



# Centre for Australian Forensic Soil Science Information Brochure

## The Issue and background

Forensic and environmental agencies in Australia do not have the capability to establish and maintain the expertise and infrastructure in soils and analytical soil science due to the focus on molecular forensic techniques (DNA testing). Hence, valuable evidence was often not collected and/or analysed, and new techniques in soil forensics were not deployed. At the request of the Australian forensic community, scientists in CSIRO Land and Water established the Centre for Australian Forensic Soil Science (CAFSS, see <http://www.clw.csiro.au/cafss/>) in 2003. The primary purpose of the Centre was to develop new techniques in soil forensics and expert input to the Australian and International forensic communities. These communities also include environmental agencies and regulators, where sources and fate of contaminants in the environment could also be assessed using advanced analytical techniques.

The CAFSS is the first formal worldwide network of soil and forensic scientists. It combines research, training and services in soil forensics to combat crime, terrorism and environmental pollution. CAFSS has been actively involved in soils forensic work, assisting police forces, government agencies and non-government organisations with the search, location and recovery of soil and mineral samples from crime and environmental disaster scenes in Australia and overseas.

Personnel include highly experienced soil science specialists in the interpretation of soil profiles, mineralogy, chemistry, biology, molecular diagnostics, geophysics as well as soil maps and topographic survey.

## Purpose and Aims of CAFSS

- To promote efficient and effective use of resources, by establishing the first formal worldwide network of soil and forensic scientists that will maintain a critical mass of research expertise in soil forensics to fight crime, terrorism and environmental pollution.
- To promote science excellence and co-operation with stakeholders by conducting research, training and communicating results and analysis techniques to forensic scientists in Australia and internationally.
- To develop new criminal and environmental forensic techniques for soils, sediments and waters (e.g. advanced X-ray diffraction, spectroscopic and isotopic methods)
- To promote confidence in forensic soil science by providing a direct service for specific or “high end” criminalistic and environmental forensic cases.
- To provide leadership and best management practice in forensic soil science.

## Partners

CAFSS is a partnership between:

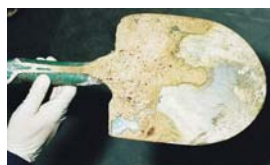
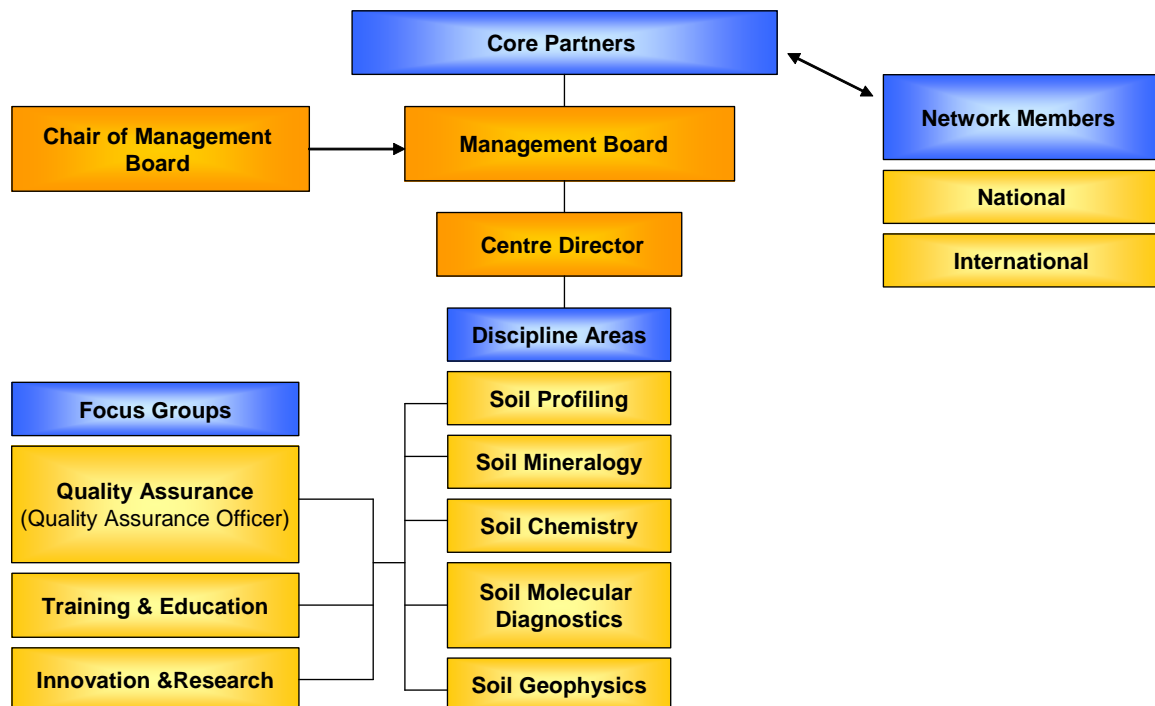
CSIRO, Flinders University, Forensic Science South Australia, The University of Adelaide, The National Institute of Forensic Science (NIFS), The Chemistry Centre Western Australia, The University of South Australia (Ian Wark Research Institute) Australian Federal Police (AFP) and The University of Canberra (Core Partners).

CAFSS is administered by CSIRO Land and Water in Adelaide, South Australia.



The Centre also incorporates network members from state, territory, and Australian federal government organisations and agencies, universities, police and international forensic science agencies. Also included are organisations such as Senior Managers Australia, New Zealand Forensic Laboratories (SMANZFL) and private industries.

The Centre has a Management Board, which confirms and monitors strategic directions and ensures that the forensic soil science activities (focus groups concerned with quality assurance, innovation & research, and education & training) are performed in a financially sound manner with due regard for the relative merits of various national and international soil/forensic-related network members.



### Contacts for further information

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**Photograph:** From CSIRO Land and Water, Pedology photography set.  
 Description: Detailed analysis of soil on the back of this shovel was used to help solve a homicide case.  
 Photographer: Rob Fitzpatrick © 2004CSIRO

### Areas in which CAFSS has taken a leading role

- Acting as a hub to connect the diverse range of individuals in Earth science forensics (e.g. forensic soil science, forensic geology and forensic archaeology specialists) investing in forensic science. Facilitating collaboration and stimulating intellectual activity and debate across the wide range of disciplines in Earth Science.
- Identifying new areas of forensic soil science and geology research; and facilitating timely and novel research projects.
- Specialised soil analyses for Australian (state, territory and federal) and international police forces and related forensic science and environmental agencies.
- Employed appropriate soil science techniques to assist in the search, location and recovery of soil and mineral samples from crime and/or disaster scenes in Australia or overseas.
- Counter terrorism activities through the deployment of new soil technologies.
- Assisted DSTO and forensic archaeologists with work on detection of near surface buried targets such as land mines, unexploded ordnance and graves.
- Enhancing the academic, public and policy impact of research and expertise on forensic soil science nationally and internationally (organised the 1st International Conference on Criminal and Environmental Soil Forensics - see below).
- Facilitate the transfer of expertise from international soil and forensic scientists to Australian researchers and industries in order to increase our national competitiveness in emerging technologies.
- Establish and contribute to collaborative research projects and focus groups (e.g. quality assurance) with these organisations.
- Produce new information about world and Australian soil properties and apply it in cutting-edge and internationally collaborative forensic research projects involving the following five discipline areas of soil science:
  - **Soil profiling:** analysis and interpretation of topography, aerial photographs and soil maps; field description of soils; collection, processing and analysis of soils from crime scenes.
  - **Soil mineralogy:** light microscopy, X-ray diffraction (XRD), X-ray Spectroscopy (XRF), Nuclear Magnetic Resonance (NMR), Electron Microscopy (SEM, TEM); Refractive index and birefringence measurements of samples to determine material source.
  - **Soil chemistry:** geochemical and physical analyses; spectroscopy (UV/visible/Diffuse Reflectance Infrared Fourier Transform, ICP-MS).
  - **Soil biology / molecular diagnosis:** soil organic matter, diatoms, pollen, DNA profiling of soil.
  - **Soil geophysics:** Magnetic Susceptibility, electromagnetic induction (EM 38 and 31), ground penetrating radar (GPR).
- Conduct workshops, seminars and training courses on soils for police, other institutional professionals and undergraduates.
- Write or contribute to major review and journal papers; encyclopaedia and book chapters.
- Provide opportunities for postgraduate students to undertake research projects related directly or indirectly to questions posed by clients.

## Research and service role

CAFSS undertakes specialised soil analyses work for a wide range of clients, including:

- Australian and international police forces
- forensic science and environmental agencies
- major public utilities
- private companies and private individuals.

The Centre also conducts research within all the main disciplines of soil science.

Many of its staff are at the fore-front of their subject areas, and are active in the development of new areas of research and methodology, including the production of new information about Australia's unique soil properties. They are applying their new methodologies in national and international collaborative forensic research projects.

CAFSS also offers a comprehensive range of advanced soil science services. Our expertise is available at every stage in the forensic planning process, from initial broad/regional assessments to targeted soil surveys and detailed field/laboratory investigations.

Our expertise spans the following disciplines:

- Soil profiling, which includes:
  - collection of soil samples from scenes of crime,
  - sample storage security and secure sealing of samples (development of protocols for continuity of evidence or soil sample chain-of-custody [Guidelines for Conducting Criminal and Environmental Soil Forensic Investigations by Fitzpatrick and Raven (2011)])
  - analysis and interpretation of topography, aerial photographs and soil maps
  - processing and analysis of soils from scenes of crime and associated objects
  - colour photography of samples (Ortery Photosimile light box)
  - morphological descriptions soils and interpretation
- Soil mineralogy, which includes:
  - light microscopy
  - X-ray diffraction (XRD) – micro-x-ray diffraction systems with a fine (sub-millimetre) X-ray beam using both “traditional” and “synchrotron” XRD systems
  - X-ray spectroscopy (XRF)
  - electron microscopy
  - nuclear magnetic resonance
  - refractive index and birefringence measurements
- Soil chemistry, which includes:
  - geochemical and physical analysis of samples to determine material source
  - spectroscopy (for example, UV/visible/diffuse reflectance infrared fourier transform spectral analysis/Raman)
  - ICP-MS
  - chromatography
  - electrophoresis
  - cathodoluminescence
  - mass spectrometry.
  - stable isotopes
- Soil biology and molecular diagnosis, which includes:
  - soil organic matter
  - diatoms
  - pollen
  - DNA profiling of soils
- Soil geophysics, which includes:
  - magnetic susceptibility
  - electromagnetics (EM 38 and 31)
  - ground penetrating radar
  - geophysical surveys.

## **Methods and Approaches: successful case investigations**

CAFSS has developed and applied a new systematic approach to discriminate soils using advanced soil morphology (e.g. colour, organic matter, pollen, diatoms), mineralogy, geochemistry (spectroscopy, magnetic susceptibility analyses) and wet chemical techniques. New rapid spectroscopic methods, coupled with chemometrics, are being developed to rapidly screen and compare crime scene samples.

CAFSS has dealt with more than 85 investigations and inquiries over the past 5 years. Some examples include:

- Expert evidence from CAFSS soil investigations has been used in over ten murder and rape cases that have been tried before State Supreme Courts. Soil evidence has been crucial in all cases. All of these investigations have relied heavily upon existing knowledge of soils and geology developed by CAFSS. In particular, most of these investigations have utilised pedological and mineralogical interpretations.
- Our current investigation, in which CAFSS has made major breakthroughs involves a highly sensitive murder case where no human DNA can be used. These breakthroughs were the result of new micro-x-ray diffraction methods and approaches being developed specifically for this case by Mark Raven, Rob Fitzpatrick and Peter Self. These new methods and approaches, which also include using X-ray diffraction (XRD) analyses at the Australian Synchrotron in Melbourne will have wide ranging applications in not only future soil forensic cases but also in several environmental earth science projects.

The following selection of criminal and environmental forensic case investigations demonstrate how we have successfully used soil properties to both discriminate between and compare soils for critical evidence.

- Solving a double murder case by identifying the similarities between mineral assemblages in soils on a shovel and also from a quarry. The soils had a common provenance and revealed the location of two buried bodies.
- Identifying the locality of stolen ferns from a conservation park.
- Identifying provenance of soil removed from a site containing aboriginal artifacts.
- Sexual assault and kidnapping cases in which comparisons were made between soil minerals on clothing and vehicles, with samples from the crime scenes.
- Identifying the provenance of an industrial dust settling on parked vehicles. The mineralogy of these dusts identified them as coming from a cement works.
- Identifying the possible overseas and/or Australian provenance of soil on boots, rakes, shovels and mattocks belonging to suspected terrorists.
- Comparing dinosaur nest, soil-like materials from imported samples and samples provided by Australian museums sourced from Henan Province, China.

## **Successful research funding and other proposals**

We have been invited to plan, develop and supply interactive exhibits for visitors and the public to view how soil information can be used to interpret soil evidence to solve a crime for the following institutions: Smithsonian Museum of Natural History in Washington DC, ISRIC – World Soil Information, Netherlands, CSIRO Land and Water, CSIRO Science Centre in Adelaide and Forensic Science SA. Several novel ideas are being developed – based on several murder case investigations conducted by CAFSS in Australia.

We are partners in the following newly developed international projects, working groups and Associations:

- The international “Geo-Forensic Network project (GIMI)”, coordinated by The Macaulay Institute, Scotland, funded by EPSRC, to undertake an evaluation of the needs and options for non-invasive methods for measurement and interpretation of physical

information to detect the presence and shape of foreign bodies/objectives in soils.

- The Australian Centre for Ancient DNA (ACAD), for the development and application of specialist equipment, which can potentially be used in forensic soil science for new functional molecular biology techniques.
- The Working Group on Forensic Geology (WGFG), which was set up in 2009 as part of the International Union of Geological Sciences (IUGS), Commission for Geoenvironmental Management (GEM).
- International Association of Forensic Geology (IAFG) (in 2011 Dr Laurence Donnelly, UK appointed Chair and Professor Fitzpatrick appointed Vice Chair)

### **1<sup>st</sup> International Workshop on Criminal and Environmental Soil Forensics**

While the advances described above have set new benchmarks in forensic soil science, CAFSS believed the future will require still better understanding and linking of soil science, geology, geophysics, mineralogy, chemistry and molecular biology information because these techniques will have a major future role to play in forensic searching- either to locate buried anomalies, blast residue or eliminate areas from searches.

To this end CAFSS conceived, developed and organized the “First International Workshop on Criminal and Environmental Soil Forensics”, which followed the “18th International Symposium on the Forensic Sciences: Classroom to Courtroom” in April 2006. The final program and book of abstracts can be found on the workshop website at <http://www.clw.csiro.au/cafss/workshop.html>

The workshop was sponsored by the "Frontiers of Science & Technology Mission and Workshop component of the International Science Linkages Programme", CSIRO Land and Water, Chemistry Centre WA (CCWA) and the Co-operative Centre for Landscape Environments and Mineral Exploration (CRC LEME).

Scientists from the United States, Scotland, England, New Zealand, Canada, China, Italy and across Australia presented a variety of engaging overviews of established techniques of soil characterisation and comparison and case studies related to areas such as soil profiling, molecular diagnostics, environmental chemistry, grave excavation and taphonomy (the study of the fate of remains of organisms after they die). The workshop style also promoted in-depth discussion and cross-fertilisation of ideas with Australian and International researchers, consultants and students with field and laboratory expertise in employing appropriate techniques to assist in the search, location and recovery of soil and mineral samples from crime, disaster or environmental pollution. The following issues and key areas were identified for the future of forensic soil science:

- Need for increased collaboration and communication between research groups in different countries. There needs to be a willingness to share ideas and methods to ensure that any new techniques that we may adopt are the best and most robust. As well as ensuring that we don't re-invent the wheel, collaboration is important when methods reach the 'forensic validation' stage (e.g. recent DNA profiling/fingerprinting T-RFLP method developed by the research group at ESR Ltd, New Zealand). An openness to share methodology and results means that a very thorough forensics validation (and trials between different labs) will be possible and this is vital before any forensic molecular DNA analysis is used in court.
- The growing focus on security related issues and counter terrorism is one of the most significant challenges facing soil forensics in the future. There is a paradigm shift from not only providing soil forensic information for 'evidence' but also for 'intelligence'.
- There is a need to establish a broader commonality between “Forensic geology” and “Forensic soil science”. Although in principle geology and soil science are closely related, there remains significant gaps in basic knowledge and lack of communication between these two disciplines. Major gaps are in the exceedingly limited amount of shared language. Particularly in the use of standard procedures and terms for describing and sampling soils (e.g. methodology for describing soil colour, consistence and texture developed by soil scientists over a period of more than a 100

years). The nature of soil databases and digital maps (GIS) requires consistent and correct use of terms. Finally, the word “source” in geology infers “geographic location of the original ore deposit for say Pb” whereas in soil or environmental sciences “source implies “type of material”, for example soil or paint containing say Pb.

- Continue to undertake 'high end case investigations' that require soil as evidence in criminal and environmental forensics.
- Publish results / case studies where soil properties have been used successfully to both discriminate between and match soils for critical evidence.
- Continue development of new and improved sampling and description methods.
- Continue to refine current methodologies and techniques for reliable identification of soil properties.
- Development of isotope and DNA profiling/fingerprinting techniques, which are scientifically and legally robust,
- Focus on education and training. Proposal to hold a second “Hands-on Forensic Soil Workshop” over five days in Adelaide (approach NIFS for joint ideas). A recent proposal is for CAFSS to run this as a summer school / honours course (approval has been granted by Flinders University and The University of Adelaide to run this as a joint venture)
- Development of field and laboratory protocols for criminal and environmental soil forensic investigations: work has commenced with the Australian Federal Police (AFP) and South Australian Police (SAPOL).
- Proposal to construct, test and validate a soil sampling kit for crime scene investigators. A prototype kit has been developed by CAFSS.
- Plans were made to hold the “Second International Workshop on Criminal and Environmental Soil Forensics” in Scotland. An organising committee chaired by Dr Lorna Dawson of “The international “Geo-Forensic Network project (GIMI)” at The Macaulay Institute, Scotland was established with assistance from the British Society of Soil Science and CAFSS.

## 2<sup>nd</sup> International Conference on Criminal and Environmental Soil Forensics

The 2nd International conference on Criminal and Environmental Soil Forensics was held at the James Watt Centre, Edinburgh Conference Centre, Edinburgh, United Kingdom, from 30th October – 1st November 2007. The conference was organised by the Macaulay Institute, Aberdeen Scotland and several staff from CAFSS were on the organising committee. [Conference website](#)

**Themes:** Environmental Soil Forensics, Criminal Soil Forensics, Geoforensics, Geographic Information Systems and Communications, Analytical Diagnostics, Application to case work.

**Aim** - This conference explored novel approaches in soil forensics. It provided an international focus for discussion of research and development in forensic soil science for the benefit of both environmental protection and criminal investigation. This is relevant to the high priority areas of environmental health and international terrorism.

**Audience** - The conference brought together key international researchers, police, forensic services and consultants.

**Publication of book** – A book entitled “Criminal and Environmental Soil Forensics” has been published by Springer Science+Business Media B.V. (Eds. K. Ritz, L. Dawson and D. Miller) ISBN: 978-1-4020-9203-9. Book website:

<http://www.springer.com/new+%26+forthcoming+titles+%28default%29/book/978-1-4020-9203-9?detailsPage=to>

## 3<sup>rd</sup> International Conference on Criminal and Environmental Soil Forensics

The 3rd International Conference on Criminal and Environmental Forensics was held from 2nd to 4th November, 2010 at Long Beach California. It was organised by Marianne Stam from the California Department of Justice, Riverside Crime Laboratory, Riverside, CA, 92509, USA Crime Laboratory. CAFSS was on the organising committee and presented one keynote and one oral paper (see publication list below).

## Recent Publications on Criminal and Environmental Soil Forensics

Fitzpatrick R.W. (2011) Getting the dirt: The value of soil in criminal investigations. *Gazette*, Vol. 73, No 1, pp. 22-23. A Royal Canadian Mounted Police Publication. <http://www.rcmp-grc.gc.ca/gazette/index-eng.htm>  
<http://www.rcmp-grc.gc.ca/gazette/vol73n1/esubmission-ereportage4-eng.htm>

Fitzpatrick R.W., and Raven M.D. (2011). Guidelines for Conducting Criminal and Environmental Soil Forensic Investigations: Version 2. Centre for Australian Forensic Soil Science. Report No. CAFSS\_076. 25th March 2011. 33pp.

Mark Raven, Rob W Fitzpatrick and Peter G. Self and (2011) Forensic Examination of Small Red Brick Fragments by Laboratory Source and Synchrotron XRD Techniques. Abstract – Poster paper. Australian X-ray Analytical Association 2011 Workshops, Conference, and Exhibition (AXAA 2011), 6 -11 February, 2011, Sydney, Australia, Star City. Proceedings (Program and Abstract Book). Abstract No PP036. <https://custom.cvent.com/A96F1FCE15164661A466B58D03796161/files/e67d916f7b574640b179c42b05183ff7.pdf>

Fitzpatrick R.W and Mark Raven (2010) Forensic Soil Science Support for Environmental Crime Investigations. 16<sup>th</sup> International Forensic Science Symposium, **INTERPOL** General Secretariat – Lyon, France 5-8 October 2010 Thematic session on “environmental crime” Forensic Soil Science Support for Environmental Crime Investigations. Published on DVD (Abstract and PowerPoint also available on: <http://www.clw.csiro.au/cafss/publications.html>)

Robert Fitzpatrick and Mark Raven (2010) Guidelines for Criminal and Environmental Soil Forensic Investigations. Abstract – Invited Plenary Address. **Third International Conference on Criminal and Environmental Soil Forensics** 2<sup>nd</sup> November, 2010. Long Beach California. p. 61319. <http://a-c-s.confex.com/crops/2010am/webprogram/Paper61319.html>

Mark Raven, Pamela A Smith, Peter G. Self, Rob W Fitzpatrick and Soren Blau (2010) Soil forensic investigations of frontier conflict sites in far north-western Australia using advanced XRD techniques. Abstract – Oral paper. **Third International Conference on Criminal and Environmental Soil Forensics**. 3<sup>rd</sup> November, 2010. Long Beach California. p. 63321. <http://a-c-s.confex.com/crops/2010am/webprogram/Paper63321.html>

Robert Fitzpatrick (2010) The Role of Pedotechnology in Solving Forensic and Drought Induced Soil Problems. Abstracts – Invited keynote paper. 2010 International Annual Meetings of the Soil Science Society of America. Symposium - Applying Soil Chemistry to Solve Soil Problems in the "Milky Way": Honoring the Impact of Malcolm Edward Sumner. October 31 to November 4, 2010. Long Beach California. p97-6. <http://a-c-s.confex.com/crops/2010am/webprogram/Paper57512.html>

Fitzpatrick RW (2009) Soil: Forensic Analysis. In **Wiley Encyclopedia of Forensic Science** (Editors-In-Chief: A Jamieson and A Moenssens). John Wiley & Sons, Ltd., The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom. 2377 – 2388. (see attached reprint)

Fitzpatrick R.W., M.D. Raven and S.T. Forrester (2009) A Systematic Approach to Soil Forensics: Criminal Case Studies Involving Transference from Crime Scene to Forensic Evidence. In *Criminal and Environmental Soil Forensics* (Eds. K. Ritz, L. Dawson, D. Miller) pp. 105-127. Springer Science+Business Media B.V.

Fitzpatrick, R.W. (2008). Nature, distribution and origin of soil materials in the forensic comparison of soils. In: *Soil analysis in forensic taphonomy: chemical and biological effects of buried human remains* (Eds. M. Tibbett and D.O. Carter). pp. 1-28. CRC Press, Boca Raton, FL.