Forensic Geology

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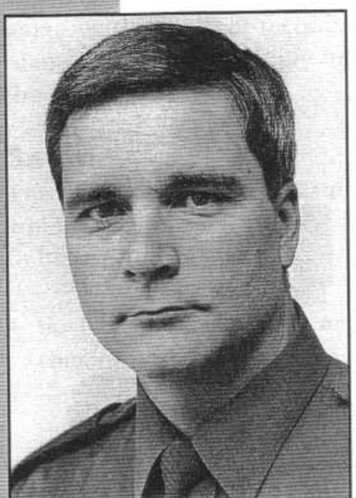


Forensic geology is best defined as the application of earth sciences to the law. It has been used randomly over many years in many kinds of investigations, ranging from theft to homicide. There are a number of publications available that detail case histories of successful applications. They make for very interesting reading and certainly alert the forensic investigator to the possible use of new forms of evidence.

The scope of this article is to provide basic fundamentals for the collection, preservation and analysis of geological evidence. Too often, valuable evidence is lost from a scene due to the lack of training and information available in this field. To properly obtain and submit evidence for analysis does not require an extensive geological background. If the proper collection procedures are followed, then a crime scene will provide a host of evidentiary possibilities.

Geological Examination

The most common question investigators will ask is, "What type of scenes or crimes would benefit from a forensic geological examination?" The answer would be, any crime that involves the transfer of mineralogical products to or from a crime scene. The scope of this type of examination is bounded by quite critical elements and is intended to be used as an auxiliary means of investigation. During a regular forensic examination, some of the geological evidence is collected as a matter of course.

Examples of this type of evidence would be contained in:

- the soiled clothing of the victim or accused;
- the particulate matter adhering to the weapon;
- the muddy footprint on the floor; and/or,
- the shakings of car floor mats.

Each of these examples would provide a suitable starting point for forensic geological examination. By careful analysis of the particulate matter, one may be able to determine if there is sufficient merit in continuing with the examination. The basic forensic examination is designed to determine the fundamentals of the crime scene. The geological examination is designed to provide an additional level of evidence evaluation.

The main basis for a successful geological examination is the concept of provenance. Due to the varied nature of most geological formations, it is difficult to establish with certainty that a particular exhibit originated from a specific site. To be able to provide irrefutable evidence that the exhibit is site specific establishes provenance. One must also establish residency times for the soils at the site using transport/weathering criteria. If the site is fast changing, the analysis may be flawed.

The most usual form of evidence presentation provides a correlation of lithological data, intended to convince the court that provenance is established. The correlation can take the form of a highly geotechnical analysis of an exhibits lithological characteristics, or a relatively simple comparison of gross features. The level of examination is predicated entirely on the circumstances of the incident and the evidence obtained from the scene.

This is why a properly conducted examination and analysis of the evidence is so critical. Usually there is only one opportunity for the identification specialists to obtain the evidence required in the subsequent scene analysis. If the specialist is aware of the value of a geological examination, the chances of a more thorough forensic analysis are enhanced.

The usual form of collected evidence is actually, soil matter, especially in an inner city environment. A great deal of cities evolved from a semi-agricultural base and are therefore, situated on arable soils that are in themselves, quite distinct. The local indigenous soil types provide a distinct base to which contaminants are added. Depending on the scene location, provenance can be established from the contamination elements of the soil.

Soil Science

To conduct a proper geological examination of soil evidence, two levels of theory are required. The first level is that of soil science; the second being pedology. Soil science is basically defined as the physical study of the chemistry, physics and biology of soil. It is this level which provides for the quantitative data often used in the provenance determination.

The second level, pedology, is a branch of soil science and deals primarily with the theoretical aspects of soil formation. The pedological analysis provides the broad framework for the conceptual data. Without a strong theoretical basis for any analysis, the weight of quantitative data is diminished. As a result, in any forensic geological examination, both levels must be considered in tandem.

Soil science has been used since early Egyptian and Greek times to aid in the growing of crops. In its rudimentary form, the science was not very exact, but the differences in soil types were noted and understood. The concept of soil being a distinct body in nature, directly influenced by the underlying geology, was not recognized until pedological principles were developed.

The early work in this field was done mostly in Russia at the turn of the century. Unfortunately, a great deal of the work went unnoticed for many years due to the wars and translation difficulties. Modern work spread from Europe and into North America where it is now a recognized field of science. The main thrust of the field is that of crop enhancement, but the value to forensic geology should not be forgotten. Virtually all of the earth's ground surface has a layer of top soil in one form or another.

As unique soil types are developed on different geological formations, a sound understanding of the geological character of a region is required in forensics. This basic understanding may allow the investigator to develop leads in a case that might otherwise go unnoticed. It is during the initial stages of investigation that the differences in soil types may be a clue. For example, should soil stains on the clothing of a victim be different from the scene materials, this would indicate that the body may have been moved from another location. Conversely, soil stains on the accused may place him/her at a scene.

However, the investigator must be aware of the uniqueness of the material to be able to establish target areas for a search, to aid in tracking a serial killer, or to provide a basis for questioning a suspect. A quote from J.S. Joffe aptly condenses an investigator's dilemma in many cases: "The soil lay at man's feet but he looked to the inaccessible heavens for help and salvation."

Scene Examination

It is this phase of the forensic examination that is the most critical due to the fragile nature of a crime scene. As an outside scene is generally where the value of forensic geology is the greatest, care must be taken in processing it. The most obvious aspect is that of contamination of the inner perimeter by tracking and disturbing the indigenous soil profile.

The micro profile of the upper layers of a soil horizon is very site specific, due to local contamination. If it is disturbed by careless movements in proximity to the body or object of examination, valuable evidence may be lost. For example, if a fine layer of sand is found covering a generally, clay-like area, the sand should be sampled separately. This can be done by careful scalpel work, taping methods or an acetate peel. This process can then be repeated for each sequential layer.

If suspect materials are to be compared to scene exhibits, then an accurate analysis can be performed, detailing the specific elements of each layer. If all the mineralogist has to work with is a shovel sample of the upper 6-8 inches of top soil, valuable observations may be lost in the mass. Elemental and optical work is very arduous at best and working from discrete horizon standards would greatly facilitate this process.

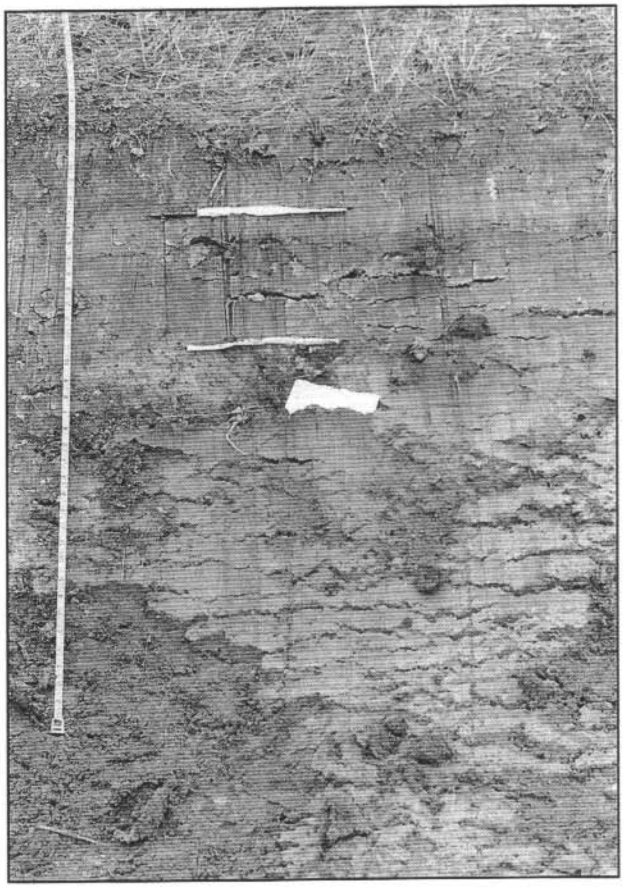
If an area is tracked over by investigators or emergency personnel attending a scene, additional contamination elements may be brought into the inner perimeter. Any additional elements in the analysis may confuse the results sufficiently to make them of no evidentiary value. Thus, tracking and mixing of soils at a scene should be avoided.

The following methods are preferred in obtaining soil horizon samples:

- Softening the clay/silt-based soil with distilled water and then laying non-adhesive lifting acetate on the surface. Careful removal of the acetate will result in bonding of the soil layers to the acetate.
- In suitably sandy or mineral-rich horizons, the horizons can be sampled with the acetate peel method. This entails the soaking of the surface with acetone and placing an acetate sheet over the sample area. The material will actually melt into the acetate and remain affixed. The sheet can then be used for direct optical examination or as a photographic negative to detail the horizon. If chemical work is required on the lifted material, then individual grains can be plucked from the sheet.
- Standard taping methods can also be used to obtain soil horizon samples. However, as in hair and fibre tapings, care should be exercised so as to not have the contaminants adhere to the sides of the tape roll.
- Micro pipettes and capillary tube samples can be taken as required for spot analysis at a scene or

In assessing the overall scene to be examined, the investigator must determine the number of distinct soil boundaries at the site. Caution must be used in establishing the actual horizon boundary as smearing of the zones may have occurred in the digging process. In this scene, the boundaries are somewhat muted as the drag down effect from the shovel smeared the top layers onto the lower one. By cutting a small inspection groove in the face, a clean view of the horizons is afforded.

Pieces of white paper are inserted into the soil horizons for reference. There are four distinct layers. The boundary between 3 and 4 is muted by a large wedge of mud that was dragged up in the digging process.



Close-up view of the site to be examined. Horizons are marked 1,2,3 and 4. Attention must be paid to the moisture content of the soil. Storage of the sample in airtight containers will allow the sample to retain its proper consistency. If the sample is allowed to dry, it may discolour or crumble to powder.

Should any special horizons, or areas of interest be observed in the wall, samples should be taken as well.

within a specific horizon.

- Scalpel and container samples would be the coarsest method of sample acquisition, but are preferred over the standard shovel sample. When a vertical channel sample is taken, a clean tool, such as a scalpel, is used to dislodge the material. The sample should be allowed to fall into a suitable container in a roughly vertical orientation, if possible. The soil sample should be cut out in a shape and size to fit the container used. The container should be airtight to retain the moisture content of the sample as collected. It should also be marked with the proper orientation. The collection site separation is dependent on lithology and the variety of soil horizons encountered. In massive deposits, samples should be taken with a six-inch vertical spacing.

While all the described techniques work for horizontal sample taking, they are also suitable for vertical examination. This type of exam would suit a grave site scene, for example. It is incumbent on the forensic examiner to obtain as much evidence from the vertical grave walls as possible. Due to the changing soil horizons with depth, any suspect in a grave would actually encounter a multitude of specific soil types.

The material encountered at the base of a grave is usually markedly different from the surface soils. As a result, a suspect may be found with unique soils on his footwear, knees, hip or shoulder areas. As one rubs against the moist soil wall, the clothing would then host a rainbow of different and unique soil types, consistent with horizon changes. With proper horizon standards with which to make comparisons, provenance may be established, placing the accused in the grave.

To facilitate taking the sample, the rough outline of the sample container may be grooved out with a clean scalpel or knife. If the horizon appears quite uniform in colour and texture, one sample representing the entire horizon may be taken. However, a full sample of the strata is ideal. Notes should be taken as to where in the horizon profile, the sample was taken.

The sample can then be taken by slipping the sample container under the grooved out area and pushing up. The sample will fill the container with proper orientation. Excess material can then be struck off at the top of the container. In sandy soils, running the lip of the container upward along the face scrapes material into the container. By filling the container from the bottom of the horizon upward, the material orientation can be roughly maintained.

When a distinct boundary can be observed, a sample should be taken as closely as possible to the boundary. In hard soils, the sample can be cut out to fit the sample container and then allowed to fall into the container.

In obtaining grave or borrow pit samples, the investigator should take sequential vertical samples, as well as the mixed and disturbed material from the surface. The natural mixing of contaminants from such a scene is also diagnostic. The value of entomology and plant science should also be discussed when considering exhibit selection.

Soil is not a simple product of weathering. Biotic activity stimulates soil alteration in a complex system of physical and chemical processes. As a result, the influence of biota can be of primary importance.

Sampling

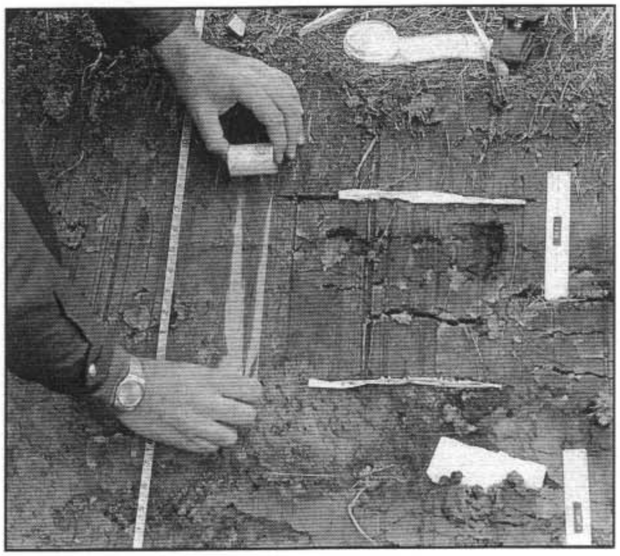
A proper grid format for sampling is preferred. The grid size is wholly dependent on the specific scene and variability of the soil types encountered. Good notes and descriptions are also very valuable from the scene as most soil types will change in appearance and colour tone as they dry. Samples taken from tire tracks are also subject to tonal alterations at the scene due to the mixing of horizons by the tires. Notes should be made on the wet and dry phases of the sample taken as both may be found under or in a suspect's automobile.

The sampling regime of a car or truck is difficult to standardize due to the variable nature of different vehicle types. It is safe to state however, that the vehicle is very valuable in sample acquisition. The vehicle is, by design, a natural collector of soil and mineralogical samples. As a vehicle is driven over dry ground, the dust from the roadway is blown up under the car and into the various vents and intakes. When wet, the soils splash up onto the vehicle and coat it entirely.

The following is a list of standard sample section points. In

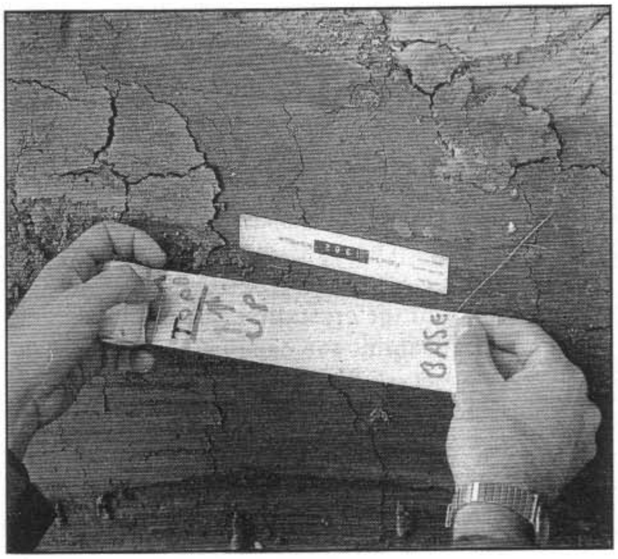
When samples are taken, reference photographs should be done with the container situated at the sample site. This will allow a forensic mineralogist to have a clear record of the sample location when examining the exhibit.

Site photographs should be taken in colour whenever possible to allow for comparisons of soil colouration in the exhibit to the wall.

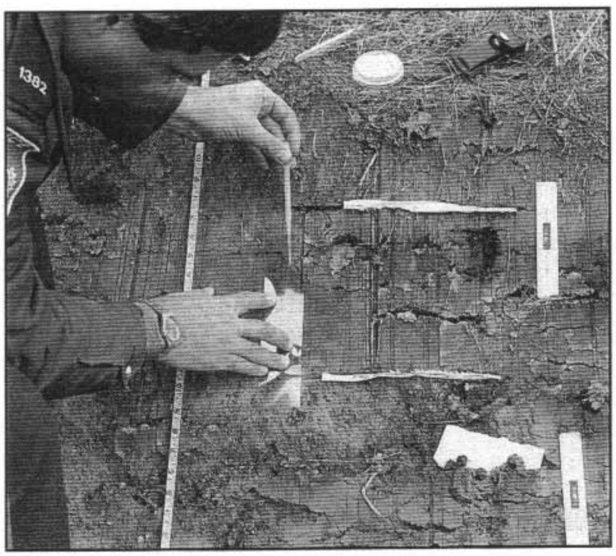


Samples can also be taken when lifting tape placed over the face. This method works especially well for sandy soils, less so for heavy clay. The tape should be placed over the horizon to be sampled and lightly pressed into the face. The tape can then be laid out on clear acetate in a similar fashion to lifting a latent fingerprint impression.

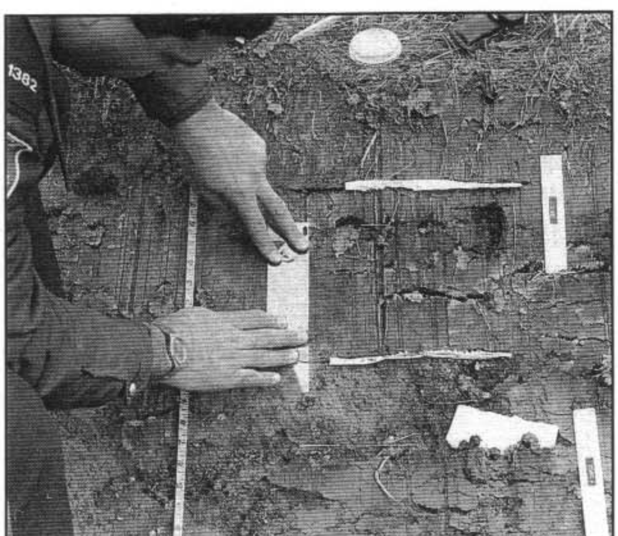
Once the tape is placed on the acetate sheet, the "lift" is then suitable for immediate microscopic examination. This method allows for any hair and fibre evidence that may be on the soil to be recovered as well. Some sandy soil types may impair the ability of the tape to adhere to the acetate. Should this occur, a cover strip of wider tape can then be placed over the sample to retain any loose grains.



The labelling of the lift is of extreme importance. The lift should be marked in a manner to ensure the orientation is not in question. Care should be taken to ensure that the markings do not cover areas of the sample that will be subject to microscopic examination.



Samples can also be obtained by using an acetate sheet and acetone. Place a sheet over the area to be sampled and with a dropper, place acetone between the sheet and soil. Hold the sheet firmly at the base and continue to flood in an upward motion. Care should be used so as to not wash out the actual horizon with the acetone.



Once the soil face is suitably moistened with the acetone, hold the sheet firmly onto the face until the acetone evaporates. During this stage, the acetone is actually melting the acetone sheet enough to allow particles to be melted into and onto the sheet.

obtaining the samples, the methods noted above are all suitable forms of collection but with vehicles, the use of a moistened Q-Tip should not be overlooked. Standard sample section points include, but are not limited to:

- the exterior of the front bumper and grill for both soil and insect types;
- inner surfaces of the front bumper and grill;
- all wheel wells and tires;
- engine compartment, including carburettor housing and air filter (also for insects);
- rocker panels;
- control arms/A-frames and leaf springs;
- tops of mufflers and condensers;
- interior of passenger compartment and trunk;
- inner and outer surfaces of rear bumper;
- rain gutter paths and windshield trim; and,
- Q-Tip or gauze swabs on the exterior painted body surfaces.

As noted, these are just some suggested selection sites for a vehicle and the investigator should make use of any other possible sites of value that may be encountered. With respect to the examination of the interior of the vehicle, care should also be used. The standard method of sample collection is the vacuum. This is probably the worst possible way of collecting mineralogical evidence. For example, when a soil-based material is deposited in a moist phase, the material will dry in a very specific fashion. Examination of the exhibit in its naturally-deposited state is critical. The vacuum method destroys the base form of the exhibit and contaminates the exhibit with a host of

Once the sheet is dry, carefully peel the sheet away from the face, starting at the base. The sheet should be pulled slowly, to allow particles to be tugged gently from the soil face. This type of sample should be stored in a stable container such as a box of the same size as the sheet. The particles will be very loosely held onto the acetate and can be easily removed. This method is also helpful in determining what types of mineral grains might come off a face most readily. In examining a suspect's clothing, only the looser minerals may be found and not the entire horizon suite. By conducting this type of test at the site, the investigator may be able to utilize this information in the analysis and in court.

particulate matter from the vehicle. If the investigator is attempting to establish provenance with samples from a vehicle, the sample taking must be done carefully with the suggested methods. In addition, foot pedal rubbers should be seized, and floor mats taped.

Samples should be stored in protected boxes so as not to jar the soil needlessly. Excessive shaking and mishandling of the sample may cause segregation or artificial lamination patterns within the sample container. Freezing of the sample may also result in the fracturing of the material, thereby destroying the in situ characteristics.

The sample collection should then be submitted to the local forensic laboratory. In Canada, this submission would normally be made to the regional RCMP laboratory. In the United States, various private labs are available, depending on jurisdiction, as well as regional FBI and state laboratories. Laboratory personnel should then make the determination as to the suitability and format of any quantitative examination. As well, various forensic geologists are available around the country on a consultative basis. Local universities are also a suitable source for consultation.

Methods of Analysis

The optimum method of analysis is solely dependent on the quality and type of exhibit to be examined. The level of examination can range from a simple visual comparison of samples to eliminate extraneous exhibits, to an intense microbial or chemical analysis. Some of the more common types of instrumentation available are:

- polarized light microscopy (PLM);
- x-ray diffraction (XRD);
- micro infrared spectroscopy (MIS);
- electron microprobe (EM);
- scanning electron microscope (SEM) with energy dispersive x-ray detector (EDS);
- environmental scanning electron microscope (ESEM);
- micro-chemical analysis and assay;
- high performance liquid chromatography (HPLC); and,
- differential thermal analysis (DTA).

All of the listed instruments have a demonstrated value in the identification of particulate evidence. While the scope of this article is not to detail all of the fundamentals of each instrument, there are some comments that should be made to highlight the key features.

The x-ray differentiation (XRD) method identifies the actual phase of the crystalline solids in an exhibit and can distinguish distinct crystalline forms of the same compound. However, polarized light microscopy (PLM) is initially required to separate and identify suitable target areas within a sample. Due to the very small particulate size of certain materials, PLM may provide only a partial characterization, even when done in conjunction with micro-chemical analysis. Therefore, XRD is also a valuable co-analytical tool.

XRD analysis is also valuable when coupled with differential thermal analysis in clay and shale examination. The XRD will establish crystal lattice particulars of the main clay, but the DTA will determine mineral percentages within the clay. Such a combination can be used to determine the provenance of clay and silt matter from scenes and would be especially useful in the examination of soil adhering to the exteriors of car bodies from road spray.

Having a solid geological and pedological framework from which to work, an investigator may be able to plot the path of a transient criminal from one part of the country to another, if the suspect vehicle is properly sampled. Another application of this instrumentation would be to aid in the tracking of growing sources of drug shipments and courier pathways across the country.

The scanning electron microscope is also a very valuable tool in the analysis of mineralogical exhibits. However, certain results are difficult and sometimes impossible to obtain due to equipment limitations. The newer environmental SEM units are probably better suited to some forms of analysis as they do not require the vacuum stage of the SEM and allow for the input of "live samples". This results in shorter equipment time and more accurate depictions of in situ materials.

Conclusion

While the range of sophisticated analytical techniques is certainly available to the investigator, the results of an analysis are only as good as the sample collection and preservation techniques employed. Only with proper field technique can the forensic investigator hope to utilize the range of potential examinations available from a forensic geologist. Should an investigator wish to trace a possible grave site or track a serial killer, the level of initial scene examination is critical to the success of a forensic geological analysis.

Cst. Richard Munroe has been a member of the Winnipeg Police Service since 1982 and is currently assigned to the Identification Unit. In addition to graduating from the University of Winnipeg with a Bachelor of Science, Major in Geology degree in 1977, he has taken several courses including: Fire Cause Determination; Forensic Identification; the Henry Fingerprint Course; and, the Low Explosives and Post Blast Evidence Seminar.

Cst. Munroe is also recognized for the following: Identification Specialist for the city of Winnipeg; Fellow of the Geological Association of Canada; Member of the Canadian Institute of Mining and Metallurgy (National, and Executive member for Manitoba Region); Member of the Canadian Sedimentology Research Group; Director of the Manitoba Prospectors and Developers Association; and, member of the American Concrete Institute.