Programme

9.20-9.30 Welcome to the conference and the Forensic Geology Group
Laurance Donnelly, Halcrow Ltd & President FGG

9.30-9.45 Mass graves in Iraq. Roland Wessling, Margaret Cox and InForce.

9.45-10.00 Integrated approach to mass grave detection. J Hunter, A Reddick and J Sterenberg, University of Birmingham

10-10.15 Multi-disciplinary studies and taught site material on a simulated clandestine grave site. Pringle, J.K., Cassella, J.P., Middleton, H., Rogers, D., Summers, R. & Cassidy, N.J. School of Physical & Geographical Sciences, Keele University & Faculty of Health & Sciences, Staffordshire University

10.15-10.30 An assessment of geophysical methods for locating animal mass graves and observations pertinent to their use in locating human mass graves. Adele L. Tempest and Paul N. Cheetham, School of Conservation Sciences, Bournemouth University

10.30-10.45 Geomaterials from Civil to Criminal Law; one small step for the Geoscientist. Andrew S Smith, Materials Group Manager, CERAM Building Technology

Coffee 10.45-11.15

11.15-11.30 Search Methodologies. Mark Harrison MBE National Centre for Policing Excellence, Wyboston Lakes.

11.30-11.45 Different scales of spatial sampling in forensic investigations: case studies from the macro to micro scale. Jennifer McKinley, Antoinette Keaney, Queen's University, Belfast.

11.45-12.00 Lets get physical: the applicability of trace soil analysis techniques in forensic enquiry. Ruth Morgan and Peter Bull, University of Oxford.

12.00-12.15 Anthropogenic destruction of a city's water supply: the crime and punishment. Wayne C. Isphording, University of South Alabama

12.15-12.30 Application of Field Portable X-ray Fluorescence (FPXRF) Spectrometry in Forensic and Environmental Geology. Elisa Bergslien, Peter Bush & Mary Bush. Earth Sciences and Science Education, Buffalo State College; South Campus Instrument Center, School of Dental Medicine, SUNY at Buffalo & Department of Restorative Dentistry, School of Dental Medicine.

12.30-12.45 Diversity, resolution, and scale in forensic palynology and botany
Patricia Wiltshire, University of Aberdeen

LUNCH 12.45 – 14.00

14.00-14.15 The effect of the habitual wearing of footwear on the pollen content of adherent materials. James B Riding, Barry G. Rawlins, Kirsten H Coley. British Geological Survey (Keyworth) and Royal Holloway (London)

14.30- 14.45 A forensic geologist's experiences in Italy. Gianni Lombardi, Dipartimento di Scienze della Terra, Università degli Studi di Roma "La Sapienza", Rome.

14.45 - 15.00 Integration of Soil Fingerprinting Techniques for Forensic Application. Lorna Dawson & Lynne Macdonald Macaulay Institute, Aberdeen/SoilFit Programme

15.00 - 15.15 QemScan. Duncan Pirrie & Matt Power, Camborne School of Mines, University of Exeter.

15.15 – 15.30 Evaluation of the significance of geological and soil trace evidence. Ken Pye, Ken Pye & Associates, Crowthorne, Berkshire.

TEA 15.30 – 16.00

16.00 – 16.15 Altered biotite as an index of forensic discrimination of granitic saprolite. Ritsuko Sugita

16.15 – 16.30 A geoscientist's role in forensic casework: Intelligence provision during search and recovery operations Matt Higginson, LGC Forensics

Posters

1. Application of micro-Raman spectroscopy in Forensic Geosciences. Alexandra Guedes, Armanda Dória and Fernando Noronha

2. Dendrogram utility in forensic geology. Martin Molina, Sandra Reyes & Maria Ballesteros, Colômbia.

There will be various commercial displays.

First, Inaugural Meeting of the Geological Society of London, Forensic Geoscience Group

Geoscientists at Crime Scenes

Burlington House, Piccadilly, 20th December 2006

Dr Laurance J Donnelly *BSc (Hons), PhD, CGeol, CSci, EurGeol, FGS*
Chartered exploration & engineering geologist
(Specialist in forensic geology, geohazards, geotechnics & mining hazards)
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Introduction & Welcome

I am delighted to welcome you to the inaugural meeting of the Geological Society of London Forensic Geoscience Group. The new group was approved by Council, on 22 November 2006.

The term 'Forensic Geology' (also known as Forensic Geoscience or Geoforensics) covers a wide range of fields but for the purpose of this new group may be considered as, '*a specialist branch of geology that is concerned with the applications of geological sciences to help with legal matters and to assist the Police in solving crimes*'.

The Geological Society of London was formed in 1807 and is the UK's national society for geoscience. It is a learned and professional body, and a registered charity. It exists to promote the geosciences and the professional interests of UK geoscientists. There are over 9000 members and several categories of membership. The Society provides the working geoscientist with lifelong continuity, offering scientific and professional advice and support at all stages of their careers including Chartered status (CGeol) & Continuation of Professional Development (CPD). There are 23 Specialist Groups and Joint Associations, 13 Regional Groups in the UK and one in Hong Kong. Next year, 2007, is the Bicentennial year of the Geological Society. This coincides with the launch of the new, Forensic Geoscience Group, and this, I believe, reflects the evolution and progression of the geosciences, into new, exciting and important fields, which serve the nation.

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).

Geologists who work on multidisciplinary forensic investigations must professionally collaborate and effectively communicate with other scientists. These may include; archaeologists, anthropologists, palynologists and ecologists) and other specialists (such as victim recovery dog handlers, search advisors, victim recovery specialists and police officers). These are particular areas which the new group will foster and encourage. The Geological Society and the Forensic Geoscience Group welcomes in-particular, these non-geological specialist and other scientists in the audience, and we value your views, opinions and contributions.

The aims of the Forensic Geoscience Group shall be to advance the study and understanding of Forensic Geoscience, by creating a network and framework of geoscientists, to review and share knowledge, to develop inter-disciplinary collaboration and to disseminate knowledge and information.

This will be achieved by a combination of the following:

- Holding meetings, conferences, seminars, workshops and field visits.
- Encourage and promote meetings with related forensic science groups.
- Encourage and promote meetings with related specialist groups within the Geological Society.
- Representing the interest and promoting the study and understanding of Forensic Geoscience nationally and internationally.
- Encouraging research, training and teaching in Forensic Geoscience.
- Promote the interests of professional, academic and practising forensic geoscientists and encourage Continuing Professional Development such other means as the Committee may think desirable, subject to the approval of the Council.

The Forensic Geoscience Group Committee members (elect) are:

- Laurance Donnelly (LJD), Chair, Halcrow Group Ltd
- Barry Rawlins (BR), Vice-Chair, British Geological Survey
- Duncan Pirrie (DP), Secretary, University of Exeter
- Kym Jarvis (KJ), Treasurer, Kingston University
- Alastair Ruffell (AR), Co-opted member, Queens University, Belfast

Finally, may I express thanks to the following individuals and organisations who have contributed enormously during the establishment of the Geological Society's, Forensic Geoscience Group; Edmund Nickless, David Shilston, Bruce Yardley, Jackie Maggs, Georgina Worrall (The Geological Society), Mark Harrison (National Centre for Policing Excellence), Tony Brett, Fiona Robertshaw (Greater Manchester Police), Barry Rawlins, Prof Martin Culshaw, Prof Fred Bell (British Geological Survey), Duncan Pirrie, Matt Power, Patricia Wiltshire (University of Exeter), Kym Jarvis (Kingston University), Alasatir Ruffell, Helen Kemp, Wolfram Meier-augenstein, Jennifer McKinley (Queens University Belfast), Howard Siddle, Huw Beasley

(Halcrow Group Ltd), Prof John Hunter, Barry Simpson (Forensic Support Archaeology Group), Rob Janaway (Bradford University), Lorna Dawson, David Miller (Macaulay Institute), Mark Yates (DSTL), Ken Pye (Ken Pye Associates), Peter Bull (Oxford University), Marianne Stam (California Department of Justice), Ray Murray, Richard Bising (McCrone Associated, Canada), Rob Fitzpatrick (CSIRO, Australia), Rosa Di Maggio (Forensic Geologist, Italian Forensic Science Police Department), Elisa Bergslien (Buffalo State College, New York), Carlos Martin Molina Gallego (Colombian Forensic Geologist). In organising the day's meeting on the 20th December, Alastair Ruffell has asked me to thank Louise Dyer and Ted Nield (Geol Soc), Louise Martin and Andrew David (English Heritage) and Nigel Cassidy (Keele University).

Name(s) (to appear in programme)	Roland Wessling
Address (to which correspondence should be sent)	Melbury House, 1-3 Oxford Road, Bournemouth, BH8 8ES
Representing (Company/Organisation if appropriate)	Inforce Foundation (Forensic Science and Operations Manager)
Talk Title (to appear in programme)	The Role of Geophysical Surveying in the Site Assessment of Mass Graves – Practicality, Reality and Possibilities
Description (please provide a short description of your paper for the conference programme)	In 2003, an team from the Inforce Foundation was send to Iraq to assess the overall situation of current mass grave investigations by local groups and to advise on future strategies for systematic forensic investigations and humanitarian recovery of remains. Part of the work were site assessments of mass graves that had been excavated, were excavated at the time and those that had not been excavated at all. The site assessments included potentially four types of geophysical surveying techniques: resistivity, conductivity, magnetometry and GPR. These surveys run parallel to optical surveying and on site skeletal analysis. The talk will focus on the practical and fundamental questions regarding the current and future role of geophysical surveying in mass grave site assessments.
Biographical Details (please provide brief details for the conference programme)	Roland is a forensic archaeologist who has worked on international cases in Bosnia, Croatia, Iraq and Cyprus as well as domestic cases in Germany and the UK. This work occasionally included geophysical surveying. Originating from Hamburg, Germany, Roland read physics and astronomy for two years at Hamburg, and then archaeology, law and soil sciences for a further two years. He came to the UK in 1996 to read BSc Archaeological Sciences at Sheffield, before reading MSc Forensic Archaeology at Bournemouth. He has been with the Inforce Foundation in varying posts for since 2003 and is currently the full-time Forensic Science and Operations Manager.

AN INTEGRATED APPROACH TO MASS GRAVE DETECTION

J Hunter, A Reddick and J Sterenberg

This paper examines the results of a series of experiments undertaken in order to detect mass graves. GIS, vegetational change and satellite imagery were utilised along the Cancari Road in eastern Bosnia in an area of known secondary burials resulting from the Sebrenica Massacre. GIS techniques were adopted in order to model potential deposition sites, and vegetational analysis was undertaken in order to recognise relevant species change. Combined with high definition satellite imagery this provided a series of target locations for further investigation. These were then assessed in the field and prioritised for geophysical survey (here resistivity and electrical imaging). The results showed the potential of the system in being able to identify specific graves, and in being able to model individual grave characteristics (eg depth, profile etc) in a non-invasive manner, thus not only preserving evidence but also informing the logistics of recovery and exhumation.

Multi-disciplinary studies and taught site material on a simulated clandestine grave site

Pringle, J.K.[1], Cassella, J.P.[2], Middleton, H.[2], Rogers, D.[2], Summers, R.[2] & Cassidy, N.J.[1]

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Abstract

A simulated clandestine shallow (0.6m bgl) grave was created in May 2006 within a heterogeneous, mixed-ground, urban environment. The grave was filled with a fully clothed resin human skeleton. Animal products (heart, lungs, liver, kidneys) were placed in anatomically correct positions before 500mls of physiological saline was poured over the assemblage. The skeleton was covered to ground level with the excavated material. The study site was accurately surveyed for topography, surface objects, geophysical sampling positions and several 1D soil-sample probes acquired to characterise any near-surface heterogeneities.
Repeat (time-lapse), near-surface geophysical investigations were undertaken over the study site; one month prior to burial (to act as control), one month and three months post-burial. Common, near-surface geophysical techniques trialled included: bulk ground resistivity (dipole-dipole), bulk ground conductivity (EM38), fluxgate gradiometry (magnetics) and high-frequency (900 MHz) Ground Penetrating Radar. Less common methods also used were soil magnetic susceptibility (MS), Electrical Resistivity Tomography (ERT) and Self Potential (SP) techniques. Most methods used sampling positions spaced 1m-apart, the six-repeat ERT profiles had 32 electrodes spaced 0.25m apart and the 1m-spaced, 2D GPR profiles had 2.5cm trace spacings. Comparisons between control and post-burial datasets, allowed quantitative verdicts on the effect of the clandestine grave material for each technique. Technique comparisons showed optimum workflows of initial targeting using comparatively rapidly-acquired geophysical datasets (dipole-dipole resistivity and conductivity) before the improved resolution and targeting afforded to GPR and ERT profiles.

Staffordshire University forensic science undergraduate students had access to scientific reporting in late September 2006, detailing the forensic geophysical results and possible interpretations. The group then decided upon their forensic intrusive investigations using police protocols and standard crime scene procedures to prevent onsite material contamination. The Staffordshire County Coroner, present onsite for the 'exhumation', then allowed material to be recovered. Undergraduates have then 'worked up' results and will present their findings at a mock-convened Coroners Court in Staffordshire. The use of a scenario allowed undergraduate students to appreciate the complexity of a murder investigation. The collaboration between *geophysicist* and *Senior Investigating Officer*, is paramount to ensure the best use of existing intelligence constraints to narrow a search area. Students were subsequently divided into teams consisting of; pathologists, odontologists, toxicologists, DNA experts, continuity officers, photographers etc. The team-working skills at the murder scene and subsequently, in order to produce coherent documentation by the forensic

scientists is essential to develop good practice *at* undergraduate level. The collaboration between *geoscientist* and *forensic scientist* has proven to be worthwhile from an intelligence, budgetary and indeed a pedagogical perspective. Undergraduate students were able to take samples for the soils and from the remaining organic material from the body to examine the taphonomic effects and the interaction between soil and 'corpse'.

Figure 4. (A) Clothed plastic skeleton with animal products and 8 pints of saline buried at 0.6m below ground level. (B) 'Recovery' after 4 months burial by Forensic Science degree undergraduates.

An Assessment of Geophysical Methods for Locating Animal Mass Graves and Observations Pertinent to their Use in Locating Human Mass Graves

Adele L. Tempest and Paul N. Cheetham

School of Conservation Sciences, Bournemouth University, Poole, Dorset, UK, BH12 5BB

This paper presents the findings obtained from a series of integrated geophysical surveys conducted on two known animal mass graves to assess the ability of the techniques to locate anomalies associated with the graves. It will focus on the results obtained from the surveys in terms of issues that may be relevant in the investigation of crime scenes involving the use of geophysical techniques to locate buried human remains. The integrated geophysical surveys, undertaken as part of an MSc in Forensic Archaeology, Crime Scene and International Investigations at Bournemouth University, succeeded in detecting anomalies associated with the known location of two graves: a 1967 foot and mouth grave in Shropshire and a lambing grave dating back to 2001 in Dorset. Ground penetrating radar (GPR), earth resistivity (ER), Slingram electromagnetic (EM) and magnetic gradiometry (MAG) were employed in the study.

Belhuish House, Dorset

A series of five surveys using the Geoscan RM-15 (twin-probe array) with probe separations ranging from 0.25m to 1.50m at Belhuish House, Dorset, produced a sequence of unambiguous results that clearly indicated anomalies associated with the grave. The EM3B vertical dipole quadrature also produced comparable results (Figure 1.). The results from the surveys using the Mala Ramac GPR at 250 MHz and 500 MHz antennas produced clear anomalies associated with the grave at Belhuish House with the 250MHZ giving the better response.

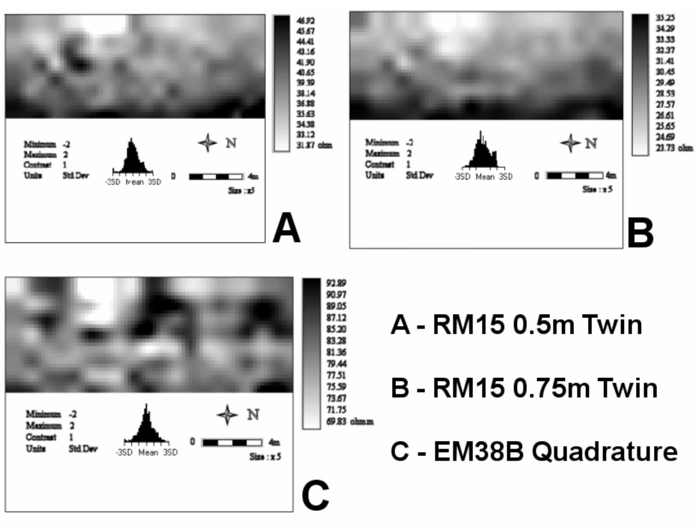

Figure 1: Belhuish House, Dorset. Comparison of RM-15 0.5m and 0.75m twin results with the EM38B quadrature phase results displayed as resistivity. Note the low resistance anomaly one third of the way along the top side of the survey area that corresponds to the position of the known animal grave from 2001.

Pear Tree Farm, Shropshire

The GPR results at Pear Tree Farm were quite different from those from the previous site and potentially inconclusive on their own. Both 250 and 500MHz surveys failed to identify any anomalies at depth and only the 500MHz appeared to delineate the grave by a area of very shallow noise presumably caused by disruption of the topsoil subsoil interface (Figure 2). The EM38B in-phase response also delimited a similar area of lower susceptibility, again probably resulting from the dilution of magnetically enhanced topsoil caused by its disturbance and subsequent mixing with subsoil (Figure 3). Also note the strong high susceptibility anomaly to the south resulting from a target also detected on the magnetic surveys. The EM38B quadrature response clearly detected the site of the grave (not shown).

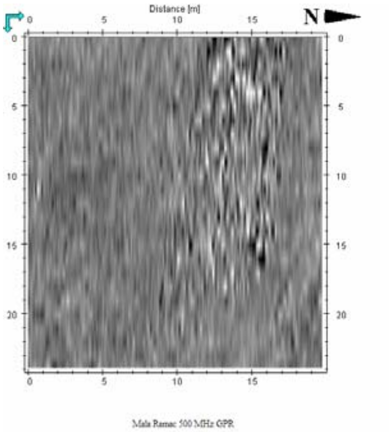

Figure 2: Pear Tree Farm, GPR @ 500MHz

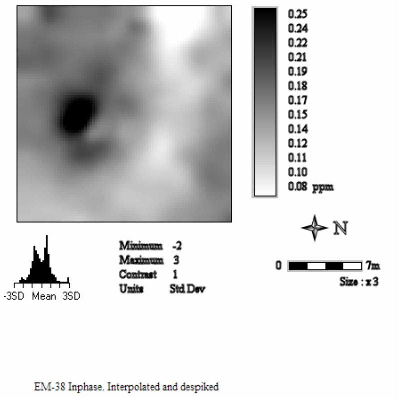

Figure 3: Pear Tree Farm, EM-38B In-phase

Magnetometry (gradiometry)

Magnetic surveys were undertaken using the Scintrex Smartmag SM4G, a Bartington 601 Dual Fluxgate Gradiometer, and Geoscan Research FM36. At both sites the instruments detected anomalies that would appear to be arising from the inclusion of ferrous materials/items into or associated with the grave fills, thus indirectly indicating disturbance and so the site of the grave.

Conclusions

In conclusion, the work on these sites suggests the EM38B conductivity and earth resistivity systems produced good and compatible results while GPR and MAG produced less consistent but still good results. The only instrument/technique that failed to produce good results the one site it was tried on was the EM31, however, this instrument may well have performed more successfully at the Belhuish House site had it been available for these surveys. Not surprisingly perhaps, these results support the widely held view that individual geophysical techniques do not provide conclusive results on their own, but that by using a combination of various techniques and configurations and comparing the results, the ability to detect and recognize anomalies associated with grave features increases considerably regardless of whether graves are 5 or 40 years old. However, this work does suggest that ER or EM (conductivity) should be there in the first choices of technique, with the ability to also provide magnetic susceptibility and metal detection data an additional advantage in employing EM instruments.

Geomaterials from Civil to Criminal Law; one small step for the Geoscientist.

Dr Andrew S Smith B.Sc., M.Sc., Ph.D., FGS., CUEW, Materials Group Manager
CERAM Building Technology

Abstract:

Forensics and expert witness investigations currently have a high profile in the media, principally in the field related to medical practitioners. The discrediting of evidence provided in the notorious Sally Clarke case by Professor Sir Roy Meadows, has made many "experts", not only medical, but also those operating in different professions, stop and take stock of how we undertake expert witness work, be it within the realm of Civil or Criminal Law.

At CERAM we have adopted and tailored a working protocol, based on the Civil Procedure Rules (CPR 35) and Expert Witness Training provided by Bond Solon and Cardiff University Law School (CUBS). This protocol is now tried and tested on our extensive Civil Law caseload. This approach is equally applicable to that of Forensic Investigations within Criminal Law cases, and gives a structured framework into which can be secured the evidence and opinions.

The presentation of expert witness reports as well as cross examinations in Court is just as important as the collection and analysis of samples, which typically is the area of specialism of the expert. Experts, especially ones who can expect to be in the witness box need to be aware of their limitations of expertise and specifically, when to "stop digging" and admit that they do not know.

The presentation covers the basics of expert witness reports and gives a flavour to the type of work CERAM undertake in Civil cases involving Geomaterials, and the "odd" Criminal investigation.

Search Methodology for Historic Burials: from Remote Sensing to Water Sampling

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A search for hidden (typically buried or submerged) materials may be initiated at many stages of an investigation into humanitarian, military, environmental or criminal activity. We take the worst case scenario of the need for recovery being initiated when a large (tens of km) area is to be searched. How do we break the landscape (or waterscape) down into manageable units for comprehensive management? Satellite imagery, aerial photography and digital terraine models provide the context for combined (mosaic) photographic and thematic imagery in target identification (mass burials, illegal waste tips). Aerial photography (IR and UV) combined with human intelligence assist in smaller target selection. Such locations are then subject to analysis of landscape change, especially geomorphology, vegetation and human influence. Digital Elevation Models, constructed from differential GPS (global positioning systems) provide cm- to metre-scale information on landform that is used to inform and assist geophysical surveys and construction of water flowpaths. In addition, DTMs can provide quantitative information on ground elevation and the likelihood of below-horizon, covert activity in specific locations. Geophysical survey methodology includes area-based methods of resistivity/conductivity and magnetic mapping that provides target locations for electrical tomography and ground-penetrating radar, as well as targeted use of cadaver dogs. Geomorphology, DTM analysis and geophysics can be built up into a shallow hydrological model, especially the domain or sector-based flowpaths that inform water sampling for total organic carbon and isotopic analysis, which isolates flow paths to targets.These can be re-surveyed for microtopography, vegetational change and geophysics. Combined with water chemistry, these provide meter-resolution of potential burials, which can then be excavated.

'Different scales of spatial sampling in forensic investigations: case studies from the macro to micro scale'

Jennifer McKinley, Antoinette Keaney and Alastair Ruffell

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The scale of study in forensic investigations, is determined by: the area designated as the crime scene; geographic information known regarding the movements of the victim and suspect(s) and the size and distribution of likely evidence. This presents the forensic investigator with two key issues. Firstly, the potential for a number of areas of varying size from which to retrieve forensic evidence and secondly, the need to integrate different scales of spatial sampling. At a suspected crime scene, relevant data for a forensic investigation may be collected non-invasively at a macro-scale (e.g. photogrammetry, GPS and TPS), at an intermediate scale (e.g. Laser Scanning, GPR, indication from dogs) and using invasive techniques at a micro scale (e.g. soil and water sampling, mineralogy). Effective analysis and integration of these different types of spatial evidence is crucial for a robust forensic investigation. Several case studies utilising potential forensic evidence collected on macro and micro scales are presented and spatial sampling at different scales discussed. The application of Geographical Information Systems (GIS) and geostatistics to the analysis and integration of different scales of spatial evidence is also described.

The macro scale case study involves a suspected burial site in open ground. GPS-referenced data provide a digital elevation model (DEM) on which layers of spatial evidence are superimposed. Laser scanning (using a Leica HDS3000) is used to capture a 3D geometry of the landscape in the form of a high density 3D point cloud. This enables visualization of the landscape, 3D modelling, detailed cross-sectioning, and 2D mapping. The GPS-referenced DEM, photogrammetry and laser scanning are integrated in a GIS- based terrain analysis approach to provide information on the geomorphological and hydrological partitioning of the landscape. Within this macro-scale framework a nested grid system of sampling is deployed to incorporate results from invasive spatial sampling techniques such as water and soil sampling. Links and spatial relationships are explored through GIS and geostatistics analysis in the investigation of this suspected crime scene.

The second case study deploys an intermediate scale spatial sampling scheme in an urban crime scene setting. Spatial mapping techniques describe the spatial variability in the distribution of transferable materials and enable a potential suspect to be placed to within a few metres of the crime scene.

The micro scale case study addresses an issue that is becoming commonplace in criminal investigations. 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. 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 and spatial arrangement of trace mud splashes on different substrate material attempts to utilise the amount of information which can be obtained at this micro scale. These mud specks are spatially-arranged and require mapping on the substrate, just as samples are taken at a scene, in order to assess variability and test the veracity of later analytical comparisons. 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 number of analytical techniques can be used to establish their origin, non-destructive techniques are therefore a top priority in this type of investigative research.

We are grateful for discussions and collaboration to a number of individuals. Case Study 1: Wolfram Meier-Augenstein, Helen Kemp, Lorraine Barry, Conor Graham, John Gilmore, Mark Harrison, Laurance Donnelly, Martin Grimes (and Ed) Steven McIlroy. Case Study 2: DCs Ian McMullan and David Hanna; DCIs Ian Gilchrist and Raymond Ramsey and SCSI Dr Graeme Kissock. Case Study 3: Lorna Dawson, Mark Russell, Chris Hunt, Gary Galbraith, John McAllister, European Science Foundation (funding).

Anthropogenic destruction of a city's water supply: the crime and punishment

Wayne C. Isphording, Department of Earth Sciences, University of South Alabama, Mobile, AL 36688 (USA)

ABSTRACT

Pensacola, Florida is a large, metropolitan center located near the northern shore of the Gulf of Mexico. Its importance lies in that it is a favorite resort area for "snowbirds" from elsewhere in the United States (especially during the winter) because of its typically mild climate and excellent beaches. It is also the site of the major training facility for naval pilots acquiring skills in landings on aircraft on carriers. Unlike most other Gulf Coast cities whose water supplies are derived from lakes, rivers, etc., however, Pensacola is unique in that it is totally dependent for drinking water on deep wells penetrating the subsurface Miocene aquifer.

Late in the 1950's, State agencies began observing elevated levels of a number of contaminants in several of the 16 deep wells that serve the city. These problems continued, and worsened, to the point where a total of 4 of the wells had to be shut down due to elevated levels of fluorine, sulfate, aluminum, nitrate and radium. The source of the contamination was finally traced to a former fertilizer manufacturing facility which was ultimately declared a Federal Superfund site in 1987. Contaminants continue to issue from the site and a class action suit was filed on behalf of numerous property owners in 2000. Though the defendants did not question that the sulfate, fluorine, aluminum, low pH's, etc. were their responsibility, they argued strongly that the radium was a "natural" phenomenon. Because the radium levels were the chief reason for closure of two of the wells, it was critical to identify the source of this material. Its origin was finally traced to the presence of monazite in the phosphate ores processed at the facility and, just days before the trial was to take place, an out-of-court settlement was reached between the defendants and the plaintiffs. As such, it amounted to the largest dollar value settlement, to date, for a groundwater contamination dispute in the United States.

Application of Field Portable X-ray Fluorescence (FPXRF) Spectrometry in Forensic and Environmental Geology: Theory and Examples

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Department of Restorative Dentistry, School of Dental Medicine, SUNY at Buffalo, 235 Squire Hall, S, Campus, Buffalo, NY 14214, USA.

Field portable X-ray fluorescence (XRF) spectrometry has become a common technique for many environmental geoscience applications. Its key characteristics are ease-of-use in a variety of environments, low sample preparation requirements, and rapid turn around time, usually on the order of minutes. These characteristics also make it an ideal tool for use at crime scenes where rapid, non-destructive screening of materials may be necessary.

A typical FPXRF system uses either an x-ray tube or radioisotope as an excitation source to irradiate samples. The incident x-rays interact with the samples atomic structure by knocking electrons from their inner shells, leaving vacancies that are filled as outer shell electrons release energy to fall in to new ground states. The energy released will be an x-ray equivalent in energy to the energy difference between the two shells. Since each element has a characteristic arrangement of electrons, the x-rays released by such transitions will be unique to that element, allowing its identification. By comparing the intensities of x-rays from an unknown sample to those of a suitable standard, elemental composition can be quantified.

Field portable units employ energy dispersive analyzers that convert the x-rays incident on the solid state detector into an electronic signal based on photon energy. The major limitations of this technique are lower detector resolution than wavelength dispersive systems and more significant spectral overlap issues that also effect resolution, especially on light elements. Laboratory based EDX systems can analyze for elements from sodium to uranium, but FPXRF systems, because they are working in air, generally are unable to detect elements lighter than phosphorus. This latter limitation has significance from a forensic geology perspective, as the most common elemental constituents of minerals, silicon, oxygen, aluminum and magnesium, are not detectable. Heavier elements can be readily detected, however, some with great sensitivity. For example, the levels of strontium substitution in calcite and barite are easily measured.

Forensic geological applications of FPXRF include distinguishing between mineralized tissue, such as bone or teeth, and inorganic materials of similar appearance. Mineralized tissues are a calcium phosphate, often called bioapatite, that closely resembles naturally occurring hydroxylapatite. Preliminary results using FPXRF, sometimes paired with x-ray diffraction (XRD), demonstrate that bioapatite might be clearly differentiated from inorganic materials, such as Plaster of Paris and powdered apatite. Both methods are non-destructive and can be used in concert to determine both elemental composition and crystalline structure. The bioapatite samples tested thus far have significantly lower strontium and iron levels than geologic materials and had no detectable barium, bismuth, chromium, manganese, sulfur or zirconium (table 1). XRD can also discriminate bioapatite from most look-alikes and the differing substitutions in the crystalline lattice appear to distinguish most bioapatite from geological apatite (figure 1).

	Apatite (Collection)	**Apatite (Cargille)**	**Plaster of Paris**	**Calcite (Cargille)**	**Bone (Cremain)**	**Enamel**	**Enamel 2**
	parts per million						
Zr	55	34	36				
Sr	2946	2413	1130	76	85	183	114
Ba	458	353	73				
Cr	147	132		76			
Mn	98			179			
Fe	742	817	1497	463	145	379	144
Zn		32	38		31	366	930
S			>10%				
P	>10%	>10%			>10%	>10%	
Ca	>10%	>10%	>10%	>10%	>10%	>10%	>10%

Table 1: Selected FPXRF Results

An operator skilled in use of the FPXRF instrument may also provide significant help at the crime scene in identifying composition of personal effects, including gemstones and other metal jewelry. One of the most significant advances of the technique is the ability to obtain usable spectra in as little as 6 seconds, allowing rapid sequential analysis and sorting of materials at the scene.

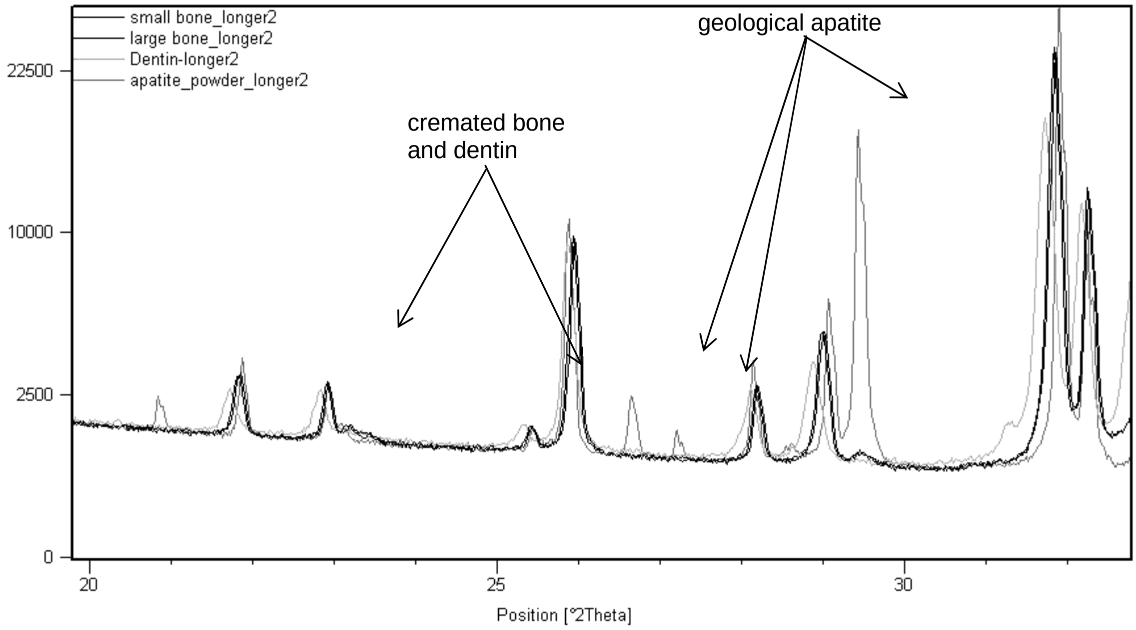

Figure 1: X-ray diffraction trace of cremated bone and dentin samples compared with geological apatite

There are many environmental applications that may also intersect the forensic arena, such as tracking pollutants in the environment to their source. A typical example involves screening soils for toxic metals. As a training exercise, several students took *in situ* measurements of various materials in a local school playground using an Innov-X Systems Alpha Series FPXRF with a tungsten tube source and a Si PiN diode detector. The excitation conditions for most of the applications discussed were 35 kV with an minimum collection time of 30 seconds. The lower detection limits are typically 10–50 ppm for titanium to plutonium, 250 ppm for potassium to scandium, and between 1–5% for phosphorous to argon.

For each measurement, the detector window of the unit was simply held flat against the surface to be analyzed. The materials assessed included wooden playground equipment, a tire mounted on a wooden beam, soil, wood chips and a nearby tree. Rather to our surprise, we determined that most of the wooden structures were built out of lumber treated with chromated copper arsenate (CCA). Arsenic levels for the wood varied from a low of 2625 ppm, on the weathered side of a vertical support post, to a high of 9687 ppm, on the underside of a horizontal beam. Soil near these wooden structures also show elevated arsenic levels (69 – 96 ppm, compared to the USEPA recommended level of less than 7.5 ppm). Soil away from the wooden structures had no detectable arsenic. These results were reported to the school officials and later confirmed by an EPA certified environmental consulting firm.

Another forensic application involves analysis of mineral and rock deposits on automobile tires, shoes, carpets etc. and direct comparison with materials found at the crime scene. Knowledge of compositional changes in geological formations may aid in tracing movements of a crime suspect or victim. In an on-going *intrusive analysis* project, 100g soil samples from selected urban, suburban and rural areas were collected in order to test our ability to distinguish their points of origin. The samples were oven dried, visually inspected, examined under a stereo microscope, and sorted by grain size. The fines were analyzed using XRD and FPXRF. Thus far, all of the urban samples show significantly higher levels of lead, iron and zinc (table 2). Underlying bedrock geology appears to be reflected in elemental concentrations of soils as well. For example, that north Buffalo is on dolostone and shale (Bertie Formation), Lancaster is on limestone and shale, and Yellowstone is mostly on rhyolite, is reflected in the calcium concentrations. Sample collection is on-going and statistical analyses are planned for this year. FPXRF can readily be used as a screening tool to differentiate soils from significantly different areas, though its utility to distinguish samples taken from close proximity has yet to be established.

	Rural (Yellowstone National Park, WY) *n = 8*	**Suburban** (Lancaster, NY) *n = 5*	**Urban** (Buffalo, NY) *n = 6*	**Urban** (Delaware Park, Buffalo, NY) *n =10*
	parts per million			
Sr	572	172	193	191
Pb	54	32	366	150
As	30		68	38
Zn	61	110	298	227
S	20639			
Ca	7061	39432	20274	17709
Ti	3356	3196	3847	4923
Ba	405	264	318	345
Cr	164	71	105	101
Mn	438	296	565	428
Fe	19260	20899	29774	28356

Table 2: Selected FPXRF Results

The effect of the habitual wearing of footwear on the pollen content of adherent earth-related materials

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Abstract

This study investigated the effect of the habitual wearing of footwear on the pollen/spore content of any adherent materials. It has been suggested that the pollen/spore signature peculiar to a specific locality will be diluted via the loss of key material and the accumulation of soil etc. from other places. There is a real possibility that soil from several localities will be adherent to shoes or boots. This study aimed to test this contention. Six rural sites in the East Midlands were visited in pristine boots, and boots which have visited the other localities. Samples of adherent soil from these items of footwear, and control samples, were analysed palynologically in order to attempt to determine pollen dilution factors.

Data from the control samples indicates that each of the six localities has highly characteristic pollen/spore signatures. This finding in itself strongly supports the concept of widespread palynological hererogeneity, and hence the continued use of palynology in forensic geoscience. Furthermore, it is clear that, in the experiments carried out here, the pollen/spore content of the items of footwear closely reflect the palynology of the last site visited. This is evident from a visual examination of the raw data. However this was tested, and confirmed, using correspondence analysis and detrended correspondence analysis. Using both these multivariate statistical techniques, the samples that produced abundant palynofloras from each locality tended to cluster closely together. Thus the samples from footwear that, for example, had last visited locality four plotted close together (i.e. with low statistical distance). Unsurprisingly, the more abundant the pollen/spores, the closer together the samples plot. Hence statistical clustering is less convincing at localities that yielded sparse palynomorphs. In these cases, the statistical results plot less closely together due to the relative sparsity of the data.

A FORENSIC GEOLOGIST'S EXPERIENCE IN ITALY

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Research activity in the field of Forensic Geoscience is very rewarding for a geologist as it stimulates the use of an assortment of techniques (both traditional or adapted to a specific problem) in order to answer the questions raised by the unlimited variety of cases he or she has to deal with. Moreover, it can be very rewarding, offering the chance to meet and interact with colleagues from other branches of science and to learn how to present scientific data to non-scientific counterparts such as courtroom testimony.

Case histories derived from over 30 years involvement of the author in criminal cases all over Italy will be presented to illustrate how the detailed analysis of the many assorted soil constituents can contribute to the solution of problems related to provenance. Topics included are: large and small samples; the value of thin section analysis for accurate mineral and rock determination and for evidence in the courtroom. The contribution of palaeontology and botany together with results obtained with the identification of anthropogenic elements (plastic, glass, paint, tar, fibres), provide powerful support to the analysis of soil samples. Paramount in all of this is the unique knowledge of surface rock and soil distribution that a geologist possesses.

A brief conclusion on the acceptance of Forensic Geoscience in the Italian Courts will conclude the presentation.

Integration of Soil Fingerprinting Techniques for Forensic Application.

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The UK SoilFit project (http://www.macaulay.ac.uk/soilfit/), funded by the Engineering and Physical Sciences Research Council, aims to integrate data from state-of-the-art soil fingerprinting methods with data currently held in spatially referenced soils databases. This approach could potentially improve both matching of evidential soil samples and prediction of probable geographical origin. Classical soil forensic measurements (including soil colour, soil texture, particle size analysis, and palynology) will be integrated with modern analytical methods including quantitative mineralology (XRPD, QEMSCAN), chemical fingerprinting (FTIR), microbial DNA profiles (TRFLP), and wax-biomarker signatures. The value of each analytical technique will be assessed both individually and in combination. Creation of a UK wide reference database will allow estimation of the probability associated with obtaining sample matches, based on the frequency of such attributes within a population. A decision support tool is being developed to assist the forensic scientist in selecting the most appropriate analytical strategy depending on sample size, type and condition. A software prototype has been written to process the data and identify, with probabilities, the soil type. This information is then fed into a prototype rules-based GIS model to identify areas with appropriate soils, which can be narrowed down by layering intelligence of other spatial data (e.g. distance from roads, broad vegetation types). These prototypes have been built to demonstrate and evaluate the approach for crime investigation.

Evaluation of the significance of geological and soil trace evidence

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After geological or soil evidence has been recovered and analysed, the next step is assessment of the significance of the results. Several steps may be involved, including data summarisation and comparison, hypothesis testing, interrogation of database information, experimentation, and formulation of an overall opinion. In many respects the issues relating to the interpretation of geological and soil evidence are also common to other forms of trace evidence, but certain specific factors must be taken into account.

The questions most frequently asked of the geological trace evidence examiner are (1) is there a 'match', and (2) if so, what is its significance? In the context of geological and soil evidence, a true match can only be said to exist in rare circumstances, for example where pieces of a broken rock form a 'physical fit'. Where no such physical fit can be demonstrated, the best that can be said is that two rock or soil samples are of the same type and have extremely similar, or even indistinguishable, physical, chemical and/or biological characteristics. The alternative possibilities that they originate from the same immediate source, the same ultimate geological source but different immediate sources, or from different geological sources which are indistinguishable, often cannot be discriminated unless there are additional identifying features which might confidently interpreted as 'unique.

Three possible conclusions can be reached after comparing a questioned sample and a control sample from a known source. First, it may be possible to identify a firm positive association, e.g. on the basis of a physical fit. Second, a confident exclusion may be possible where two samples differ in several major respects. Third, it may be concluded that there no significant differences between the questioned and control samples, and therefore the possibility that they are associated in some way cannot be excluded. The difficulty arises in attempting to provide a measure of the likely significance of the observed similarity; i.e. the likelihood that the samples actually are associated.

Most forms of geological and soil trace evidence cannot be assessed in conventional statistical probability terms. The numbers of soil, sediment or rock samples, and of possible combinations of soil and rock properties, are not fixed. Soils are inherently heterogeneous on a variety of spatial and temporal scales, and further variation may arise due to selective particle transfer onto an item, and selective retention after the transfer has taken place. The inability to place a specific statistical probability estimate on chance association has led to a widespread view that trace evidence is much weaker than DNA evidence, a problem which has been referred to as 'the tyranny of numbers'. However, as noted by Houck, (1999, p3),"the tyranny of numbers is a consequence of an over-reliance on deduction and mathematics, and these ultimately limit a discipline by requiring it to fit into a preordained model. Equating quantification with science to justify and validate its "science-ness" indicates that a "faulty notion of science, or no notion at all", is at the heart of the tyranny".

Bayesian statistical approaches have become popular in many branches of forensic science in recent years. Advocates of the approach maintain that one if its main advantages is that it provides a flexible framework within which to evaluate different scenarios using different prior probability information, but critics argue that the choice of prior probability information is often arbitrary and without scientific justification. In the case of many forms of trace evidence, including soil, prior probability information is only available in a qualitative, rather than quantitative form.

Quantitative methods, including formal hypothesis testing, clearly have an important role to play in the assessment of all forms of trace evidence, but they can rarely provide a complete answer. Issues of "uniqueness", "rarity", "randomness" and representativeness" in relation to trace evidence are usually difficult to quantify in an exact mathematical or meaningful statistical way. Statistical estimates of frequency of occurrence are usually context-dependent, based on the extent and timing of any sampling carried out, and on the methods used for sample collection and data analysis.

As pointed out by Houck (1999), "context, is in fact, the crucial component to a proper grasp of the significance of trace evidence. Without context, we are communicating mere facts with no foundation of meaning, much in the way Poincare's pile of stones is not a house". The existence of a suitable context for the evaluation of the significance of trace evidence depends partly on the experience / knowledge of the trace evidence examiner, the availability of database information relating to the materials under examination, and the willingness of those instructing the forensic examiner to provide relevant information relating to the circumstances of the case. The examiner is not always provided with information which may have an important bearing on the assessment of the *evidential value* of the scientific findings. Partly for this reason, the examiner should, normally restrict his / her assessment to the likely *scientific significance* of any apparent similarity. The wider issue of evidential significance is more properly a matter for the court.
Over the past fifteen years there have been great improvements in the methods available for the analysis and comparison of geological and soil materials which can be used as forensic trace evidence (e.g. Pye & Croft, 2004; Pye (2006). It is now possible to analyse very small samples using several different techniques which have analytical good precision. However, questions of sample 'representativeness' and evaluation of the scientific significance of apparent similarities and differences between samples remain a matter of debate. To some extent these issues have been addressed through experimental work and by the development of databases of certain soil properties (e.g. Pye *et al*., 2006a,b,c; Pye & Croft, 2006), but there is still a considerable way to go. This paper illustrates some of this development work and applications in recent casework. Particular focus is given to the development of a soil chemical database, utilising ICP-AES and ICP-MS analysis of a standardized <1 50 um size fraction of soils in England and Wales, and to procedures for its interrogation. The limitations of the database are explored, and suggestions made for future improvements in relation to this and other soil / rock properties.

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Altered biotite as an index of forensic discrimination of granitic saprolite

R. Sugita and S. Suzuki

Granitoids are amongst the common rocks found widely in Japan and other areas of the world. "Deeply weathered" granitic saprolite, which is often subjected to forensic discrimination related to crime, is widely distributed in granitic regions. Feldspar and mica often remain as brittle pseudomorphs following alteration to clay minerals, such as vermiculite and kaolin minerals depending on weathering conditions. It is not suitable to examine such saprolite with conventional methods for forensic discrimination based on traditional treatment of clay minerals, because they are easily broken into fine particles and/or washed away by chemical and physical processes which deform the brittle pseudomorph and damage the feature of original coarse saprolite. Therefore there is no information from which parent minerals the detected clay minerals come from. We have frequently found only minor differences in bulk clay mineral assemblage between comparison samples, resulting in difficulty during forensic discrimination.

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In this study the contribution of biotite and its alteration states for forensic discrimination of granitic saprolite was examined, because these minerals are often found as a major component of granitic saprolite. A number of studies suggest that there are several different alteration patterns of biotite. X-ray diffraction (XRD), elemental analyses using a scanning electron microscope equipped with energy dispersive X-ray analyzer (SEM/EDX) and an X-ray fluorescence spectrometer (XRF) were performed for the purpose. Studied samples were collected from northern Abukuma Plateau in Fukushima Prefecture, northeast Japan, where a wide exposure of granitic rocks has been reported by previous workers. Average annual rainfall and temperature of Fukushima-shi, the vicinity of studied area, are 1105mm and 12.8 respectively. A large part of the studied area is covered by 'deeply weathered' granitic saprolite with a small amount of fresh hornblende biotite granodiorite as core stones and small rock bodies. The structure of original granodiorite is well preserved in coarse grained granitic saprolite although colour varies white, red and brownish red. It contains pseudomorph of plagioclase and vermicular biotite. Potash feldspar is less altered than these minerals.

Deleted: regions. Abundant of kaolin minerals are often detected when bulk clay mineralogical XRD analysis is carried out. It makes forensic discrimination difficult. It is usually coarse grained and often contains biotite and its altered matters. Alteration of biotite is well studied and there are several different ways to change clay minerals such as vermiculite and kaolinite. ¶
¶
Biotite and its altered matters were studied in Fukushima Prefecture, Japan for the purpose of utilizing academic data to forensic geoscience.

Fresh and altered biotite were handpicked from saprolite and crashed fresh rocks. They were washed in distilled water using ultrasonic to remove particles of clay minerals from the surface. A portion of cleaned sample was crashed in an agate mortar and coarse inclusions were removed under the stereomicroscope for the powder XRD. Oriented specimens were prepared following potassium and magnesium saturation. Each sample was measured five times. Potassium saturated specimens were measured in air-dried conditiona, after heating of 300 for one hour and after heating of 600 for one hour, and magnesium saturated specimens were measured in air-dried conditions and after saturation with glycerol. For major elemental analysis by SEM/EDX, cleaned minerals were mounted with epoxy resin and coated with carbon. Mg values were calculated from obtained data. Major elemental analysis of bulk rock and saprolite was also performed by wavelength dispersive XRF. Fused glass beads were prepared for Non-standard quantitative analysis.

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As the result of XRD, altered biotite from saprolite contained kaolin and vermiculite/mica mixed layer minerals. Some of the samples showed a long period reflection at about 2.4nm and its base peaks. It was considered to be derived from a regularly mixed layer vermiculite/biotite mineral (hydrobiotite). Distribution of hydrobiotite in the area is localized when plotted on a map. Studied samples were also divided into two groups according to their Mg values, which corresponded to existence of hydrobiotite.

The result of chemical analysis of bulk rock and saprolite by XRF revealed there was a difference of Mg and Fe content among samples which showed good correlation with biotite analyses. Therefore, it was assumed that the observed difference caused by the elemental difference of parent materials.

Correspondence between results of experiments indicates alteration style of biotite is directly reflecting the composition of host materials at least in this area. Granitic rocks are well studied in the light of their original magma formation in the academic world and a lot of results of elemental analyses have been published. These local geological data could be utilized to estimate the area of crime.

A Geoscientists Role in Forensic Casework: Intelligence Provision During Search and Recovery Operations

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In criminal investigations, geoscientists play a role not just at crime scenes, but also in finding them. This presentation will describe the role of the Geoscientist in efforts to locate the body from a recent murder case investigated by scientists at LGC Forensics. The investigation began as a missing person case.

Intelligence information suggested that the victim had been buried within a search area of approximately 15 miles radiius from the primary crime scene (total area of approximately 700 sq. miles).

Police investigations led to the recovery of several suspect digging implements from which pollen and soil were recovered. Since the search area contained a number of distinctive geological formations (including Upper Cretaceous Chalk and Lower Cretaceous Mudstone overlain in places by Quaternary Head deposits), the identification of specific particulate components on the digging implements facilitated elimination of large swathes from the original search area (including locations originally favoured by police intelligence).

A synthesis of geological and botanical profiling information will be presented as well as the construction of a detailed search strategy. Combined with more traditional police search protocols (such as accessible distance from roads), details of the success of the search and recovery operations will be discussed.

Application of micro-Raman spectroscopy in Forensic Geosciences

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Forensic scientists use a wide variety of materials to solve crime. Most of these materials, whether they are soils, minerals, rock fragments, paint pigments, or dusts have a geological origin. New developments in techniques for determining the origin of these materials are making the science of detection much more precise.

Micro-Raman Spectroscopy (MRS) is a highly sensitive technique used to characterize materials since provides unique spectra, which is as a sort of fingerprint. This analytical technique combines the attributes of reliability and sensitivity, with those of being non destructive and amenable to *in situ* studies. It does not require sample preparation and may be performed in samples with different sizes. Therefore, MRS is an ideal toll in forensic geosciences and the applicability of Raman spectroscopy to solve geoforensic problems is being improved in the recent years.

The MRS set-up of Geology Centre of Porto University (CGUP) consists of a Labram spectrometer coupled to an Olympus microscope with different objective lens (x100, x50 and x10 and a macro x4). Spectra were excited using the 632.8 nm emission line of a He–Ne laser at a power of 2 mW. The microscope is used to focus the laser beam on the sample and also to collect the scattered radiation. A highly sensitive CCD camera is used to collect the Raman spectra.

The use of this equipment in the Centre of Geology of Porto University for forensic problems is mainly related to mineral identification and characterization, gemstones and pigment identification, the characterization of the carbon component in writing inks, and the identification of rock fragments and components of soils, among some other problems. Samples can be measure without extraction and contact, with high speed of analysis and preventing sample contamination. The equipment allows an analysis of the chosen spot, which can be as small as 2μm.

This research Centre has been developing and implementing analytical protocols for the identification and characterization of different geological materials and databases to be applied in judicial situations related to different types of crimes. Therefore gemstones, minerals, rock fragments, pigments applied in sculptures and paintings and types of writing inks are being studied in order to organize databases of geomaterials that are more frequently used in Portugal, following procedures developed by other researchers and that can be found in the literature.