FORENSIC GEOLOGY

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Contents

Summary

Forensic geology can be considered to be any aspect of geologic science that is subject to public debate in a court of law. Forensic geology applies the defining principles of the geologic sciences to the identification/evaluation of geologic materials that may be related to forensic problems. Forensic geology also applies these principles to the definition of the appropriate geologic context of a forensic scene or site. Evaluation and substantiation of compliance to procedures, standards, and ethics relative to professional practice falls within the purview of forensic geology. Forensic geology encompasses involvement as expert witness and the provision of expert testimony relative to geologic activity or circumstance. Geologists working within any forensic context must be conversant with the legal parameters that define this context: e.g., legal sufficiency, chain-of-custody of evidence, and protocols relative to the collection, preservation, and validation of evidence. Law enforcement and forensic professionals must likewise

recognize the contribution that geologic science can make to a range of problems and concerns that they routinely face. While forensic geology will probably not become a widely recognized sub-discipline of geologic science in the near term, its contribution to the solution of a variety of forensic problems will become apparent both to law enforcement personnel and to geologists themselves.

1. Introduction

Geology is the science of the earth: the study of earth's origin, history, processes, and materials. Forensic geology addresses the legal aspects and legal ramifications of the examination of earth processes and materials. Forensic geology constitutes any aspect of geologic science that becomes the subject of public debate within a court of law.

The scope of forensic geology is made apparent by the interconnected geologic and legal implications posed by the following questions:

- What is this material?
- Where did this material come from?
- Is it, or could it be, unique to a crime scene or unique to circumstances under which a criminal act was committed?
- What is the geologic context of the crime scene and what are the ramifications of this context relative to the containment, preservation, and recovery of evidentiary material that may include weapons, remains, and personal effects?
- How is the geologic context of a forensic site or potential forensic site going to influence the methods used to address the forensic questions posed by the site?
- How do the geologic characteristics of a clandestine gravesite relate to the conditions and circumstances of burial?
- Can a clandestine burial site be better defined in a non-intrusive, non-destructive manner?
- Were recognized, ethical standards and procedures employed in the geologic aspects of a given project or concern?

The practical aspect of forensic geology involves the direct application of geologic principles, practices, and procedures to an array of forensic problems and legal issues. Geology is in part, a collaborative science drawing on other scientific disciplines to support, to expand, and to help define the principles on which geologic science is based. Forensic geology is equally collaborative in character and should be viewed as only one of a number of technical and scientific disciplines involved in the elucidation of any given forensic problem. In certain instances, the ultimate answer to a forensic question may be identifiably and absolutely geologic in nature as in the case of materials identification and characterization. In other instances, geology may contribute to the solution of a forensic problem or to the answer of a forensic question as in the location of a clandestine gravesite or buried evidence where geophysics, remote sensing, image interpretation, botany, entomology, canine sweep, or witness interrogation play equally important roles.

Forensic geology also encompasses the interpretation and application of accepted professional codes of ethics, procedures, and standards of performance under forensic circumstances and controversy. Expert testimony and legal debate help define, substantiate, and in some cases, help revise and modify such codes, procedures, and standards as applied generally to the earth sciences.

2. Geologic Science

The traditional view of science has long had a physics bias emphasizing experimentation, quantification, and prediction as its essential and fundamental attributes. In contrast, geology tends to be conceptual, observational, and largely descriptive. It is a philosophical and an intellectual science. The 4.6 billion year age of earth and the ample expanses of time in which all earth processes function constitute the science's fundamental concerns with profound and abundant time. Geology's absolute foundation of profound time inhibits the comprehensive and indisputable definition of phenomena that have occurred in the long and distant past. Rigorous experimentation is also largely excluded from geology's scientific methodology as the time context of the most basic geologic processes, events, and phenomena cannot be meaningfully modeled or in any way incorporated into the experimental process. Geologic explanations tend to have a more probabilistic character and therefore, geologic conclusions often tend to be probabilistic.

This is not to say that some aspects of the geologic sciences cannot be distinctly quantifiable and subject to rigorous and meaningful experimentation: e.g., geophysics, petrophysics, geochemistry, and geostatistics.

Another fundamental concern of geologic science is that of uniformity of process over deep time. The fundamental precept of uniformity of process over time is termed "uniformitarianism". The dictate of uniformitarianism holds that the existing physical and chemical processes forming and modifying the earth at present have acted in the same manner throughout earth's history. Further, it is considered that these processes are sufficient to account for all geologic change. In essence, uniformitarianism states that water has always flowed down hill, sedimentary strata have always been deposited horizontally, earth's crustal plates drift with time, and earth's surface continues to be impacted by space debris.

Two less philosophical but none-the-less basic precepts of geology serve to frame a portion of forensic geologic methodology. These precepts or "laws" are referred to as Steno's Principles—after Nicolaus Steno (1638-1686) a Danish geologist and theologian—and include the "law" of original horizontality and the "law" of superposition. The law of original horizontality simply states that sedimentary strata are originally laid down horizontally under the effects of gravity. The boundary between two different strata will likewise be horizontal. Unless disturbed by subsequent geologic processes, sedimentary strata will remain essentially horizontal and boundaries will likewise remain flat. A corollary to the law of original horizontality that can have distinct forensic ramifications is that objects or material located within the same stratum are of the same relative age. The law of superposition states that within any sequence of sedimentary strata that has not been disturbed since deposition, the youngest stratum is at the top of the sequence and the oldest at the bottom of the sequence. The order of deposition of any sedimentary sequence is from the bottom of the sequence upward.

These principles and precepts largely form the basis of application of the geologic sciences to forensic concerns and circumstances. These principles (and others like them) are utilized in the search for recovery and preservation of physical evidence at a forensic site or crime scene. These principles provide the intellectual framework that is the basis for the definition and comprehension of the contextual relationship between recovered evidence and its environment of deposition and mode of occurrence. These principles also serve as a basis for the evaluation and interpretation of laboratory analyses of geologic materials that reflect upon the broad context or setting of a given forensic site or forensic circumstance.

3. Geologic Methodology

The basic field methodology utilized by the geologist differs little from that utilized by other field scientists: archaeologists, anthropologists, botanists, or indeed, crime scene investigators. Those differences that do exist are largely philosophical and/or focus on the intellectual specifics of a particular science.

A major concern of many forensic problems may be the location of the scene of activity within three-dimensional space generally manifested as a map of some form. The mapping of a forensic site can take many forms ranging from a simple sketch to a highly accurate topographic map compiled to stringent survey standards. Any map no matter how rough, should include recoverable or identifiable reference points for both horizontal and vertical control, a north arrow or some other orientation designation, and a scale no matter how approximate. For completeness, any map should be dated, it should contain information relative to the circumstances of compilation, and the compiler’s name(s) documented. Existing topographic maps like those published by the United States Geological Survey serve as excellent bases for the mapping of areas of concern. Today many of these topographic maps are available both in hard copy and in electronic form. Precise scene maps if needed, can also be developed on site by professional topographers and surveyors.

Aerial photographs and hybrid topographic maps utilizing a photographic base are also useful in determining the location of a given site. As will be discussed below, these photographs are available from a number of sources. The orientation and scale requirements of maps also apply to aerial photographs regardless of source.

A rectilinear grid may facilitate site mapping and provide precise reference relative to material recovered from a site. The specifics of any grid depend upon the requirements of the circumstances. Grid dimensions can be in English or metric units and can be laid out to accommodate the geometry of a particular site. The grid itself can be constructed with builder’s cord or thin rope connecting corner stakes. PVC tubing can also be effectively used in the construction of a grid. Any grid must be referenced to a known and/or recoverable point to establish horizontal control. A vertical control point must also be established. Any material collected within a grid square should be referenced in three-dimensional space to that particular grid square. The established grid should be included within any site map developed and the control points relative to the grid, both horizontal and vertical, documented on this map.

A problem always exists as to what to map at a given site. What parameters are critical to the site and how one maps them? Usually these critical features become apparent as mapping proceeds; initially it is probably more advantageous to map too many features than too few. When an initial mapping effort is completed it may become obvious that critical elements were omitted or over looked and that a second phase of mapping is required. In the three-dimensional mapping of an excavation it is essential that photography is closely integrated into the mapping process and that all evidentiary material is carefully photographed within the grid prior to removal to enable further excavation. It should be kept firmly in mind that any field map and all associated field notes become evidentiary material themselves and are therefore subject to subpoena and discovery. For this reason alone, all field mapping must be done in a thorough and professional manner. Maps and notes must be legible, they must be as accurate as possible under existing field conditions, and they must be as comprehensive as possible. Final versions of maps, drawings, and associated graphics can be completed under office conditions for reports and presentation but it is often the field versions of these documents that are contested within a court of law.

The acquisition and interpretation of aerial photographs and digital imagery are engineering and scientific disciplines unto themselves. A basic understanding of these disciplines and the contribution photographs and images can make to the definition and evaluation of a forensic scene is helpful. There is a wide range of sources of aerial photographs and a variety of digital imagery. Governmental sources at all levels may include geological and topographic surveys, military departments, soil conservation agencies, forest and rangeland management services, and environmental agencies. Sources at the state and local levels may include land use planning and zonation entities, water conservation and water use authorities, utility providers, and tax authorities of various levels. Private sources of aerial photographs and digital images may include civil engineering and construction companies and a wide range of property and site development companies.

Photographs and images available through governmental or commercial sources are often acquired periodically and every effort should be made to acquire scenes before and after any postulated forensic circumstance. Both digital and analog imagery can be professionally enhanced and processed to aid in interpretation.

Where available, photographs and images should be obtained in stereo format. When collected, images in stereo format have a sequential twenty- to fifty-percent coverage overlap on a scene-by-scene basis. This overlap permits a viewer/interpreter to see a particular scene in three dimensions with the use of a stereoscope. A stereoscope is a simple optical device that forces each human eye to focus on an single scene of an overlapping pair. Because of the overlap, each individual scene of the sequence is photographed at a slightly differing angle. The brain merges these slightly differing scenes into one scene but that scene is “seen” in three dimensions. The mechanics and optics of scene acquisition and view enhance the vertical dimension of the scene and thereby steepens topography and emphasizes structure heights. Such vertical exaggeration can be advantageous in interpretation and evaluation of the scene portrayed.

Aerial photographs can be acquired for any forensic scene using a variety of camera equipment and a fixed- or rotary-wing aircraft for a platform. Such acquisition should be done on some form of a grid basis to ensure as comprehensive coverage as possible. Any forensic scene should be photographed within a relatively broad context to document general access, relationship to regional topographic features, and relationship to associated cultural features.

Both seasonal and temporal variation can aid in the evaluation and interpretation of aerial photography and some digital imagery. Sun angle tends to emphasize shadows that help define surface disturbance and therefore if shadow is critical, photography obtained in the morning or the evening may be optimal. Seasonal plant growth, plant robustness, and/or season-end plant wilt can prove useful in the definition of soil profile disruption. Light snowfall can emphasize subtle topographic relief and can help delineate cultural features such as trails, tracks, or little-used roads. Both time and seasonal variation should also be taken into account in do-it-yourself acquisition of photographs or imagery.

Any forensic site, whether designated as a crime scene or not may be complex due to the presence of law enforcement personnel, coroner and/or medical examiner staff, interdisciplinary colleagues and representatives of the media. In some instances the forensic geologist may work alone or with earth science colleagues but it is likely that he will find himself functioning professionally as part of an interdisciplinary team. He must therefore be prepared to communicate information to non-technical co-workers in a clear and understandable manner that is both useful and relevant to the problem at hand. The thrust of information sharing should be clarification not simplification. Every effort should be made to keep professional jargon and obscure scientific terminology to an absolute minimum.

The forensic geologist must become conversant with the general requirements of crime scene discipline that include establishment of scene walk lines, personnel restrictions at particular scenes, scene sign-in and sign-out procedures, evidence collection process and procedure, and conventions in dealing with the media. Discipline can vary from scene to scene and from circumstance to circumstance but all personnel at a given site need to abide by the protocol established at that particular site.

4. Site Specific Geologic Context

Forensic problems often involve earth's surface, disruption of that surface, or material derived from that surface. In addressing the specific problem of clandestine gravesite location and evaluation, the ability of any investigator to reconstruct events/circumstances prior to, during, and subsequent to interment of remains (and potentially, evidentiary material) is dependent on the collection, preservation, and comprehensive evaluation of data collected relative to those remains. These data are contextual data that address the broader aspects of the actual grave and its contents: its location with regard to its topographic setting; the physical access to the gravesite; the physical and chemical characteristics of its setting; and, the character of the grave itself with regard to location, size/depth, and host material. But establishing the context for any forensic problem or circumstance transcends the specifics of the individual clandestine gravesite: it has broader application. Geologic information may constitute only part of the contextual data relevant to a site and must be developed within the broad interdisciplinary scope afforded by most forensic scenes or circumstances.

It is the job of the forensic geologist to explore and define the geologic context of any forensic scene or problem. This geologic context may include the geomorphology; the bedrock setting of all potential lithologic host and source material; the character, distribution, and profile of extent soils; the broad groundwater regime; and the mining or other minerals exploitation history of a given area. The forensic geologist must be conversant with information sources such as geologic maps, soils and groundwater maps, drainage maps and surface water reports/summaries, mine/quarry reports and maps, and applicable regional geologic studies relative to the site or scene of interest. Further, the forensic geologist must be prepared to work within the standards, procedures, and ethics of his profession as they relate to forensic problems and circumstances.

4.1 Geomorphology

Geomorphology constitutes study of landforms. The geomorphology of a forensic site is basically "the lay of the land" and what controls the character of the land surface: its topography and its drainage. Geomorphology often determines land use, it often controls surface drainage, and it controls intensity and direction of groundwater flow. Point-to-point visibility is controlled by geomorphology but it is often compromised by vegetative cover.

Topographic maps and air photos are invaluable in developing an understanding of an area's geomorphology, as are fixed- or rotary-winged aircraft over flight, road reconnaissance, and ground traversing. In clandestine grave search point-to-point visibility and access may be critical location factors. An understanding of the geomorphologic context of an area can help to focus the ground search dictated by a broad range of forensic circumstances.

4.2 Rock Type

The rock type at a forensic scene may be important relative to its definition, its source, or the circumstances of its presence at the scene. Rock or rock-derived material may be present at a forensic scene either as residual material related to outcrop and/or outcrop weathering processes or as material transported to the scene from an outside source. Examples of transported materials would be any rock-derived construction materials such as sand and gravel, decorative stone, backfill, riprap, and paving/surfacing materials. Transported materials would also constitute materials brought to a site on the clothes of either a victim or suspect and/or related to vehicular transport to and from a specific site.

Acquisition and review of geologic maps relative to a particular forensic site or scene along with in-field traverse, observation, and sampling can help define rock types present. Attention should be paid to the general distribution of rock types within a particular site and to the relationship between rock type and soil character. Some evaluation should be made relative to the uniqueness of rock type to a specific locale or the definition of unique recognition characteristics of rock from a particular site.

Transported, rock-derived materials need to be characterized as to composition, nature, and possible source. Unique characteristics especially relating to ultimate source need to be defined and documented. If appropriate, samples of transported material should be collected for reference to potential source. Geologic maps and engineering or geologic reports can prove helpful in the determination of source of transported, rock-derived materials. Interrogation of local construction company personnel and of local materials haulers can prove helpful in determining the source of materials and the timing/circumstance of haulage, distribution, and deposition. Geologic evaluation of ultimate sources of transported materials may be warranted. Such evaluation may require identification of material and definition of unique characteristics that could potentially link material source to material present at a specific forensic site.

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Biographical Sketch

J.W. Lindemann's career as a geologist encompasses over 35 years of worldwide, field-oriented, professional activity working within corporate environments and as an independent consultant. Professional endeavors have been broadly focused to include the identification and evaluation of mineral resources, investigation and amelioration of environmental problems, and application of geologic principles and methodology to a wide range of forensic problems. Mr. Lindemann holds a Professional Degree in Geological Engineering from the Colorado School of Mines and a Masters Degree with Distinction from the University of London along with the Diploma of the Imperial College, Royal School of Mines (London). Mr. Lindemann maintains professional certification through the American Institute of Professional Geologists and is a Fellow of the Geological Society of America. Mr. Lindemann is among the initial founders of NecroSearch International and is active within the organization serving on its Board of Directors, participating in various committee activities, and providing in-field, professional contribution to the organization's casework. In this capacity Mr. Lindemann has worked with a variety of law enforcement agencies including FBI, DEA, state and urban police departments, sheriff's departments, and coroner's investigators in the practical application of geological knowledge to particular forensic problems and investigation.