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Experimental forensic studies of the preservation of pollen in vehicle fires

R.M. Morgan [a,b,*], J. Flynn [c], V. Sena [c], P.A. Bull [c]

[a] UCL Department of Security and Crime Science, Jill Dando Institute, 35 Tavistock Square, London, WC1H 9EZ, United Kingdom
[b] UCL JDI Centre for the Forensic Sciences, 35 Tavistock Square, London, WC1H 9EZ, United Kingdom
[c] Oxford University Centre for the Environment, South Parks Road, Oxford, OX1 3QY, United Kingdom

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ABSTRACT

The implications of the recent recommendations of the Law Commission regarding the use of admissibility tests have the potential to be far reaching for forensic disciplines that rely on the expertise of highly qualified expert witnesses. These disciplines will need a concomitant body of peer-reviewed experiments that provides a basis for the interpretations of such evidence presented in court. This paper therefore, presents such results from two experiments which were undertaken to address specific issues that were raised in cases presented in the British courtroom. These studies demonstrate that there is a variability in the persistence of Lily, Daffodil and Tulip pollen when exposed to high temperatures between 0.5 min and 1440 min (24 h). It was possible to identify all three pollen types after 30 min of exposure to 400 °C, and after shorter time frames the threshold for successful identification was 700 °C after 0.5 min for all pollen types tested and 500 °C for Daffodil and Lily after 5 min of heat exposure. Over longer time periods (18 h (1080 min)) the different pollen types were found to persist in a viable form for identification at 300 °C (Lily), 200 °C (Daffodil) and 50 °C (Tulip). These findings, albeit from a small sample of pollen types, provide empirical contextual information that would contribute to such evidence having sufficient scientific weight to meet admissibility criteria and be viable evidence for a court. These studies demonstrate the value in seeking pollen evidence from even such extreme crime scenes as encountered in vehicular fires.

1. Introduction

The UK has experienced rapid and significant changes in the structure of the practice of the forensic sciences in the last 20 years. These changes have included the closure of the Forensic Science Service (FSS) as well as the introduction of competitive tendering for forensic analysis and the establishment of the Forensic Regulator's Office. Whilst it was recognised that Forensic Science is critical to the efficiency and effectiveness of the criminal justice system by the House of Commons 'Science on Trial' report in 2005 [1], it was also acknowledged that there are significant areas of research and development in this discipline that need to be addressed more fully to ensure that the forensic sciences are in a position to provide strategic solutions for the future of crime detection. Most recently, the Law Commission's 2011 paper addressed the admissibility of expert evidence in criminal proceedings in England and Wales [2] and these findings have the potential to have far reaching implications for the future changes in legislation in England and Wales relating to the provision and admissibility of forensic evidence in a court. Indeed such a change has the potential to change the means of presenting forensic evidence by expert witnesses and has serious ramifications for the collection, analysis and presentation of trace evidence such as geoforensic materials including soils, minerals and pollen.

Perhaps the area that will be most significantly affected will be the forensic disciplines that rely on the expertise of highly experienced and qualified expert witnesses but where there is a lack of an extensive corpus of peer reviewed, experimental work to provide the foundations of the discipline in a form that will be recognised by a reliability test. Forensic palynology is known to be a highly valuable, accurate and effective means of forensic reconstruction which has been used by a number of experienced scientists in the last 30 years to provide forensic intelligence and evidence in selected legislatures [3–5]. There is however a disproportionately small body of forensic palynology literature in comparison to the value and reliability of the technique in practice, and the majority of the literature that has been published provides case study examples of where and how palynology was able to aid forensic investigations [3,6–9]. Should the recommendations of the Law Commission be adopted in the England and Wales legal system there is the potential for helpful, accurate and insightful forensic evidence to be ruled inadmissible if it is not accompanied by experimental work that establishes the nature and behaviour of different forms of trace evidence in forensically relevant situations in a manner that meets the criteria for admissibility of

* Corresponding author at: UCL Department of Security and Crime Science, Jill Dando Institute, 35 Tavistock Square, London, WC1H 9EZ, United Kingdom. Tel.: +44 20 3108 3037.
E-mail address: ruth.morgan@ucl.ac.uk (R.M. Morgan).

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evidence. The challenge is to ensure that disciplines that are applied in the forensic arena have the concomitant experimental (and forensically relevant) research base to ensure that their admissibility is assured in the British courtroom and valuable evidence is not lost simply because the accrued expertise and knowledge of the experts is not available in a format required by the court.

This paper therefore, seeks to demonstrate the value of even the most simple experimental studies in forensic palynology for addressing admissibility tests in the UK courts. A case is presented where pollen evidence was considered to be important at trial. The key question in an investigation often relates to the behaviour of a trace material in a specific forensic situation and over a particular time frame. Whilst much can be gleaned from the traditional palynological literature as to the behaviour of pollen under different natural situations and through different means of dispersal, in criminal investigations it is vital for the interpretation and presentation of the evidence for the specific variables impinging on the case to be taken into account. In a criminal prosecution in England in 1998, the defence argued that particulate evidence recovered from within a car which had been set on fire would have been affected and modified by the subsequent fire to render the evidence unusable and therefore sought to exclude the particulate evidence (which included soil and pollen). The mineral evidence was still presented to the court as the subsequent analysis demonstrated the particulates not to have been altered enough to render them unusable. However, if a Daubert-style test had been required at the time, all of this evidence may well have been excluded as inadmissible. Due to the vehicle fire, the pollen evidence was not deemed to be viable and no analysis was undertaken. We present here experimental studies in a forensic context that provide the preliminary evidence that counters the defence argument that pollen and soil particulates would have been destroyed by the vehicle fire.

Experimental work, of an allied nature, has demonstrated that it is possible to recover quartz grains for forensic surface texture analysis after exposure of up to 1200 °C (or 900 °C in the presence of salts) [10] and also fingerprints with sufficient ridge detail for analysis [11]. Therefore, an experiment was designed to establish whether pollen grains can be recovered for subsequent successful forensic analysis after their exposure to extreme heat/fire conditions and thus have evidential value in a forensic investigation. It is of course well known in the field of archaeology that pollen can persist for hundreds or thousands of years and withstand domestic fires and can therefore provide valuable insight in the use and age of particular sites of interest [12]. It is also well documented in the geological literature (micropalaeontology) that pollen can persist for tens of thousands or millions of years and is often found in association with charcoal and other evidence of natural fires [13,14]. Although the heat attained by geological processes affects pollen grains, it does not have the same oxidative potential that a fire would. There is a parallel however, in that pollen in the geological record does show different reactivity to geologically imposed heat according to species type and this may suggest that different pollen types will respond differently to fire as well [15–17]. However, in forensic investigations, exposure to fire and its heat is often comparatively brief and the questions asked of the samples are rather different to those posed in palaeoarchaeological and palaeontological investigations.

This present study aims to assess the threshold temperature at which pollen grains are sufficiently morphologically intact for forensic identification, and the degree to which that threshold varies over time and provide some insight into whether or not the pollen recovered from the sediment samples from the vehicle exposed to fire and heat in the 1998 case mentioned previously could have been viable evidence. The importance of such a study is not only found in assessing the viability of the trace evidence and thus influencing the collection and analysis stages of the investigations, but also in providing a scientific, experimental basis that provides the evidence base necessary for such evidence to meet a reliability test in the style of Daubert.

2. Experimental work

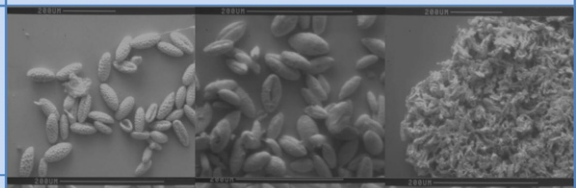
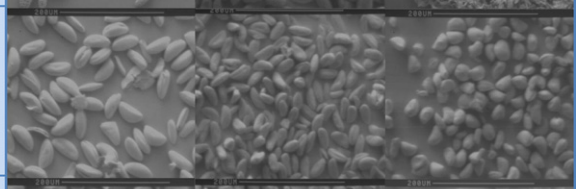
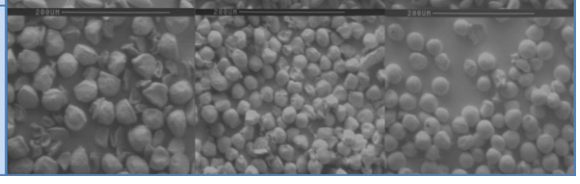
Three types of pollen were selected; Lily (*Lillium*), Daffodil (*Narcissus*) and Tulip (*Tulipa*) due to their relative abundance and their ease of accessibility for domestic decoration within dwellings in the UK. The flowers were allowed to mature and were then dried at room temperature before the pollen was extracted and transferred to sealed containers. A small quantity of pollen was placed into a ceramic crucible and put in a pre-heated furnace. Given the preliminary nature of this study, only the effects of furnace heat were considered. Future work could helpfully include the effects of direct flame contact and the extent to which these two conditions elicit different responses of the pollen that would affect morphological identification.

In experiment 1, discrete samples of pollen was exposed to different temperatures of 100–1000 °C (at 100 °C increments) for 5, 10, 15, 30, 60 and 120 minute intervals ($n = 66$). This temperature range was chosen after the work of Putori and McElroy [18] that demonstrates the temperature ranges typically found in house fires and the work of Morgan et al. [10] that demonstrated the typical temperatures experienced in vehicle fires. The samples were then allowed to cool in the crucible and subsequently analysed using binocular light microscopy and scanning electron microscopy (SEM). Pollen grains were grouped into four categories according to the degree to which the species of pollen could be identified through comparison with a control sample. Pollen grains were classified as follows:

1. Pollen grains retain their shape (*identifiable*)
2. Pollen grains show signs of thermal stress (*identifiable*)
3. Pollen grains become severely misshapen and/or conglomerated (*unidentifiable*)
4. Pollen destroyed (*unidentifiable*)

In classifications 1 and 2 the pollen species were identifiable and could be used for forensic analysis. As Table 1 illustrates, in classification 1 the pollen grains retained their shape and showed no adverse effects as a result of heating. In classification 2 the pollen grains were still identifiable, but showed some signs of thermal stress, such as a reduction in grain size or a partial distortion in shape. In classification 3, pollen grains were severely distorted in shape and size and were likely to have conglomerated. In classification 4 the pollen was completely destroyed (no sample recovered). It was deemed that when pollen grains were classified as 3 and 4 that the pollen was unidentifiable and therefore unsuitable for forensic analysis.

Table 1
Classification of pollen grains.

Pollen type	Classification 1	Classification 2	Classification 3
Lily			
Daffodil			
Tulip			

An initial experiment was undertaken with Lily pollen and these results (Table 2) showed that after 5 min of exposure, Lily pollen was destroyed between 500 and 600 °C. After 5–10 min of exposure the threshold dropped to between 400 and 500 °C, where it remained for up to 60 min of exposure. Between 60 and 120 min this threshold dropped further to 300–400 °C. Since most fires in a forensic context (particularly vehicular and building fires) burn for between 5 and 60 min [13] this experiment was then repeated at 20 °C intervals, between 400 and 600 °C (for Lily, Tulip and Daffodil). In experiment 2, discrete samples of each pollen type were exposed to different temperatures in a similar manner to experiment 1. However, the temporal persistence and preservation of the pollen was further tested by exposing the three pollen types to a wider range of temperatures of 25–1000 °C for 0.5–1440 min so as to ascertain the effects of temperatures under 100 °C, the effects of heat over a longer time frame (180–1440 min) and also to establish in greater detail the behaviour of pollen grains in the first 5 min of exposure (0.5–5 min).

3. Results

3.1. Experiment 1

The summary results for experiment 1 are presented in Fig. 1. After 5 min of exposure, Lily pollen was destroyed between 520 and 540 °C (Table 3). At this point, the pollen became severely distorted, breaking apart, and in some instances formed organic conglomerates. These effects began at around 480 °C. Between 5 and 15 min of exposure, this threshold dropped to 480–500 °C. At 30 min, Lily pollen was destroyed between 440 and 460 °C and by 60 min this threshold dropped further, to between 400 and 420 °C. Daffodil pollen, after 5 min of exposure, had a slightly lower persistence than Lily (500–520 °C) (Table 4). Between 5 and 10 min this threshold dropped significantly to 400–20 °C where it remained for up to 1 h of exposure. Tulip pollen had a persistence of between 440 and 460 °C for between 5 and 15 min — lower than both Lily and Daffodil pollen (Table 5). Between 15 and 30 min, this threshold dropped to 400–420 °C. At high temperatures (>460 °C) or over longer periods of exposure (60–120 min) Tulip pollen became more spherical in shape (see Table 1).

3.2. Experiment 2

In experiment 2, Lily was preserved at 700 °C between 30 s and 2 min and 500 °C between 3 and 5 min of exposure dropping to 400 °C for 10–60 min. In comparison, Daffodil was preserved at 800 °C for 30 s, 600 °C between 1 and 2 min, 500 °C between 3 and 5 min before dropping to 400 °C for 10–60 min of exposure. Tulip pollen was preserved at 700 °C for 30 s, 600 °C for 1–2 min before dropping to 500 °C at 3 min and 400 °C between 4 and 60 min (see Fig. 2).

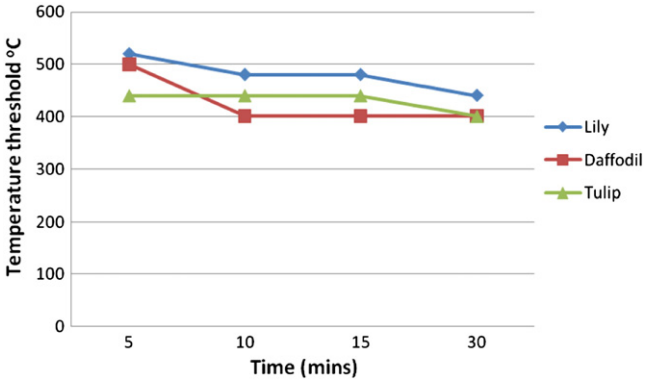


Fig. 1. Temperature thresholds identified in experiment 1.

The longer time frames of exposure (60–1440 min (the equivalent of 1–24 h)) demonstrated that the preservation of all three types of pollen was reduced, but not as dramatically as might have been expected (see Fig. 3). The threshold for Lily preservation was 300 °C for 2–18 h (60–1080 min), which dropped to 200 °C for 24 h whilst Daffodil was preserved at 300 °C for 2–3 h (120–180 min) before dropping to 200 °C for 4–18 h (240–1080 min) and then 100 °C for 24 h (1440 min). Tulip was the least resilient having a threshold of 200 °C at 2 h (120 min) of exposure which reduced to 100 °C with 3 h (180 min) of exposure and then only 50 °C between 4 and 24 h (240–1440 min). The thresholds achieved at each point during the full duration of the experiment are presented in Fig. 4.

4. Discussion

In this experimental study, pollen does appear to persist under high temperature conditions and this persistence demonstrates variability according to the time frame and pollen type. Over short time frames (5–30 min) these three different types of pollen had a threshold of 400 °C above which damage occurred to the grains. Over longer time frames (120 min to 1440 min) the threshold was reduced and more varied for the different types of pollen. The threshold for Tulip was much lower (200 °C at 120 min falling to 50 °C after 240 min) than Daffodil and Lily, and these latter two types of pollen also displayed different thresholds after 180 min with the threshold of Daffodil falling to 200 °C (between 240 and 1080 min) whilst Lily pollen grains exhibited the greatest resilience with a threshold of 300 °C (between 180 min and 1080 min).

These experiments demonstrated that over shorter timescales the temperature thresholds were higher than might have been expected with all three pollen types persisting at or above 700 °C after 30 s (the threshold of both Lily and Tulip pollen was 700 °C and Daffodil

Table 2
Lily pollen results from the initial experiment.

Temperature (°C)	Time (min)					
	5	10	15	30	60	120
1000	4	4	4	4	4	4
900	4	4	4	4	4	4
800	4	4	4	4	4	4
700	3	4	4	4	4	4
600	3	4	4	4	4	4
500	2	3	3	3	4	4
400	2	2	2	2	2	3
300	1	1	1	1	1	1
200	1	1	1	1	1	1
100	1	1	1	1	1	1
25	1	1	1	1	1	1

Table 3
The persistence of lily pollen between 400 °C and 600 °C over 120 min.

Temperature (°C)	Time (min)					
	5	10	15	30	60	120
600	3	4	4	4	4	4
580	3	3	3	3	4	4
560	3	3	3	3	4	4
540	3	3	3	3	4	4
520	2	3	3	3	4	4
500	2	3	3	3	4	4
480	2	2	2	3	3	3
460	2	2	2	3	3	3
440	2	2	2	2	3	3
420	2	2	2	2	3	3
400	2	2	2	2	2	3

Table 4
The persistence of daffodil pollen between 400 °C and 600 °C over 120 min.

Temperature (°C)	Time (min)					
	5	10	15	30	60	120
600	3	4	4	4	4	4
580	3	3	4	4	4	4
560	3	3	3	4	4	4
540	3	3	3	4	4	4
520	3	3	3	3	4	4
500	2	3	3	3	3	3
480	2	3	3	3	3	3
460	2	3	3	3	3	3
440	2	3	3	3	3	3
420	2	3	3	3	3	3
400	2	2	2	2	2	3

was 800 °C) which steadily decreased to 500 °C for Daffodil and Lily and 400 °C for Tulip after 5 min of exposure (see Figs. 1 and 2).

Previous experimental work undertaken on vehicles that were set alight in a similar manner to the vehicle in question the 1998 case mentioned previously provides an indication as to the heat and fire conditions of vehicles set alight in this way [10]. All the vehicle fires were allowed to reach maximum intensity and a significant degree of cabin destruction. The duration of the fires did not exceed 20 min and the time the fires reached their peak temperatures did not generally last for more than 5 min. The study demonstrates that the temperatures reached in the footwells and wheel arches (the two most common places to be able to recover geoforensic sediments) were found to be between 226 and 476 °C for the footwells and 285 °C for the wheel arches (only one car experienced elevated temperatures in the wheel arches due to the source of the fire being in the boot). These findings indicate that in a forensic investigation of a vehicle fire that has been subject to arson, it is highly likely that if geoforensic material can be recovered from the vehicle, the constituent pollen grains are likely to be sufficiently morphologically intact for forensic analysis.

5. Conclusions

These experimental studies have demonstrated that

- There is a variability in the persistence of Lily, Daffodil and Tulip pollen when exposed to high temperatures between 0.5 min and 1440 min (24 h).
- All three pollen types can be identified after 30 min of exposure to temperatures of 400 °C.
- After shorter time frames (3 min and less), the threshold is at least 500 °C and pollen can also persist after exposure over longer time frames with thresholds of 300 °C (Lily), 200 °C (Daffodil) and 50 °C (Tulip) after 18 h (1080 min).
- Pollen in vehicles, particularly in the footwells and wheel arches, may well be preserved particularly if these areas are shielded from the source of ignition or the subsequent blaze, as it is possible that the temperatures reached in these locations will not reach the time or heat thresholds for pollen destruction.

Table 5
The persistence of Tulip pollen between 400 °C and 600 °C over 120 min.

Temperature (°C)	Time (min)					
	5	10	15	30	60	120
600	3	3	4	4	4	4
580	3	3	4	4	4	4
560	3	3	3	4	4	4
540	3	3	3	3	4	4
520	3	3	3	3	4	4
500	3	3	3	3	4	4
480	3	3	3	3	3	3
460	3	3	3	3	3	3
440	2	2	2	3	3	3
420	2	2	2	3	3	3
400	2	2	2	2	3	3

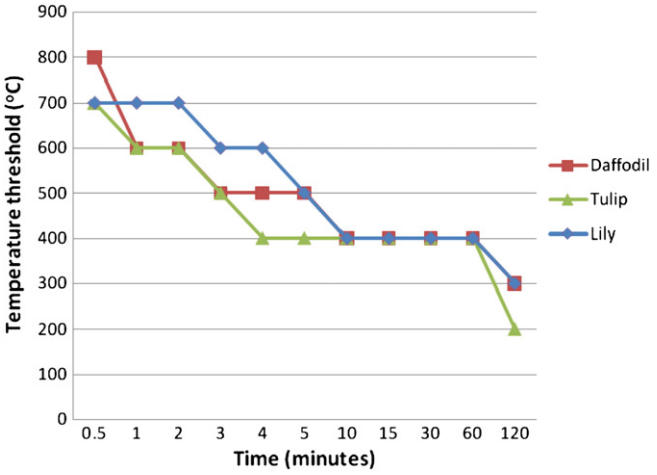


Fig. 2. Temperature thresholds achieved by the three pollen types (0.5–120 min).

Findings from such studies work towards the provision of peer-reviewed experimental literature that satisfies the Daubert-style admissibility tests which may soon be introduced to the British Courts. These conclusions illustrate that monocot pollen is likely to be preserved in vehicles that have been subjected to arson in a form viable for subsequent morphological identification. This is a highly valuable finding given that these pollen types are relatively fragile to both chemical and heat degradation in comparison to other pollen types. This not only has implications for the collection stage of the forensic investigation by providing evidence for the potential survival of such evidence, but also provides substantial context for the accurate interpretation of the analysis of recovered pollen. In a court where admissible evidence must pass a reliability test, such studies will become integral to ensuring that viable forensic material is not only collected and analysed to provide useful intelligence, but is also able to provide evidence in a court and aid a jury. These studies are of course but a small contribution towards the acceptance of a forensic palynology discipline in court that requires an admissibility test as a prerequisite. Further work needs to be carried out on a broader range of pollen types and could also very usefully include taking into account the thickness of the pollen wall of

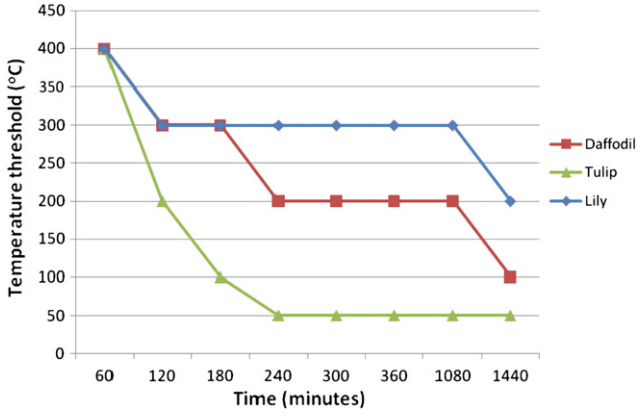


Fig. 3. Temperature thresholds achieved by the three different pollen types (60–1440 min).

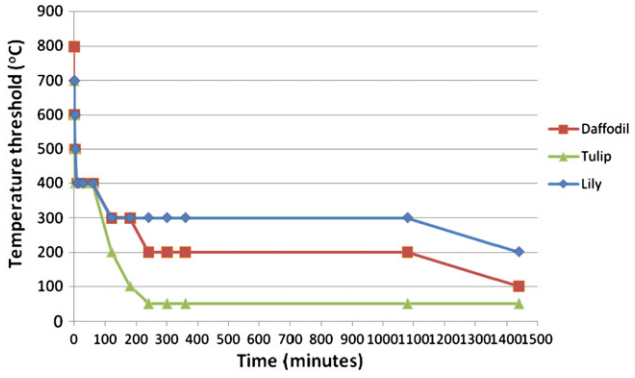


Fig. 4. Temperature thresholds achieved by the three different pollen types for the duration of experiment 2.

different pollen types to assess the degree to which preservation is a function of this characteristic. However, all future work must take into account the fact that forensic palynology can provide only exclusionary evidence and intelligence rather than providing positive associations as is portrayed in television crime dramas and the popular press [19–21].

Statement of novelty

This paper represents an empirical experimental study to ascertain the spatial and temporal characteristics of trace pollen evidence that undergoes exposure to extreme heat and fire conditions. The paper presents the first data to provide a means of establishing an empirical knowledge base for the interpretation of trace pollen during forensic investigations where fire or arson has been a feature. We believe that this paper provides the first findings of this nature within a forensic context in the published academic literature.

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