Forensic Geology

Review: 2007 to 2009

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1. Introduction

This review article covers developments and topics in the field of forensic geology during the period from 2007 to 2009. The title of this review is “Forensic Geology,” but the review is not restricted in narrow definition of “geology”; it includes a wider meaning (1). Some practitioners have preferred to use the term “forensic geosciences” in recent years instead of “forensic geology.” This change in designation may indicate that more people of the field of geology and its related sciences are being noticed and getting involved in the science for criminal investigations. In this review, papers on environmental forensics have not been included.

2. Networking and Meetings

Networking was accelerated rapidly in the period between 2007 and 2009. The most significant movement was the establishment of GIN (Geoforensic International Network), which is a worldwide network of forensic geoscientists. Further, the international working group of forensic geology was agreed upon by IUGS-GEM (International Union of Geological Sciences – Geosciences for Environmental Management) in 2009 (2, 3). Dr. Donnelly had enthusiastically led forensic geoscientists around the world to build a network. Before the establishment of an international group, a key network of geoforensics was begun in the United Kingdom (GIMI: Geoforensics and Information Management for crime Investigation). There are also two ongoing projects in the UK. One is the SoilFit (Integration of Soil Fingerprinting Techniques for Forensic Applications) project (4), which is being carried out to investigate the potential of advanced analytical methods in providing soil forensic intelligence to police investigations. It is being carried out by a multi-disciplinary group of experts of the UK academic and law enforcement organizations. As part of this project, the group has examined various problems related to soil as both intelligence and evidence in a forensic context, such as establishment of a statistical framework, assessment of the variability of soil, and development of a geographic search tool. The other ongoing project is the SoilFUN (5) (Soil Forensic University Network), which was begun as a daughter project of the SoilFit project, based on the collaboration of universities and institutes in the UK. Morrison *et al.* (6) have reported the preliminary results of this project. A large number of undergraduate students enrolled in forensic science courses are learning how to apply their skills in a forensic context.

The Second International Conference on Environmental and Criminal Forensics was held in November 2007 at Edinburgh (7). The conference included seven sessions, namely “environmental soil forensics,” “criminal soil forensics,” “geoforensics,” “geostatics, databases, and geographical information systems,” “biological and chemical analytical diagnostics,” “forensic taphonomy,” and “communications and advocacy” with a public lecture “the global way forward” by Dr. Robertson, and 31 presentations from the conference were published as a book titled “Criminal and Environmental Forensics” in 2009 (8). The third conference is planned in November 2010 in California, USA. FGG, the Forensic Geoscience Group of the Geological Society, held a meeting “Geoscientific Equipment and Techniques at Crime Scenes” in 2008 (9). In the annual meetings of the Geological Society of America (GSA), presentations on forensic geology were included every year (10). The topics cover a broad range of topics related to forensic geology, including education, analytical methods, and case reports.

3. Books

In addition to the book of Ritz *et al.* (8) introduced in the former section, at least three titles were published in the review period. Pye (11) published a book on this issue titled “Geological and Soil Evidence: Forensic Applications” in 2007. It describes the types of geological evidence, the techniques applied, and the evaluation of the obtained results for people not familiar to geology and for geologists who have little experience of forensic application. Ruffell and McKinley (12) released a book titled “Geoforensics” aiming “to show how various geoscience techniques are used in forensic investigations.” Tibbett and Carter (13) edited “Soil Analysis in Forensic Taphonomy: Chemical and Biological Effects of Buried Human Remains,” which is the first book on the chemistry and biology of soil related to the decomposition of human remains.

4. Analysis of soil, sediment, and rock evidence

Color examination is one of the fundamental methods of forensic soil examination. Sand and dune sediments from the beaches of Portugal were analyzed using spectrophotometer, and the results were compared (14, 15, 16). A unique attempt of color analysis was reported by Marumo (17) using computerized image analysis software.

Morphological features of grains using an optical microscopes and/or a scanning electron microscope (SEM) were discussed by several researchers. The quartz grain surface was observed by SEM and examined to determine whether the surface texture changes at a car fire temperature by Morgan *et al.* (18). Millette *et al.* (19) examined coke and coal particles by observing them under both an optical microscope and an SEM in combination with an energy dispersive X-ray (EDX) analyzer. The analysis of the chemistry of light minerals in soil by an SEM-EDX system was reported by Aoki and Oikawa (20) to discriminate soil and an automated SEM-EDX to analyze grain chemistry; the shapes were described by Pirrie *et al.* (21, 22). Schwandt (23) presented a soil grain analysis using optical microscopes and digital x-ray maps, which could also provide information about the bulk chemistry of the sample by manipulation. The elemental data of feldspars sampled at the beaches of a prefecture obtained by an X-ray analyzer attached to an SEM was plotted on a mineralogical triangle diagram; the samples were successfully discriminated by the geological backland (24). The trace amount of soil and the smear of soil on cloth were examined by a variable-pressure SEM-EDX; and was considered useful for the screening of a forensic soil examination (25).

Isphording(26) stressed the importance of heavy minerals even if the amount of these minerals in the soil was small because the types and their chemistry reflected their crystallizing conditions. Biotite and its weathered material are very common in immature surface soil in granitic rock regions. Their chemical composition reflected the composition of other heavy minerals stated by Isphording (26); this finding was considered to be useful information for forensic soil investigation (27, 28). Bowen (29) stated some principles of forensic soil comparisons and described the use of additional information such as morphology, chemistry, and isotopes of mineral grains to individualize soil samples.

The use of cathodoluminescence was described to screen and discriminate mineral grains (30). Infrared (IR) spectrometry has long been used for providing the compositional and structural information of various types of substance, including minerals before the wide usage of X-ray diffractometry (XRD). It has been revisited and examined as a rapid identification method for mineral species in forensic evidence by Weiger *et al.* (31). Newly developed analytical techniques such as confocal Raman, laser induced breakdown spectrometry, and laser ablation inductively coupled mass spectrometry were introduced and compared to analytical methods currently applied to forensic geology by Walker (32).

Pye and his co-researchers continuously improved an analytical procedure by inductively coupled plasma (ICP)–atomic emission spectrometry (AES) and mass spectrometry (MS) as already mentioned in the last review (1). Pye *et al.* (33) assessed compositional differences between different size fractions and different samples. The method was also applied to develop a searchable database by Pye and Blott (34).

Isotope ratio mass spectrometry (IRMS) is a significantly developing field of forensic chemical analysis, and a network was recently established in the forensic community (35, 36). The application of IRMS analysis to determine the origin of carbonate rocks related to a crime was reported by Roelofse and Horstmann (37).

The magnetic susceptibility of beach and dune sediments was measured for forensic application (15, 16). A unique application of magnetics used in the case of a car accident related to soil was reported (38) in which analytical results were obtained from the evidence and samples of two suspected origins, where the pedological features were very similar and were compared for discrimination.
The work flow proposed by Graves (39) in 1979 was modified as a simple and easy-to-learn method (40). Iconology was introduced in addition to mineralogical, micropalaeontological, and petrographical studies to link a suspect to the crime in a simulation case work (41). A study utilizing X-ray fluorescence spectrometry (XRF), total organic carbon content, and ion chromatograph were performed to distinguish and estimate a region by Nagahama *et al.* (42) in a volcanic soil area. Melo *et al.* (43) applied a sequential extraction analysis for a forensic soil examination using various instrumental analyses such as ICP-AES, XRD, and visible ultraviolet spectrophotometry. Molina *et al.* (44) and Reyes *et al.* (45)

examined the application of petrographical, mineralogical, and chemical analyses for characterizing soil for forensic purposes.

The organic components of soil have not been considered to a great extent as compared to the physical and elemental composition of soil. Bommarito *et al.* (46) applied high-performance liquid chromatography (HPLC) and ion chromatography to discriminate soil evidence.

5. Biological materials

The importance of palynology was eagerly discussed in many articles during last period of review (1). Wiltshire (47) stated the requirement to a forensic palynologist. Nesterona *et al.* (48) reported cases using pollen in urban surface soil, which often changed by construction, for forensic investigation. The preliminary result of a unique attempt utilizing *testate amoebae* for the discrimination of soil was reported by Swindles and Ruffell (49). *Testate amoebae* was recovered from dried sediments on clothing 10 years after the case. Microfossil has been used frequently for environmental or age estimations in conventional geology. It is applied to discriminate concrete (50) in combination with a mineralogical examination. The plant wax in soil was examined by Mayes *et al.* (51) for the forensic discrimination using GCMS.

Sensabaugh (52) overviewed the present state of microbial community profiling utilizing a DNA analysis in soil and discussed the challenges to overcome for forensic application. The spatial variation of bacterial DNA profiles was examined by Heath and Saunders (53) for a forensic soil comparison on soil samples obtained from three different ecosystems. As a result, small-scale variability can be a problem, but the precise location can be identified. Meyers and Foran (54) reported that bacterial DNA profiling may be useful although variables, especially the time difference, should be considered on the basis of the study on bacterial DNA in soil over a one-year period. Mcdonald *et al.* (55) examined the bacterial, archaeal, and fungal DNA in air-dried soil and found that fungal DNA was less altered than bacterial and archaeal DNA.

6. Taphonomy and soil

The number of papers on taphonomy with respect to soil environment has increased during this review period and includes the book edited by Tibbett and Carter (13). Carter *et al.* (56) reviewed the formation and ecosystem of gravesoil. Microbial activities and the chemistry of soil around a buried cadaver were studied (57, 58). Prangnell and McGowan (59) applied a soil temperature calculation method used in civil engineering to estimate the temperature of the burial site. The effects of the state of the buried tissue were studied. Stokes *et al.* (60), including changes in the chemistry and microbial activities in soil.

7. Search of clandestine graves and missing person

Searching clandestine graves by geophysical, geographical, and geochemical methods are now discussed eagerly. Ruffell and McKinley (61) spared a large volume to these issues in their book.

Jervis *et al.* (62, 63) presented the result of an experimental survey on simulated clandestine graves considering ground water and soil data obtained by the electrical resistivity survey method. The result of the comparison of GPR and electron resistivity tomography (ERT) for the forensic search of clandestine graves was reported by Pringle *et al.* (64, 65).

The effectiveness of the combination of geophysical and geochemical (including hydrochemistry) as well as the role of geoscientists in the search was described (66–69). Harrison and Donnelly (69) described the effectiveness, limitation, and devices of a geophysical survey, and the usefulness of hydrochemical and geochemical examinations. McKunley *et al.* (68) recommended the application of spatial methodology, including geophysical information system (GIS), GPR, hydrochemistry, and cadaver dogs to a forensic search. Parker *et al.* (70) reviewed the search of freshwater bodies using seismic waves, compressed high intensity radar (CHIRPS), side scan sonar, GPR, magnetometers, and other techniques for forensic purposes. An experiment to detect a clandestine grave using the difference in vegetation was also reported by Watson and Forbes (71). The examination of the use of nynhidrin to detect gravesoil was also presented (72, 73).

The significance of this topic is that there are many case reports on this topic as compared to the other type of issues related to forensic geology. Ruffell *et al.* (74) reported a false-positive case of the application of ground penetrating radar and victim recover dogs to search for a suspected location as a “grave” of a missing person with a discussion. Ruffell *et al.* (75) described a search for historical mass graves using historical and anecdotal information, aerial photographs, GPR, and metal detectors. Congram (76) reported the prospection and excavation of a clandestine burial in Costa Rica utilizing a conventional search such as the slumping and different plant growth and by improvising a conventional archaeological excavation method. Billinger (77) introduced the case of the utilization of GPR for the location of a potential human burial under concrete.

8. Education

Forensic geology was introduced at different levels of education, including high school (78–81). In Colombia, “Ibero-American course on forensic geology” was conducted to assimilate geological methods for forensic investigations (82, 83).

9. Database and evaluation

Attempts to create a database for forensic purposes were reported. Pye and Blott (84) gathered existing data from their past examinations of elemental analyses in England and Wales to create a searchable database. The SoilFUN (4, 6) aims to produce analytical data on urban soils, which are relatively little known as compared to non-urban soils. Bergslein and Hovey (85) reported a progress on a project to establish a database on the soil in western New York using XRF and XRD. The difficulties and requirements were discussed by Aitken (86) to determine the likelihood ratio of the obtained data sets of the chemical analyses for a forensic soil examination. A geostatistical method was proposed to utilize spatial databases for solving an intelligence problem by Lark and Rawlins (87).

10. Case report

Cases related to geology and crimes are not only geological materials as trace evidence (88), but as objects of mining fraud cases (89). Criminal cases and fraud cases of mines, gems, and art were introduced to determine how geology can help in solving crimes by Murray (90). He also introduced a new and traditional microscopy technique applied to forensic geology. An experiment was reported to prove a continuous gas leakage from an underground gas pipe by the color of soil derived from the redox state of iron (91). Schneck (92) presented case studies in which a broad range of materials were involved.

11. Miscellaneous

Seismology is one of the very important fields of geosciences, but it is not considerably valued in the field of forensic science. It can provide the time, the scale of explosion, and additional information of an incident by using its network to help forensic investigation (93). Information on the persistence of grains was provided through case works (94) and experiments (95). The advantages and disadvantages of spatial sampling were discussed by McKinley and Ruffell (96).

The trace evidence concentrator system was introduced for the separation and concentration of trace evidence from the soil by Smucker and Siegel (97). The system used a hydropneumatic elutriation method for a rapid examination.

A review on the forensic sediment analysis was written by Morgan and Bull (98). The difficulties of communication are not the problem exclusive to forensic geology but of any occasion when specialists and non-specialists wish to share knowledge. Donnelly (99) reported on this issue with some case work and Rold (100) discussed the difference between geology and forensic geology. The status of forensic geology in Russian Federation was described in two reports (101, 102). Stam and Murray (103) compared the situation of the USA and the UK. Molina (104) reported the history of forensic geology in Colombia.

There were also several papers written about the forensic geoscience for geologists, who were not involved in forensic science (105, 106).

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