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Critical review of forensic trace evidence analysis and the need for a new approach

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ABSTRACT

The historical development, contributions and limitations of the two traditional approaches to trace evidence analysis are reviewed. The first approach was as generalist practitioner, looking broadly at an assemblage of many different particle types. The second was that of specialist practitioner, with attention focused on one specific particle type. Four factors have significantly impacted the effectiveness of these approaches: (1) increasing technological capabilities, (2) increasing complexity in the character of manufactured materials, (3) changes in forensic laboratory management, and (4) changing scientific and legal expectations. The effectiveness of each approach is assessed within the context of these changes.

More recently, new technologies have been applied to some trace evidence problems, intended to address one or more limitations. This has led to a third approach founded on discrete, highly technical methods addressing specific analytical problems. After evaluating the contributions and limitations of this third approach, we consider the different ways that technologies could be developed to address unmet needs in forensic trace evidence analysis. The route toward effective use of new technologies is contrasted with how forensic science laboratories are currently choosing and employing them. The conclusion is that although new technologies are contributing, we are not on a path that will result in their most effective and appropriate use. A new approach is required.

Based on an analysis of the contributions of each of the three exisiting approaches, seven characteristics of an effective trace evidence analysis capability were determined: (1) particle traces should be a major problem-solving tool, (2) there should be readily available, straightforward methods to enable their use, (3) all available and potentially useful particle types should be considered, (4) decisions to use them should be made in the context of each case, guided by what they can contribute to the case and how efficiently they can do so, (5) analyses should be conducted using appropriate technologies, (6) findings should be timely and directly integrated with case-specific problems, and (7) new technologies should be used to improve the overall effectiveness of the capability.

Clearly new technologies have the potential to revolutionize forensic trace evidence, but just as clearly some of the traditional capabilities have been rendered ineffective, or lost entirely, by the way we have come to approach the problem. Having critically defined the current limitations of and the desired outcomes, the next focus should be consideration of alternative approaches that might achieve such a result.

1. Introduction

It is undisputable that forensic trace evidence analysis has undergone major changes since the times when analysis was confined to broadly trained general practitioners analyzing a wide range of traces using a light microscope. Some of these changes parallel those that have occurred generally within the forensic sciences, others reflect the impact of changing priorities, and others reflect the impact of new technologies.

A complex problem has emerged that is reflected in the diminishing use of trace evidence, reductions in funding and open debate regarding the viability of the discipline. This paper is offered as a critical review of the nature and causes of the problem, helping to define and understand objectives, but stopping short of considering possible alternative solutions. This is intentional. It is both confounding and confusing to hold the debate about a problem together with a debate about the solution; disagreements about one become interwoven with disagreements about the other. Solutions can be offered and debated based not on how they

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address a well-defined problem, but rather because those offering the solutions view the problem differently. It is our strongly held view that to compare different solutions we must start with a common problem and, as such, this work is intended to provide the foundation for constructive consideration of alternative solutions (or indeed, a more focused debate on the problem).

Forensic trace evidence analysis has traditionally been approached in one of two fundamentally different ways: as a generalist practitioner, looking broadly at an assemblage of many different particle types, or as a specialist practitioner, with attention focused on one specific particle type.

This paper begins with descriptions of these two traditional approaches, their historical development and an analysis of their respective contributions and limitations. Over time, the significance and impact of the limitations has evolved in response to increasing technological capabilities in the laboratory, increasing complexity in the character of manufactured materials, changes in laboratory management and changing expectations in the scientific and legal communities. The effectiveness of each approach is assessed as it currently exists within the context of these changes.

The more recent changes in technology have the potential to revolutionize trace evidence analysis. At the same time there has been an increased emphasis on scientific practices and standardization within forensic laboratories. These have had an impact on the traditional approaches and have led to a third approach, founded on component processes that employ new technologies.

After evaluating the contributions and limitations of this third approach, we consider the different ways that technologies could be developed to address unmet needs in forensic trace evidence analysis. The route toward effective use of these new technologies is contrasted with the ways that forensic science laboratories are currently choosing and employing them. The conclusion is that although new technologies are contributing, we are not on a path that will result in their most effective and appropriate use. A new approach is required.

The paper concludes with a summary of the hallmarks of an effective trace evidence capability and delineation of some key elements that we expect to be included in new approaches that attempt to address current limitations.

2. Traditional approaches to forensic trace evidence analysis

Forensic scientists have long recognized the tremendous variety of particles that are ubiquitous in our environment. Hans Gross proclaimed that particle dusts are our "environment or surroundings in miniature" [1,2]. Edmond Locard echoed that they "may be formed of all the debris of all kinds of bodies... all the substances, organic or inorganic, existing on the earth" [3,4]. Heavily represented particle types on this list are minerals, plant and animal debris, microbes, industrial dusts, and fragments of man-made materials, but, as noted by De Forest [5] essentially anything can be encountered as crucial trace evidence in casework.

This tremendous variety of particles occurs on items collected as evidence: clothing, bodies, and weapons – on virtually any object and within virtually any product. The particular combination of particles in or on an item is the result of a history of exposures and contacts, modified by the dynamics of adhesion and loss. As Locard noted, the particles are "the mute witnesses, sure and faithful, of all our movements and all our encounters" [3]. Particles are present and ready for analysis, in almost all casework [6].

The large numbers of adhering particles, as well as their variety, provide an extremely rich source of potential information, but they pose a correspondingly complex analytical problem. What is a reasonably efficient approach to the analysis and interpretation of many thousands of particles, occurring in many hundreds to thousands of different types? Two traditional approaches have been developed to address this complexity. The first approach is that of a generalist, founded upon broad expertise and examination of many particle types. The second approach is one of data reduction, specializing in the detection and analysis of a very few particle types that occur prominently and frequently on evidentiary items.

2.1. First generation approach: generalist practitioners

Microscopes began to be commonly used in legal cases in the second half of the19th century, leading to extensive application in forensic toxicology [7] and the detection of food adulteration [8]. The first applications of trace evidence analysis began in the same period and were closely associated with forensic medicine [9], focusing on the analysis of body fluids [10], feces [11], stomach contents [2] and hair [12]. More generalized applications developed in the casework of individual practitioners who used the microscope to identify and compare transferred particles [13]. Microscopic particle analysis was extremely effective, providing a broad range of information that contributed to the solution of a broad range of problems.

Popular fiction romanticized these cases in the form of the boutique scientist, a renaissance man with broad expertise in the recognition and exploitation of minute traces [14–16]. The regular application to criminal investigation was conceptualized and encouraged by Gross [1,2], who strongly advocated engaging experts in microscopy. In the early 1900s case reports appeared frequently in the popular literature and in works on legal medicine. Summaries can be found in Locard [3,4,17,18] and elsewhere [19,20]. Notable case reports during the early 1900s included the work of Popp [20], Heinrich [21], Schneider [22–24], and Bertillon [25]. During the same period, an academic focus on criminalistics emerged in Europe [26–29].

Trace evidence was brought into the mainstream of criminal investigation through the development of dedicated police laboratories [28,30,31] and the publications and practices of Locard [3,4,17,18,27].

The early applications of microscopy to the analysis of trace evidence are striking in their multidisciplinary nature, yet they depended almost entirely on the application of the knowledge and skills of individual boutique practitioners. Three factors encouraged and enabled this capability. Firstly, expertise in analytical microscopy was much more common. Microscopes were a primary analytical tool used in chemistry [32–34], industry [35–40], pharmacy [41–43], geology [44–51], food analysis [42,43,52,53] and botany [54–58]. Secondly, a broad expertise in the microscopy of materials was reasonably achievable. Compared to later times, there was a much more restricted range and complexity of man-made materials to be encountered (textile fibers and paints are directly relevant examples). Thirdly, analysis with the microscope was state-of-the-art. Microscopical analysis, together with directly associated microchemical or microbiological methods, revealed all of the then-attainable character of the trace evidence.

With this foundation of microscopy, and within the emerging crime laboratory structure, the 1930s and 1940s saw the development of trace evidence methods focusing on specific materials, notably glass fragments [59–65], paint [66,67], other building materials [68–71], hairs [72–76] and fibers [76–79]. Microscopy, supplemented by increasingly sophisticated microchemistry [80,81] and a generalist approach [82] remained dominant into the 1950s and 1960s [83–87]. This approach ensured efficient, responsive application to individual cases. Any particle types encountered by an expert microanalyst were addressed by the methodology and their findings could be put immediately into the context of the individual case by the expert generalist practitioner. In this way the relevance of