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Soil examination for a forensic trace evidence laboratory–Part 3: A proposed protocol for the effective triage and management of soil examinations

Brenda Woods [a,b,*], Chris Lennard [c], K. Paul Kirkbride [d], James Robertson [b]

[a] Chemical Criminalistics Team, Forensics, Australian Federal Police, Canberra ACT, Australia
[b] National Centre for Forensic Studies, University of Canberra, Canberra ACT, Australia
[c] School of Science and Health, University of Western Sydney, Richmond NSW, Australia
[d] School of Chemical and Physical Sciences, Flinders University, Adelaide SA, Australia

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ABSTRACT

In the past, forensic soil examination was a routine aspect of forensic trace evidence examinations. The apparent need for soil examinations then went through a period of decline and with it the capability of many forensic laboratories to carry out soil examinations. In more recent years, interest in soil examinations has been renewed due–at least in part–to soil examinations contributing to some high profile investigations. However, much of this renewed interest has been in organisations with a primary interest in soil and geology rather than forensic science.

We argue the need to reinstate soil examinations as a trace evidence sub-discipline within forensic science laboratories and present a pathway to support this aim. An examination procedure is proposed that includes: (i) appropriate sample collection and storage by qualified crime scene examiners; (ii) exclusionary soil examinations by trace evidence scientists within a forensic science laboratory; (iii) inclusionary soil examinations by trace evidence scientists within a forensic science laboratory; and (iv) higher-level examination of soils by specialist soil scientists and palynologists. Soil examinations conducted by trace evidence scientists will be facilitated if the examinations are conducted using the instrumentation routinely used by these examiners. Hence, the proposed examination protocol incorporates instrumentation in routine use in a forensic trace evidence laboratory. Finally, we report on an Australian soil scene variability study and a blind trial that demonstrate the utility of the proposed protocol for the effective triage and management of soil samples by forensic laboratories.

1. Introduction

Previous papers in this series [1,2] have considered how the examination of soils in a forensic context can contribute to the investigation of alleged criminal events by the provision of intelligence that may inform the direction of an investigation. The related scientific findings may provide an association between a suspect, victim or an object with a particular scene or indicate that such an association is not supported.

Whilst not all will agree, we would argue that along with an overall decline in the use of trace evidence in general, there has been an even greater reduction in the number of forensic laboratories that conduct forensic examinations of soil. More recently, however, there has been a welcomed renewed interest in the use of soil examinations, with some contributing to the investigation of serious crime around the world [3–9]. Certainly, specialist geologists and/or soil scientists are to be found in some operational forensic laboratories but much of this increased interest involves individuals or groups working in parent organisations whose core business is geology or soil science and not forensic science. Without doubt, this engagement has benefitted forensic science with several recent books on the subject [10–13] and a renewed focus on this evidence type through international groups such as the International Union of Geological Sciences Initiative on Forensic Geology (IUGS-IFG). Unfortunately, in many instances, operational forensic laboratories no longer have the skill set and knowledge to contribute to the analysis of soil samples. Hence, in the main, soil examinations are performed by soil scientists from outside the mainstream forensic science sector. These scientists may be experienced geoscientists, but they are not

* Corresponding author. Tel.: +61 262036178.
E-mail address: brenda.woods@afp.gov.au (B. Woods).

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primarily concerned with the specific requirements of multi-disciplinary scientific analyses for court purposes, including an awareness of biological material, fingerprints and other relevant forms of trace evidence. Further, these laboratories are not usually accredited for forensic science testing [14].

One of the major challenges facing scientists working in a non-forensic science facility is translating methods and approaches developed for examining and analysing samples they typically encounter to dealing with the types of specimens typically submitted for forensic science work. One aspect of the latter is the often very limited specimen size encountered in forensic work; however, it is more complex than simply limitations imposed by specimen size. Soil scientists will typically be able to select their own samples and work under relatively controlled circumstances and environments. The latter is far from the situation facing the forensic science examiner who will usually be faced with a soil specimen that may not accurately represent material at the crime scene due to issues of transfer and persistence [15] or simply a lack of experience in appropriate sampling.

As a consequence of the renewed interest in soil examination, investigators are now more aware of the potential value of soil as evidence. In turn, this has led to more requests for soil examinations. With soil science experts being a scarce resource, there is pressure on operational forensic laboratories in terms of how they respond to requests for soil examinations. One solution to relieve this 'pressure point' would be for operational forensic laboratories to re-instate some level of capability to examine soils, particularly with respect to the preliminary screening of samples.

On the other hand, one significant challenge facing scientists working in forensic science facilities is that the analytical methodology available to them has been acquired to facilitate examination of typical trace evidence such as textile fibres, paint and gunshot residues. As a consequence, typical laboratories are equipped with infrared microspectrometers, scanning electron microscopes equipped with energy-dispersive X-ray spectrometers but do not have the capability to carry out genetic profiling of soil micro-organisms, X-ray diffraction or high-end electron microscopes capable of quantitative evaluation of mineral particles.

Clearly a partnership approach is required in order to exploit the strengths of specialist soil examiners and specialist trace evidence examiners with a view to re-establishing soil comparison as a value trace evidence type. A partnership approach will withstand an increase in demand for case examinations–both serious and volume crime cases–that inevitably will follow if forensic soil examination gains greater prominence.

Forensic laboratories are increasingly expected to be able to provide quick advice to investigators and this has led to business re-engineering with an enhanced focus on evidence triage, forensic intelligence and early case management. Hence, in this paper, an operational protocol for soil evidence triage is described using standard analytical instrumentation commonly employed in a trace evidence laboratory. Using an Australian soil set, significant levels of discrimination were achieved by the examination of soils using a combination of colour measurement, analysis of organic and inorganic content, and elemental profiling. In order to further validate this approach for casework application, the results of an Australian soil scene variability study and a blind trial are reported.

Finally, a soil examination protocol that utilises the skill set of crime scene examiners, trace evidence scientists and specialist soil scientists is presented. A four-stage approach is recommended that would see a continued increase in the use of soils as forensic evidence and a re-emergence of soils as a material of interest to chemical criminalists.

2. Materials and methods

For the scene variability study and the blind trial samples, colour measurement was performed using microspectrophotometry (MSP), organic and inorganic content using attenuated total reflectance Fourier transform infra-red spectroscopy (ATR-FTIR), and elemental composition using X-ray fluorescence spectroscopy (XRF). The elemental composition of the blind trial samples were further examined using scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM-EDX) and laser induced breakdown spectroscopy (LIBS). The details of the soil treatment, involving dry sieving and the analysis of the $<38\ \mu m$ sieve fraction using the instrumental methods MSP, ATR-FTIR, XRF, SEM-EDX and LIBS, were previously reported by Woods et al. [1,2].

3. Scene variability study

A scenario based scene variability study was conducted in the Canberra area to test the practical use of the suggested instrumental examination procedure for the analysis of forensic soil samples in Australia. The scenario involved an incident occurring at scene 1. A person of interest denied ever going to scene 1 but had been at scene 2. Three pairs of shoes and three shovels all with soil attached were collected from the person of interest's house.

At scene 1 and 2 a standard sample collection scheme was utilised for the collection of the know soil samples by establishing a five metre by five metre square grid with 9 sampling locations employed within this grid. Additional known soil samples were collected from scene 1 (three samples) and scene 2 (two samples) along a path leading to the sampling site. At each collection position, the surface debris and leaf litter were removed then the surface soil (0–5 cm depth) collected. The collected known soil samples were not combined. Table 1 presents the details for the soil sites used in this study.

Two new identical shovels were used for the known soil sample collection at scene 1 and 2. Two new identical pairs of sneakers were worn whilst walking along the paths to the known soil collection sites and during the soil collection process at scene 1 and 2. At scene 3, a small hole was dug to dirty a third identical shovel and a third identical pair of shoes was worn during this process. No reference soil was collected from scene 3. The shoes and shovel used at scene 3 were collected to ensure the study included some samples that did not originate from a known reference, thereby making a blind study. After sample collection, the shoes and shovels were placed into individual brown paper bags and labelled with the soil site number. In the laboratory, the shoes and shovels

Table 1
Scene variability sample collection site details.

Soil Scene	Area	Latitude/Longitude	Landscape
Scene 1	Mount Ainslie	35°16′09″S/ 149°09′50″E	Large, steep slope with native dense bushland vegetation and an established walking trail
Scene 2	Pialligo	35°18′57″S/ 149°10′59″E	Flat, cleared land with grasses
Scene 3	Black Mountain	35°17′11″S/ 149°04′51″E	Crushed granite walking trail