The soil sleuth

Forensic geologist Lorna Dawson has pioneered methods to help convict criminals using the dirt from their shoes.

BY CHELSEA WALD

On a Saturday night in October 1977, Lorna Dawson was studying in her dormitory at the University of Edinburgh, UK, when two 17-year-old girls disappeared off a nearby street. The teenagers had been on a pub crawl with friends, stopping at an old Scottish tavern called The World's End before vanishing. Police officers remembered seeing two men with them. The next day, the girls turned up dead eight kilometres apart — one on a beach and another in a remote wheat field. They had both been raped, beaten and strangled. Despite a nationwide manhunt, police could not find the assailants.

Dawson was a country girl, new to the city, and was working towards a geology degree at the time of the crime, later dubbed the World's End murders. "It was my first time away from home," she says, and the case left her "terrified to go out".

It also left her with a passion for justice. Now at the James Hutton Institute in Aberdeen, UK, Dawson runs one of the world's only labs dedicated to forensic soil science, where in the past decade she has worked on more than 70 cases from around the globe. At the time of the murders, soil was rarely used as evidence, and techniques were "elementary", she says. But today, soil evidence regularly leads to bodies, overturns alibis and reveals the origins of artefacts. That is in no small part due to Dawson, who has advanced methods in soil forensics and worked to disseminate the techniques to others.

"Lorna has been instrumental in promoting the new renaissance in forensic geoscience throughout the world," says Marianne Stam, who recently retired from the Riverside Crime Laboratory of the California Department of Justice. But Dawson says that there is still more to be done. She is now part of an international collaboration developing a method to profile microbial communities using DNA. This could make soil more valuable for crime fighting, says Rob Fitzpatrick, who founded the Centre for Australian Forensic Soil Science in Adelaide, Australia. "What Lorna is doing is pioneering new ground, developing methods that others could use and should try more."

Dawson says that she does it for the victims, such as the girls in the World's End murders — a case she would return to several times in her career. "Getting some sort of closure for the victims' families, it's a really rewarding thing to be able to do," she says. "That's what drives you on into the hard hours."

BEYOND SHERLOCK HOLMES

Forensic soil science was nearly 150 years old by the time Dawson took it up. Police in Germany used sandy soil to solve a crime in 1856 and Arthur Conan Doyle noted the forensic potential of dirt three decades later in his first Sherlock Holmes mystery, *A Study in Scarlet*. In the story, Watson says that Sherlock "tells at a glance different soils from each other. After walks, has shown me splashes upon his trousers and told me by their colour and consistence in what part of London he had received them."

In the real world, forensic soil science advanced little beyond analyses of "colour and consistence" for the next century. "It was really just about the larger components of the soil. You took a sample and you shook it up in a test tube and noted its colour, that sort of thing," says retired forensic scientist Dave Barclay. From 1997 to 2006, he was head of physical evidence at the National Crime Faculty, a forensics agency that helped UK police departments with the most serious crimes. When he looked at the state of soil forensics, he was dismayed. "It wasn't being used, or it was being done on a sort of cottage-industry basis," he says. "It wasn't being done necessarily to the standards of normal science."

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A few scientists were starting to rigorously apply new techniques, such as specialized scanning electron microscopy for mineralogy, but other practitioners continued to use unsophisticated methods to give investigators the answers they wanted, he says. In other countries, the situation was similar or worse.

Barclay wanted to make sure that UK investigators drew on the firmest science, whether or not it supported the prosecution's case. "What we needed was a sort of unifying group who would work to strict forensic and scientific practices, and I could then use them to coordinate the work of other people or to get them to peer review other people's work," he says. To develop that expertise, Barclay approached Dawson's institute (then called the Macaulay Land Use Research Institute) in 2003 because it was already doing soil analysis for government agencies. That led him to Dawson, who was eager to participate and was already well versed in analyses that could be adapted to forensics work, such as X-ray diffraction, scanning electron microscopy and Fourier transform infrared spectroscopy.

Although the World's End murders had affected her deeply, Dawson had never thought of crime solving as a career. Dirt, on the other hand, came naturally. She grew up on a farm in Angus county, south of Aberdeen. A favourite time of year for her had been the "tattie holidays", when kids could earn pocket money harvesting tatties, or potatoes. "I just loved that, working outside. You used to make enough money that you could buy a new bike," she says.

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After completing her undergraduate degree at Edinburgh, she went on to do a PhD in soil science at the University of Aberdeen, and then worked her way up at the Macaulay, doing a mix of projects related to agriculture and environmental science. When she got the call from Barclay, the offer to work on forensics intrigued her. "It's just another, different sphere of life that the soil can contribute to, really," she says.

Dawson and Barclay put together a team of scientists, investigators and lawyers, which got a grant from the UK Engineering and Physical Sciences Research Council to develop standards for using soil-science techniques in forensic investigations. It was important to get it right, Barclay says, because the high costs of lab work meant that soil science would typically be used only in the most serious cases.

Dawson saw opportunities to develop new techniques, especially for soil's organic matter — the part made up of dead and decomposed plants and organisms. The advantage of studying organic characteristics is that they vary on the scale of centimetres or metres, whereas inorganic components may be broadly the same over kilometres. "The organic takes you to a much finer spatial scale of resolution," she says. When combined with soil-survey databases that document a variety of soil characteristics, that resolution could help investigators to use soil attached to a suspect's shoe or tyre to locate a burial site, for example.

Soon after starting her work in soil forensics, Dawson had a chance to help on a familiar case — the World's End murders. Barclay had been looking into the cold case and he asked Dawson to analyse some dirt and plant material that had come from the bare feet of one of the murdered girls, Helen Scott. But Dawson could not learn much from the soil when she looked at it in 2003 because there was too little to be analysed by all but the most powerful microscopes.

Frustrated but determined to do better, Dawson devoted herself to adapting chromatography and mass spectrometry — techniques she knew from her work in agriculture and environmental science — for use in forensic cases. She was able to substantially reduce the necessary sample size — from about a teaspoon down to about 20 milligrams, roughly the equivalent of a grain of rice. Then she put it into practice. In one case, she was able to use organic characteristics to match soil from getaway vehicles to a crime scene on a remote farm track. When the suspects learned of the soil evidence against them, they pleaded guilty.

Dawson also spread the word about soil forensics by organizing conferences and training in Australia, the United Kingdom, the United States, Russia and elsewhere and by

JEREMY SUTTON-HIBBERT

holding events for public audiences at home. She collaborated with crime writers such as Ann Cleeves and Stuart MacBride, as well as the BBC, as a way to show the public — and potential jurors — that real forensic evidence is not as clear cut as it is often portrayed on television shows such as *Silent Witness* and *CSI*. At the same time, she demonstrated how useful soil could be in solving crimes. When MacBride fashioned a minor character after her, he gave her a fitting catchphrase: "The soil never lies."

BURIED DRUGS

In her own research, Dawson has kept abreast of developments in soil science, hoping to adapt them to forensics. That is what brought her, clad in hiking boots and gaiters, to a farm southwest of Aberdeen last May. Investigators wanted to know whether a stash of illegal drugs buried at the top of a hill could be linked to dirt samples taken from a suspects' boots and spade.

Dawson hoped to use microbial DNA to solve the case. Soils host vast communities of microbes (up to a couple of billion cells per gram), and those communities can vary on scales as small as millimetres. For several years, forensic scientists have argued that the DNA of those microbial communities could serve as another kind of soil fingerprint (L. M. Macdonald *et al. J. Appl. Microbiol.* **105,** 813–821; 2008).

Such soil fingerprinting has been tried before with mixed success by investigators in Italy, Spain and the Netherlands, which have legal systems that readily consider new forensic techniques. It is much more difficult to use new techniques in trials in common-law countries such as the United Kingdom, United States and Australia, where expert testimony must pass a test to establish the reliability of the methods used. Among other things, judges look for whether the methods have gone through peer review, are generally accepted in the scientific community and have appropriate standards in place.

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Dawson, working with a European Union-funded international collaboration called MiSAFE, is trying to meet this high standard for the microbial genetic-profiling technique. That is why the May farm investigation was not a real case, but a mock crime scene. The 'drugs'? White powder. The 'suspects'? Dawson herself and a Hutton staff member.

Back at the Hutton institute, molecular microbiologist Thomas Freitag did the analysis for the mock crime scene: he amplified then chopped up a marker gene that codes for the 16S ribosomal RNA molecule from all the microbes in a clump of soil. Cataloguing these fragments by length leads to a "coarse portrait" of the community, Freitag says. No two clumps' profiles will match exactly, but clumps that are close together should be roughly similar.

Because the profiling method uses the same technology that forensic units are using today to analyse human DNA, forensic scientists worldwide should be able easily adopt it, says MiSAFE coordinator Edouard Jurkevitch of the Hebrew University of Jerusalem.

In the case of the mock crime scene, the tests performed as hoped. Freitag's analysis revealed, correctly, that the spade belonging to the suspect had been used at the drug-burial site. Dawson presented early results from MiSAFE at a meeting on forensic geosciences in London last December.

The collaboration is now fine-tuning the approach. But Dawson says that she is confident enough in the technique to add microbial DNA profiling to her arsenal as soon as the project wraps up in May.

Dawson's forensic work eventually led her back to the World's End case. Last year prosecutors brought a suspect, Angus Sinclair, to trial. By then, Sinclair was considered the worst serial killer in Scotland's history. DNA from his semen had previously linked him to the World's End murders but it was not enough to convict him during a trial in 2007.

Prosecutor Deborah Demick called on Dawson to reanalyse the soil and plant material from Scott's bare feet. Sinclair claimed that he and his brother-in-law, Gordon Hamilton (who has since died), had had consensual sex with the two girls in their van that night, which explained the presence of his semen on Scott's coat. But Sinclair said that the girls were "alive and unharmed" when Hamilton had dropped him off at a fishing spot, and that Hamilton must have killed the girls later on his own.

By 2014, forensic science had finally advanced enough to refute this alibi and construct an alternative timeline. Investigators reanalysed DNA from inside the knots binding the girls' limbs, showing that Sinclair had helped to tie them. They also concluded that Sinclair had deposited his semen on Scott's coat just minutes before he left her body in the field.

The debris pressed into Scott's soles helped to fill in the details — and the brutality — of those final minutes, Dawson told the jury on 22 October. Some bits of soil contained traces of plant wax that matched the wheat field where Scott's body was found; other bits matched its grassy border. A similar conclusion emerged from studies of the husks and grains recovered from the dirt on her feet. "The pattern of the soil on her feet suggested that she had walked or stood in that particular field," Dawson says.

The prosecutors used this and other evidence to argue that Sinclair had helped to tie up Scott and forced her to walk from the van into the field, where he beat and strangled her to death. On 14 November, just over 37 years after the attack, the jury convicted Sinclair of the double murder. His life sentence of 37 years was Scotland's longest ever, and the media hailed the historic case as a triumph of forensic science. Dawson's contribution was small but crucial, Demick says, because it "enabled the Crown to have a clear narrative of events and emphasize to the jury the sheer horror of what had happened to Miss Scott — being walked into the field to her death".

For Dawson, the case was poignant and powerful. Her career had come full circle and she had helped to ensure that Sinclair would never again terrify young women. Dawson thought of her own daughters, and how one had almost died several years earlier of leukaemia. She thought of Helen Scott. And she thought of herself at university, studying geology in her dorm room. "Life's so precious, and if it's taken away for whatever reason, particularly if it's taken away by someone else's actions, then I think that there's no cost that you should stop at to try and find justice, to find that person who's done that." ■

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Police search fields in 1977 near Haddington, Scotland, for the body of murdered teenager Helen Scott.

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