When Australian police were alerted to the disappearance of two women from their home outside the city of Adelaide in September 2000, they found blood and broken glass in the house, and one of the family cars was gone.

Police discovered the empty vehicle the next day, 100 miles from the women’s home; in the trunk were a bloody knife and a shovel caked with dirt. They soon arrested the 22-year-old driver, but he refused to give them any information to help find the women: his mother and grandmother.

With so little to go on and such a large area to search, detectives took the unusual step of contacting a team of soil scientists from CSIRO, the Australian national science agency, for help with the investigation.

To scientist Robert Fitzpatrick and his colleagues at the Land and Water lab outside Adelaide, the material on the shovel spoke volumes. It was smeared and compacted in a way that suggested that it had been used to both excavate and tamp down soil in a wet location, and its pH value showed it to be more acidic than the soils of the peninsula where the vehicle had been found. Under a microscope, it contained particles with an angular shape typical of materials created by a human activity, such as mining. And a mineralogical analysis revealed the presence of talc, a mineral found only in the area’s mountains and foothills.

Based on that analysis, his soils team recommended searching in the industrial gravel quarries of the Adelaide Hills, far from the place where the suspect had been arrested. The correct quarry was identified, and the two bodies were ultimately recovered. For the man in custody, Matthew Holding, the case ended in a guilty plea and a sentence of 18 years in prison.

But for the scientists and the police, the case was a powerful demonstration of the ways standard soil science techniques could aid criminal investigations. This collaboration would lead to the 2003 establishment of the Centre for Australian Forensic Soil Science (CAFSS), with Rob Fitzpatrick as its director and an active advisory board made up of law enforcement and forensic science experts from around the country. To date, CAFSS has advised on more than 100 cases, including violent crimes such as rape and homicide, counterterrorism and other issues of national security, and more esoteric crimes, including dinosaur egg smuggling.

“We’re using normal, ordinary pedological tools,” says Fitzpatrick, referring to soil color, morphology, chemistry, and other standard means of classification and analysis. “The big challenge for us was to understand the forensic and the police way of doing things and how to operate in court. So we’ve done training courses on how to deal with a jury and how to communicate with a jury. We’ve also had to develop a guideline manual as to how we deal with a sample when it comes in.”

At the CAFSS labs, each soil sample is bar-coded so that the chain of custody, or the record of each time someone takes possession of it, can be easily and reliably documented. An expert in sample security visits the lab every three months to certify its procedures.

“That is all really new stuff that you don’t normally do in soil science,” Fitzpatrick says. “And putting these things together, we can play a major role in assisting the police.”

Perhaps the earliest documented case of a forensic comparison of soils was in Berlin to solve a crime that took place on a Prussian railroad in April 1856. A barrel containing silver coins had been emptied and refilled with sand during transit. Professor Ehrenberg, a scientist from Berlin, acquired samples of the sandy soil from all the stations along the railway line. Using a light microscope, he then examined features of the sandy soil particles, such as color and shapes, to compare them with the soil from the barrel and determine the station from which the sand originated.

Later, in 1891, the Austrian Hans Gross, considered one of the fathers of foren-
Soils can be a very potent type of trace evidence for linking a suspect to a crime scene, Fitzpatrick says. For one thing, a trace of soil may be so small as to be almost invisible, causing even a wary wrongdoer to overlook it. There are increasingly good analysis techniques available, and even a very small sample can yield a meaningful result. Soil evidence is relatively easy to collect and can often be analyzed quite rapidly. Soils are highly varied and individualistic, with more than 100,000 types catalogued in the U.S. alone. Clays and sand in particular are likely to cling to someone who’s come in contact with them—and criminals may not be as scrupulous about trying to dispose of soil evidence as they would be about blood or DNA.

Soils may also be very durable. “We’re now dealing with a lot of cold cases,” Fitzpatrick says, including decades-old murders, “because the DNAs not there, but the soil is.”

While DNA evidence may not have been collected in a decades-old case, or may have degraded over the years, an evidence locker may still contain mud-stained clothing or a sandy pair of old boots that can be sent to the CAFSS laboratory for study.

In addition to Fitzpatrick, the Adelaide-based CAFSS lab has three specialist mineralogists and experts in X-ray diffraction (XRD), a technique that identifies crystalline minerals by the patterns their atoms scatter back when X-rays are directed at the sample. Because the atomic structure of crystals is, by definition, regular and predictable, each mineral has a distinct and recognizable profile.

“Our group here is very, very good at quantifying and identifying minerals in just about any sample you can think of,” Fitzpatrick says. (Team members Mark Raven and Peter Self won the international Reynolds Cup competition for XRD sample analysis in 2010—an honor Fitzpatrick compares to winning the America’s Cup for sailing.)

Robert Fitzpatrick’s group deals with a number of cold cases. In one case, the body of a drowned teenager was located in a wetland. Police arrested a suspect and impounded clothing as evidence to be closely examined. The suspect’s tracksuit pants (top) showed traces of two different soils, but police couldn’t positively relate them to the wetland area where the body was found. Samples of grey soil from within the wetland (middle), and yellow soil on the fringe, were taken to the laboratory

Soil Horizons
for detailed inspection and analysis. The morphology (color) and mineralogy of the two samples taken from the suspect's clothing (bottom) were similar to the two samples taken from the wetland area. The soil evidence gathered indicated that the suspect had been present at the site where the victim drowned.

When Fitzpatrick presents XRD findings to a jury, he uses the analogy of a fingerprint match. Overlaying two profiles from two different samples, he can show the nuanced pattern of peaks and valleys that indicate which minerals are present in each sample and in what quantity. The jury can see for themselves whether the two are a close match as Fitzpatrick describes the likelihood that both came from the same source.

“From experience, we’ve found that X-ray diffraction is by far the most powerful way to explain our work to the jury,” Fitzpatrick says. “While the science might be complicated, it’s a lot, lot easier than showing, for example, a whole lot of chemical data in a table.”

Counterterrorism and Dinosaur Eggs
CAFSS is administered by Australia’s national science agency, the Commonwealth Scientific and Industrial Research Organisation (CSIRO); its criminal investigative work is funded in part by CSIRO and in part by consulting fees from local law enforcement agencies.

When approached about a possible case, Fitzpatrick works up an estimate of what CAFSS could do to help and what it may cost. At least 20% of the time, he says, police departments decide not to use them for soil evidence consulting, either for budgetary reasons or because they feel it’s not absolutely necessary to the case.

The center’s work is not limited to Australia, however; about 20% of the caseload has been counterterrorism in both Australia and Afghanistan, according to Fitzpatrick, who received a top-secret security clearance so that he could work on those cases.

For national security cases, Fitzpatrick has been able to use even more sensitive and sophisticated analytical tools, including synchrotron XRD, which is much more powerful than the X-ray diffraction they can do in the lab but costs $10,000 a day. Using the synchrotron, a subatomic particle accelerator about the size of a football field, they were able to examine poorly crystalline samples, such as minute brick particles and traces of burnt soil, for a case in which a burned-out vehicle was one of the primary sources of evidence.

Another case with international ramifications was the case of the Chinese dinosaur eggs. Under Chinese law, fossilized dinosaur eggs and nests are protected relics, and both their sale and purchase are banned in Australia. Nevertheless, illegal fossil trafficking is a billion-dollar industry.

CAFSS was called in when two Australian collectors were being investigated for possessing suspect nests, which they claimed were not Chinese but legal American fossils.

Fitzpatrick’s team compared the nests against soil samples from the Hunan Province in China where the eggs were believed to originate. “We then compared dinosaur eggs from the U.S., from a museum, and we found totally different mineralogy,” he recalls. “And these people were convicted, and the dinosaur eggs were sent back to China.”

Staying One Step Ahead of the ‘Baddies’
When Fitzpatrick is testifying in court, sitting sometimes just a few yards away from an accused pedophile and murderer while describing how the soils collected from the man’s shoes link that person to the crime scene, he’s well aware that there’s an emotional dimension to this type of work that’s significantly different from non-forensic soil science.

“We did a cold case where I revisited the exact site where this girl had been raped and then smothered in a little dam and drowned,” he recalls. “And that emotionally for me was bad because I stood right there where she’d been murdered 25 years ago.”
Soil Horizons

Teeth, skull, and bones from a victim that was excavated in a reddish-brown clayey soil from a backyard, which relates to a 20-year-old cold murder case.

details of the shovel in the Matthew Holding case for five years and have only recently received permission to discuss it more fully. And if Fitzpatrick uses crime scene photos for a training or a conference presentation, he makes a point of deleting them from the slide show if it might be posted on the web.

“Our website gets a lot of hits around the world,” he says, “and I’m trying to put less stuff on there that could be used to train baddies.”

In conversation, Fitzpatrick tends to call everyone from petty thieves to terrorists by the slang term “baddies”—possibly finding its Aussie understatement helpful in preserving some emotional distance from the tougher types of cases his team handles.

And while CAFSS continues to produce materials to help police understand ways that today’s soil evidence could help an investigation, they’ve turned down several offers to dramatize one of their cases “CSI”-style on television for a general audience.

“If a piece of soil is on a baddie or is on his clothes, they wouldn’t even think that we could use it,” he says. “If they saw blood or lipstick, they would immediately try and get rid of it, but they wouldn’t think that soils could be used. And we want it to stay like that.”