids using GC. The potential value of unidentified GC peaks (not necessarily associated with conventional plant waxes) was also assessed. Preliminary results based on soil hydrocarbon analysis for all gardens, indicate that there were close matches of samples taken from the same flowerbed, whereas in general, the hydrocarbon profiles differed profoundly between gardens. These results suggest that GC analysis of urban garden soils for plant wax markers and related compounds have potential value in 'fingerprinting' for soil matching purposes, and could complement palynology as a forensic tool.

Challenges in environmental and forensic soil education

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The general reduction in the numbers of students entering the classical sciences at school and tertiary level is a widespread phenomenon. This reduction in feedstock and a decline in geology departments will threaten the continued viability of Forensic Soil investigations. Many of the areas which used to be taught in Geology can now be found in part of an Environmental or Environmental Forensics or Analytical based degree. These degrees have strong cohorts of interested students with some exposure to some aspects of soil science but may be leading students up a different path – be it agricultural, environmental or sustainable of soil. However, purists will say that there is no substitute for spending three years looking at rocks and minerals. Perhaps we need to rethink what we are trying to teach. Can we compromise and provide sufficient exposure to students to gain an initial grounding in soil science. We could also develop material that can be provided for other existing graduates and professional workers who want to extend their area of interest from related areas such as glass or paint to soil. Training of existing forensic practitioners may be a more cost effective approach and may have a higher success rate than chasing after a large number of undergraduates to produce a few soil scientists. The author has written and presented undergraduate teaching laboratories that offer a hands-on approach to practicals which makes them time consuming and labour intensive but of more educational value. They also have a conclusion where the students collect and prepare and analyse their own samples – so they get a feel for realistic samples and realise that not all evidence comes with a label and a number on it. The laboratory does not intend to churn out fully kitted out optical mineralogists but to give the students the ability to differentiate between major minerals and have the ability to know where to go to extend themselves later. This paper will present options on different approaches to forensic soil education and halting the decline in student numbers, and will hopefully generate some lively discussion.

Forensic and environmental responses to pandemics through an applied taphonomic approach

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The threat of potential pandemic poses health and environmental problems for governments worldwide, especially regarding the challenge of dealing with high numbers of 'excess deaths' that could exceed the capabilities of existing burial and funeral facilities. This places unprecedented pressure on environmental agencies and related authorities to find a practicable and sustainable solution based on rigorous scientific research. Existing research into atrocity-based mass graves and epidemics such as the UK Foot and Mouth outbreak can be used to inform government policy on the creation and management of communal burials in pandemic scenarios. We suggest that application of taphonomic knowledge could be informative in these circumstances. Our 'applied taphonomy' methodology will investigate the interactions between bodies and the soil in which they are buried. It will particularly concentrate on how the organic material decomposes in the soil substrate and examine its effects on soil functions, vegetation and fauna. It will also evaluate any potential contributions of this process to climate change, pollution, erosion and run-off. This research will analyse how this process differs between varied climates and soil types, including reference to the value of soil databases in the UK and abroad. This could inform site selection and management of such sites for purposes of conservation and sustainability.

This taphonomic approach also facilitates the application of this research to forensic investigations in terms of search and location of mass graves and post mortem interval estimation, as well as to consider innovative uses for affected soils.

Stable isotope composition of human tissue can aid victim identification

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Forensic science already uses a variety of methods often in combination to determine a deceased person's identity if neither personal effects nor next of kin (or close friends) can positively identify the victim either due to absence of personal effects or mutilation or advanced deterioration of the body. While disciplines such as forensic anthropology are able to work from a blank canvass as it were and can provide information on age, gender and ethnical grouping, techniques such as fingerprinting and DNA profiling do rely on finding a match either in a database or as a comparative sample from a putative next of kin.

A technique yielding forensic intelligence with regards to lifestyle (e.g. dietary habits), geographic origin and history of recent geographic movement could help establishing nationality and/or ethnicity of a victim and would thus be of tremendous assistance as a preliminary sifting criterion that would help target locations to look for a DNA or fingerprint match in case of disasters with mass fatalities and also could bring focus to a criminal investigation. With the help of isotope ratio mass spectrometry, even the very atoms from which a body is made can be used to say something about a person to help focus human identification using traditional techniques such as DNA, fingerprints and odontology. Stable isotope fingerprinting works on the basis that almost all chemical elements, and in particular the so-called light elements such as carbon (C) that comprise most of the human body, occur naturally in different forms, namely isotopes. The overwhelming majority of chemical elements and their isotopes are stable isotopes such as 13C and 2H, and the abundance of these isotopes varies with source (e.g. who or what made a particular compound) and origin (i.e. the geographical location where the compound was made). The various isotopes are taken up by the human body through food and drink, so we literally are what we eat and drink.

Stable isotope analysis of various chemical elements in different human tissue such as hair, nails, bone and teeth enables us to construct an isotopic ‘fingerprint’ that may not necessarily permit to establish the personal identity of a murder or mass disaster victim but it may provide sufficient information to construct a profile for intelligence lead identification stating where a victim was from (point of origin), what their ‘life style’ was and even if they had recently travelled and where to and from. The principles of Stable Isotope Fingerprinting in aid of victim identification are exemplified in three actual police investigations.

Session 5 Biological and Chemical Analytical Diagnostics

Toxicological and chemical fingerprinting of pollution incidents in soils and water

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Toxicological fingerprinting, based on the use of whole cell microbial biosensors, offers a powerful tool in the identification and diagnosis of pollution of soils and waters. It also complements chemical fingerprinting approaches such as those exploiting lead, carbon and sulphur isotope signatures. The biosensors for toxicological fingerprinting are constructed by placing *lux* reporter genes downstream of strong, constitutive cell promoters in environmentally relevant bacteria. Light output from the biosensors therefore reports on the metabolic activity of the bacteria and hence informs on the toxicity experienced due to pollution. The response addresses the bioavailable fraction of the pollutants and so integrates the many factors determining pollutant bioavailability in soils and waters. The biosensors have been used successfully for toxicological fingerprinting in two ways: 1) the kinetic response (a three-dimensional response surface is produced of light output over time to a range of dilutions of the environmental sample) of the biosensors to soil, soil extract and water samples is used to diagnose unknown contaminants. 2) a range of sample manipulations, coupled to biosensor interrogation before and after the manipulation, is carried out to investigate the nature of toxic constraints to site bioremediation so that the constraint can be alleviated using field scale remediative engineering.

In this paper, case studies are presented where the above approaches to biosensor-based toxicological fingerprinting have been used, as well as chemical fingerprinting. In one case study, two major pollution incidents which damaged the microbial community and associated function of a large water treatment works in N England were fingerprinted, identified and tracked to the polluter. In a second, an unknown soil-derived toxin damaging a Scottish crop was fingerprinted and identified. In a third, unknown constraints to bioremediation of a large contaminated petrochemical site in Germany were identified, alleviated and the site successfully remediated. In two further case studies, lead isotopic signature techniques have been used to identify the sources of potentially toxic pollution in St Kilda and at a major garden conservation site in NW Scotland.

The advantages and limitations of DNA-typing soils and trace detritus from drug seizures using DNA arrays to assess the products from high-gain amplifications: an update

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Although unlikely to displace physical studies of soils, the usage of DNA methodology is clearly coming of age in the characterisation of soils and other detritus. Soils and detritus can be compared on DNA arrays and the pros and cons of this methodology to other DNA techniques are becoming clearer. Classic soils and mere detritus, as contained within drug seizures are, in principle, the same problem in forensics although the amounts of DNA are usually quite different. In practice, all our drug seizures acted as if they contained orders of magnitude less profileable DNA than classic soils and much of this is often human DNA; the rest will be discussed. Drug seizures often appear to contain sample-distinctive DNA contents and the interpretation of these contents will be discussed. DNA arrays are surprisingly robust and reliable tools because spotting patterns are easily duplicated to get many replicates. Their practicality in a forensic environment is being explored. Sequence-profiling of soils and detritus should provide excellent data for objectively combining in a Bayesian fashion with other objective data. Well-tested and extensive data-bases will be essential but this is, or will soon be the case, for almost all forensics.

Utilising the soil organic component for forensic application

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Soils are a valuable resource in forensic investigations because they contain signatures relating to origin and soil analysis has the potential to discriminate and match soils for use as critical evidence in forensic investigations. Soil is often found as trace evidence on items such as clothing, vehicles and carpets etc. at crime scenes, but this evidence is rarely used. Three methods which have received considerable attention in the last two years have focused on the organic component of soils, Fourier Transform Infra Red Spectroscopy (FTIR), organic wax biomarkers and microbial DNA profiling. Using crime scene scenarios, we combine and compare the matching/discriminatory power of these methods for use in forensic case work.

In situ FTIR analysis of soil evidence on clothing

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Soil could potentially be found as forensic evidence adhering to clothing in a wide range of crimes. As it is likely that the same clothing will also provide other types of forensic evidence, FTIR using a DATR sampling accessory was investigated as a non-destructive and fast means of analysing such soil in situ. Soils of varying degrees of wetness were applied to two commonly occurring fabrics and allowed to dry. Spectra were first recorded of the untouched soil stains. Spectra were also obtained for soil which was brushed off the fabric and for the resultant ‘brushed fabric’. The spectra generated were compared with spectra of the original dried soil and a finely milled portion of the soil. In cases where there was interference from the fabric spectrum, a spectral subtraction was carried out. Results were very promising, with good similarity between the sample spectra and the organic and clay portions of the reference soil spectrum. The absence of the profiles of other minerals in the sample spectra was attributed to scattering of the IR radiation by the larger mineral particles. This was confirmed by SEM where the presence of these mineral particles was clearly shown.

Trace evidence concentration from soils by hydropneumatic elutriation

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Little to no trace evidence extracted from soils is available at many criminal court trials. Discovery of trace evidence from soils is greatly limited by the presence of mineral particles in grasslands and wood lots where many of the most serious crimes are committed. The hydropneumatic elutriation of materials less dense than mineral soils is a revolutionary new technology that quantitatively extracts and concentrates trace evidence such as personal body hair, skin fragments, clothing fibres and bone materials. Additionally, the TEC cleans glass fragments, auto headlamp filaments, paints, and unexploded ordnance lost at the scenes of violent accidents and crimes. This patented TEC system utilises the concept of density gradient separation by combining centrifugal and surface tension forces during hydropneumatic elutriation separation technology. The trace evidence concentrator (TEC) approach enables crime scene investigators to extract adequate quantities of trace evidence objects from soils for chemical-physical or DNA verification that identifies individuals beyond a reasonable doubt. This new TEC system for extracting and concentrating trace evidence from soils increases the transparency of trace evidence previously lost in soil. This recent patent obtained by two professors in the criminal justice and soil physics faculties at Michigan State University provides a fantastic opportunity for revolutionising homeland security investigations at scenes of most criminal activities. Further development of the TEC will produce commercial models that can revolutionise investigations for homeland security, the local police investigations of crime scenes as well as many environmental clean-up programs. To date, this new technology extracts 100% of trace evidence from soil samples at rates much faster than conventional dry sieving and manual separation. The new TEC system requires less labour to concentrate more evidence more rapidly, reducing the human error accrued by several technicians using conventional dry sieving methods for separating trace evidence from soils. The extraction of more trace evidence, at a faster rate, from more crime scenes will decrease the time lapsed between criminal activities and delayed court decisions.

Rapid, reliable and reviewable mineral identification with infrared microprobe analysis

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The vibrational spectrum of a molecule is considered to be a unique physical property and is characteristic of the molecule. As such, the infrared spectrum can be used for identification by the comparison of the spectrum from an unknown with a previously recorded reference spectrum. This concept has been readily accepted and used by the forensic science community to increase the value of evidence. Microscopy and infrared spectroscopy are united with the application of the infrared microprobe to detect, document, evaluate, analyse and identify trace evidence. This technology is well established for the forensic analysis of fibre, illicit drug, and paint evidence; however is not widely applied to other types of evidence such as soil samples. Advances in the field of infrared microprobe analysis make it possible to perform fast identification of minerals found in soil evidence.

Infrared microprobe analysis of minerals is made possible through the use of the diamond attenuated total reflection (ATR) microscope objective. Using the diamond ATR microscope objective allows for the selective isolation of individual minerals for simultaneous collection of microscopic, optical and infrared data, thus enabling the indisputable identification of minerals. Infrared microprobe analysis requires virtually no sample preparation, and enables direct infrared spectroscopic analysis of unknown mineral samples. When coupled with a preliminary examination using traditional methods of polarised light microscopy, complete analysis of an unknown mineral can be performed quickly and easily. Thus a mineralogical profile of a soil sample can be obtained in a short time. Infrared microprobe analysis enables rapid, reliable and reviewable mineral identification. The ability to integrate polarised light microscopy with infrared microprobe analysis to minerals in soil samples is unprecedented.

Session 6 Forensic Taphonomy

A contrived experimental approach to forensic taphonomy

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Forensic taphonomy aims to provide information useful to courts on the cause, manner and time of death based on information from gravesites. Clandestine graves are a common way to dispose of human (or animal) remains. Burials provide an easy disposal route for cadavers, and perpetrators of crimes rely on the decomposition of corpses to hinder identification and obfuscate estimates of time since death or burial. However, the burial environment is a complex and dynamic system of interdependent chemical, physical and biological processes. These processes influence, and are influenced by, the inclusion of a body and its subsequent decay.

The very nature of forensic taphonomy, and its focus on human cadavers, has led to a science based primarily on case studies or unreplicated research work. Whilst a large amount of useful information has been collated through these means, there is now increasing use of alternative mammalian analogue tissues and cadavers in taphonomy. This approach frees the discipline to take an experimental approach in both laboratory and field settings. The reductionist-based research that this permits allows for the effect of contrived single and combinatory factors to be tested independently, based on a priori hypotheses. This paper will present the findings of a series of experiments conducted in different soils from across the globe in the field of forensic taphonomy.

Do soil type and its native microbiota have an effect on the decomposition of animal cadavers in a model system?

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Forensic taphonomy is an area of growing interest; much of the available information is related to the fields of anthropology, archaeology and entomology with little attention paid to the soil. A cadaver is often in intimate contact with its surroundings and, when considering a grave, it is likely to be in a soil environment. However, this area has previously been largely neglected and suggestions have been made about the negligible contribution that the soil ecology has on the overall decomposition process.

A controlled laboratory experiment was designed using juvenile mouse (*Mus musculus*) cadavers buried in three different soil types commonly found around Perth, Western Australia. Two treatments were applied to each soil type: living soil; and gamma irradiated soil, giving a total of nine experimental treatments when controls were included. Over the course of the experiment, soil microcosms were sequentially destructively harvested and the soil directly surrounding the cadavers (detritosphere) was sampled and chemically analysed for pH, nitrate, ammonium, phosphorous and potassium. Microbial activity (CO_2 respiration) was also monitored over the course of the experiment. This presentation will demonstrate the effect that soil type has on the decomposition of a cadaver and the impact that removing the microbial population of a soil has on decomposition and the surrounding detritosphere chemistry.

Post mortem interval estimation using microbial biomarkers

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The microbiological community associated with human decomposition is extremely complex, with hundreds of microbial species thought to be involved. Previous studies have shown that, as decomposition progresses, the bacterial community associated with the body changes considerably, raising the possibility of using microbial indicators to help estimate the post mortem interval. Determining the time elapsed since a person died is essential in medico-legal investigations, and new methods that provide accurate estimates are constantly sought. The bacterial and fungal communities associated with pig and human decomposition have been examined using an array of molecular methods including T-RFLP, DGGE and sequencing. Additional analysis using phospholipid fatty acid analysis (PLFA) has been used to provide a biochemical comparison and a quantitative description of these transformations in the soil microbial community. The results of these microbial community changes are discussed in the context of the cadaver decomposition process. The potential exists for the development of a PMI estimation tool based on soil microbial community succession.

Using ninhydrin to presumptively test for gravesoil

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Ninhydrin reacts with organic and ammonium-nitrogen (collectively known as ninhydrin-reactive nitrogen: NRN) and can, for instance, be used to locate latent fingerprints on porous surfaces such as paper. Considering that a cadaver can comprise as much as 3% nitrogen, there is great potential for NRN to be released into gravesoils. As a consequence, we hypothesised that cadaver decomposition will result in a significant increase in NRN in soil. A field experiment was conducted at two disparate field sites in tropical savannah ecosystems during the dry season (March 2003). Site 1 comprised a loamy sand soil (84% sand, 11.1% silt, 4.9% clay) and was located in Yabulu, Queensland, Australia. Site 1 receives an average rainfall of 140 mm during the dry season (March-October) and average maximum/minimum temperature equals 22.9 °C/16.7 °C. Site 2 comprised a medium clay soil (30.9% sand, 20.8% silt, 48.3% clay) and was located at Wambiana, Queensland, Australia. On average, Site 2 receives 117 mm of rainfall during the dry season and the average maximum/minimum temperature is 20.5 °C/13.7 °C. The resulting vegetation at the two sites was dominated by grasses with scattered trees. Juvenile rat (*Rattus rattus*: ~18 g) cadavers were buried (2.5 cm) in the centre of a 2 m^2 plot. Gravesoil and control soil (soil not associated with a cadaver) was collected at 7, 14, 21, and 28 days following burial.

Gravesoils contained 2-5 times more NRN than control soils. This difference was observed within seven days of burial. The concentration of NRN in gravesoils remained constant until the end of the experiment (day 28), by which time the cadaver had been skeletonised for a minimum of 14 days. This rapid and stable increase in NRN has great potential to become a standard presumptive test, considering that the analysis of NRN in gravesoil can be conducted in less than one hour.

The biochemical alteration of soil by decomposition products

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Decomposition chemistry refers to the chemical degradation processes which occur in soft tissue as decomposition proceeds. These processes involve the breakdown of the body's main constituents including proteins, carbohydrates and lipids. Lipids represent an important biomarker of decomposition as they are not easily degraded and can be retained in the soil environment for extended periods. The aim of this study was to investigate the relationship between the release of decomposition fluids into a soil environment and their potential correlation with the post mortem period. This study utilised soil from a decomposition period of 100 days to determine the total microbial biomass by measuring the extractable lipid phosphate content, as well as investigating variations in total carbon, nitrogen, phosphorous, pH and moisture content. The study identified a significant increase in the amount of total nitrogen and soil extractable phosphorous released into the soil. However, the total available carbon did not increase significantly with time. Lipid-phosphate concentrations also increased confirming that there was a flux in the microbial biomass present in the soil. Although the preliminary results could not be directly correlated with post mortem interval, this pilot study was able to highlight the forensic potential of these techniques and the necessity for further research in this area.

Taphonomic changes to the buried body in arid environments: evidence from field experiments in S. Peru

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This talk summarises previous work into soft tissue preservation within arid environments and presents new data from experimental fieldwork in coastal southern Peru. We introduce the audience to examples of soft-tissue preservation using archaeological examples, casework evidence from the SW Continental US, and previous taphonomic research. We present data from a two year large scale taphonomic project involving human body analogues buried in Southern Peru with continuous monitoring of environmental parameters. We contrast differences in preservation observed in graves backfilled with sediment, in which the body is in intimate contact with the burial medium, with cist burials in which there is an air void around the body. We relate these observations directly with archaeological parallels and also place the importance of these observations within a broader forensic context.

A multi-disciplinary approach to soil forensics and crime investigation - the road to the courtroom

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It is widely accepted that there are three main methods of detecting crime: witnesses, confessions and forensic science. The instances of witnesses and confessions are declining and thus more reliance is placed on forensic science. DNA has held the spotlight and imagination of the public for the last 20 years but what happens when something new comes along?

This session provides an escape from the science and will examine how new methods in forensic investigation can develop and the hurdles and issues that need to be addressed for such techniques to be accepted into the fold of the criminal justice system. This will include

integration into the investigation process, pitfalls in expert witness evidence and the attitudes and needs of the legal profession when introducing such techniques into the courtroom.

March of the gladiators – scientists entering the arena of lawyers

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Drawing on personal career experience as a courtroom advocate, mainly prosecuting criminal cases in northern England, and then as the Force Solicitor advising and representing a midlands police force, he's now served at Cumbria Police Authority of major criminal cases and alleged miscarriages of justice (historic and current); cases where forensic evidence and/or its disclosure was often the key element.

Session 7 Communications and Advocacy

Expert scientific evidence and the law: some important pitfalls

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Expert evidence is a special form of evidence to which particular rules apply. Those who seek to introduce it in a criminal case should be aware of some of the pitfalls that can jeopardise or reduce the impact of such evidence on the judge or jury. Not all expert evidence is admissible and courts have made it clear that they must first be satisfied of the science behind any such evidence. This could mean that, in cases where the groundwork has not been adequately prepared, the evidence never even reaches the jury. In cases involving new or seldom used scientific techniques, the courts are cautious. While most people think about fingerprint, DNA or ballistics evidence when asked to consider the main examples, the courts have been willing to entertain the possibility of expert evidence from any scientific or technical background. However, it will be more difficult to persuade a court that evidence in a new and emerging science should be accepted as valid, and a number of tests, developed in cases in the United States, are applicable in such instances. Even where expert evidence is admitted so that it goes to the jury, the adversarial system that exists in most of the common law jurisdictions encourages robust reliability challenges by defence lawyers seeking to cast doubt on the value of this evidence. These challenges may include contrary expert testimony.

Finally, there is the issue of the method of presentation of such evidence in court, in particular in jury cases, where complex scientific concepts should, where possible, be presented in a user friendly and interesting way. This presentation will aim to draw attention to some of the fundamental legal obstacles in place to the successful presentation of expert testimony in the criminal courts. As a result, the expert witness will have an understanding of aspects of the court process which will enable him/her to be more prepared before entering the daunting arena of the courtroom.

Mud Sticks

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It has long been known that soil analysis can be used to help in the investigation of crime. It can be used evidentially as well as to direct investigations, for example, by narrowing search parameters, helping to target valuable resources, saving investigators time and reducing costs but it can also help to point towards suspects. Useful data can be drawn from a range of techniques from macro analysis to the micro analysis. Soil expertise can be used in conjunction with other forensic techniques and joint expert analysis will always be beneficial. Traditionally the use of forensic soil analysis has been directed toward serious crime but with the application of modern techniques and new forms of analysis it could help provide investigators with valuable avenues for the detection of offenders at wider crime types such as burglary as well as additional benefits for serious crime.

Session 8 Public Lecture

Digging for clues. How soil is helping to solve crimes

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In a world in which it could be argued that forensic science is capable of doing 'more with less', the need to recognise and develop specialities such as the examination of soils in a forensic context has never been greater. Soil examination typifies the value of forensic application in science bringing together many scientific disciplines and necessitating cross discipline dialogue to produce an holistic treatment. By way of example, the author will use his personal experiences over a 30 years time span in forensic science to illustrate the critical issues and challenges which require consideration in the area of forensic soil examination. He will discuss how this holistic area of study needs to develop if it is to gain wider acceptance and application. Finally, he will discuss forensic education for future scientists working in this area.

Poster abstracts

The preservation of three-dimensional footwear evidence in soils: the application of optical laser scanning

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Footwear impressions are important but a frequently undervalued source of evidence within a range of criminal investigations. This is perhaps surprising since every step someone takes causes deformation of the substrate, or results in the transfer of trace materials and residues from the shoe or foot to that substrate. Although not all such impressions will be visible, or detectable, the potential is high for trace evidence to be left. The skill of the forensic investigator is to first anticipate, look for, and record this evidence at a scene and then to make an accurate evaluation of this evidence to help profile a suspect or place them at the scene. The traditional approach to the collection and preservation of such evidence is to cast and/or photograph the footwear impressions at the crime scene. The authors have pioneered the application of three-dimensional optical laser scanning for the collection, preservation and analysis of human footprints within the archaeological record. In this paper they illustrate, using the results from a series of experiments, the forensic potential of such an approach to the collection and analysis of footwear impressions in soils.

Manganese staining of medieval bone from Hulton Abbey

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The site of the medieval Cistercian Abbey was excavated by The Potteries Museum & Art Gallery's Archaeology Unit between 1987 and 1994 (Monument number 35857). The Abbey was founded by Henry De Audley in 1219. Following the dissolution (1538), the site was lost until 1884 and located during a chance excavation. The abbey was part of a Cistercian Order; income was received for wool produced from sheep kept on the land around Hulton. By 1291 a tannery, watermill and fishpond could also be found on and around the monastery. The remains of 91 individuals were recovered from medieval deposits at Hulton Abbey. The burials took place over a 300 year period and a number of graves were disturbed by overlying or adjacent interments. From a total of 70 individuals excavated during the 1987-1994 excavation, 57 were adult and 13 were immature (20 years or less). A number of skeletons demonstrated congenital abnormities (e.g. congenitally dyplastic or dislocated hips) and some had arthropathy.

Many of the skeletons excavated (which were of 'high-status' individuals) demonstrated a dark staining which was intermittent across the skeletal remains. Some skeletons did not demonstrate this staining and there appears to be no correlation between the staining and the location of the grave within the abbey building. Some skeletal material has been examined using qualitative X-ray microanalysis in the scanning electron microscope. These samples have demonstrated the presence of manganese and iron. Soil (auger) samples have been taken from a number of the graves for analysis using atomic absorption spectroscopy to determine if manganese is present in the heavy clay and could account for the manganese staining. A possible explanation may be the tannery or indeed other small industries that were present in the abbey environment. ICP analyses carried out as part of the 1987-1994 excavation did show the presence of MnO in the clay ranging from 0.04-0.13µg/g of the element.

Despite some discussion in the literature concerning black staining attributable to manganese, little is known about this process. The origin of manganese coatings may be the result of diverse species of manganese-oxidising bacteria.

Rational and research methodology for development of a forensic soil database

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Collaboration between the leading Australian government research institute in forensic soils investigations (CSIRO), a research university (Flinders), and the provider of forensic services (FSSA) and input from the South Australian Police has lead to an inter-institution, inter-disciplinary research project being conducted to establish a test database of soil sample analysis for forensic soil investigations. This poster will indicate the development of the rationale behind the selection of sites of interest, the sampling and storage methods and the analytical investigations and database development and interrogation. Account has been taken of the original conditions, anthropogenic activities and other perturbation in the area of investigation coupled to knowledge of soil profiles and distribution, crime rates and crime hot-spots, availability, cost and discriminatory power of chemical and analytical techniques for differentiating soils when developing and planning all aspects of the project. In addition all information needs to be in a form that can be collated in a searchable database that will be a test site for the validity of the research methodology and can lead to extensions to investigations over a wider area. The rationale and methodology will be explained. Initial results will be presented. The eventual outcome of the project will be a tested and validated database of details from soils and extra information that can lead to computer searching of characteristics from modern analysis of soils for provision of intelligence and evidence.

SoilFit: integration of soil fingerprinting techniques for forensic application

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To date the application of soil evidence in criminal cases has been largely under-utilised. The SoilFit project (http://www.macaulay.ac.uk/soilfit/) is funded through the Engineering and Physical sciences research Council (EPSRC) Crime Initiative to investigate the potential of advanced analytical methods in providing soil forensic intelligence to police investigations. Combining advanced soil fingerprinting methods with spatially referenced soil databases and rigorous statistical approaches will potentially provide new tools for police intelligence. The SoilFit project will: i) test the potential of advanced soil fingerprinting methods in distinguishing soils; ii) build an analytical soil database containing modern fingerprinting methods; iii) develop a 'decision support' tool to facilitate appropriate soil analysis; iv) develop software for statistical based ‘soil matching’ to help identify unknown soil evidence, and to combine a GIS tool to refine search areas in crime investigation.

Scanning electron microscopy study for a 'cold case'

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An unsolved murder case was re-investigated after a number of years. Scanning Electron Microscopy (SEM) was used to perform a comparative analysis between two control soil samples and three evidence samples. The aim of the SEM study was to provide new information on the origin of the evidence samples in order to assist in the understanding of the sequence of events. The comparative analysis was carried out on the inorganic particles present in all samples using parameter such as grain size, shape, sorting and nature of the particles using Energy Dispersive Spectroscopy (EDS). The study allowed us to dismiss one of the control samples as a source of origin for any of the evidence samples, to ascertain that two of the evidence samples presented characteristics similar to the second control sample and to assess that the third evidence sample originated from a completely different source.

Forensic characterisation of soil fungal communities in response to cadaver decomposition

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An accurate estimation of time since death is an important aim of every medico-legal investigation and its determination can direct an entire forensic case. The potential for using biochemical and molecular methods to characterise the dynamics of soil fungal communities during the process of cadaver decomposition has been investigated. Analyses have been performed on soil that has been sampled periodically from under human cadavers during the process of decomposition, and associated control sites at the Anthropological Research Facility at the University of Tennessee. Phospholipid fatty acid analysis (PLFA) and 16S ribosomal DNA terminal restriction fragment length polymorphism (T-RFLP) community profiling has been used to provide a qualitative and quantitative analysis of these transformations in fungal populations.

Soil is a complex medium, within which, its diverse community of microbiota is significantly influenced by edaphic and environmental factors. When the human body undergoes decomposition, this dynamic breakdown process releases nutrients and cadaver-derived microflora into the soil. Microbial succession is a progression of species assemblages whereby microbial communities are altered in a sequential manner. This succession process may provide the basis for a new method to determine the post mortem interval (PMI). Forensic taphonomy can benefit from applying more quantitative methods to the study of decomposition. Therefore, the process of decomposition has been treated as a semi-continuous variable and used in conjunction with accumulated degree-days, which is a measure of accumulated heat expressed in approximate units called degree-days.

The results of these fungal community changes are discussed in the context of the cadaver decomposition process. The potential exists for the development of a PMI estimation tool based on soil fungal community succession.

Where dunnit? Narrowing areas of search by overlaying multiple attribute, geo-referenced soils data with additional spatial intelligence.

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The UK SoilFit project (http://www.macaulay.ac.uk/soilfit/), funded by the Engineering and Physical Sciences Research Council (EPSRC), aims to integrate data from state-of-the-art soil fingerprinting methods with data currently held in spatially referenced soils databases within a Geographical Information System (GIS). This approach could potentially improve both matching of evidential soil samples and prediction of probable geographical origin, especially where additional location-based intelligence, such as travel time/distance, is available. This paper will describe the development of the SoilFit GIS interface. The interface takes probabilistic soils attribute data based on both standard and groundbreaking laboratory analysis, which is used as selection criteria in a rules-based GIS decision support tool to weight geographic areas according to their likelihood of being the source of the forensic sample. The area of search can then be narrowed down by layering intelligence of other spatial data (e.g. distance from roads, broad vegetation types etc). A prototype interface has been built to demonstrate and evaluate the approach for crime investigation.

Geological Society of London, Forensic Geosciences Group

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There are a number of geologists in the UK, and internationally, who currently work with, or have recently worked with the police, other law-enforcers, environmental agencies and humanitarian organisations to help bring some types of crimes to successful conclusions. Some geoscientists have also been involved in forensic investigations in the mining, engineering, minerals and water sectors of industry, or during the investigations of geohazards (also known as natural disasters). The common ground for all these sub-disciplines is that geoscience practice and results may end up as part of a public, international or legal enquiry by government or in courts of law.

Forensic Geoscientists may be broadly divided into two principal fields, depending on their skills, expertise and capabilities. Firstly, there are the laboratory-based geologists who may include for example; geochemists, mineralogists, petrologists, micro-palaeontologists and isotope specialists. These may be involved with forensic investigations to; provide physical evidence for use in court, assist in an investigation, provide intelligence or identify the location of a crime scene. In short, geoscientists may link an offender (or object) to the scene or link the victim to an offender. Secondly, there are field-based geologists, who use their skills in exploration (including for example; geophysics, geochemistry, geomorphology, hydrogeology, environmental geology, remote sensing and geotechnics) to search the ground (to locate murder victim's graves, weapons and other objects).

An urban investigation using soil alkane profiling for land-use discrimination

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Every soil possesses a unique, complex combination of materials which makes it the ideal candidate for trace evidence analysis in forensic investigations. However, soil analyses are only currently utilised in the context of serious crimes. This project investigated the potential of differentiating between urban soils from four different land use vegetation (LUV) classes, across the city of Aberdeen, using alkane concentrations as a quantitative measure.

The four LUV classes sampled, each representative of a potential ‘scene of crime’, were council-managed park flowerbeds, man-made mineral roadside laybyes, semi-natural deciduous woodland pockets and residential garden flowerbeds. The city was split into four regions - north, central, south east and south west. Each region hosted four sites, representing the different LUV classes, from which four replicate samples were recovered.

Quantitative analysis using Gas Chromatography permitted both the total alkane concentration and odd-chain alkane concentration (C_{21} – C_{35}) of each LUV class to be considered. Using the total alkane concentrations it was possible to discriminate the woodland pockets and roadside laybyes from the park and garden flowerbeds.

Further investigation considering the concentration of only the odd chain alkanes, which tend to be most persistent in soil and are proven to vary between different species of plant, resulted in all four LUV classes being discriminated from one another. From a forensic perspective, this technique therefore holds potential for identifying sites and land-use types of unknown soil samples.

How soil evidence helped solve a double murder case

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The Centre for Australian Forensic Soil Science has developed a display to exhibit the successful use of soil expertise in helping solve a double murder case in Australia. Morphological, chemical, physical and mineralogical properties were used to identify similarities between soil found on a shovel taken from the suspect’s vehicle and soil subsequently located in a quarry. Samples were indistinguishable or strongly matched in terms of all comparison criteria used, thus revealing the location of two buried bodies.

The case is presented under the following headings: 1. The Crime & Evidence – *wife, mother and son missing; with locality map. 2.* Enter The Scientists – *soil clues on the shovel found in the suspect’s car.3.* Closing in on the Site – *evidence from soil maps and field survey*; 4. Case Solved - *matching of soils and locality of buried bodies; suspect confessed and convicted of murder without the need for a million dollar court case.*

The display illustrates how the following soil clues were used to help solve the crime:
Visual observations (colour, texture, structure and particle shapes) of yellowish-pink fine grained soil with inclusions of many small angular quartz particles and a few three-millimetre white fragments or flakes on the shovel; Chemical (pH, electrical conductivity) and mineralogical evidence (X-ray diffraction); Soil and geological maps and field soil survey investigations.

The uniquely successful conclusion to this case in 2000 led to the establishment of the Centre for Australian Forensic Soil Science (CAFSS) in 2002. Since then, the centre has advised on over 50 criminal and environmental forensic investigations. This educational display is on permanent exhibit at several research institutes, forensic science centres and museums in the USA, UK, Europe and Australia.

A geoforensic comparison of physical and chemical analysis of soils from the plateau region of Switzerland

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This poster presents the results of a comparison of the international, regional and local scale physical and chemical analysis of soils taken from lowland Switzerland (Martigny, Lausanne, Geneva, Yverdon and Fribourg). Fourteen samples were taken from each location at distances of 0m (source), 1m, 10m, 100m, and 1000m and each source site was chosen as one that would be suitable for the disposal of a body. Quartz grain surface texture analysis and grain typing was undertaken in the manner identified using British soils (Bull and Morgan 2006) on each sample and complementary chemical analyses using XRF on the same samples were undertaken. Canonical discriminant function analysis (CDF) of the quartz grain typing for the five locations showed a statistically significant discrimination between the different sites and a remarkably low within-site variance. This confirms that quartz grain typing can be undertaken in even the most complicated of Quaternary deposits which may be reasonably considered to have been re-worked and re-transported on many occasions thus making the identification of micro-facies untenable in such a melange deposit. We conclude that it is possible to exclude the samples identified by grain typing in this study from any on the British quartz grain type database. In addition, similarities and differences between the sites identified by chemical analysis require confirmation by visual physical analysis, preferably by scanning electron microscopy. Further, we can identify the exclusionary power of the quartz grain typing between British and Swiss lowland soils.

Comparative study of soils from several Romanian regions and their contribution on DNA degradation in old and very old tooth samples

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The soil samples collected from different archaeological sites from various heights (from the surface, from medium height and from the depth where tooth samples were discovered) were analysed. Qualitative and quantitative determinations were carried out to establish morphological and compositional differences between soils. XRF and SEM EDS/WDS analytical techniques were used. In order to correlate the soil contribution on tooth sample degradation and implicit on DNA degradation, we determined a degradation index based on spectophotometric readings on DNA extracts obtained from old and very old tooth samples (Neolithic, Bronze Age, First Iron Age, Romano-Byzantine Age, VIII-X century).

Detection of buried corpses using georadar

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A georadar emits electromagnetic waves into a medium; the expansion of the waves depends on electrical characteristics of the medium into which the waves are emitted. The radar signal spreads out at a constant speed, and is reflected at discontinuities which can be detected using receiver aerials. As the propagation speed of the waves is known, the duration can be used to calculate the covered distance. The range of the radar in the soil is limited by the absorption (high electrical conductibility) and scattering of the signal (the result of inhomogeneous soil), and is also affected by the type of granular soil, the amount of dissolved salts and humidity.

The signal amplitude is registered at the receiver independently from time as 'signal trace'. Radargrams, which resemble depth slices, are obtained by stringing the signal traces along the measured distance. Laminar measurements can be used to calculate maps of higher reflection signals (known as time slices) for any depth. The radar detects reflecting structures, e.g., soil faults, tubes, pits, remains of walls. If their presence cannot be deduced from remains found at the soil surface, the detection of corpses buried in soil or graves is difficult, even when using specially trained sniffer dogs. The georadar (ground penetrating radar, GPR) represents a promising method to overcome these difficulties. We will present the successful application of GPR in the sanitation of graveyards and in the elucidation of forensic cases.

The use of micro-Raman Spectroscopy in soils characterisation

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Micro-Raman Spectroscopy (MRS) provides unique spectra used to characterise materials, as it acts as a sort of fingerprint of each material. MRS combines the attributes of reliability and sensitivity with the amenability of *in situ* studies, without previous sample preparation. Samples can be measured quickly and without sample contamination. The utilisation of MRS in forensic study of soils is related to the characterisation of soil components. The identification of minerals in the sand fraction is essential since it is one of the major constituents of soils. However, this analytical technique can also be very useful in the identification of unique particles such as fibres, glass fragments and organic matter that can be found in soil sample under investigation.

Using a Labram Dilor-Jobin Yvon spectrometer attached to an Olympus microscope and an excitation of 633nm lines of a He-Ne laser, MRS analyses were carried out on two soil samples from unknown sites, with a representative sample from each soil examined. By allowing direct microscopic examination, the MRS analysis permitted not only the identification and characterisation of mineral grains by interpretation of Raman spectra, but also the visualisation of the morphology and grain size in each soil sample.
The specific mineral spectra obtained in one of the soils, and the grain size together with the existence of plant fragments and Raman bands typical of carbon material and related to the thermal decomposition of organic matter in the other studied soil permitted us to conclude that the studied soil samples were taken from different sites. The research was supported by Project PTDC/CTE-GEX/67442/2006 of FCT Portugal and POCI 2010.

Practical issues in the provision of expert support to forensic investigation

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Provision of expert support to forensic investigations demands the constant application of high standards of both quality of thought, integrity and technique. Where there is a geoenvironmental implication, the demands for investigation is no different. Experiences with providing support to analyse crime scene sites serve to illustrate and reinforce those many challenges that can exist in providing support to help answer those general questions: How did it occur? When did it occur Where does it occur - how extensive is it? Who caused it?

This poster will summarise the practical factors borne out of experiences to be taken into account throughout the investigation process. This will centre on ensuring infrastructure is available for what can be a most demanding operating window where matters may often start from a very low information base, and a high degree of flexibility may be called for at short notice. Factors highlighted will be taken from: gaining initial access to the incident site; investigation phase - the operating site environment; site release – handing back to owners.

Does the soil microbial community adapt during the decomposition of skeletal muscle tissue?

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Microorganisms are known to be agents involved in the decomposition of organic matter. However, little is known about the participation of the microbial communities during the decomposition of mammalian muscle tissue. This study investigates the capacity of the soil microbial community to adapt to the decomposition of skeletal muscle tissue in the soil and has implications for the study of mass graves and sites of repeated burial. A controlled laboratory experiment was designed to assess the adaptability of the microbial communities present in three distinct soil types found near Perth, Western Australia. This experiment was split into two main stages. The initial decomposition stage involved the addition of porcine skeletal muscle tissue (SMT) (*Sus scrofa*) to each of the soil types and these were left to decompose for a period of time. Controls were set up along side, which had no porcine muscle tissue present. The second stage involved a second addition of SMT to soil obtained from the initial decomposition stage with its respective controls so that for each soil, SMT was either decomposed in soil that had been pre-exposed to SMT or not. The experiment was replicated 5 times. Throughout the experiment sequential destructive harvests were carried out on the soils where the SMT and the soil surrounding the SMT were removed. From these, the tissue mass loss was calculated and the microbial activity (CO_2 respiration) and microbial biomass (substrate-induced respiration (SIR)) were monitored. The functional diversity and the community structures of the microbial populations in the soil were assessed using Community level physiological profiling (CLPP) and Phospholipid fatty acid analysis (PLFA) analyses respectively. These characterisation techniques were carried out on soil samples from the initial and second decomposition stages. The microbial activity and tissue mass loss both showed significant results to support the hypothesis that the soil microbial community can to adapt to the skeletal muscle tissue decomposition. Variations were also observed when comparing these results between the soil types. The results for the PLFA, CLPP and SIR will be discussed in the context of microbial adaptation to organic substrate addition.

Exploring the forensic potential of novel soil profiling methods

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Forensic examination of soil evidence conventionally considers soil colour, particle size, mineralogical and palynological analyses. These techniques provide comparative information, and in combination can provide powerful information in crime investigations. Typically, less than 5% of soil is composed of organic matter, with the primary constituent of most soils being mineral particles. The organic component of soil contains a wide variety of biochemical signatures. The diversity in these signatures offers potential for developing novel investigative and evaluative tools for forensic application. LCF-alkane and LCF-alcohol profiles in soil have been proven useful to indicate plant litter inputs and provide a powerful, rapid and cost-effective profiling tool of plant-derived OM. Similarly, the biological component of the soil has tremendous diversity which might be harnessed to provide powerful information from

small traces of soil. We present preliminary studies examining the discriminatory power of 1) long-chain fatty (LCF) alkanes and alcohols, 2) soil microbial DNA profiles.

The implementation of geophysical investigation in the frame of soil and groundwater pollution

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It is well known that geophysical investigation is used to differentiate lithological units. Beside this, geophysics is also useful to detect, define and monitor the pollution in the ground on the condition that the pollution, due to spills, leakage or illegal discharges causes a significant difference in conductivity/resistivity. The methodology of geophysical investigation in environmental issues will be illustrated.

The first presented method is the electromagnetic profiling method which measures the lateral variation in ground conductivity using a transmitter and a receiver. At the transmitter coil, a time-varying electromagnetic field is induced by an alternating current. This field interacts with the ground proportional to ground conductivity. The resulting field is measured and recorded by the receiver. The background conductivity needs to be defined along the profile in a non-polluted zone. Subsequently, all the collected data can be used to plot the lateral variation in conductivity. Areas with higher conductivity reflect, in most cases, pollution from which the source can be traced.

A second method is the geo-electrical tomography, which is a combination of resistivity profiling and sounding where a large number of electrodes are placed at a constant distance along a line. During each measurement, the electrical potential caused by a current sent into the soil by two current electrodes is measured between the two potential electrodes. By automatically addressing a combination of four electrodes and increasing the distance between the electrodes, the penetration depth increases. Considering the corresponding resistivity of the lithology, the pollution along the profile can be delimitated vertically and horizontally. Last but not least, the investigation of the conductivity (resistivity) carried out with borehole loggings delivers information of the vertical distribution of the conductivity in the groundwater reservoir which results in the vertical delimitation of pollution close to the borehole.

The great advantage of these methods in soil pollution is that they avoid direct contact with the pollution, resulting in a reduction of health risks. These methods are non-destructive and fast. They will be illustrated by case studies where the results are validated based on the analyses of groundwater samples.

Geoforensics for information management and crime investigation

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The Geoforensics for Information Management and Crime Investigation (GIMI) network aims to identify 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, reducing areas of search for investigators and issues of information management, interpretation and communications. It is an extended network of partners with a stakeholding in forensic applications in relation to soils, vegetation and landscape, drawing on the expertise of over 40 scientists and forensic professionals from six countries.

The network members are currently reviewing and evaluating existing and new technologies in the topics of analytical fingerprinting of soils, 3D image analysis, knowledge-based data mining for soils and vegetation. These come under four broad headings of stakeholder needs and priorities: analysis of soil; sediment and vegetation properties; signal and image processing; databases and communications.

Expertise and interests in the themes of the network are being exploited in a number of specific initiatives. For example, within the analytic theme, a sample sharing programme has been designed to enable the comparison of approaches to the analytical methods being applied to soil samples from burial sites, with samples being shared between Canada, USA, New Zealand, Australia and the UK. The expected outcome is an improved understanding of the robustness of approaches for subsequent consideration of their role in investigations.

The network is also being used to facilitate exchanges of information and increased awareness of participants of new methods, opportunities for exploiting new types of data and databases, and increasing the understanding of researchers as to the needs of investigators. In aid of this activity the network was one of five which contributed to the International Crime Science Conference, held in London, July 2007, and the 2nd International Conference on Criminal and Environmental Soil Forensics, Edinburgh, October 2007. Each of these events has attracted the participation of a range of stakeholders the outputs from which are disseminated via scientific literature, information sheets and the WWW.

The network is funded by the Engineering and Physical Sciences Research Council (EPSRC) and is hosted by the Macaulay Institute. Further information about the network can be found at: www.macaulay.ac.uk/geoforensic.

Perspectives of environment soil forensics in Russia

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The development of environment forensics in Russia is a formidable problem because of extensive environmental contamination by industrial pollutants, emissions of various harmful substances, illegal forest clearing and other ecological crimes. The foundation of environment forensics as an independent class of expert investigations is based on scientifically and practically sound processes. The aim of environment forensics is to discern the effects of anthropogenic activities. For this reason, a department of forensic ecological examination was founded in the Russian Federal Center of Forensic Expertise. Currently, environmental forensics includes the following types of expertise: soil-ecological, bio-ecological, radiological, hydroecological and ecological expertise of urban environment.

Special attention should be paid to clarifying the conditions of the infraction by conducting environment soil forensics. Forensic examinations are done to establish the connection between the environmental soil crime and its negative consequences. Specialists in environment soil forensics carry out a study of soil properties, to allow one to draw persuasive conclusions about type, mechanism and grade of environmental pollution in a localised area. The facilities for the environmental soil forensics, as well as training of the experts specialised in this field, are concentrated in the state institution of the forensic expertise, belonging to the Ministry of Justice of Russia.

Dirt, death and DNA – getting down and dirty with decomposition

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The microbiological community associated with human decomposition is extremely complex, with hundreds of bacterial species alone thought to be involved. Previous studies have shown that as decomposition progresses, the bacterial community associated with the body changes considerably, raising the possibility of using bacterial indicators to help estimate the post mortem interval. Determining the time elapsed since a person died is essential in medico-legal investigations, and new methods that provide accurate estimates are constantly sought. The bacterial communities associated with pig and human decomposition have been examined, including the interaction of soil and environmentally derived bacteria in the decomposition process. A suite of molecular techniques including T-RFLP, DGGE and DNA sequencing were used, as well as biochemical and enzymatic assays, to further our understanding of the bacterial component of decomposition and its potential as a forensic timekeeper.

An urban investigation using colour for land use discrimination

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Soil has many different attributes, making it potentially useful as physical evidence. However, soil is not routinely used as physical evidence. This project investigated whether urban soils could be differentiated into land use vegetation (LUV) classes across different city loci using soil colour as a relatively simple quantitative measure. Four LUV classes, chosen to be potentially realistic forensic sites, were woodland, scrubland, municipal park flower beds and lay-bys. Within Edinburgh, three different loci were selected and four replicate samples of each LUV class were taken at each location.

Using quantitative spectrophotometer colour analysis, the soil samples from the Heriot Watt site could be distinguished from the other two. At the Braids loci, samples of all contrasting LUVs could be easily discriminated, while at Corstorphine, the park and shrubland could not be differentiated from each other. At the Heriot Watt site, only the layby samples could be separated out from all LUVs. Although some discrimination has been observed using colour alone, it was not successful at distinguishing between all individual LUV classes or all sites. Lay-bys were the only LUV class that stood out from the rest, probably due to distinctive mineralogy and lower amounts of organic matter. The site with most difficulty in differentiation was Heriot Watt, which was relatively young, with undeveloped vegetation. As many criminals are known to operate within a specific field of activity radiating out from where they live, such information could assist in locating likely places visited. Colour analysis could therefore provide useful initial intelligence, inexpensively and quickly, particularly for older established loci, but is likely to be limited for evidential value. Further work is required, with fuller replication to address site specific variability, to test whether comparison using this and other quantitative methods may be of use in forensic investigations.

The Midlands Burial Research Group

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Formed in 2006, the Burials Research Group was established by Keele and Staffordshire Universities to provide a national centre of excellence in the Midlands for the detection of clandestine burials, and brings together four complementary disciplines, forensic geophysics, forensic geoscience, forensic pathology and crime scene investigations. Members are academics, researchers and post-graduate students, with research presented at international conferences and findings published in peer-reviewed academic journals.

Three examples of current research are presented:
(i) Time-lapse forensic geophysics over a simulated clandestine grave

(ii) Quantitative monitoring of decomposing pig cadavers
(iii) Forensic Geophysics for medieval monk remains.

Forensic soil comparisons based on bacterial population profiles

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Soil samples can be found as trace evidence in various forensic cases and can add valuable information to the process of truth finding. A soil sample can be used to predict a source of origin or can be compared to other soil samples. Soil samples contain various biotic and abiotic traces or parameters and the use of a combination of traces/parameters can provide a solid base for soil sample comparisons. One of these parameters can be the bacterial population as described by other research groups. Direct DNA extraction from soil, bacterial DNA-marker amplification followed by terminal restriction fragment length polymorphism (tRFLP), can be used to generate a bacterial profile from soil samples in a cost effective way and is not labour intensive. We tested several DNA extraction methods, suitable DNA-markers, restriction enzymes and capillary electrophoresis conditions. This tRFLP-method was tested for its robustness, reproducibility and compared with other profiling techniques in order to estimate its value. To test the discriminatory value, a series of soil samples from locations throughout the Netherlands were analysed. A method to normalise data and align duplicate analyses was designed to compare data from these samples. Subsequently, both presence/absence of peaks in the profile and the peak area were used to calculate a distance coefficient. Finally, distance coefficients between samples from the same/different origins were used to construct a decision model which can be used to compare samples of unknown origin. This model can be used in a ‘Bayesian’ approach to determine the odds of finding a given distance coefficient between samples presuming a different origin against finding this distance presuming the same origin. The choice for the best distance coefficient, the criteria for database samples and other parameters are also discussed.

Development of methodology for analysis of small soil samples for plant wax biomarkers enabling their use in forensic investigation

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The waxy material on the outer surfaces of plants is a complex mixture of aliphatic lipids, including long-chain hydrocarbons, fatty alcohols and fatty acids, which differ in composition according to plant species. As plants senesce or die, organic matter is added to the soil, where the plant wax signatures can remain for hundreds of years. Although these compounds have been little used as forensic biomarkers, they have the potential to act as a soil fingerprint, reflecting the vegetation species associated with the location. For many forensic applications, such as matching samples of soil from shoes to crime scenes, methods of chemical analysis need to accommodate sample sizes of a few milligrams. Typically, one gram of soil is used in conventional analyses for wax markers. The aim of this project is to modify the existing methodology to allow very small soil samples to be analysed, while minimising adverse effects on accuracy or precision. Modifications including ball-milling the soil to maximise sample homogeneity and miniaturising extraction and clean-up procedures using limited redistilled solvent volumes and exclusive use of glass wear were made.

Data is presented on the effect of reducing sample size on concentration estimates and relative precision of analyses carried out for *n*-alkanes and long-chain fatty alcohols in homogenous dried samples of typical mineral and organic soils, and plant material. It is hoped that further reduction in analysed sample size is possible and that a similar approach could be adopted for other potential biomarkers present in soil, such as fatty acids, sterols or ketones.

A method for the combined extraction of pollen, diatoms and phytoliths from soil samples

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Biological traces in soils can be combined with other techniques to characterise and compare soil samples. In general, a variety of biological traces, like pollen, diatoms and phytoliths, can be used. However, the extraction of one type of biological trace from soil often destroys the other types. If enough soil is available, multiple extractions are possible and the different biological traces can be combined. In many forensic cases the available amount of soil is so small that only one extraction is possible. Therefore, a choice must be made which trace is to be extracted without prior knowledge. In this poster a new extraction-method for small soil samples is tested in which multiple biological traces are extracted simultaneously. The method can be used to assess the abundance and quality of the biological traces and help decide which specific trace to extract further. With this information the biological trace which is most informative for forensic research can be chosen. In addition, the data on the other traces can be used for comparison or exclusion. The first series of experiments have optimalised the method for a sandy soil and the results are promising. The next series of experiments in which the method is tested on other soil types are discussed.

Challenges in environmental and forensic soil education

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The general reduction in the numbers of students entering the classical sciences at school and tertiary level is a widespread phenomenon. This reduction in feedstock and a decline in geology departments will threaten the continued viability of Forensic Soil investigations. Many of the areas which used to be taught in Geology can now be found in part of an Environmental or Environmental Forensics or Analytical based degree. These degrees have strong cohorts of interested students with some exposure to some aspects of soil science but may be leading students up a different path – be it agricultural, environmental or sustainable of soil. However, purists will say that there is no substitute for spending three years looking at rocks and minerals. Perhaps we need to rethink what we are trying to teach. Can we compromise and provide sufficient exposure to students to gain an initial grounding in soil science. We could also develop material that can be provided for other existing graduates and professional workers who want to extend their area of interest from related areas such as glass or paint to soil. Training of existing forensic practitioners may be a more cost effective approach and may have a higher success rate than chasing after a large number of undergraduates to produce a few soil scientists. The author has written and presented undergraduate teaching laboratories that offer a hands-on approach to practicals which makes them time consuming and labour intensive but of more educational value. They also have a conclusion where the students collect and prepare and analyse their own samples – so they get a feel for realistic samples and realise that not all evidence comes with a label and a number on it. The laboratory is not intended to churn out fully kitted out optical mineralogists but to give the students the ability to differentiate between major minerals and have the ability to know where to go to extend themselves later. This paper will present options on different approaches to forensic soil education and halting the decline in student numbers and will hopefully generate some lively discussion.

The implementation of geophysical prospection in the frame of criminal soil forensics

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Years of experience with geophysical prospection at our research unit have shown the advantages of profiling methods. The drawing of iso-resistivity maps for the investigation of the heterogeneity of soils have recently been successfully used in criminal soil forensics. Different case-studies will be presented. The first group of secrets hidden in the soil can be related with buried corpses. Even though the vegetation has been restored, there might be changes in resistivity due to digging. More importantly, due to the decomposition of the corpse, the resistivity in the soil can be changed locally. This will be shown with an electromagnetic investigation of where pig carcasses are buried. The same can be done for archaeological investigations and hidden remaining constructions can be localised. The constructing materials have different resistivities due to different porosity. Differences in anthropogenic use of the soil can be detected including special anomalies. In the case presented, a detected anomaly proved to correspond to the former location of a dog kennel. The existence of caves in the subsoil will also be detectible. When the caves are filled with air, resistivity increases, while when they are filled with water, resistivity decreases. The contrast with the surroundings will prove the presence of the caves. This will be illustrated. Electrical resistivity methods have recently proven to be very useful for detecting anomalies in constructions. In this case, special equipment was developed. The method provides information about building stability, weathering of materials and eventually hidden holes or objects. They usually correspond with anomalies on iso-resistivity maps. Resistivity will change as a result of differences in porosity, humidity, and/or compaction. A case study will be presented. Geophysical investigation provides powerful evidence and, based on the above examples, is proven to be an effective tool for forensic work.