Forensic Soils: An Integrative Laboratory Exercise for Introductory Soil Science

B. D. Lee,* T. N. Williamson, R. C. Graham, L. J. Lund

ABSTRACT

Enthusiasm and interest in introductory soil science courses can be enhanced by integrating fundamental concepts into exercises relevant to actual employment opportunities. We designed an integrated laboratory exercise to introduce students to forensic soil science, an alternative employment choice to the traditional agriculture, and environmental careers. Students evaluated soil properties such as color, texture, effervescence, and mineralogy on several samples in an effort to solve a hypothetical criminal case involving stolen property. Students easily differentiated samples based on soil color, particle-size analysis, effervescence, magnetic susceptibility, and heavy/light ratios, but had difficulty quantifying mineralogy by optical microscopy. All students positively identified the stolen property, therefore successfully completing the exercise. The data generated from several criteria and the analyses of those data to solve the crime engaged the students in data interpretation, encouraged independent thought, and held the students' attention.

INTRODUCTORY soil science students typically complete exercises related to specific aspects of soil science, including morphology, physics, chemistry, microbiology, and fertility during weekly laboratory periods (Thein and Graveel, 1996; Palmer and Troeh, 1995; Kroontje et al., 1985). The relevance and linkages of these subdisciplines of soil science can be highlighted with laboratory exercises that integrate and apply previously studied concepts. Levy and Graham (1993) presented a pedologic approach toward integrating concepts and found it to be effective and enthusiastically received by students. We propose that forensic soil science also offers an exciting arena for reinforcing and integrating fundamental concepts in soil science.

From the time of the fictional character Sherlock Holmes, criminal investigators began to see the applicability of soil observations. Today, most major crime laboratories throughout the world, both public and private, study soils on a routine basis (Murray and Tedrow, 1992). Recently the number of criminal cases that utilize soil evidence as well as the number of law enforcement agencies that submit soil material for forensic examination has increased (Murray and Tedrow, 1992). Significant interest by law enforcement agencies in agricultural crime (e.g., stolen produce from rural orchards, nonpoint-source pollution from feedlots) substantiates a need for qualified scientists to conduct investigations dealing with soil properties and characteristics. For example, earth scientists have assisted criminal investigators by examining various soil samples including those from suspects' shoes, automobile tires, automobile fenders, and cadavers. Some geology departments have responded to these needs by introducing forensics into their courses to increase interest and to illustrate an application of rocks and minerals to solve crimes (Harder, 1991; Fakundiny, 1978). Alternatively, criminal justice departments see the importance of earth science within their discipline (Coogan and Trebonik, 1978).

This paper provides an example of a forensic soils laboratory exercise, showing how specific soil science concepts can be integrated into a laboratory exercise that involves the collection and interpretation of data. The exercise also introduces students to an important application of soil science that is not commonly recognized.

MATERIALS AND METHODS

The exercise was designed for a 3-h laboratory period. Each of five laboratory sections had approximately 12 students, with all sections taught by the same instructor. Students were not specifically monitored for independent work, but with the limited number of students, the instructor could observe and assist those who had difficulties. Since the laboratory session was the last of the semester, students had experience with several analytical techniques. Grades were based greatly on participation, moderately on the accuracy in a table of information completed by each student, and on whether or not students could solve the problem correctly. The exercise was based on the following scenario.

> Burt returned to his cactus nursery in Arizona after the Thanksgiving holiday to find that two of his prized potted saguaro cacti (*Cereus giganteus* Engelm.) were missing. Burt called the police, who came out, surveyed the scene, and spoke to the neighbors. One neighbor reported seeing a suspicious-looking van in the nursery parking lot on Saturday evening. With the help of the neighbors, the police tracked down the van and searched the suspect's house. The police found approximately 20 saguaro cacti at the suspect's house; five of these cacti were similar in size and age to those stolen from Burt's nursery.
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> You, a soil scientist working in an environmental laboratory that conducts basic soil chemical and physical analyses similar to those completed in previous laboratory exercises, get a phone call from an energetic assistant district attorney. She requests your expertise in the case of Burt's missing cacti. You are informed that, although the suspect has been identified, an arrest cannot be made until evidence (soil data) has been provided to link the cacti to the victim's nursery.
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> Burt told the police that he had planted several cacti, including the two that were missing, at the same time and with the same potting mixture (a soil potting mix recipe passed down from his great-grandfather). Burt makes this unique potting soil mixture at his nursery, so it is uni-

Department of Soil and Environmental Sciences, 2208 Geology Bldg., Univ. of California, Riverside, CA 92521-0424. Received 27 Jan. 1998. *Corresponding author (bdlee@citrus.ucr.edu).

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Table 1. Data table of soil analyses; correct answers provided. Students measured all properties except heavy/light mineral ratios.

Sample	Color	Texture			Effervescence	Heavy/light mineral ratio	Grain count					Ferrimagnetic minerals
		Sand	Silt	Clay			AG†	HB	BT	MG	SP	
			%						%			
Victim's soil	10YR 3/2	28	30	42	No	0.20	42	58	--‡	--	--	No
Suspect 1	7.5YR 3/3	24	27	49	No	0.41	--	--	--	37	63	Yes
Suspect 2§	10YR 3/2	28	30	42	No	0.22	42	58	--	--	--	No
Suspect 3	5YR 4/4	48	36	16	No	0.05	23	--	77	--	--	No
Suspect 4	10YR 3/3	36	40	24	Violent	0.21	81	--	19	--	--	No
Suspect 5§	10YR 3/2	28	30	42	No	0.18	42	58	--	--	--	No

† AG = augite, HB = hornblende, BT = biotite, MG = magnetite, SP = serpentine.
‡ Mineral not present in sample.
§ Samples 2 and 5 are soils from the stolen cacti pots and match the victim's soil.

form and different from any potting mixture sold in a store. Your job is to help the district attorney by determining if the suspect possesses any of Burt's cacti.

Students were asked to compare soil samples from the suspect's five cacti to Burt's potting mix to determine if any of the five were from Burt's nursery. Soil analyses performed included: (i) soil color, using Munsell color book; (ii) particle-size analysis by a modified hydrometer method (Gee and Bauder, 1986; organic matter and carbonate pretreatments omitted; 1-h settling time for clay determination); (iii) effervescence with 2% HCl (Soil Survey Division Staff, 1993); (iv) magnetic susceptibility, determined with waxed-paper around a hand magnet (Laird and Dowdy, 1994); and (v) grain counts of fine sand quantified by optical microscopy (Drees and Ransom, 1994). Because this was the last laboratory in the quarter, all students had been exposed the analyses of soil color, particle-size analysis, and effervescence in previous laboratory exercises. At the beginning of the laboratory period, students were introduced to the mineralogical identification principles of magnetic susceptibility, heavy/light mineral ratios, and optical microscopy. Due to the shortage of petrographic microscopes, biological microscopes utilizing plain light were used in optical analysis. Although the use of biological scopes limits optical microscopic techniques, the crystal habit, grain morphology, cleavage, and color were adequate to identify distinct mineralogy of the synthesized samples. Additional heavy/light mineral ratio data were provided (Laird and Dowdy, 1994); this analysis was not performed by the students due to time constraints. Soil pH and organic matter were not included in this laboratory exercise because, in most criminal cases dealing with soils or sediments, emphasis has traditionally been placed on mineralogy (Murray and Tedrow, 1992).

Students were provided with a data table for recording results from their soil analyses at the beginning of the 3-h laboratory period (Table 1). All students completed the data table and returned it at the end of the period. Each of the five laboratory sections was split into a minimum of five groups of two or three students each. Individual groups were responsible for completing all analyses for each sample, with the exception of particle-size analysis. In an effort to utilize time efficiently, each group was responsible for only one particle-size analysis, and the resulting data were shared within each laboratory section. Most groups divided the workload among students and compared answers; however, this approach was discouraged for the introduced mineralogical techniques of optical microscopy and magnetic susceptibility.

RESULTS AND DISCUSSION

A discussion of sample variability immediately followed completion of the data table, due to students' concern about identifying the correct samples without having precisely accurate data. Most concerns were quelled as students realized the numerous lines of evidence they had generated by different analyses that they could draw on when making a conclusion.

Sixty-three students completed the forensic soil laboratory and accompanying data table in the fall of 1997, the first time this laboratory exercise had been utilized. Two of the five soils analyzed matched the soil from Burt's nursery (Table 1). Each student identified at least one of the two soils; 34 identified both.

Student Response

Students were asked which of the five soil characteristics provided them the most confidence. Fifty-one students selected one of the five criteria; however, several students were unable to select only one answer to this question; some selected as many as four. Nineteen had the most confidence in the particle-size analysis data. Eleven had the most confidence in the heavy/light mineral ratio data. Approximately equal numbers of students had the most confidence in the calcium carbonate (8), soil color (7), and grain count (6) data.

To generate thought about other analyses, students were asked what other soil properties they would suggest be analyzed to better determine which soils matched the victim's sample. Most suggestions were analyses that had been done in other laboratory exercises during the quarter (soil structure, cation exchange capacity, pH, bulk density, soil acidity, and microbiological analyses). Other suggestions included shrink-swell analysis, x-ray diffraction, scanning electron microscopy, elemental analysis with atomic absorption spectroscopy, and inductively coupled argon plasma spectroscopy, all of which had been mentioned in the lecture portion of the course throughout the quarter. While there was not enough time during the laboratory to perform these analyses, it would have been valuable to have a follow-up discussion to address the advantages, disadvantages, and applicability of the students' suggested analyses.

Students' Interests

After completing the laboratory exercise, students were asked to describe their interests in soil science. Most of our students are interested in environmental (43 students), agricultural (10 students), and forensic (10 students) applications of soil science. Only 15 students had previously heard of forensic applications to soil science. Of these 15, some had heard of forensic soil science on the Discovery Channel, some as a result of the O.J. Simpson trial, and others knew people involved in criminal cases. Forty-one students concluded they would consider forensics as a career.

Sixty-two of the students said they enjoyed the exercise. All of the students recommended that the laboratory be taught again next year. Some students made suggestions for improving the laboratory exercise, including that it be more difficult to identify the matching soil. Several of the students suggested use of this exercise as a lab final, noting that it was comprehensive and a good review of the techniques that they had learned throughout the semester.

CONCLUSIONS

This laboratory exercise generated enthusiasm and engaged the students in lively discussion about the data. It gave the students an opportunity to examine different types of soil data and to consider the significance of each soil characteristic, both independently and in conjunction with other soil data. It also forced students to consider to what degree soil samples can be differentiated and how the methods of soil analysis used may limit the certainty of the answer.

The authors were pleased with the students' performance and the overall effectiveness of the laboratory exercise. In an effort to improve the exercise, we intend to make modifications before its utilization next fall:

1. Because particle-size analysis takes up a significant amount of time and the students have already completed a previous exercise involving particle-size analysis, we plan to provide these data, therefore freeing up more time for a longer introduction to mineralogical techniques, which are often used in forensic investigations (Murray and Tedrow, 1992).
2. We plan to incorporate an out of class assignment asking students to suggest an alternative method of analysis and provide details of the technique by conducting a literature search.

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