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Review article

Applying archaeology to fire investigation techniques: A review

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ABSTRACT

Archaeology and Fire Investigation do not appear to have much in common on the surface. Scratch beneath however, and the similarities begin to reveal themselves. Both disciplines require the investigation of physical remains by employing an analytical approach in order to reconstruct sequences of events. Before recovery employing an archaeological stratigraphic recording method at fire scenes, provides the opportunity for a sequential recording of both debris layers, recording objects and their relationship to the immediate environment. This approach is particularly pertinent in Fire Investigation, as the recovery of evidence can lead to destruction in cases of fragile evidence and remains.

Contents

Archaeology and Fire Investigation do not appear to have much in common on the surface. Archaeology is the study of human history and prehistory through the analysis of cultural and material deposits, while Fire Investigation is the determination of the origin cause and development of a fire or fire-related event.

Scratch beneath the surface however, and the similarities begin to reveal themselves. Both disciplines require the investigation of physical remains in order to reconstruct a sequence of events, which in heavily modified scenes and sites are often presented in a 3-dimensional format. Both disciplines take generalised principles that are then applied to a substrate. In archaeology it is the material record, while in fire investigation it is the fire debris, and applying them via systems that differ from nation to nation (distinctions in standard excavation styles and recording systems in the case of archaeology, the requirements of different legislatures in forensic fire investigation).

In gaining understanding of both sites and scenes, these disciplines undertake investigations employing an analytical approach. This methodology follows the scientific method for both disciplines (see Table 1).

1. Converging fields of fire investigation and archaeology

Evidence of fire is often found within the archaeological record throughout the world. Treated as a cultural artifact, it can provide insight into the occupancy and use of sites. Understanding of archaeological aspects of heat and fire is frequently isolated within specific specialisms. Common foci of such understanding includes cremation studies [1–6], ceramic production [7–9] cooking processes and the identification of fire hearths [10–13].

Recently, the adaptation and application of fire investigation, the understanding of fire movement, and consideration of fires'

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Table 1
Scientific Methodology for Archaeology and Fire Investigation.

Scientific Method	Archaeologist	Fire Investigator
Identify and define the scene/site	Desk based assessment, Geophysics and the archaeological/ historical record	Call out from control. Discussions with Incident Commander and first pumps attending.
Collect Evidence	Excavating and recording within predefined areas. Record measurements, photograph, and plan. Recognising and contextualise differentiation.	Observe and record fire patterns of scene and fire debris, potential ventilation factors, arc mapping, obtain witness statements. Plan and photograph scene.
Analysis	Review interaction of deposits and associated depths, building materials and structure shape. Use experts to date materials excavated, change working hypothesis if required.	Review: heat interaction, burning properties of fuel loads. Use experts for laboratory analysis. Review fire dynamics and experimental data, change working hypothesis if required.
Hypothesis	With data collected form an initial hypothesis on the use/ purpose and development of land.	Inductive reasoning – using the data collected, form initial hypothesis of the fire point of origin and ignition source.
Test Hypothesis	'Test' the hypothesis outcome by comparing evidence against other possible interpretations. Consider the veracity of the hypothesised interpretation in comparison with a broader understanding of the associated archaeological record. Amend and retest when required.	Test the hypothesis via formal reconstruction and experimental burn as appropriate. Consider outcome by comparing evidence against other potential possibilities (alternative hypotheses). Amend and retest when required.

Fig. 1. South wall building 77, Çatalhöyük. ©Harrison 2008.

interaction with materials and structures, has begun to be utilised within an archaeological template. This endeavour attempts to understand the mechanisms that contributed to the development of historical fires.

A key area of observational analysis and research is the interaction of heat and flame within the immediate environment throughout a fire's growth, and approximation of temperatures reached within burnt archaeological structures [14,15]. This utilisation of data from excavations, combined with fire investigative techniques, and fire modelling in the format of computer fire test simulations, has enabled 'accidental versus intentional' debates to be conducted with a more scientific foundation [16]. This is especially poignant within a prehistoric context, as there are no written records to support the varied hypotheses presented on house-burning [17,18].

2. Historical perspectives

The process of recording site-specific depth chronology has its origins in geological studies, categorising periodisation through natural geological strata. This sequential method of recording was adapted within archaeology by Mortimer Wheeler in the 1920′s and was further adapted by Kathleen Kenyon to include other anomalies within a context, such as pits and ditches [19]. This has resulted in the ability to record stratigraphic evidence of both natural (geological) and cultural (manmade) variances in a sequential method. These can be adapted in several ways via standardised context descriptions, a drawn and annotated record and an abstracted diagrammatic matrix format, depending on the site and information to be recorded.

The predominant method of recording stratification is through application the 'Harris Matrix'. Developed by Edward Harris in 1973, the matrix draws upon the relationships between contexts identifying layers or anomaly areas to construct an abstract in both horizontal and vertical planes, whilst investigating the relationship of these areas in respect to both chronology and contemporaneous distinctiveness. Recording in this manner, enables a diagrammatic interpretation of the site stratification to be documented [20,21]. Enabling the identification and recording of geological and man-made artifacts in their strata, this single context technique has become a best practice standard within the UK archaeological community.

In more recent excavational investigations, fire investigation and archaeology have been undertaken in collaborative analysis to recognise, understand and create a narrative around patterns of burning found in historical excavations. The archaeological sites and fire damage are as variable as fire itself, such as the burnt Iron Age houses at Lejre, Denmark [22] Church of Santa Maria Antiqua, Rome (Harrison, pending publication), the intensive archaeological excavations of settlement burning at Çatalhöyük Turkey [23], and the ancestral Puebloan cultures of South Western United States [24]. {{{Fig. 1}}}.

In 2005, a fire destroyed the reconstruction of a 'Farmers House', at West Stow Country Park, which was an experimental Angle-Saxon building constructed in the 1980 s. It was subsequently investigated as an archaeological research project [25].

Ironically, the Farmers House was one of several structures that were built as proposed reconstructions of original early medieval structures that had stood on the site, some of which had been destroyed by fire in the 7th Century AD. Funding by English Heritage facilitated an archaeological investigation of the structural remains, enabling detailed analysis of fire dynamics within a reconstructed traditional timber and thatch structure through excavation.

The archaeological terms 'excavation' and 'excavate' are frequently used in fire investigation literature, where they relate to the removal of objects and debris from a fire scene, often to enable a reconstruction [26]. The term 'excavate' originates from the Latin word *excavare*, from *cavare* to make hollow; the English Dictionary definition is 'to remove (soil, earth, etc) by digging; dig out/ hollowing or removing the centre or inner part / to unearth methodically'. The discipline of archaeology primarily employs this technique to record and assist analysis and understanding of material remains scientifically.

3. Employing archaeological techniques within fire scenes

The potential use of employing archaeological techniques within fire-scenes has been recognised and proposed intermittently over the past 30 years[27–29]**.** Whilst the terminology is frequently utilised, little of the underpinning principles are referred to in fire investigation texts. As the science of fire investigation has progressed over the past 30 years, so has the way in which scenes are processed; with the gradual adoption of some archaeological techniques, such as grid excavation [30–32] for the more complex, and fatal fire scenes. Using archaeological techniques in the search and recovery of the fatal fire victim has been shown to improve the volume of remains identified and recovered [4,33].

With UK Fire and Police Services working collaboratively at fire-related crime scenes, understanding of the forensic applications of scene examination is required by fire investigation personnel, as education, research, and technology combine with analysis, and investigation [34]. In the current legal climate where Fire Investigators take the stand in court as an 'expert witness', there are questions regarding the validity of this status [35], especially in light of the variability in Standard Operating Procedures (SOP's) and training between the different Fire Services themselves. This inconsistency has been challenged, and attempts have been undertaken to bring fire investigators from both private and front-line roles into line, with the publication of a new Code of Practice [36].

This growing awareness for forensic evidence recognition and recovery, has also impacted upon the use of traditional archaeology methods within the context of forensic investigation. This approach has led to methodologies being integrated and/or adapted into the scientific discipline of Forensic Archaeology. Forensic Archaeologists are primarily employed to locate, excavate and record buried human remains from a clandestine environment (i.e. the concealed remains of victims). Within this sphere of activity is the forensic recording of any items associated with the burial (in a UK context of operation). The stratigraphic relationship between these items and their deposition is documented [37], by undertaking both scene sketches and context recordings.

4. Best practices

It is seen as best practice to produce a scene sketch at fire scenes. These may include scene dimensions, furniture positioning, fire point of origin, forensic evidence or human remains [38,39]. However, such sketches are 2 dimensional, and do not allow for an understanding of the depth of the debris field.

Lentini states in his work on fire scene methodology, that the most valuable evidence is that which shows sequential data [39]. Employing this method of recording within a fire scene, provides the opportunity to record objects and their relationship to the immediate environment before recovery. Nevertheless, in cases of extremely fragile evidence/physical remains, it can lead to destruction [29].

In areas where the investigator identifies the potential origin of the fire, it may sometimes be located within or beneath a dense debris field. This combination of identification and recording of both layers and evidence, provides an invaluable reference tool in addition to scene photographs, sketches, and contemporaneous notes.

To demonstrate this process, a small-scale experiment was undertaken at the burn facilities of Dorset and Wiltshire Fire and Rescue Service premises. First a wooden block was used as a base, covered with cotton material, upon which an open magazine was placed. Next hair tongs were placed upon the magazine, with loose paper inserted in between the tongs' pads. Finally, two pieces of clothing were placed on top. This set up was assembled within a burn container and exposed to a flash over environment. Following suppression, the material was then excavated to determine the point of origin, as would be undertaken in a fire investigation. {{{Fig. 2}}}.

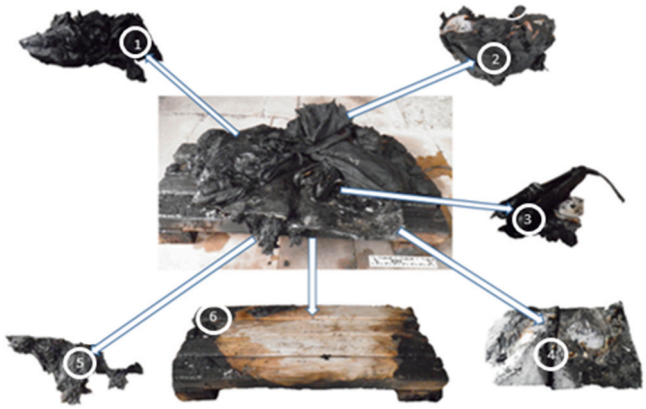

Fig. 2. Small scale point of origin experiment. 1.Clothing 2.Clothing 3.Hair straighteners with paper 4. Open magazine 5. Cotton material 6.Wooden Bench.

Converting the stratigraphy of the above into a matrix (see Fig. 3 below) results in a format easily discernible to the lay-person and aids the interpretation of fuel loads at a point of origin. Additionally, should any evidence be recovered from the immediate area, this can also be recorded within the matrix by inserting of details within a different shape to illustrate the exact location/depth it was discovered.

The utilisation and adaptability of this technique is not confined to forensic case work. Recently, in 2018, a second extensive fire rampaged through the building of The Glasgow School of Art, Mackintosh Building. The first fire in 2014 utilised the services of Forensic Archaeologists to aid excavation of the debris and retrieval of material from the library. Using a grid system of 1 m square, the debris was excavated in 25 cm context format to identify items for recovery. While this system was not utilised within the activity of emergency services fire investigation, it was undertaken primarily within the framework of salvage operations. It was however noted by the excavator Gordon Ewart of Kirkdale Archaeology, that "in recording the location of artifacts there was evidence of the fires development within the room" (Ewart. Pers. Comm.).

In a more developed fire where there is a structural collapse and the area of origin is undetermined, this technique has the potential to enhance and aid the interpretation of a fire's development, and any associated structural deformation [40]. Not only through the recording of structural layers such as ceilings, upper story floorboards and spalled wall rendering, but also by recording the stratigraphy through the preservation evidence of protected layers.

5. Standards of care

As the shape and format of frontline UK Fire Services continues to restructure, the role of Fire Investigators is becoming more diverse and subject to budgetary constraints, whilst at the same time being required to conform to ISO Scientific Standards. A similar pattern has arisen regarding forensic analysis of fire scenes, as forensic services have largely been outsourced and are subject to provider contracts. Some Fire Services employ visual aids teams that can be directed to photographically record elements of the investigation photographically. A large proportion of Services however, now rely upon the investigators themselves to photograph evidence. This approach creates the potential of omission of the stratigraphic association of evidence, since the Investigator is focuses primarily on the act of excavation as one of evidential recovery, rather than digitally recording the exposure of evidence. This is particularly pertinent when

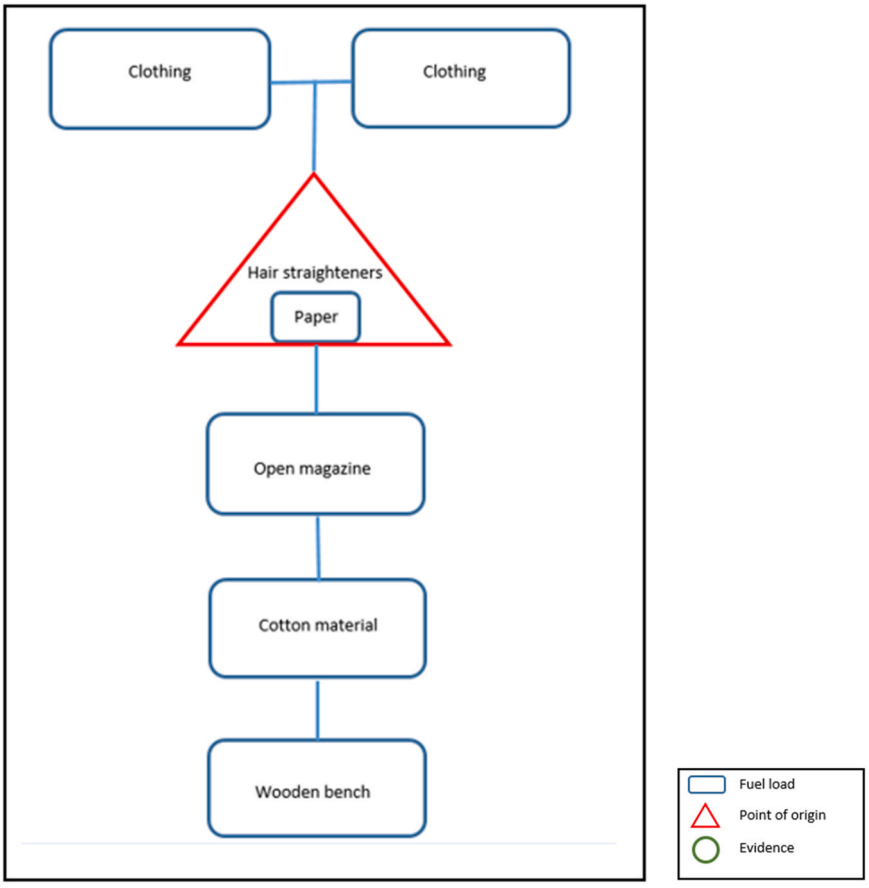

Fig. 3. Point of origin matrix.

there is pressure to identify the point of origin and ignition source in a time-sensitive environment.

The importance of contemporaneous scene documentation has been highlighted within the United States Department of Justice which published a report stating that 'Written scene documentation recreates the scene for investigative, scientific analysis, and judicial purposes and correlates with photographic evidence' [41]. The absence, or incompleteness of contemporaneous notes, can lead to a serious challenge of an investigator's testimony in a court of law. In one such case, Michigan Millers Mutual Insurance Corp v. Benfield, 140 F.3d 915 (11th Cir.1998), the fire investigator was excluded from testifying due to failure in correctly documenting observations at the scene [42].

Even when following a scientific approach to investigation, the interpretation of fire indicators can be subjective and reliant on an investigator's breadth of practical experience [43,44]. In the current climate of forensic science and specialist fire investigation provision in the UK, what were considered key fire interpretation techniques in recent decades, such as char depth and pool burning [45], are being evidenced as being either more complex than previously thought, or entirely debunked as an untruth [46,47].

In order to assess the awareness of fire investigators to developments in knowledge and techniques regarding establishing the point of origin, in 2005 the Bureau of Alcohol Tobacco and Firearms and Explosives (ATF) undertook experimentation. Two nearly identical compartments were built and then burnt, with suppression approximately 2 min following flashover. Then 53 Investigator participants were then asked to identify the quadrant where they considered the point of origin.

Shockingly, only 3 of the participants identifyied the quadrant correctly for each of the compartments. However, it should be noted that the 53 participants were given only a brief time period to assess the fire scenes. In actual scene examinations, the investigator would be given more time in studying fire patterns, the direction of fire travel, participating in destructive examinations, and collecting evidence in the debris.

Further analysis revealed that some investigators given only the brief amount of time, the area of deepest char indicated the point of origin. These results initiated the production of training modules, and publications to inform and educate the fire investigation industry [48].

Wrongful arson convictions are being identified [35,42,49] resulting in some individuals being exonerated through the re-examination of historical cases. These re-examinations take place through The Innocence Project, Texas State Fire Marshal's Office and the Texas Forensic Science Commission. It is clear that the accurate and timely recording of scenes and evidence, and resulting conclusions by Investigators, requires a further defined procedure.

This re-examination of historical cases is currently being addressed in the UK. This approach is through the assimilation to ISO Forensic Standards, and the establishment of the Certified Fire Investigator (CFI) accreditation program. To qualify for the CFI, the Investigator must evidence experience, undergo training and assessment, and provide documentation. In contrast, not a compulsory certification, more experienced Fire Investigators are undertaking the accreditation, results in current practices being assessed against a rigorous criterion, rather than being unscientifically subjective and based upon an Investigators experience.

Unfortunately, even with a wealth of experience in conducting investigations, most Fire Investigators are unaware of the approaches that can enhance their scene examinations. This approach is gained by recording stratigraphic scenes in an archaeological

contextual record, by reconstructing sequences of events [28]. This is especially pertinent for archaeology and fire investigations, which are destructive forms of scene examination that once undertaken, can never be recreated.

Recording scene evidence and utilising the range of techniques discussed above, not only enables a more rigorous procedure of peer review by colleagues, but also solidifies the evidence in its sequential manner. This makes it dynamic rather than a passive piece of evidence within the sceneas excavations progress, evidence is recovered and logged. This recording also assists in the future understanding of a scene [50], affording both an accurate and timely assessment of fire debris, and minimises the loss of evidence.

Finally, it is considered by the authors that this contextual recording format provides investigators with an alternative way to present their evidence in an ordered and easily understood display of stratigraphy; thus enabling a lay person and potentially a jury, an understanding of a fire scene. As the development of fire investigation continues to become more rigorous and scientific, it is anticipated that this review of the application of dynamic stratigraphic on-scene recording may open further dialogue regarding the recording of both debris layers, and evidence, within the fire scene.

CRediT authorship contribution statement

Harding, Mary-Jane: Conceptualization, Methodology, Study design, Validation, Investigation, Resources, Data curation, Writing – original draft, Writing – review and editing, Visualization. **Harrison, Karl:** Conceptualization, Methodology, Study design, Validation, Investigation, Resources, Writing – review & editing, Visualization. **Icove, David:** Conceptualization, Methodology, Study design, Validation, Investigation, Resources, Writing – review & editing, Visualization, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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