Clay mineralogy as significant evidence in 4 murder investigations involving a wide range of earth materials from Perth, Adelaide, Melbourne and Sydney

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Abstract
Through 4 completed case studies involving 1 attempt of murder, 1 cold murder (19 years ago) and 2 contemporary murder investigations (past 5 years), this paper will demonstrate how detailed pedological and mineralogical investigations, especially using X-ray diffraction (XRD), have been critical in developing reliable soil information, from landscape to microscopic scales, to help in forensic investigations, which were used as evidence in Australian State Supreme courts. A wide range of natural soil types (sandy coastal dunes, sandy swamps and clayey colluvium) and human-made soil types (comprising road, brick and bone fragment materials) across Australia were used in these forensic investigations to associate materials taken from questioned items, such as shoes, clothing, shovels or vehicles, with a specific control location or the crime scene. To illustrate the power of soil analysis in criminal investigations it is beneficial to share successful case examples to demonstrate the potential value of this somewhat underutilized forensic tool. The significance of using forensic soil science can be highlighted by discussing a range of case studies. Here we will discuss how pedological and clay mineralogy expertise has been used to solve both historical (cold) and recent criminal cases.

Keywords: Forensic science, soil science, clay mineralogy, X-ray diffraction

Introduction

Earth materials such as soils, rocks, minerals and human-made mineral particles like bricks provide excellent evidence to link criminals to crime scenes. Forensic earth scientists such as soil scientists and geologists are now also using advanced automated techniques, which have the ability to acquire information from smaller samples to make earth forensics an increasingly popular tool in criminal investigations. The aim of soil forensic analysis is to associate soil, rock or mineral samples taken from questioned items, such as shoes, clothing, shovels or vehicles, with a specific control location or the crime scene. Earth materials are powerful, perhaps ideal, pieces of contact trace evidence to help in criminal investigations (Fitzpatrick, 2013a,b; Fitzpatrick and Raven 2012). When examining soil evidence, there is a range of stages involving screening soil tests that help provide pieces of a puzzle and then more detailed tests that provide definitive answers (Fitzpatrick and Raven 2012; 2013). With enough puzzle pieces a picture starts to form as indicated in the 6 case studies / murder investigations, which are briefly summarised in this paper. This paper will demonstrate how field, laboratory and synchrotron approaches, especially X-ray diffraction (XRD) have been critical in developing predictive, soil-regolith models, from microscopic to landscape scales, to solve soil-based criminal investigations.

Methods

Comparing soils is no easy task, especially if the questioned samples are very small submillimetre particles (<0.5mm diameter) with the amount of material weighing less than a milligram. In addition, forensic materials may contain trace amounts of mineral particles, such as: (i) rutile or anatase within small paint or plastic flecks, (ii) polycrystalline minerals, cristobalite and mullite such as in small brick or burnt regolith particles and (iii) poorly-crystalline hydroxylapatite and well-crystalline hydroxylapatite in unburnt and burnt small bone fragments respectively.

Traditional X-ray diffraction (XRD) techniques using low-background Si wafer holders are useful for measuring XRD patterns from samples with weights as low as several milligrams. However, these techniques are generally too insensitive to measure XRD patterns from samples weighing less than a milligram or comprising submillimetre particles. The mineralogy of small fragments (<0.5mm) can be determined with micro-XRD techniques using fine (submillimetre) monocapillary attachments on laboratory XRD instruments. While these instruments are adequate for determining dominant components, synchrotron XRD with high X-ray intensity provides far greater sensitivity and resolution than laboratory source XRD systems. This enables identification of minute amounts of mineral components.

Case studies

Case Study 1: **Body in Clayey Wetland (Cold Case) – New South Wales**

The body of a drowned teenage girl was located by police in a wetland in 1988 but no suitable soil samples were analyzed. A suspect's tracksuit pants (Figure 1) and shoes, which were kept by police since 1988, were re-examined by forensic soil scientists in 2005 (17 years later) to showed traces of grey and yellowish clayey soil. These soil traces were removed and characterized. Samples of clayey grey soil from within the wetland and yellowish soil on the fringe were sampled in 2005. The morphology and mineralogy from XRD analyses (Figure 1) of the two control samples taken from the suspects clothing were similar to the two samples from the wetland area – despite being sampled 17 years later. The soil and clay mineralogy evidence gathered indicated that the suspect had been present at the site where the victim drowned.

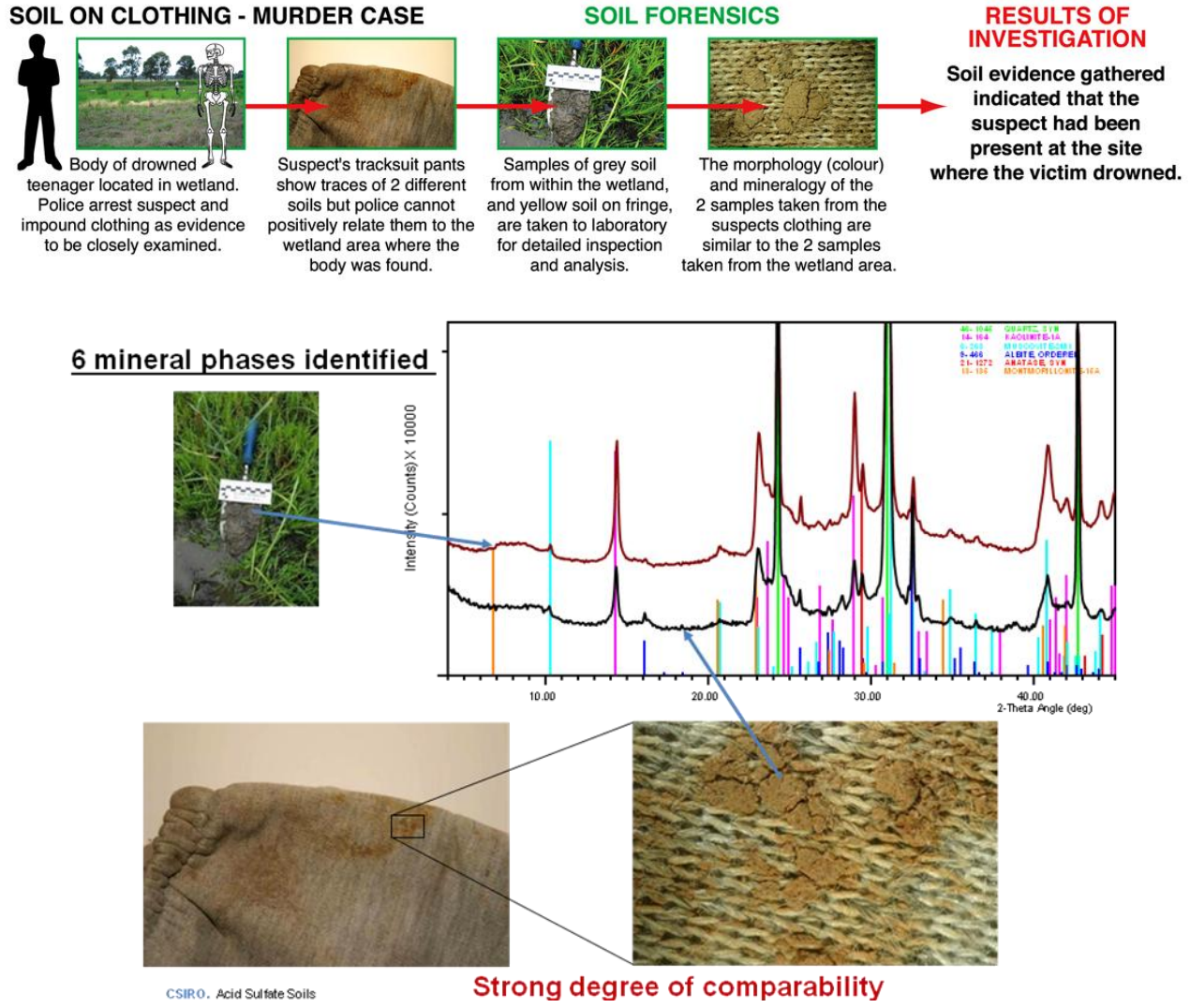

Figure 1. Summary of the "body in clayey wetland cold murder case" in Sydney, New South Wales

Case Study 2: **Body on Sandy Beach – South Australia and Victoria**

A teenage body was located in shallow water on a beach (crime scene) in South Australia. Police located shoes from two suspects on a beach in Victoria, which is approximately 1000 km from the crime scene. The morphology (colour, size, and shape) of the sand grains and mineralogy of shell fragments from XRD analyses (aragonite, calcite, Mg-substituted calcite, goethite and quartz) of the samples taken from within the shoes of both suspects were similar to beach samples at the crime scene in SA. Equally, they do not resemble the sand samples collected from the beach in Victoria where the shoes were retrieved by police, clearly confirming both suspects were present at the crime scene. A man is found guilty of murder by a jury and sentenced to life imprisonment.

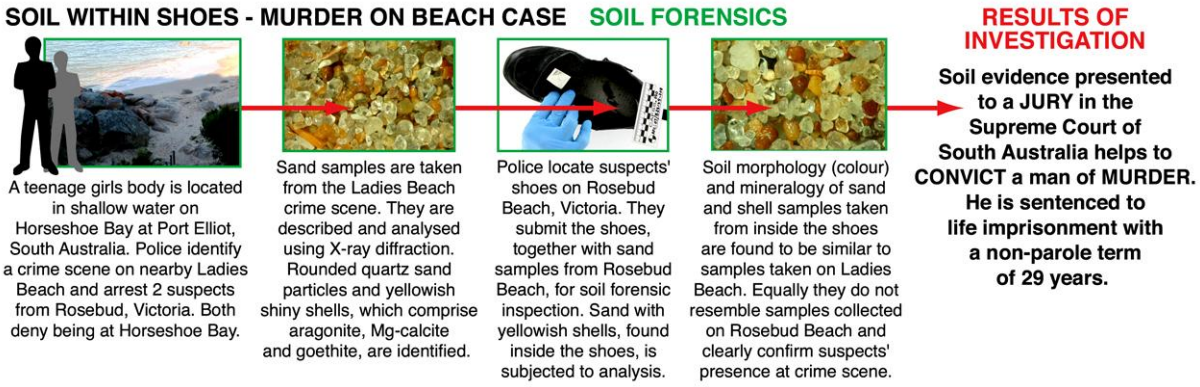

Figure 2. Summary of the "Body on sandy beach murder case, South Australia and Victoria

Case Study 3: **Clay soils on shoes: Attempted murder and kidnapping: Victoria**

XRD analysis (i.e. arguably the most significant for identification, characterization, semi-quantitative and quantitative analyses of minerals in soils) provided mineralogical information on the nature and amount of the minerals: (i) located in the treads of the suspect's shoes, which had been washed in a washing machine (Figure 3), (ii) the known soils at the crime scene and (iii) from the victims clothing/shoes (Figure 3). All samples contained quartz, andesine/anorthite, mica, kaolin, smectite, hematite, pyroxene (augite), ilmenite and anatase in similar amounts (Fitzpatrick and Raven 2010). However, six (6) of the seven (7) samples did not contain dolomite and the 7th sample (CAFSS 056.4: runners -item 21) contained only a trace amount of dolomite (probably accumulated on the runners from a previous and/or subsequent activity).

In summary, the directed sampling of clayey soil in the wet area of the crime scene where there was an attempted murder (stabbing and drowning), followed by definitive soil characterization using X-ray diffraction, indicated that the soil morphology and clay mineralogy to determine the major similarities and differences between samples. Consequently, it was established that there was a "very strong degree of comparability" of the soil materials from the clothing (three samples) and shoes (three samples) with the soil sample from the crime scene, confirming all suspects were present at the crime scene. Two persons were found guilty of attempted murder and kidnapping by a jury.

Figure 3. Summary of the "attempted murder and kidnapping case, Victoria" showing the suspect shoes with small amount of soil (after washing) and Victim shoes with large amount of soil from wet area adjacent to river

Case Study 4: **Small brick fragment on clothing: Rayney Murder case – Perth**

This case represents the first successful development and application of a new advanced laboratory source and synchrotron XRD technique to identify and quantify the mineralogy of polycrystalline minerals (e.g. cristobalite and mullite) in soils and small submillimetre brick particles (<0.5mm diameter) on questioned clothing (bra), hair and seed pods in the Rayney homicide case in Perth to establish the origin of the small submillimetre brick particles (Fitzpatrick Fitzpatrick, Raven and Self 2011). The CAFSS report and

presentations/cross examination in the Perth Supreme court provided a "predictive, soil-regolith model, from microscopic to landscape scale", which established that soil and brick particles/fragments found on the victims bra and hair (via two seed pods) originated from the front yard of the victims home at Como in Perth. The Judge (Justice Martin) agreed with this assessment, as indicated in the following 2 paragraphs of his 369 page report: "**Para 971 -** At the suggestion of both counsel, Professor Fitzpatrick and Mr Raven gave their evidence concurrently. They were impressive witnesses who were careful in staying within their areas of expertise. **Para 1136 -** In broad summary, the soil and artefacts recovered from the deceased and her clothing provide a significant link between the deceased and the home at Como."

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