Chapter 17
The Application of Forensic Soil Science in Case Work and Legal Considerations

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Abstract Forensic soil science is now an accepted discipline in many nations worldwide such as the UK, the Netherlands, Germany, Australia, Russia, Italy, Japan and the USA. Other nations are adopting the approach suitable for their own types of soils, crimes and land cover. There are a range of methods which can be used, with new methods being researched, developed and tested all the time. This chapter will not discuss the specific analytical methods used but instead outlines suggested strategies for examination and analysis and the presentation and communication of these results in court. The methods adopted for analysis in case work will often depend on the case in question, the examiner, the soil type and the individual country and legal system involved. Forensic soil science application can in general be divided into two main areas: (1) for intelligence gathering, such as providing information on search and narrowing down areas of interest, or in crime reconstruction and (2) for trace evidence comparison, evidence provision, evaluation of data and presentation in court. As the area of forensic soil science is relatively well established, this chapter concentrates on legal aspects of the use, acceptance and application of new methods, particularly acceptance and admissibility in court.

17.1 Introduction

Forensic soil science has developed over a long period of time, beginning in Roman times when people used the soil information on the hooves of their enemies' horses to tell from where the enemies had travelled. Techniques and approaches have advanced considerably since that time, although the same general principles remain. This chapter focuses on the current situation in the UK, although forensic soil science is used to good effect in many countries worldwide, including Russia, Japan, USA, Australia, Spain, Germany, the Netherlands and Italy. In some other nations (such as

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in Brazil, Argentina, Belize, China and India, for example) this science is currently under development. Forensic soil science application in the United Kingdom can be divided into two main areas: (1) for intelligence gathering, such as informing on search, or in crime reconstruction and (2) for trace evidence comparison, evidence provision, evaluation and presentation in court. As the area of forensic soil science is relatively well established, this paper concentrates on legal aspects of the use and application of new methods, particularly in court.

Any forensic soil scientist engaged by Law Enforcement or forensic agencies to carry out work should be aware that they may be required to report on their findings and ultimately could be required to present their findings in court. Forensic means relating to or denoting the application of scientific methods and techniques to the investigation of crime/relating to Courts of law [1]. The position with regard to expert witness reporting, court evidence (testimony) and some of the main legal evidential questions, which are likely to affect soil and wider geoforensic evidence, are discussed in this chapter. This chapter will focus on the legal system operating in England and Wales, albeit many of the general principles are applicable worldwide.

Each country has its own unique legal system, developed over centuries, reflective of the political, cultural and historical development of that individual country. Even between countries with very similar legal systems, the precise rules around the leading of evidence will be (although often marginally) different. Forensic soil science evidence can feature in a criminal case in any jurisdiction. It is critical therefore that any method or new approach is developed, interpreted and presented in such a way that it can withstand judicial skepticism and challenges from lawyers, even in the toughest of legal environments.

One of the most challenging environments for any expert evidence is the common law court with its adversarial procedures, such as is in the UK, comprising three separate jurisdictions: England and Wales; Scotland and Northern Ireland. Less challenging are the courts in the inquisitorial regimes. If the evidence can survive in the adversarial system, it is unlikely to encounter difficulty in the inquisitorial arena. Criminal cases of a serious nature are held in front of a jury in the UK, and so experts must be able to communicate their science in a clear manner to legal experts and to the general public (juries). In the UK, expert witnesses may also be appointed by defence counsel to challenge the expert opinions provided on behalf of the prosecution.

Expert work carried out for the court is commissioned by the prosecution or defence or in some cases by the Criminal Cases Review Commission (CCRC). The role of the expert (whichever scientific discipline they are from) is to assist the court in understanding the evidence that they present. The prosecution authorities in the UK (all working in line with the common law tradition) are: England and Wales—the Crown Prosecution Service (CPS), Northern Ireland—the Public Prosecution Service (PPS) and Scotland—the Crown Office and the Procurator Fiscal Services (COPFS).

Standards—When providing evidence, it is important that any authoritative guidance, protocols and approved standards are adhered to. Many forensic methods are accredited by the United Kingdom Accreditation Service (UKAS) to the international laboratory ISO17025 quality standard. This accreditation ensures that forensic laboratories follow standard procedures and encourages the delivery of precise, accurate data and reporting. All other methods followed in forensic geoscience laboratories follow similar quality control procedures and are, in general, covered by the standard, ISO9001. Laboratories carrying out case investigations are encouraged by the Forensic Science Regulator (FSR) to have UKAS accreditation, to help ensure that a minimum acceptable and externally regulated standard is met.

Currently, there is no approved standard for conducting ground searches, although some papers on general guidance exist [2]. The Forensic Science Regulator (FRS) UK works with the UK Home Office and ensures that the provision of forensic science services across the criminal justice system is subjected to an appropriate regime of scientific quality standards. The FSR also collaborates with the authorities in Scotland and Northern Ireland who have expressed their willingness to be partners in the setting of quality standards which will be adopted within their justice systems. This, at time of writing, is a very important topic across the forensic science disciplines, with all areas having different issues. The House of Lords has undertaken an inquiry on the topic of forensic science provision in England and Wales (https://www.parliament.uk/forensic-science-lords-inquiry).

Ethical context—Adherence to high moral and ethical standards is also of paramount importance for the practising of forensic soil science/geology: fundamental to settling issues related to crimes against people, society, our built environment, our natural environment and our heritage. The geosciences face legal aspects related to offences and crimes of various and many types, of a civil and criminal nature.

There is a need for practitioners in this area to ensure compliance with appropriate ethical standards in their work, in order to protect themselves, their workplace, their profession, the community, customers, and the built and natural environment. Forensic soil science also relates to aspects of engineering geology, of particular importance in civil cases. Geoethics is an emerging subject within geoscience research and practice which promotes an ethical way of thinking and practising the geosciences, within the wider context of the social role of geoscientists. It aims to improve both a high quality of professional work and emphasizes the important acceptable social credibility of geoscientists, to foster excellence in the geosciences, and to assure sustainable benefits for communities under a scientific perspective. It should protect local and global environments and create and maintain the conditions for the healthy development of future generations.

Soil—Soil science is a fundamental part of the geosciences. Soils are composed of both inorganic (i.e. minerals, elements) (Fig. 17.1) and organic (i.e. primarily plant derived) constituents (Fig. 17.2). The approach taken and methods chosen when characterizing soil in forensic case work often depend upon the availability of the equipment, costs, resolution, as well as the size and condition of the questioned samples available. Consideration also should be given to the destructive nature of an analysis technique and the sequence of analysis. It is essential to carry out non-destructive analyses before the sample is destroyed. In addition, consideration should be given to the potential strength of evidence which depends upon the type of analysis, the number of measurements made [3] and the complementarity of such measurements [4].

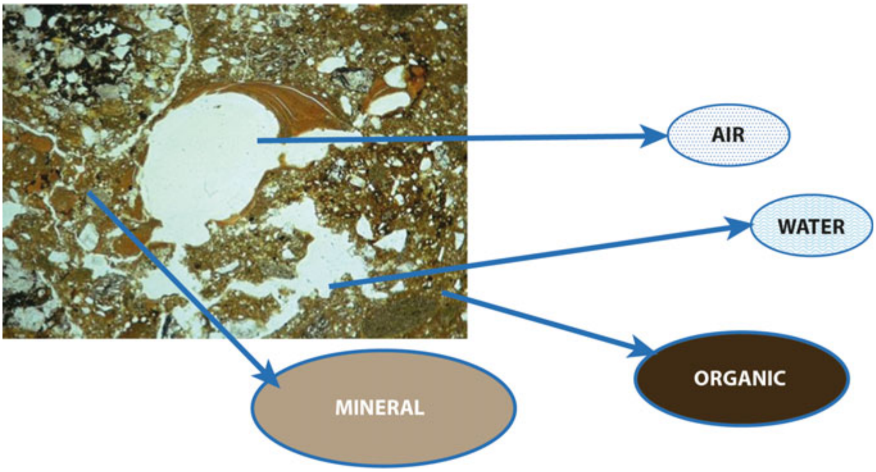

Fig. 17.1 Soil composition: inorganic and organic components in an annotated impregnated thin section of soil

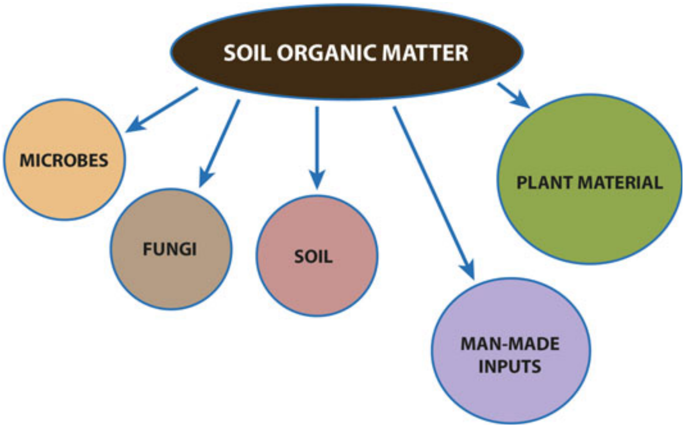

Fig. 17.2 The range of some of the main soil organic matter types used in forensic characterization

Historically, inorganic methods such as chemical and mineralogical approaches have been most generally applied in casework. Persistent biological approaches, such as the use of palynology or wax marker analysis, has also been used in some countries (e.g. UK, New Zealand, and The Netherlands), either in addition to the characterization of the inorganic component, or on its own, often when a restricted sample is available. The combined approach provides a greater evidential value. It is recommended that the two distinct phases of soil (organic and inorganic) are both characterized where sample size permits to provide the best possible comparability of any two samples [4]. Recently, however, analysis of individual largely single source aggregates has allowed greater comparator analysis involving soil organic matter (such as presented in evidence in UK court cases *R v. Muir*, 2013, *HMA v. Sinclair*, 2014 and *R v. Halliwell* and *R v. McKie*) [pers comm, Dawson]. The recovery and analysis of the individual aggregate approach (Fig. 17.3) minimizes the risk of contamination and reduces the issue of the questioned sample possibly originating from multiple sources, i.e. a mixture, which makes any comparison with a scene sample (known location sample, sometimes referred to as control or reference samples) difficult.

Questioned soil samples (those from an unknown location, such as a suspect's shoe, vehicle, spade etc.) can often be very limited in size, which may restrict the range of options for analytical methods to be used. In addition, these samples may contain many more materials than are considered 'natural' components of soil, e.g. brick, fly ash, cement. The anthropogenic source material can, however, be useful in comparing two soil samples, particularly when the material is unusual in nature. Transfer and persistence of material has also to be considered when evaluating any results, and careful assessments must be made of the data so that similar size fractions are compared in any analysis [5]. The moisture content of the soil at time of transfer is also important for transfer, as is the condition of the contact location soil and the depth of contact with, for example, a puddle on the road.

Detritus picked up from urban pavements and street gutters, as well as introduced material such as faecal material of various origins (e.g. animal, human, bird) can also be analysed using the same combined inorganic and organic component approach [4]. The broad spatial variation in soil, roadway, water, building materials, and air and water borne particles can be contrasted with the variation in urban materials, from dwellings to streets or parks or gardens, along with micro-spatial variation in each [6, 7]. Microplastics are another group of materials that can potentially be included in

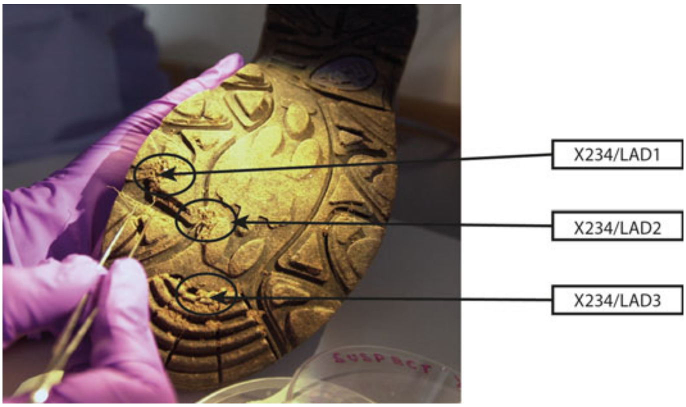

Fig. 17.3 Image of the sole of a suspect's shoe (X234) showing visually distinct and likely different source material adhering (LAD1, LAD2 and LAD3). These three different samples were recovered and analysed separately thus increasing the chance of single source comparison with a known source or sources

the multi-component characterization approach which can help increase evidential strength of any comparisons made of the trace evidence. One issue with including such anthropogenic particles is the current lack of relevant databases which makes any estimate of likelihood very difficult.

17.2 Case Work, Search

Most intelligence work involving forensic soil science is carried out directly for police forces. This is predominantly in the role of assisting with ground search operations for missing people, unmarked homicide graves and for concealed objects. This uses predictive geolocation in narrowing down areas of potential search. Predictive geolocation is the use of the physical, chemical and biological attributes of a soil sample in the identification of its provenance (e.g. sand grain shape, metal concentrations, vegetation fragments, etc.). The overall aim of predictive geolocation is to determine the area from which a soil sample was most likely derived [8].

Many aspects of the texture and composition of a soil sample have spatial significance, and the more of these which can be determined, the clearer and more spatially resolved the geographical profile will be [e.g. 9]. The precision of such spatial predictive analysis often depends upon the quality and spatial resolution of the associated databases. In the UK, there are very good soil (James Hutton Institute, Cranfield University) and geological (British Geological Survey) maps as well as digital databases. Often, the attributes measured on the soils in the available databases will have been for agricultural, environmental or exploration purposes; they will not have been collected at the most suitable depth and are thus not ideally suited for forensic application. Such geolocation analysis will therefore often not point to a specific single location (X on a map) and investigators need to be aware from the outset of any location work that the analysis is in most cases unlikely to allow a discrete specific location to be determined. Instead, an environmental profile can be established which is likely to include: (a) the soil types present in the area, e.g. sand, loam (b) the nature of the underlying bedrock geology and any superficial deposits, e.g. granite, sandstone (c) the nature of chemical and physical processes operating in the area, e.g. erosion (d) vegetation cover and a description of the overall habitat(s), e.g. heathland, coniferous forest (e) the geographical ranges of biological species identified in the soil sample e.g. upland, coastal (f) abundance and types of man-made particulate materials (plastics, fly ash particles) and their location significance along with other data in determining the likely human activity and processes in the source area.

Many of these parameters can be overlain using spatial data (often in a Geographic Information System model) to narrow down and focus the description of the likely source area. Geographical Information Science (GIS) is routinely used in the UK to integrate and analyze the different types of geocoded data with information from databases useful to forensic investigations. An example of this is where a test questioned sample was submitted for analysis with no other information available, other than it was somewhere in Scotland, and the location of where it had originated was pinpointed to within 800 m of where the test presenter from BBC4 had walked[1] (Fig. 17.4). Working with the law enforcement agencies, the impact of such approaches has resulted in a more informed and integrated approach which has enabled a higher degree of quality assurance and a prioritization of potential search areas. Forensic geoscience is a niche discipline, not provided within the larger forensic service providers, but usually subcontracted to individual experts with relevant experience and qualifications. This environmental profile can then be used by the investigating officers in conjunction with other layers of evidence (e.g. automatic number plate recognition (ANPR), mobile phone use analysis, eye witness accounts, line of sight analysis, etc.) to help focus search assets in potential target areas. Whilst the derived geographical profile is by nature generic, it also means that many other locations with different environmental profiles can be excluded as the likely source for the questioned soil (i.e. the SIO can be confident that the questioned soil could *not* have come from any areas of clay soil, or woodland, or arable or nor is it close to habitation, etc.). Once this data is mapped and spatially constrained using the available police intelligence, often only one or two areas are consistent with all the measured required attributes and thus can help prioritize areas for search activity saving valuable time and resources.

Such an approach has been adopted in the USA [10]. One example of this "geo-provenancing" approach used in the UK in search was in the search for murder victim Pamela Jackson on the moors near the M62 [11]. The victim's body was located using comparative soil analysis of material brushed from the back of a pair of gloves found in the boot of the suspect's car with possible sites where the suspect's car had potentially been parked. Another example is the successful location of a grave in the Pennines, England, where the victim's body had previously lain undiscovered for at least 10 years [12]. UK geoscientists have also provided formal and informal advice, training and operational support for law enforcement led searches throughout Europe, Asia, Africa, Australia, Canada, USA and Latin America.

17.3 Case Work, Trace Evidence

In the UK, forensic soil science is used mainly in cases of serious crime such as murder, rape and in ground searches associated with organized crime or counter terrorism. Different techniques and approaches have been used, depending on the individual case in question and on available laboratories. For example, microfossil and pollen analysis was used in the *R. v. Ian Huntley* double murder case where the evidence was used to show that Ian Huntley had driven his car on the remote track where the bodies of his child victims Holly Wells and Jessica Chapman were found in 2002. A complementary approach was adopted using both inorganic and organic soil analysis as trace evidence provision in the search, recovery and in the trial of Adrian

[1] https://www.bbc.co.uk/programmes/p02l4px7.

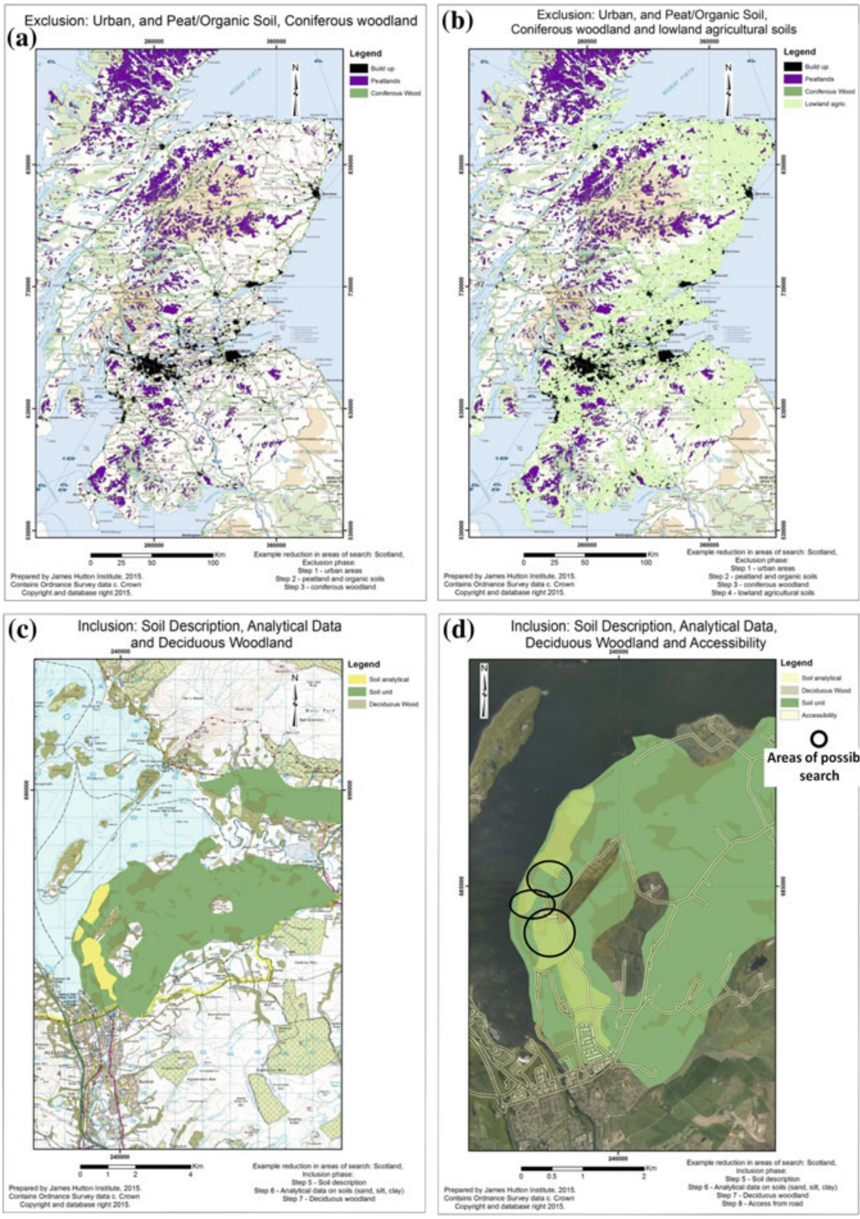

Fig. 17.4 Example Geographical Information Science (GIS) maps produced from a single questioned soil, examined under light microscopy, for organics, mineralogy and texture to narrow down areas of search in Scotland. **a** Exclusion of soils which are urban, peats or coniferous woodland soil, **b** exclusion of areas of lowland agricultural soils, **c** inclusion of areas of soil texture, pH and deciduous woodland and **d** inclusion of accessibility factors such as distance from road. *Maps produced by David Miller, James Hutton Institute*

Muir (*R. v. Adrian Muir*, 2013). In the murder of Rebecca Godden, culminating in the trial of Christopher Halliwell in 2016 (*R. v. Christopher Halliwell*), soil recovered from tools in Halliwell's garden shed was virtually indistinguishable from soil found at the grave site where Rebecca Godden was discovered (pers comm, Dawson). In Scotland, in the investigation of the Worlds End murders and associated trial in 2014 (*HMA v. Angus Sinclair*) soil samples from the feet of one of the victims (Helen Scott) were shown to contain wheat grains and characteristics of the grass verge and the wheat field where Helen Scott was found murdered in 1977 (pers comm, Dawson).

Forensic soil science is generally a comparison between two or more samples to ascertain whether they likely originated from the same, or alternatively, from different sources. When any two soil samples are indistinguishable in measured characteristics, the possibility that they originated from a single source cannot be eliminated. Such evaluation of comparability between samples requires expert opinion. The samples can be excluded, however, as coming from a common location if their analytical characteristics are different. The use of a comparison with database values is very important for this, in particular relevant context databases, and the possibility of applying Bayesian statistics or likelihood ratios being calculated (see evaluation below) [13].

Whilst we do not advocate the use of a standard soil analysis or a standard operating procedure (SOP) across the world, there are several general guidelines which would usually be expected to be followed in a lab carrying out forensic soil science examination and analysis. In general, most examination and analysis will start with the broad scale and subsequently become more focused at a more detailed scale—for example a visual examination of the soil trace would be carried out first, followed by examination using binocular microscopy and then a more detailed chemical, biological or physical analysis. Initial visual or binocular microscopy is commonly required before the subsequent analytical pathway is recommended to the investigator. Samples submitted to the forensic soil scientist for analysis can be variable with a consequence being that the analytical pathway required will differ enormously between cases. Soil samples are usually composed of a mix of (i) naturally occurring inorganic minerals and elements and particles, (ii) organic materials, including organic particles such as plant debris, spores, pollen, vertebrates and invertebrates and micro-organisms (including micro-fossils) and (iii) man-made particulates such as metals, plastics, hairs, fibres, paint, etc. Depending upon the relative amounts of these three phases present in a soil being examined, different analytical approaches will be recommended to the investigating authority and subsequently applied. As a result, the initial examination of soil samples is a very important stage (not least to ascertain how much material is present in the questioned sample) which will exclude the use of some methods which require a certain minimum size of available sample e.g. Inductively Coupled Plasma (ICP), or quantitative X-ray diffractometry (XRD). Sample mass will usually constrain what analyses can be carried out and as the questioned samples can be significantly less than 1 g, methods which can be applied to trace amounts of samples and provide quantitative values are advantageous. The methods chosen to use in each individual case will be the ones which best address the questions being asked of the sample on each individual case question.

The general procedure is one of starting with non-destructive methods followed by destructive methods. In addition, it is good practice to retain a portion of sample for possible subsequent re-analysis or retesting by defence experts. At the initial stages, visual methods are therefore an advantage, as are spectral methods such as Infra-red spectroscopy or micro-spectrophotometry. Initial screening will not provide quantitative data but will significantly influence the analytical pathway. This is an essential stage in the description of a sample and should ideally be documented through the collection of representative digital images. Evidentially, visual screening of a soil sample may be the only analysis required as it may demonstrate that questioned samples are clearly distinct (different) to reference samples from the scene (although the true variability at the scene needs to be known to safely draw this conclusion). A multi-proxy approach for analysis is better than relying on a single method and one based on inclusion, and where possible, to include both phases of inorganic and organic [15]. If multiple, independent or semi-independent variables within a single sample can be measured, then this will strengthen the degree of confidence in any subsequent evaluations made and conclusions drawn of comparability. In some cases, a multidisciplinary approach will be required, which can be used to independently test any conclusions drawn (botany, geology, palynology, etc.). Some methods can be used to effectively exclude a comparison between two samples, but they are not sufficient analytical to determine that a questioned and known sample were derived from the same place. For example, if a questioned soil is grey in colour and sandy in texture whilst the known reference soils from the crime scene are all orange in colour and are clay in texture (and they all have the same moisture content), then it can be concluded that the grey sandy soil has not been derived from the crime scene (orange clay) and can be excluded as sharing a common origin. However, even if two soils are both grey in colour and sandy in texture, this information is insufficient to conclude that they necessarily came from the same location. In addition, it is important to make a comparison of similar fractions of the questioned and known soils. For example, if a clay fraction has been transferred to an item of clothing, then the clay fraction from the reference samples at the crime scene should also be separated and subsequently analysed, not the whole soil. This is important as on many occasions the questioned soil can be a mixture of sources (e.g. deposited over time on a wheel arch or recovered from a foot well mat), and thus we advocate recovery of individual aggregates with similar colour and texture from any questioned item under examination. The range of analytical methods available for the forensic soil scientist to potentially use is huge [14] and is increasing as new methods are validated through research. However, prior to being used in evidence any new methods must have been thoroughly tested, peer reviewed and the new approach accepted by peers.

17.4 Evaluation of Soil Data

Despite being widely discussed across many forensic disciplines, probabilistic reasoning within a Bayesian framework has had very limited penetration within the discipline of forensic soil science or geoscience. Current advances within the discipline have a strong focus on the application of increasingly sophisticated analytical methods to discriminate between different soil or geological trace sources. While analytical advances may well be important additions to the tools available to the forensic geoscientist, the development of a probabilistic approach to underpin an expert's opinion based on the outcomes of these analytical techniques may be useful in addressing some of the key issues within the growing debate over approaches to such evidence. In the past, various methods have been used for evidence evaluation: numerical and verbal scales [3] exclusion principles (as used by the US Department of Justice) [15] and indices of comparability [16]. In evaluative mode, in a Bayesian framework approach, an appraisal of a likelihood ratio (LR) for the scientific observations is offered as a measure of the weight of the evidence.

The role of the expert in this evaluative mode is to help the decision maker(s) in a court of law arrive at a decision on the questions of provenance (source) or activity—it is the expert's role to assist the court in coming to the best decision. Application of this interpretative framework in forensic soil science, as becoming adopted in other forensic disciplines, could prove useful in advancing forensic soil science by helping to define relevant populations from which to collect data, guiding the design of forensic research studies, facilitating the combination of the results from multiple analytical techniques and providing a common approach to interpretation and the communication of expert soil science opinion. However, before this can be achieved, the relevant and representative databases will be required to be made available.

17.5 Report Writing and Presenting Evidence

Although a report should adhere to general guidance on expert reports (see below), the information and structure of a witness report is often in an expert's own style. However, there is certain mandatory content for expert reports, and these will vary depending upon the jurisdiction (country) in which the crime has been committed. These requirements (where they exist) should be closely followed by the expert. Where in doubt, advice on any such requirements should be sought from the police or lawyers in the relevant country.

The other important consideration is adherence to good practice. There is some advice, albeit in the context of civil cases, from the UK Civil Justice Council. Although references to the Civil Procedure Rules (CPR) will not apply in criminal cases, some of the general advice on the instruction of experts and the content of expert reports is relevant in both civil and criminal cases.

In this chapter, the English and Welsh jurisdiction is focused on. The Civil, Criminal and Family Procedure Rules, Practice Directions and the Guidance in English law [17] do all have requirements which must be followed. In particular, certain declarations and statements must be included in the reports. There are rules for Criminal Proceedings too in relation to experts. Rule 19.2 of Criminal Procedure Rules (CrimPR) provides for "Expert's Duty to the Court": https://www.justice.gov.uk/courts/procedure-rules/criminal/docs/2015/crim-proc-rules-2015-part-19.pdf.

Rule 19.2 describes the expert's duty to the court, rule 19.3 the introduction of the expert evidence, rule 19.4 the report content, rule 19.6 prehearing discussion of expert evidence, rule 19.7 single joint expert rules and rule 19.8 instructions to a single joint expert, with rule 19.9 describing the Court's power to vary requirements under the Part. Although these are only applicable to England and Wales (there is no Scottish equivalent, and rules in other jurisdictions will be different) they are a useful guide, especially on content (rule 19.4 in particular). Many of the principles will apply to other jurisdictions and can be used, for example, if there is no precedent available from the requesting authority.

The Criminal Procedure Rules are continually reviewed. For example, amendments came into force **on April 1st 2019** whereby under amendments to Criminal Procedure Rules 19.2 and 19.3, experts have a duty to disclose to those instructing them anything of which they are aware which might reasonably be thought capable of:

- undermining the reliability of the expert's opinion, or
- detracting from the credibility or impartiality of the expert.

The party instructing them will have to serve notice on the other side, together with the expert's report, of anything which falls under the categories above. The original 19.3(c) required disclosure, by the instructing party, of anything reasonably thought capable of "*detracting substantially from the credibility of that expert*". There was, however, no explicit duty on the expert to disclose to their instructors. The new wording focuses on matters affecting the reliability of the expert's opinion and the credibility and impartiality of the expert and places a clear duty on the expert to make that disclosure.

Accreditation. When providing evidence, it is important that authoritative guidance, protocols and approved standards are adhered to (see section above). Practising forensic geoscientists in the UK may become Chartered Scientists or register through their own professional societies or through membership of their professional organizations (e.g., the British Society of Soil Science, the Geological Society). In addition, individual scientists can register with the National Crime Agency (NCA) if they are invited to do so by the police.

The FSR UK works with the UK Home Office and ensures that the provision of forensic science services across the criminal justice system is subject to an appropriate regime of scientific quality standards. The FSR also collaborates with the authorities in Scotland and Northern Ireland who have expressed their willingness to be partners in the setting of quality standards which will be adopted within their justice systems. The FSR is also represented on some of the working groups.

17.6 Court

The jury in an adversarial system consists of lay-persons. The duty of the expert is to assist the court in the area of their expertise and the court will consider that evidence in deciding the case and whether the case has been proved to the requisite standard and burden of proof. The expert's role is to provide independent assistance to the court by way of objective, unbiased opinion in relation to matters within his expertise and he should not advocate on behalf of one party or the other.

In some adversarial jurisdictions, there are legal rules which provide for the duties of the expert to the court. The main authorities in the UK are the cases of *National Justice Compania Naviera SA v Prudential Assurance Co. Ltd.* ('*The Ikarian Reefer*') (1995) [18] and *R. v Harris* (2006) [19] where the main duties of expert witnesses were outlined as follows:

- The expert must be independent and uninfluenced by litigation;
- he/she must offer independent and unbiased assistance to court;
- any facts or assumptions on which his/her opinion is based must be stated;
- any material facts detracting from his/her opinion must not be omitted from his/her evidence;
- if a matter falls outside the area of expertise of a witness, he/she must say so;
- if insufficient data is available, the expert must indicate that his/her opinion is provisional;
- the expert must, in his/her evidence, set out the full range of available expert opinion in the relevant area, even including opinions that are contrary to his/her own.

In each jurisdiction, these will differ, and sometimes there will be regulatory or professional body considerations too. These duties focus on the witness and not on the evidence.

Juries will not be accustomed (as a judge is) to sitting through long, detailed and technical explanations often in a language they do not understand. Concepts need to be explained for the sake of jurors in an interesting and brief, accurate way. If the jury does not listen and absorb the evidence, the testimony will have been for nothing.

Essentially, most of the jury will not be interested in the details of the science behind the conclusions reached by the scientist. They are interested in what those conclusions are and how they apply to the case they are determining. One tactic to assist in understanding which might enable that to be done effectively is to use analogies to demonstrate the science. For example, it is sometimes useful to refer to everyday objects, and when asked what size is the minimum size of sample that can be analysed, one can describe it as a grain of rice or the volume of a swimming pool etc.

The use of visual aids such as graphs, charts, DVD/video presentations, picture cards, computer simulations (on such simulations see [20]) or even live demonstrations, might liven up the evidence without "dumbing it down". Any unusual method of presentation (anything other than straight oral testimony) should however be brought to the attention of the court and the other party to the case well in advance, so that approval can be sought from that party and, if necessary, from the court. There may also be logistical considerations involved in setting up technology or equipment in the court, although courts in many jurisdictions are now equipped with impressive technology.

Another possible technique involves the use of evidence arising from 'tailor made' scientific experiments that could be performed especially for the case in question; these may involve effectively reconstructing the incident in question, as has happened in the Scottish criminal courts in *Campbell v HMA* [21].

The presentation of evidence to a non-expert in a mock session is a good way to practice the art of communication to a jury. However, if training is carried out prior to a court case, familiarisation is fine, but the expert must not discuss the case or in any way be 'coached'. In addition, the jury will expect an expert witness to present his evidence in an authoritative manner, without adopting a condescending tone. An expert may have a very good knowledge of his/her subject area, but it is just as important to present that knowledge in a confident and engaging manner. Useful in this context are 'primers' and books which have simplified the background science, containing soil and other ecological evidence types. Effective communication with key audiences is vitally important [22].

17.7 Admissibility of Novel Expert Evidence

Admissibility is the legal concept which refers to the assessment by the court (usually the judge even in a jury case) as to whether or not evidence should be admitted for the fact finder (usually a jury) to assess. When it comes to scientific evidence (especially of a novel nature) the court is concerned with reliability of that evidence, and in particular with the techniques for its collection, storage and interpretation. The issue is that judges have a tendency to be worried about the 'mystic infallibility' [23] of experts. Although the wording differs from one jurisdiction to another, the overall thrust of admissibility of novel evidence is similar. Some of the main considerations for whether the courts may permit a scientific technique to be examined in court are as follows:

- necessity of evidence (can the jury reach conclusions on the issue without it?);
- the qualifications of the expert;
- the reliability of the science underlying the conclusions;
- testing of the scientific technique;
- peer review history;
- error rate;
- acceptance within the scientific community;
- is there a mathematical formula, probability statistic, database or some other objective touchstone?

In the US in particular, the courts have demonstrated a willingness to examine in detail each of these factors, and others, during a *voir dire* (a special hearing, including oral testimony, on whether the evidence is to be permitted, held before the final hearing), to come to a final conclusion on admissibility. This can lead to extensive and detailed scrutiny, perhaps lasting several days, or even weeks. While there is variance across jurisdictions in the rigour with which the courts approach admissibility examinations of expert scientific evidence (roughly speaking, the US at the most rigorous end and the UK at the other, with Canada and Australia somewhere in between), it is suggested that it is best practice to assume a fully rigorous examination of the factors above when considering how to defend any proposed expert scientific evidence. After all, even if these factors are not used to argue against admission of the evidence, they will be relevant to the questions of reliability and weight, questions which apply to the assessment of all expert evidence by all decision makers.

The courts have shown willingness to open doors to evidence of all kinds, from any background of knowledge, not just the traditional scientific fields. Recently there has been a dramatic increase in the types of evidence presented by experts in courtrooms. Expert scientific evidence has found a place in courts for a long time, and some forms of expert evidence are commonplace and well established in court, including fingerprint evidence, DNA evidence, ballistics evidence and some forms of physical trace evidence. However, where the evidence involves a new technique, even where it is a variation in the area of an already established field, the courts will apply the same basic tests; in some jurisdictions, they will proceed with extra caution.

Some of the considered new areas of expertise include footwear comparison, ear print identification, CCTV footage facial mapping, hypnosis, voice comparison analysis, hair analysis and psychological autopsy evidence. Given that soil forensic science in many cases uses existing and accepted scientific techniques [3], although applying them to the analysis of soil, there would seem little room for an argument that soil forensic evidence (in a general sense) should not be presented as expert evidence. Of course, whether such evidence should be produced in a particular case is a different question.

In the US, given the rigour of the *Daubert* formula as it applies to any expert evidence [24], there is no sign of a more cautious approach in the case of novel scientific evidence. However, the courts do accept certain forms of evidence which have an established pedigree, such as DNA evidence (*US v Martinez* [25]).

According to Cross and Tapper [26] and the Court of Appeal in *R v Dallagher* [27], the same appears to be the case in the less rigorous jurisdiction of England and Wales.

In Australia, the court in the *Bonython* case [28] indicates:

> If the witness has made use of new or unfamiliar techniques or technology, the court may require to be satisfied that such techniques or technology have a sufficient scientific basis to render results arrived at by that means part of a field of knowledge which is a proper subject of expert evidence.

This signals a more cautious approach in cases where novel evidence is proposed. This was applied again in Australia in R v Murdoch (No. 2) [29] a case where certain DNA evidence was held to have passed the admissibility test. The Bonython court cites earlier examples of new evidence, such as R v McHardie and Danielson [30], a case involving a new mathematical formula used in voice identification.

In Canada, in the landmark case of R. v Mohan [31] the Supreme Court offers the following guidance:

> …expert evidence which advances a novel scientific theory or technique is subjected to special scrutiny to determine whether it meets a basic threshold of reliability and whether it is essential in the sense that the trier of fact will be unable to come to a satisfactory conclusion without the assistance of the expert.

The court in that case approved the approach in an earlier Canadian decision (*R v Melaragni* (1992) [32]), in which additional criteria in this area were set out:

(1) Is the evidence likely to assist the jury in its fact-finding mission, or is it likely to confuse and confound the jury?

(2) Is the jury likely to be overwhelmed by the "mystic infallibility" of the evidence, or will the jury be able to keep an open mind and objectively assess the worth of the evidence?

(3) Will the evidence, if accepted, conclusively prove an essential element of the crime which the defence is contesting, or is it simply a piece of evidence to be incorporated into a larger puzzle?

(4) What degree of reliability has the proposed scientific technique or body of knowledge achieved?

(5) Are there a sufficient number of experts available so that the defence can retain its own expert if desired?

(6) Is the scientific technique or body of knowledge such that it can be independently tested by the defence?

(7) Has the scientific technique destroyed the evidence upon which the conclusions have been based, or has the evidence been preserved for defence analysis if requested?

(8) Are there clear policy or legal grounds which would render the evidence inadmissible despite its probative value?

(9) Will the evidence cause undue delay or result in the needless presentation of cumulative evidence?

This list is not necessarily exhaustive; furthermore, the importance of any one or more of these factors will vary depending upon the particular circumstances of the case.

In the US, there are some commentators who take the view that soil forensic evidence would not currently pass the *Daubert* test [33]. Others form the view that forensic geology evidence is a 'valid source of scientific evidence' and it has been used in the context of a range of criminal charges including hit and run, rape, murder, assault, and in many civil suit contexts too [34]. In a recent court case in Virginia, it was stated that soil evidence did not undergo a formal admissibility challenge within the US court systems until January 2016. The challenge in *State of Kansas v. Kyle Flack*, (2016) [35] involved the admissibility of soil comparisons at the trial, as well as the qualifications of the forensic geologist who conducted the examinations. The forensic geologist was questioned on a range of topics including: (1) the witness's education and training, experience performing and testifying in forensic soil examination cases, and history of participation in proficiency testing, (2) the accreditation and quality system of the laboratory, (3) the methods used and if these methods were in common use outside of a forensic context, (4) the results of the examination in this specific case, (5) the interpretation of these results, and (6) the forensic report technical review process. The defence challenged the conclusion reached by the forensic geologist and sought the exclusion of the soil evidence at trial. The judge, however, ruled that the soil evidence, as examined and reported, was admissible in the subsequent criminal trial, and placed no limits on the geologist's testimony [36].

17.8 Conclusions

Forensic geoscience provision in the United Kingdom involves aspects of intelligence, investigation, trace evidence and expert witness communication of evidence within the criminal justice system. This can be provided at any, or all of, the following stages from attendance at the crime scene, through sample examination and analysis, data evaluation, report writing and effective communication in court.

Standards are continually improving and being carefully audited and there are a growing number of well represented networks of experts which enable good collaboration and shared good practice internationally, such as the International Union of Geological Sciences-Initiative on Forensic Geology (IUGS-IFG) and the European Network of Forensic Science Institutes-Animal Plant and Soil Traces (ENFSI APST) [37] all offering a range of complementary and accredited skills of great value in assisting police and forensic and legal practitioners across the UK and abroad. It is reassuring that, although innovative developments in the discipline of soil science and forensic geology are being taken up by forensic practitioners and accepted by law enforcement agencies, caution, clarity and integrity remain the key principles in the application of new approaches, in particular, of new analytical methods.

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