This document sets forth background materials on the scientific research supporting examinations as conducted by the forensic laboratories at the Department of Justice. It also includes a discussion of significant policy matters. This document is provided to assist a public review and comment process of the related Proposed Uniform Language for Testimony and Reports (posted separately). It is not intended to, does not, and may not be relied upon to create any rights, substantive or procedural, enforceable by law by any party in any matter, civil or criminal, nor does it place any limitation on otherwise lawful investigative and litigative prerogatives of the Department.

SUPPORTING DOCUMENTATION FOR DEPARTMENT OF JUSTICE PROPOSED UNIFORM LANGUAGE FOR TESTIMONYAND REPORTS FOR THE FORENSIC GEOLOGY DISCIPLINE

Background

Geology, the scientific study of the Earth, has existed since man first contemplated the origin of the universe. The use of geologic materials in criminal cases to link people, places and objects of investigative interest has existed for over 100 years.[1] Dr. Walter McCrone, a well-known microscopist of the 20th century stated, "Soil samples are so diverse in origin…that rarely are two samples from different locales confusingly similar microscopically."[2]

Modern geoscience has evolved greatly during the last century with the development of sophisticated analytical equipment. The development of instrumental methods such as x-ray diffractometry (XRD) and electron microscopy in the 20th century enhanced the capabilities further.[3] While microscopy remains the primary technique used in the analysis of geologic materials, numerous instrumental methods, including confocal Raman spectroscopy, laser induced breakdown spectroscopy (LIBS), laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), and isotope ratio mass spectrometry (IRMS)[4] may add additional discrimination potential when comparing geologic materials. Geographic Information Systems (GIS) – based geographic attribution tools are also being developed that may improve the interpretation of geologic materials for both investigative and intelligence applications.

In the last decade there have been numerous publications about forensic geology, outlined in the Interpol Forensic Science Review.[5] As a result of these publications and interest by

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[1] Murray, R.C., "Forensic geology: yesterday, today and tomorrow: in Pye, K. and Croft, D.J, (eds.), *Forensic Geoscience: Principles, Techniques and Applications.*, Geological Society, London, Special Publication No. 232, 2004, p. 7-9.

[2] McCrone, W.C., "Forensic Soil Examination," *The Microscope,* Vol. 40, 1992, p. 109-119.

[3] Needham, G.H., *The Practical Use of the Microscope Including Photomicrography,* 2nd ed., Charles C. Thomas, Springfield, Illinois, 1977, p. 4-6.

[4] Sugita, R., "Forensic Geology: A Review: 2007 to 2010", 16th Interpol Forensic Science Symposium, Lyon, France, October, 2010.

[5] Sugita, R., "Forensic Geology: A Review: 2007 to 2010", 16th Interpol Forensic Science Symposium, Lyon, France, October, 2010; Sugita, R., "Forensic Geology: A Review: 2010 to 2012", 17th Interpol Forensic Science Symposium, Lyon, France, October, 2013.

geologists, an international working group on forensic geology was established in 2009. This working group was sponsored by the International Union of Geological Sciences (IUGS), one of the largest and most active, non-governmental scientific organizations in the world. In 2011, the IUGS Executive Committee established the Initiative on Forensic Geology (IFG).[6] The IUGS-IFG is chartered for five years to promote global awareness of forensic geology through training and outreach to law enforcement, scientists and universities.

Principles of Forensic Geology Examinations

Forensic geology may be defined as a subdiscipline of the geosciences[7] that applies geological information and methods to questions to be presented before a court of law[8] and involves the examination of geologic materials (e.g. soil, rocks, minerals, gemstones), geologically-derived materials (e.g. bricks, concrete blocks, ceiling tile), and unknown materials. For the purposes of this document, these will be collectively referred to as "geologic materials." Within the field of forensic geology there is considerable overlap with other closely related disciplines, including archaeology, anthropology, and botany.[9] There have been innumerable books and peer-reviewed journal articles written on the geologic theory, examination of geologic materials, validation of geologic examinations, and interpretation of the results of geologic examinations in geologic literature and in the literature of other related disciplines.

Forensic examinations of geologic materials are conducted for investigative and intelligence purposes to: 1) determine if two or more geologic materials originated from different sources; 2) identify an unknown material; 3) assess the geographic attribution (provenance) of geologic materials; 4) determine the origin/end-use of geologically-derived materials; and, 5) determine the significance of finding two or more geologic materials indistinguishable. To do this, the forensic geologist must possess a thorough knowledge of geology, and integrate principles of chemistry, physics and their subdisciplines.[10]

Forensic examination of geologic materials requires the comparison of class characteristics that may eliminate materials as originating from the same geographic location or group of manufactured materials. Depending on the nature of the item(s) and the examinations conducted, a Geologist/Forensic Examiner may arrive at different conclusions regarding the identity and/or characteristics of a geologic material(s). Only when two or more geologic materials physically fit together can it be said that they were once part of the same broken object (e.g. brick). Geologic materials analysis may also be used to estimate provenance or "forensic geolocation."[11]

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[6] http://www.forensicgeologyinternational.com/

[7] The many subdisciplines of geology such as geophysics, geochemistry, paleontology, are collectively referred to as geosciences, but are also commonly referred to as "geology."

[8] Pye, K. and Croft, D.J., "Forensic geosciences: introduction and overview: in Pye, K. and Croft, D.J, (eds.), *Forensic Geoscience: Principles, Techniques and Applications.* Geological Society, London, Special Publication No. 232, 2004, p. 1-5.

[9] *Id*.

[10] Pye, K., *Geological and Soil Evidence,* CRC Press, Florida, 2007.

[11] *Id*.

Forensic examination, identification and comparison of materials demands rigorous protocols and any conclusions drawn from such analysis must be based on a strong scientific foundation.[12] The preferred methods employed in the forensic examination of geologic materials are based on techniques used in the fields of geology, geochemistry, and soil science; are suitable for very small samples; are non- or minimally-destructive; require a minimal amount of sample preparation; and vary based on specimens. The standard operating procedures (SOPs) that are used by the Department are based upon well-established geological and instrumental techniques that are universally accepted in the scientific community. These techniques are not limited to forensics and are routinely used in a variety of industries as well as in academia. While instrumentation has advanced to become more sensitive with shorter analysis times, the same basic methods and theories have been employed for decades.

There are myriad peer-reviewed publications validating the methods used and the data interpretation in geologic materials analysis.[13] Further research in these areas is continually ongoing. In addition to the Department laboratories, these procedures or variations thereof are used by many other laboratories including, but not limited to: the National Research Institute of Police Science, Tokyo; the Centre for Australian Forensic Soil Science, Perth; the California Department of Justice, Riverside; and private forensic laboratories such as Microtrace, LLC.

Geologic Materials Examinations

Analysis

Identification and comparison of geologic materials for the purposes of determining the possibility of a common origin is accomplished by using one or more analytical techniques. These techniques can include:

- Color designation: Color descriptions are conducted on air dried specimens in a controlled environment using standard illumination: at a minimum, a light box set to simulate natural daylight. Additional lighting conditions can be used as necessary. Items are compared visually and their color described by reference to the Munsell Soil-Color

[12] Kirk, P., *Density and Refractive Index: Their Application in Criminal Identification*, Charles C. Thomas, Springfield, IL, 1951, p. 4-5.

[13] e*.g.*, Sugita, R., "Forensic Geology: A Review: 2007 to 2010", 16th Interpol Forensic Science Symposium, Lyon, France, October, 2010.; Sugita, R., et al., "Forensic Geology: A Review: 2010 to 2012", 17th Interpol Forensic Science Symposium, Lyon, France, October, 2013.; McCrone, W.C., "Forensic Soil Examination," *The Microscope*, Vol. 40, 1992, p. 109-119.; Antoci, P.R. and Petraco, N., "A Technique for Comparing Soil Colors in the Forensic Laboratory," *Journal of Forensic Sciences*, Vol. 38, No. 2, p. 437-441.; Murray, R.C., and Tedrow, J.F.C., *Forensic Geology – Earth Sciences and Criminal Investigation*, Rutgers University Press, New Brunswick, NJ, 1975, P. 109-112.; Schatz, W. and Saale, H., "Dirt Scraped from Shoes as a Means of Identification," *The American Journal of Police Science*, Vol. 1, No. 1, 1930, p. 55-59.; "Soil as Evidence," *Law Enforcement Bulletin*, Federal Bureau of Investigation, April 1975.; Murray, R.C., *Evidence from the Earth-Forensic Geology and Criminal Investigation*, Mountain Press Publishing Company, Missoula, Montana, 2004.; Bowen, A., "Individualizing Minerals: A Proposed Approach for Forensic Soil Comparison," *Microscope*, Vol. 55, No. 2, 2007, p. 59-73.

Charts.[14] Comparison of color is often the only test needed to differentiate specimens from two different source locations.[15]

- Textural analysis: Texture includes many features such as the grain and ped *(i.e.* natural soil aggregate) morphology, particle size distribution, weathering, and inclusions of the constituent particles. Most textural features can be determined visually with the aid of light microscopy. In addition to light microscopy, scanning electron microscopy (SEM) can be useful in characterizing particle morphology.[16] Particle size distribution can be determined by a variety of techniques including sieving[17] and microscopy (stereobinocular, petrographic, and electron).[18]
- Mineralogical determination: Identification of components present and their relative proportions are determined by standard mineralogy and optical mineralogy methods, using stereobinocular and petrographic microscopes. Additional techniques for identification and characterization include XRD, x-ray fluorescence spectroscopy (XRF), SEM with energy dispersive x-ray spectroscopy (EDS), or other methods as needed.[19]

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[14] Soil colors are measured by comparison with a color chart. The collection of charts used with soils is a modified version of the collection appearing in the Munsell Book of Color and includes only that portion needed for soils, about one-fifth of the entire range found in the complete edition (From: The US Department of Agriculture Handbook 18 – Soil Survey Manual).

[15] Gemological Institute of America (GIA). *GIA Gem Identification Laboratory Manual.* 4th ed. Gemological Institute of America, Carlsbad, California, 1998.; *Munsell Soil-Color Charts with genuine Munsell® color chips*, Munsell Color x-rite Productions, Michegan, 2009.; Olson, G.W., *Soils and the Environment,* Chapman and Hall, New York, 1981, p. 17-22.; Nickolls, L.C., *Methods of Forensic Science,* F. Lundquist, Ed., Vol. 1, Interscience Publishers, New York, 1962, p. 355-358.; Nickolls, L.C., *Methods of Forensic Science,* F. Lundquist, Ed., Vol. 1, Interscience Publishers, New York, 1962, p. 355-358.; Dudley, R.J., and Smalldon, K.W., "The Evaluation of Methods for Soil Analysis Under Simulated Scenes of Crime Conditions," *Forensic Science International*, Vol. 12, No. 1, 1978, p. 49-60.; Dudley, R.J., "The Use of Colour in the Discrimination between Soils," *Journal of the Forensic Science Society*, Vol. 15, 1975, p. 209-218.; Sugita, R. and Marumo, Y., "Validity of color examination for forensic soil identification," *Forensic Science International*, Vol. 83, 1996, p. 201-210.; Birkland, P.W., *Soils and Geomorphology,* Oxford University Press, New York, 1984, p. 14-15.

[16] Pye, K., "Forensic Examination of Rocks, Sediments, Soils and Dusts Using Scanning Electron Microscopy and X-ray Chemical Microanalysis," Geological Society of London Special Publication, vol. 232, 2004, P. 103-121.; Le-Ribault, L., "Exoscopy and Endoscopy of Quartz of Detrital Origin," Masson, 1977.

[17] Pye, K., *Geological and Soil Evidence*, CRC Press, Florida, 2007.

[18] Federal Bureau of Investigation. Laboratory Division. Trace Evidence Unit: Soil Examinations. In: *Trace Evidence Unit Standard Operating Procedures Manual.* FBI Laboratory, Quantico, Virginia, November 19, 2007.; Morgan, R.M., et al., "Quartz Grain Surface Textures of Soils and Sediments from Canberra, Australia: A Forensic Reconstruction Tool," *Australian Journal of Forensic Sciences,* Vol. 42, No. 3, September 2010, P. 169-179.; Pye, K., "Forensic Examination of Rocks, Sediments, Soils and Dusts Using Scanning Electron Microscopy and X-ray Chemical Microanalysis," Geological Society of London Special Publication, vol. 232, 2004, P. 103-121.; Sugita, R., and Marumo, Y., "Screening of Soil Evidence by a Combination of Simple Techniques: Validity of Particle Size Distribution," *Forensic Science International,* Vol. 122, 2001, p. 155-158.; Morgan, R.M., et al., "Quartz Grain Surface Textures of Soils and Sediments from Canberra, Australia: A Forensic Reconstruction Tool," *Australian Journal of Forensic Sciences,* Vol. 42, No. 3, September 2010, P. 169-179.; Folk, R.L., "Stages of Textural Maturity in Sedimentary Rocks," *Journal of Sedimentary Petrology,* Vol. 21, 1951, p. 127-130.

[19] Palenik, S., "Microscopical Technique for the Examination of Soil in Criminal Cases," 10th Triennial Meeting of the International Association of Forensic Sciences, Oxford, UK, 1984.; Lynn, W. and Thomas, J.E., Petrographic Microscope Techniques for Identifying Soil Minerals in Grain Mounts. In: *Methods of Soil Analysis Part 5 – Mineralogical Methods,* Soil Science Society of America, Madison, Wisconsin, p. 161-190.; Palenik, S., Heavy Minerals in Forensic Science. In: *Developments in Sedimentology, 58, Heavy Minerals in Use*, Maria Mange and

The actual tests performed by examiners are dependent on the type(s) and quantity of the geologic material(s) present, and the needs of the examination/analytical requirements. All results are confirmed by a second qualified examiner.

Interpretation

The identity of an unknown geologically-derived material may be determined using the techniques described above and subsequently reported.

Color, texture, and composition are used as comparison criteria when a sufficient quantity of material for reliable and reproducible results is present. When these factors can be determined, they can be used to assess the significance of finding indistinguishable soils. There are four possible conclusions when comparing geologic materials: [20]

- The compared items were once part of the same broken object. This conclusion is reached when two or more items from geologic/geologically-derived materials (e.g. concrete blocks, rock fragments) physically fit together.
- The possibility that the compared item(s) originated from the same source as the known exemplar cannot be eliminated. This conclusion is reached when the item(s) cannot be differentiated from the exemplar using all observed characteristics. The significance of finding two or more items indistinguishable will vary depending upon the rarity of the materials involved.
- No conclusion can be reached on whether or not the compared items could have originated from a common source. This conclusion can be reached for several reasons, including insufficient quantity for either the compared item(s) or the exemplar, when there is mixing with other materials, or when there has been deleterious change of the item(s) or exemplar.
- The possibility that the item(s) originated from the same source as the exemplar is eliminated. This conclusion is reached when the item(s) can be differentiated from the exemplar, and no mixing or deleterious change is indicated.

Limitations

David Wright eds., Elsevier, Amsterdam, 2007, p. 937-961.; Lynn, W., Thomas, J.E. and Moody, L.E., Petrographic Microscope Techniques for Identifying Soil Minerals in Grain Mounts. In: Ulery, A.L, and Drees, L.R. (eds), *Methods of Soil Analysis Part 5 – Mineralogical Methods,* Soil Science Society of America, Inc., Madison, WI, 2008, p. 161-190.; Fry, W.H., "Petrographic Methods for Soil Laboratories," *US Department of Agriculture Technical Bulletin,* Vol. 344, 1933.

[20] The following statements are those currently used by the FBI Mineralogy Group (December, 2015).

Soil:

Soil properties vary both across the land and below the land surface as a function of parent material,[21] climate, biological activity, geography, and time, yielding soil that is different from location to location and with depth below the surface. These differences can occur abruptly or gradually. Therefore, the exemplar soils from a specific site must be interpreted to represent only that site, and may not be representative of all soils in the area or soil that may have been present in the past.

Due to the possible variations in soil, the boundaries of a homogenous soil cannot be predicted with absolute certainty. Soil and geologic studies and maps of an area may assist in defining the approximate extent of a homogeneous soil.

Geologically-derived materials:

It is usually not possible to predict the total number of items in a class of materials produced with the same characteristics. In materials with greater compositional and morphological variability (e.g., bricks), a smaller percentage of the total number of items in a class will be indistinguishable than in materials with very little variability (e.g. a particular variety of fiber glass).

Policy Considerations

In 2006, Congress authorized the National Academy of Sciences to conduct a study on forensic science, which culminated in a 2009 report.[22] Although the NAS report did not provide specific criticism or guidance regarding forensic geology examinations, it did recommend that all forensic reports include the following: identification of the tests conducted, certain results of testing, and potential sources of error and statistical error. To conform to the NAS recommendations, soil and geologic materials reports include a discussion of the tests performed, the relative strength of the findings, and the limitations associated with a given series of examinations.

[21] The material, mineral or organic, from which a soil develops.

[22] National Research Council. (2009) Strengthening Forensic Science in the United States: A Path Forward, National Academy Press, Washington, D.C. (http://nap.edu/catalog/12589.html).