Inferential Source Attribution From Dust: Review and Analysis

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ABSTRACT: The analysis of dust allows inference of exposures to geographical areas, environments, activities, and processes. This activity of *inferential* source attribution is distinguished from that of *comparative* source attribution, where the focus is on the degree of correspondence between two sources in relation to other possible sources. Review of source attribution efforts in the forensic and broader scientific literature shows that most efforts are limited in one or more of four principal ways, which are classified as: (a) methods based on attribution by direct comparison; (b) methods based on closed-set item classification; (c) analysis using restricted methods and characteristics, and (d) requirement of a large sample size. These limitations provide the context for the requirements of more generalized inferential source attribution. Occurring much more rarely, and almost exclusively in the forensic literature, are individual source attribution case reports that have a microscopical, multidisciplinary perspective. Collectively these are an excellent illustration of potential and their common features demonstrate that (a) a diversity of laboratory expertise and methodology is required in order for source attribution to be successful; (b) different tools need to be applied in different cases, and (c) a process must be in place that allows a facile choice among this diversity of tools, in response to the particular investigative problem and the specifics of the samples that are available. Alternative collaborative mechanisms are considered and recommendations are made for related research and programmatic application.

KEY WORDS: animal products, botanicals, crime scene location, DNA, drugs, dusts, environment, explosives, foods, forensic, geography, geolocation, human activities, human remains, IEDs, insects, investigation, land use, microorganisms, microscopy, multidisciplinary analysis, particle analysis, signatures, source attribution, trace evidence, wildlife.

INTRODUCTION

Fine dust particles, adhering to virtually any object and within virtually any product, are the result of a history of exposure. Routinely, such dusts contain a tremendous variety of particles, including those of mineral, botanical, zoological, microbial, and anthropogenic character [240–242]. The large numbers of particles in dusts, as well as their variety, provide an extremely rich source of potential information — translating into a powerful inferential tool — when the particles are appropriately analyzed and appropriately interpreted.

Inferential source attribution is the ability to use dusts to infer the geographical areas, environments, and human activities or processes to which an object or individual has been exposed. This capability supports the systematic search for (and identification of) the associated locations, or provides evidence of association with activities and processes of forensic or investigative interest.

Inferential source attribution is distinct from *comparative* source attribution. Comparative source attribution uses the results of analyses on *two* specimens to infer the strength of association that follows from the degree of correspondence, relative to their degree of correspondence to other possible sources. Both inferential and comparative source attribution are important in forensic science and comparative source attribution has the more prominent role. In forensic science it is routine to be faced with specimens from crime scenes and specimens from suspects, and to be tasked with the performance and evaluation of tests for correspondence. But before potential sources are identified, the task is one of inferential source attribution: determining source characteristics, suggesting possible suspects, and linking cases or materials such as weapons and contraband.

Inferential source attribution methods begin with collection, evaluation, and identification of trace materials and particles. The geographical or environmental origin of these particles and traces is determined based on characteristics of the individual particles [305], their joint occurrence, and the geographical distributions of these particles. In cases where the geographical distribution of a specific particle type is not known, its potential geographical distribution can be estimated based on (for example) the geological, ecological, or climatic conditions necessary for its occurrence. Prior geographical history of the object or individual is inferred, within the context of other investigative information and taking into account transfer characteristics such as particle transport, adhesion, and retention. The value of an inferential source attribution capability is determined by its ability to address questions of forensic concern in a specific application. Two aspects

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ABOUT THE AUTHORS

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David A. Stoney has a bachelor's degree in chemistry, a master's degree in public health, and a Ph.D. degree in forensic science from the University of California (Berkeley, CA). He is chief scientist at Stoney Forensic, Inc. (Chantilly, VA).

After six years at the Institute of Forensic Sciences, Criminalistics Laboratory in Oakland, CA, Dr. Stoney was named director of forensic sciences at the University of Illinois at Chicago (Chicago, IL). After eight years there, he became director of the McCrone Research Institute in Chicago for 10 years. He left Chicago to form Stoney Forensic, Inc., a company in northern Virginia that is focused on applied particle analysis and the development of nontraditional solutions that integrate these methods to solve problems of interest to forensic science and the federal government. Over the past 20 years, Dr. Stoney has led applied research using specialized forensic and particle analysis to address problems that cannot be solved using traditional methods. He has conducted casework and research augmenting capabilities of federal investigative agencies, U.S. national laboratories, and large commercial scientific companies.

Dr. Stoney is a fellow of the American Academy of Forensic Sciences and a member of the California Association of Criminalists (CAC). He was associate editor and editor of The Microscope (15 years) and served on the editorial boards of the Journal of Forensic Sciences (20 years) and the Journal of Forensic Identification (five years). He has more than 75 publications in the areas of chemical analysis, particle analysis, evidence interpretation, and forensic science; has taught more than 50 courses on particle analysis, trace evidence analysis, and evidence interpretation; and has made more than100 professional appearances. Invited appearances include: CAC (Interpreting Trace Evidence), International Association of Forensic Sciences (Evaluation of Associative Evidence), American Chemical Society (Interpretation of Transfer Evidence), American Society of Criminology (Relevance and Analytical Precision in the Evaluation of Associative Evidence), International Symposium on the Forensic Examination of Trace Evidence in Transition (Statistical Applications in Trace Evidence), and Fine Particle Society (Light Microscopy and Solid State Characterization).

Andrew M. Bowen has a bachelor's degree in chemistry from the University of Virginia (Charlottesville, VA) and a master's degree in forensic science from the University of Illinois at Chicago (Chicago, IL). He is a forensic chemist at the National Forensic Laboratory of the US Postal Inspection Service (Dulles, VA) and a consulting laboratory analyst with Stoney Forensic, Inc.

Mr. Bowen has extensive advanced continuing education coursework (25+) covering forensic analysis of small particles using microscopy, microchemistry, infrared and Raman microspectroscopy, and X-ray spectroscopy. Prior to joining the U.S. Postal Inspection Service, Mr. Bowen worked for Stoney Forensic, Inc., for seven years, as well as for the McCrone Research Institute (Chicago, IL) for three years. At Stoney Forensic, he performed applied forensic microscopical analysis of an extremely broad range of materials (e.g., explosives, tape, drugs, minerals, soil, building materials, glass, plastics, paints, paper, hair, and fibers). He is proficient in the isolation, identification, and forensic analysis of extremely small quantities of materials present in complex mixtures. Over the last 10 years Mr. Bowen has been the primary instructor for more than 60 training courses in microscopy and microanalysis for forensic scientists and analytical chemists.

Mr. Bowen is an associate member of the American Academy of Forensic Sciences and a member of the American Society of Trace Evidence Examiners, the Scientific Working Group for Geological Materials, and the State Microscopical Society of Illinois. He has more than 15 publications and more than 25 professional presentations and appearances.

Paul L. Stoney has a bachelor's degree in economics from the University of California (Santa Cruz, CA) and a master's degree in business administration from Stanford University (Palo Alto, CA). He is currently president of Stoney Forensic, Inc.

Mr. Stoney has six years of U.S. Navy experience and more than 15 years managing scientists engaged in forensic science and the related earth/space sciences. As departmental administrator of the Department of Earth & Space Sciences, University of California (Los Angeles, CA), he supervised technical, administrative, and research staff and managed research support facilities including mass spectrometry, X-ray diffraction, electron microprobe, and computer design. At Stoney Forensic, he manages federally funded programs with systematic design, development, and application of forensic science methods focused on investigative mission areas. He was directly responsible for the successful development of small-particle-based source attribution, overseeing the processes from concept through R&D to operational deployment. Major programs at Stoney Forensic include integration of these methods with routine high-throughput analysis for target substances to provide: (a) rapid upfront triage analyses supporting design of efficient and effective sample analysis plans; (b) forensic analysis of unknown materials outside the scope of routine analyses; (c) design, testing, and delivery of field and laboratory analysis SOPs to address specific deficiencies; and (d) design, delivery, and subsequent operation under a forensics QA/QC program for those operations falling outside the scope of those QA/QC programs then in place.