‘The coldest case of all’ – fire investigation at the Viking Age ring fortress of Borgring, Denmark

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ABSTRACT

During excavations of the Viking Age ring fortress Borgring, Denmark, traces of a devastating fire was uncovered. The National Forensic Services of the Danish Police were invited to participate in a novel collaboration, applying contemporary forensic fire investigation to an archaeological site. This paper presents the results and sets a benchmark for future applications. The investigation leads to a revised reconstruction of the fortress and the development of the fire. The application of fire investigation methods, following the Daubert standard criteria, enhance the documentation and analysis of archaeological sites, while archaeological methods show significant potential at modern fire scenes.

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1. Introduction

The methods of fire investigation, as used in contemporary forensic science, are developed to analyse the material evidence of fire sites to understand the origin and cause of fires. Despite pertinence to problems commonly encountered in archaeology, the potential of these methods to archaeological contexts is only sporadically explored (Harrison 2013). Beyond individual experimental burnings to create analogies to compare with the archaeological record (Christensen et al. 2007; Harrison 2012), no systematic fire investigations of archaeological sites are previously reported.

During excavations in 2016 of the Viking Age ring fortress Borgring, Denmark, a major destruction layer with well-articulated, charred timbers, and other evidence of a conflagration were encountered in the east gateway of the fortress. It was realised that interpretation of these remains would require a full understanding of fire dynamics and familiarity with the structural evidence of fire sites. Accordingly, the National Forensic Services (NKC) of the Danish Police was invited to participate in the investigation. The unusual collaboration resulted in what was reported in media as ‘one of the coldest cases of all’ (The Huffington Post 05/July/2016).

The involvement of the NKC in the study was also motivated by the potential to develop technical fire investigation methods and to advance practical and theoretical approaches to the investigation of complex fire sites. The interaction with the archaeologists in the process of investigating a ‘cold case’ was recognised as an opportunity for method development.

This paper demonstrates how scientific methods of fire investigation can contribute to the characterisation and interpretation of an archaeological site. It reports the investigations of the fire debris examined *in situ*, together with technical analyses of the remains, and reviews their significance with regards to understanding the construction of the gateway, and the sequence and origin of the fire at the site.

2. Materials and methods

2.1. Fire investigations and archaeology

Fire investigations (DeHaan and Icove 2013) aim to interpret fire scenes to reconstruct how the fire has affected the materials and constructions. Fires leave a pattern of fire damage, and together with tactical information of significance for fire research and reconstructions, these are used to assess hypotheses. During the interpretation, the appearance of the fire damage is compared with conditions such as: which materials are burned; which materials are undamaged; and how much and where the materials are burned. This provides opportunities to assess the fire's spread and how intensive it was. This may then be compared to information on materials present prior to the fire (Drysdale 2011).

NKC defines the national standards for fire investigations in Denmark. In connection with this, NKC has authored the Danish Fire Manual (DBM), based on the *Best Practise Manual for the Investigation of Fire Scenes* authored by the European Network of Forensic Science Institutes (2016). The NKC follows the criteria of the Daubert standard (Pakkanen, Santtila and Bosco 2014; International Association of Arson Investigators 2017, 148) when assessing scientific quality. This defines the conditions under which forensic investigations can be applied in court cases, and calls for particularly transparent procedures of investigation and presentation.

The investigation report must reflect how the investigator has reached his conclusion regarding the origin and cause of the fire, including which considerations have been made along the way. Hypotheses and the process of elimination and verification of these are limited. Thus, hypotheses based on second- or third-order hypotheses are avoided. Relevant questions with regard to the criterias (NFPA 2012) are:

- Has the method, theory or technique been tested, peer reviewed, and published?
- What are the known or potential errors?
- Are current standards met, and how are these standards maintained?
- Is the method generally accepted in the scientific community?

In this paper, we apply the structure and standard of a fire investigation report, from observations and hypotheses to test and verification. A clear distinction is maintained throughout between assumptions, observations, and conclusions (Molander 1990; Tilstone, Hastrup and Hald 2019).

2.2. The Borgring excavations

In 2014, Borgring near Køge, Denmark, was identified as the fifth geometrical Viking Age ring fortress in Denmark, complementing an exclusive

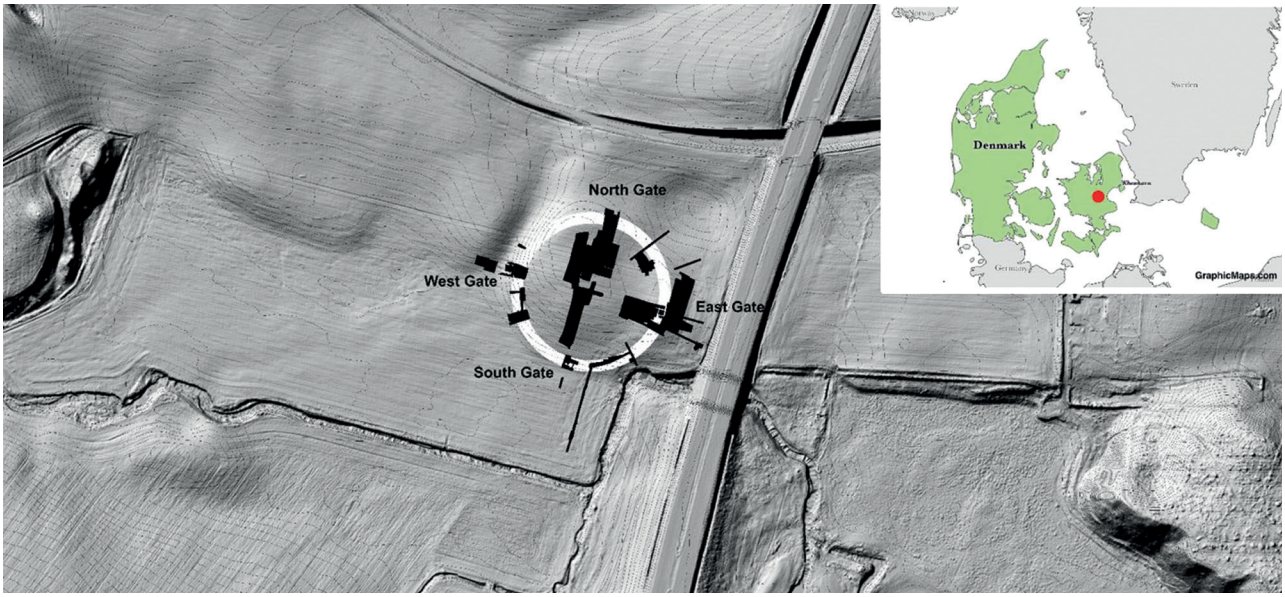

Figure 1. Plan of Borgring with indication of the areas of investigation. Cut-out: map of Denmark with the site marked in red (Plan: Museum Southeast Denmark).

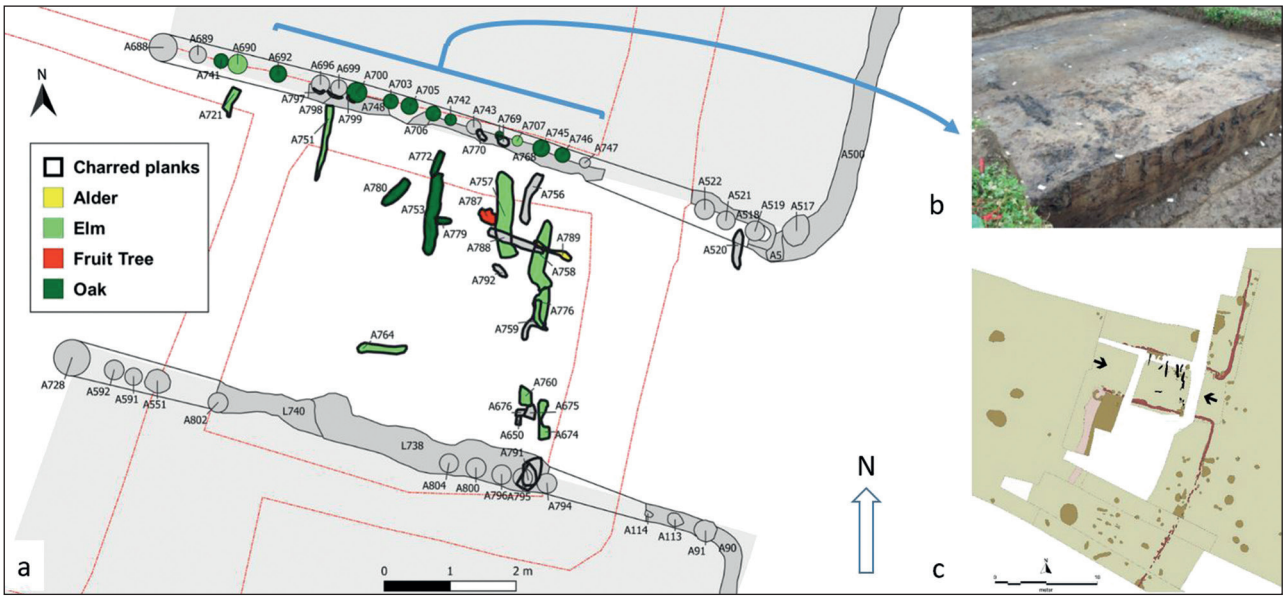

Figure 2. The east gateway with traces of standing posts in the sides and charred planks that has fallen into the doorway after fire. a) plan showing identified wooden structures; b) photo looking southeast; c) overview (Plans and photo: Museum Southeast Denmark).

group of monuments which includes the best-known example, Trelleborg (Goodchild, Holm and Sindbæk 2017). A major programme of excavations and surveys conducted by Museum Southeast Denmark and Aarhus University in 2016-2018 have examined parts of the ring fortress and its hinterland.

The excavations have uncovered a circular rampart built of stacked turfs with heavy, humic clay and a mixture of clayish subsoil (Figure 1). The rampart was preserved to a height of *c.* 1 m and describes a perfect circle of *c.* 454 m in circumference, with an outer diameter of 144.4 m and a width of 10.6 m at its base. Below some parts of the rampart, a >1 m thick levelling layer was spread to prepare the building site. The outer perimeter of the rampart is characterised by shallow postholes from a front of vertical timbers, while the inner side may have been sloped or stepped. The fortress had four gateways, oriented with great precision exactly 90° apart along the perimeter, and pointing approximately towards the cardinal points of the compass. Each gateway consisted of two parallel rows of postholes, creating a *c.* 4.6 m-wide opening through the rampart. Extensive excavations both inside and outside the ring fortress have not led to the identification of traces of buildings or permanent occupation. There were no traces of a moat, but the fortifications were strengthened by streams and wetlands on the western, southern, and north-eastern sides. Charred wooden constructions from Borgring have been ^{14}C-dated to the 10th century (Goodchild, Holm and Sindbæk 2017, 1039; Christensen et al. 2021, 14-15).

2.2.1. The east gateway

The east gateway was investigated in 2016. This part of the fortress was heavily eroded by agriculture, and only 20-40 cm of stratigraphy remained below the ploughed soil. Parts of charred posts were visible in the side of the gateway together with charred timbers scattered horizontally inside the gateway. The layers were excavated and documented individually, and part of the soil was water sieved in a 4 mm mesh, leaving behind two baulks across the gateway. A section was made along the northern side of the gateway in which the outer side of the postholes were visible.

The gateway was constructed with two parallel lines of vertical timber posts, one on each side of the entrance through the rampart (Figure 2). The gateway was 10.7 m long and 4.20-4.75 m wide as measured between the inner face of the timbers. The corner posts at the front of the ramparts were very substantial and deeply set, suggesting that a gate was placed here. The other posts were comparatively thinner and less deeply set in a trench or

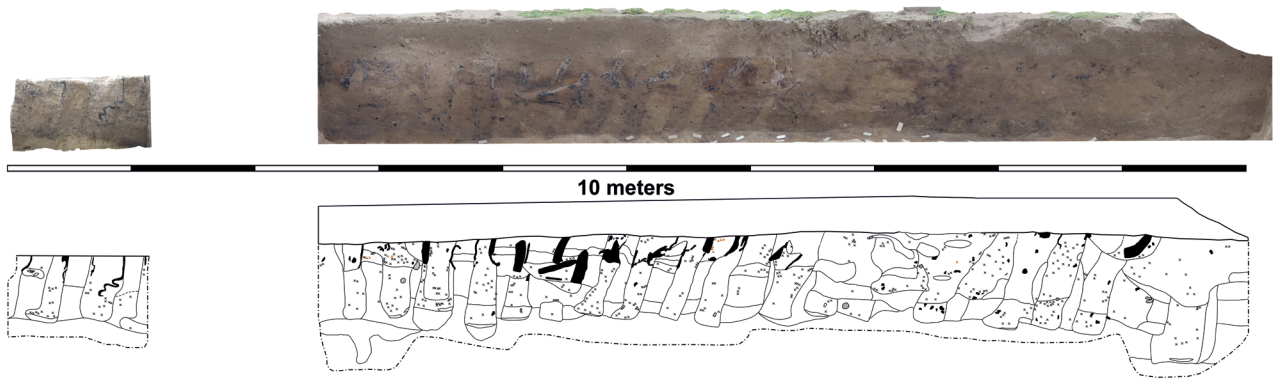

Figure 3. Section 51 along the northern side of the east gateway, looking south. Cuttings are marked in thin outline, charred wood in solid black (Drawings and photo: Museum Southeast Denmark).

pits dug 35-65 cm into the ground. The relationship between posts and rampart fill was investigated in several places, including section 51 (Figure 3). Here the turfs of soil are seen to touch the posts in both the northern and southern side of the gateways.

The posts in each side of the gateway had a diameter of 16-25 cm and were placed with gaps of 10-16 cm. The postholes were seen as charcoal-mixed, discoloured soil. Some of the posts were inclined, with the top leaning 10°-20° towards the inside of the fortress. Indications are that this must have been intentional, as the contours of the posts and the filling layers between them were without signs of disturbance.

Analysis of 32 samples of charred posts and timbers from the gateway show an eclectic use of wood: 13 samples were from elm (*Ulmus* sp.), one from ash (*Fraxinus excelsior*), one from alder (*Alnus* sp.) and one from fruit tree (*Pomoideae*), while the remainder were from oak (*Quercus* sp.) (Baittinger 2018).

The primary floor of the gateway was laid out as a layer of clay and humic clay, and the trenches of the gateway walls were dug through it. There were no traces of a plank road. Above this, the fill layers consisted of soil mixed with charcoal, and parts of charred timber planks. In the southern part of the gateway the layers were more fragmented and several depressions had been dug through the layers with burned timber.

Finds from the east gateway comprise a wooden box with iron tools and scrap found in a depression in the south-eastern part of the gateway. The tool cache was placed in a pit dug through the unburned layer, which was spread after the fire. In the same depression, whetstones and small sherds of Early Glazed Ware were also found. The ceramics places the layer in the very late tenth century or early eleventh century. Underneath the layers that showed signs of fire, in layers that are interpreted as being from the primary use of the fortress, a whetstone was found, while three glass beads came to light in a younger layer in the southern side of the gateway.

2.2.2. Other traces of fire

The subsequent excavation in 2017-18 has shown that three of the four gates of Borgring were partially destroyed by fire. Extensive traces of fire were thus noted in the north gateway: the two sides of the gateway were visible as elongated features containing postholes and charcoal, and both sides were marked by fire. A number of charred timbers lay horizontally near the eastern side of the gateway. The north and east gateways show similar constructions with no demonstrable points of difference. The traces of fire also have a similar general appearance and led to substantial damage to the gate. The subsequent use of the two gates is different, however, with the north gateway showing use as a roadway.

Charred traces were also seen in the west gateway, which was uncovered but not excavated due to conservation considerations. Again, the fire does not seem to have affected the solid corner posts. By contrast, the south gateway, facing the Køge river valley, was fully excavated, but no evidence of burning was observed. The outer face of the rampart was investigated in several places, but no traces of fire were seen.

2.3. The fire investigation

2.3.1. Investigation

The scene of the fire was partially excavated by the time of NKC's first visit. Further visits to the site were made continuously as the excavation progressed, and four samples (KT 2-5) were collected for further analysis at the NKC laboratory. The study was concentrated to the areas at the posts along the sides of the gate, and to the floor of the gateway area. No studies were carried out on other parts of the fortress, but information from previous excavations in 2014 were available, and information on the subsequent 2017 investigation of the north gate was also taken into account for the assessment.

The objective of the fire investigation is an interpretation based on the traces found in connection with the excavation. The interpretation and assessment of the fire aims to understand a possible fire process and to form a picture of the construction of the rampart and the gateway. It is assumed that the construction was made from suitable materials (wood) and by accomplished constructors and good craftsmen. It is also assumed that activity in the ring fortress took place for a continuous period of time. These assumptions should be seen as a delimitation in hypotheses. Furthermore, weather, mechanical wear, and possibly impregnation treatment has significance for the verification.

2.3.2. Tactical information

The excavation showed that a part of the gateway had been exposed to fire. Charred timber planks could be seen in layers inside the gateway, and the posts in the northern side of the gate were charred towards the side facing the gateway. There was no corresponding charcoal trail on the southern side.

No traces of fire were found to affect the outer wooden cladding of the rampart or the outermost post of the gateway (feature A517, cf. Figure 2). From the second post (A519) and further into the gateway, large amounts of charcoal were seen in and around the remains of the posts, together with heat-induced reddening of the clay (Figure 4). The sides of the posts facing the gateway were charred halfway around, while the sides facing the rampart were untouched by fire. A *c.*1 m-long stretch of the central part of the north wall had been affected in another way. Here, minor posts both standing and lying down had been charred all the way around, indicating that the air had been able to circulate on both sides of the wall.

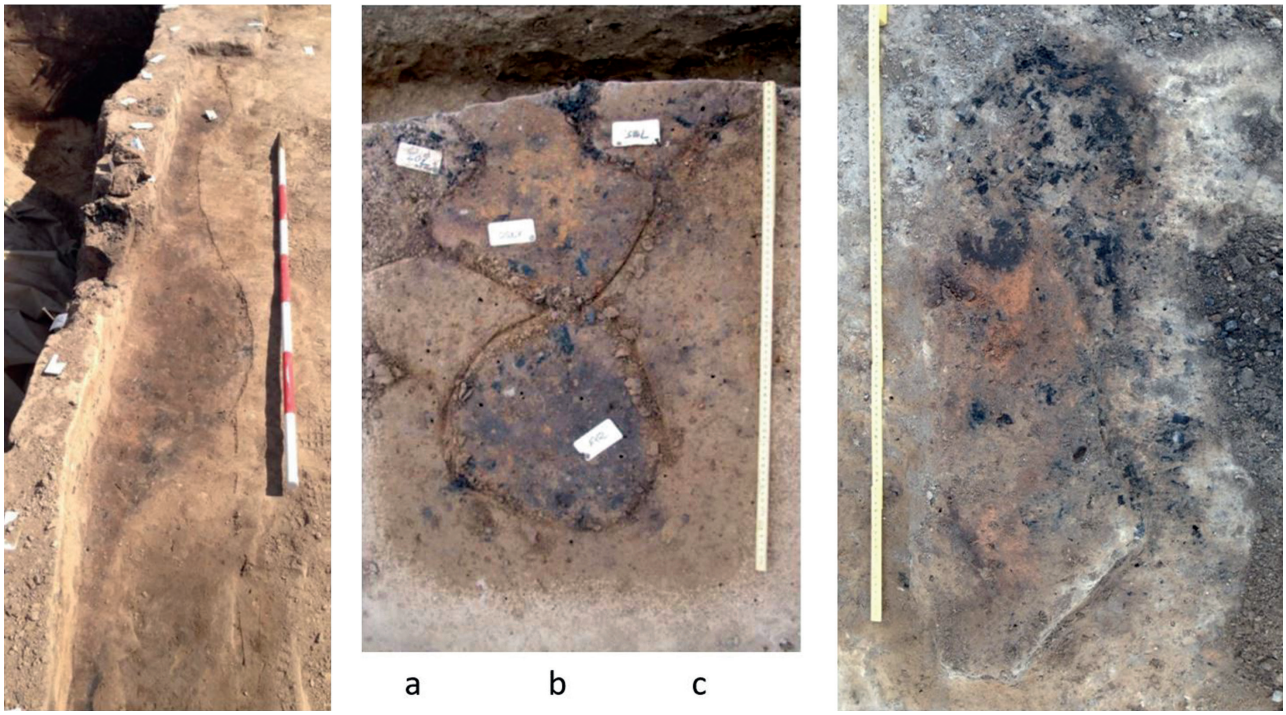

Figure 4. a) Strong red coloration formed by heat around the posts A697 and A699 (looking east) and b) posts A703 and A705 (looking north); c) Remains of a fireplace found approximately in the middle of the gateway, and used subsequent to the main fire event (Photos: Museum Southeast Denmark).

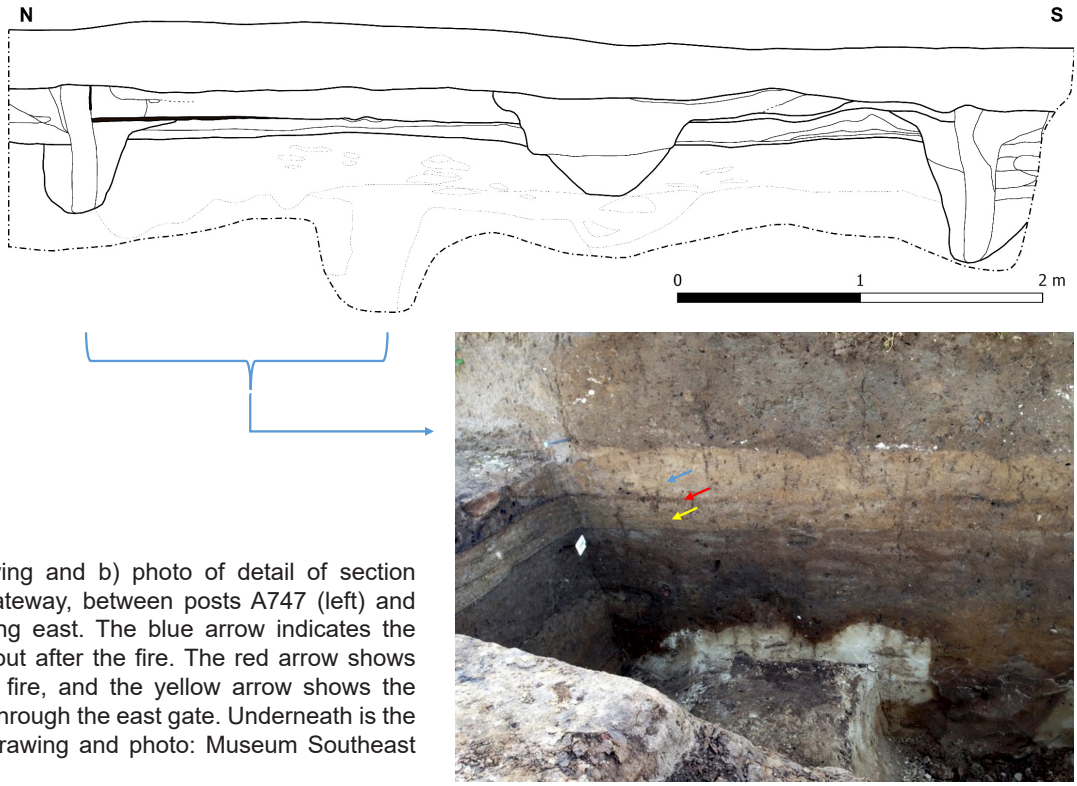

Figure 5. a) drawing and b) photo of detail of section across the east gateway, between posts A747 (left) and A794 (right), looking east. The blue arrow indicates the clay layer spread out after the fire. The red arrow shows the horizon of the fire, and the yellow arrow shows the original roadways through the east gate. Underneath is the original surface (Drawing and photo: Museum Southeast Denmark).

In an area in the middle of the gateway, at a level from above the original floor, the posts were seen as an outer shell of charcoal with a thickness of 2-5 cm, while the core was filled with sandy soil. It was clear that the outside of the post had been charred by fire, while the core had not burned. The rest of the posts had slowly decomposed and gradually been filled in. Below the original surface there was no shell of charcoal, and the remains of the posts below ground appear to have slowly decomposed, leaving only soil with bits of charcoal, which had sunk down from layers above.

The observations of fire damage to the posts in the northern side of the gateway can be divided into three groups:

- Unknown position on posts
- Posts charred on all sides and found in a leaning position
- Posts charred on the side facing the gateway, i.e. halfway around

The stratigraphy inside the gateway is documented by a cross section *c.*2 m from the front of the gate (Figure 5). In the top of the fill were visible remains of charred wood pieces, which were mostly oriented across the gate. These pieces of wood had the size and character of planks with widths ranging between 12 and 25 cm. Under the charred planks was a compact layer of clay. In the northern part of the gateway, this layer was found to reach to the charred posts, yet without being affected by heat. A fireplace was found approximately in the middle of the gateway, showing a hard-burned red mantle formed in the clay.

As excavation continued, a layer of soil strongly mixed with charcoal was uncovered, in which the clay was reddened by fire. Around the posts A697 and A699, *c.*6.5 m inside the gateway as measured from the outer face of the rampart, a strong red coloration was seen in the fill layers. A similar coloration was seen around the posts A809 and A747, just 3 m from the front of the gateway. Apparently, only the northern side of the gateway had burned. On the southern side there were charcoal pieces in the ground, but no charred, standing timbers were detected.

2.3.3. Reconstructions

At a modern fire site, investigators typically have a full knowledge of the constructions and their properties and dynamics. In an archaeological site, these factors are often subject to uncertain reconstructions. A reconstruction of a Viking Age fortress at Trelleborg, Sweden (Figure 6), gives an esti-

mation as to what the constructions at Borgring may have looked like, as a basis for assessing the fire (Jacobsson et al. 1995).

Another important factor, the behaviour of wooden constructions in contact with soil, has been studied by Hansson (2010). This study shows no correlation between the climate at a macro level in various years and the lifetime of the wood. Other factors were of greater importance: fungal attack, the micro environment, and the durability of the wood species. All woods have a certain natural resistance to rot, but there is great variation between different wood species, as well as differences in each wood with respect to sapwood and core wood. Decomposition of wood occurs either through biological, mechanical, or physical factors (e.g. UV rays and wind).

Structural protection of wood may be achieved through specific constructive solutions that remove or reduce one or several causes for wood degradation. It is known (Trulson 2008) that heat treatment/burning has been used to protect wooden constructions. This burning prevents the wood from decaying by altering the chemistry of the wood, resulting in a better protection against fungi and rot. The appearance of the wood changes, and the wood becomes more brittle and consequently is less useful in load-bearing structures.

Considering the charred timbers from the east gateway of Borgring, detailed investigations of samples have demonstrated that they had a uniform appearance: the examined pieces had a charred crust of 2-4 cm and the cross section appeared with a curvature (Figure 7). After the fire, they seem to have been untouched until the fortress was abandoned. Eventually, the inside of the timbers rotted away and was replaced by soil.

Figure 6. References for fire investigation. Gateway of reconstructed fortress at Trelleborg, Sweden. a) view from inside (left) and outside (right) the gateway; b) roof cover from inside the gateway (Photos: NKC Photo).

Figure 7. Detailed investigation of charred timbers from the east gate of Borgring. The examined pieces had a charred crust of 2-4 cm and the cross section appeared with a curvature (Photo: NKC).

2.3.4. Hypotheses

Based on the investigation at the fire scene, together with the tactical information, the following hypotheses may be pointed out as being relevant for the case (Figure 8).

The construction of the gateway:

- Model 1: Fully completed (as in the Trelleborg reconstruction, cf. above) construction in two levels
- Models 2A and 2B: Simple gateway with plank cover, either with or without soil above, possibly in a partially unfinished state of construction
- Models 3A, 3B, 3C: A ruined state, in three different stages

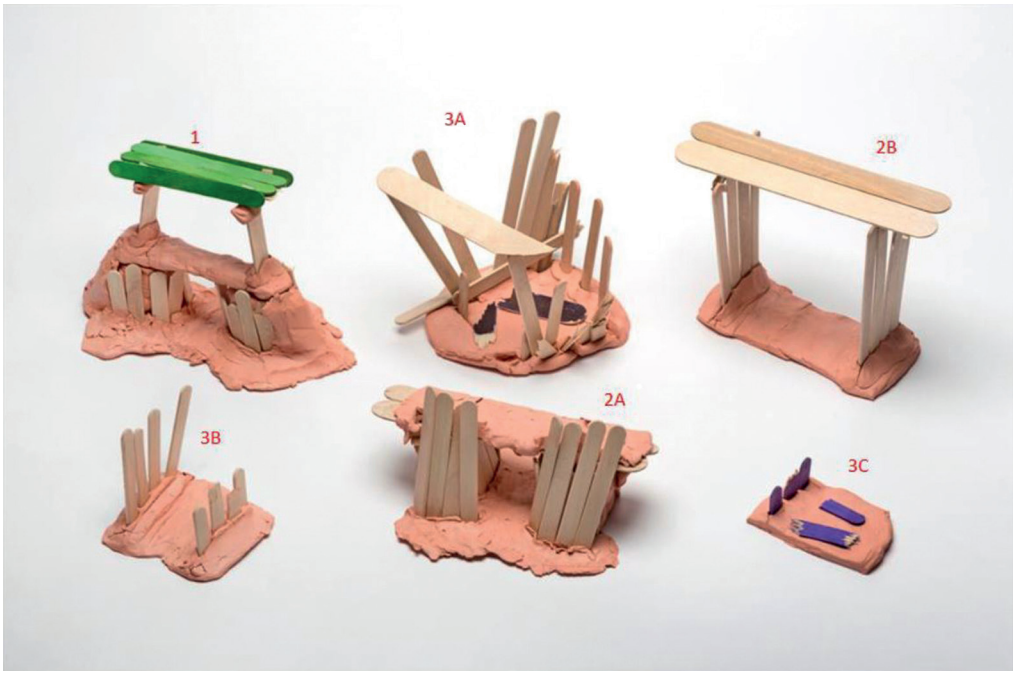

Figure 8. Models of the east gate in different stages: 1: Fully finished construction. 2A: Almost finished construction with roof and with soil cover. 2B: Almost finished construction with roof, but without soil over. 3A: Partial ruin with roof over some places. 3B: Partial ruin without roof. 3C: Ruin (Models: Eva Ljungkvist NKC. Photo: Johnny Thomsen NKC).

The origin of fire:

- Hypothesis 1. From the west (inside the fortress) and moving into the gateway and up
- Hypothesis 2. From inside the gate and on to the west (inside the fortress) and east (outside the rampart)
- Hypothesis 3. From the top of the rampart and moving along the sides and then into the gateway
- Hypothesis 4. From the east (outside of the rampart) and moving into the gateway and up
- Hypothesis 5. A combination of several of the above simultaneously

The sequences of the fire/-s:

- One fire
- Two simultaneous fires with controlled and uncontrolled fires respectively
- Two fires with time separation, either:
  - Controlled fire first, or
  - Uncontrolled fire first

A controlled fire is defined in this report as a fire that is managed in terms of spread and intensity, such as a bonfire.

2.3.5. Assessment

In reconstructing what the gateway looked like before a fire, observations of the fire residues can be interpreted in several ways. Besides observations of the actual fire debris and unburned construction remains, it is important to emphasise what cannot be seen during excavation, for example roof and walls. The apparent absence of things may have several causes:

- They were never part of the design, or
- They were removed or decayed over the years, or
- They were not recognised, albeit there may have been traces of them on site

2.3.5.1. Constructions

The function of the posts: The posts in the side of the gateway may have had several functions in the construction of the gateway: to keep the soil from the rampart in place or to carry a roof. The remnants of posts found show that the posts were placed at a certain distance. As such, they cannot have kept the fill of the rampart in place by themselves. If, as is likely, the rampart was built from stacked turfs, it could have stood without further support. As the posts are not very deeply entrenched in the ground,

the most obvious interpretation of their function is that they were to carry a roof above the gate. As the turfs are seen to lie directly against the posts, the wooden gateway structure must have been erected prior to the construction of the earthen rampart and may have been completed, even if the rampart itself was not.

The side walls: The posts have a charring all the way round, and the finding supports the hypothesis that the oxygen needed for the combustion was in place, and that the posts were thus not totally nor partly covered by soil. If, on the other hand, the posts supported horizontally mounted planks or some other dense construction to hold the soil in place, it would be expected that residues of the horizontal planks would be found, and we would expect to find uneven fire damage to the posts. The fire damage suggests that there could hardly have been a planked wall, as it would have prevented the uniform charring all the way around the upright posts seen in the east gate. The charring requires air supply around the posts from the ground surface and up.

A more open design, such as a fill of horizontal rafters or wattle, might explain the charring of the posts on all sides. The irregular uncharted branches and rafters would allow oxygen circulation and at the same time be combustible. However, the observation of turfs touching the posts makes this option unlikely. In conclusion, the posts must have stood with no further cover or fill, partly leaning against the turf wall, partly (in the middle of the gateway) with some distance to the soil rampart.

The roof: The sequence of events of the fire testifies that there were, as a minimum, transverse beams above the gateway that tied the vertical posts at the sides together. It is unlikely that a clay floor could have been maintained or that the posts in the gateway withstood pressure from the soil unless they carried a roof across the gateway. From the above argument, model 1 does not seem likely.

The residues of planks found lying across the gateway may have come from a roof. However, if the roof construction was more elaborate, it would be expected that more timbers in different dimensions would have been found. Several posts were found with the top leaning to the west. The shallow depth may have made the structure liable to collapse if the supportive effect of other parts of the structure, for example the roof, was damaged by the fire. Against this background, models 1, 3B, and 3C do not seem likely.

Our analysis does not yield a definite conclusion, but it indicates that the construction was neither built as in the Swedish Trelleborg reconstruction, nor was it in a state of a ruin. This implies that the construction was at least partially finished. It is considered most likely that the construction was wholly or partially finished with roof cover. That leaves the construction alternatives 2A, 2B, and 3A, and it is considered that the construction is more likely to be a combination or alternative of 2A and 2B, and not 3A.

2.3.5.2. Fire

The damage from a fire depends on the extent and intensity of the process. The fire-affected materials will be deposited depending on the development of the fire process. It is expected that the materials that are first affected by the fire lie at the bottom of the fire residues, while the residues of the structures which burn last or are most stable are at the top.

The sequences of the fire/-s: During excavation, it became clear that two different layers with charred wood were found, and that there was a certain amount of time between the fires that caused these. The reddened clay in the upper layer may be remains from a hearth, but the burnt post remains are inconsistent with damage from a hearth. The fire damage to the posts indicates an uncontrolled fire that burned the posts all the way around. A fireplace that gets out of control and thus becomes a fire could be a possible cause, but in this case the charcoal remains (e.g. KT 2) and the red-coloured clay do not appear at the same level.

Based on the above arguments, it is unlikely that the residues relate to one fire only. For the same reasons, it is assessed that there were not two different fires simultaneously.

The posts in the middle part of the northern side of the gateway were burned all the way around. The core of the posts, however, was not burned. This may mean that the fire was put out at a time when the fire had only partially consumed the posts. At least some parts of the timber construction seem to have stayed in place after the fire,

during the time when the fireplace was in use and the box with iron objects was deposited.

The origin of the fire: It has been considered to which extent the thickness of the charcoal layer can contribute to the assessment of the fire process. However, there are several factors that are important in assessing the length of the fire cycle. These include the intensity of the fire, oxygen circulation; the wood type, resistance to degradation and fire, as well as treatment; moisture in the wood; and possibly the degree of decomposition. For this reason, it is not possible to provide a reliable estimate.

The observations indicate that the spread of the fire probably did not proceed from west or east (outside) and further into the gate (Hypothesis 1 and 4), nor did the fire start on top of the rampart and move along the sides and into the gate (Hypothesis 3). Based on the fire traces found in the gateway the fire may have started inside the gateway and then moved both east and west (Hypothesis 2) but the amount of fire traces found in connection with other traces found during the excavation of the gate does not clearly point out an area of fire origin. Traces of fire was only found in one side of the gate, but exactly where the fire began is unclear.

3. Conclusion and perspectives

The interdisciplinary collaboration between archaeology and the fire investigation of the east gate of Borgring led to critical and unexpected evidence of both the construction and destruction of the structure (Figure 9).

In the initial assessment, during excavations, the gateway was assumed to be a massive construction with dense wooden walls, as seen, for example, in the reconstructed Swedish fortress (Figure 6). However, the fire investigation reveal that the gateway was built as a light construction of undressed posts with a simple plank roof. It is even possible that the structure was in a partially unfinished state when a fire struck and ravaged the north wall and probably the roof cover or parts of it.

There is no conclusion as to where the fire began, though there are no traces of burning on the four corner posts or the timber clad front of the rampart. Neither is there evidence of fire inside the ring fortress. Considering the intensity and the duration of the fire too many factors are impossible to assess and therefore these questions are unanswered.

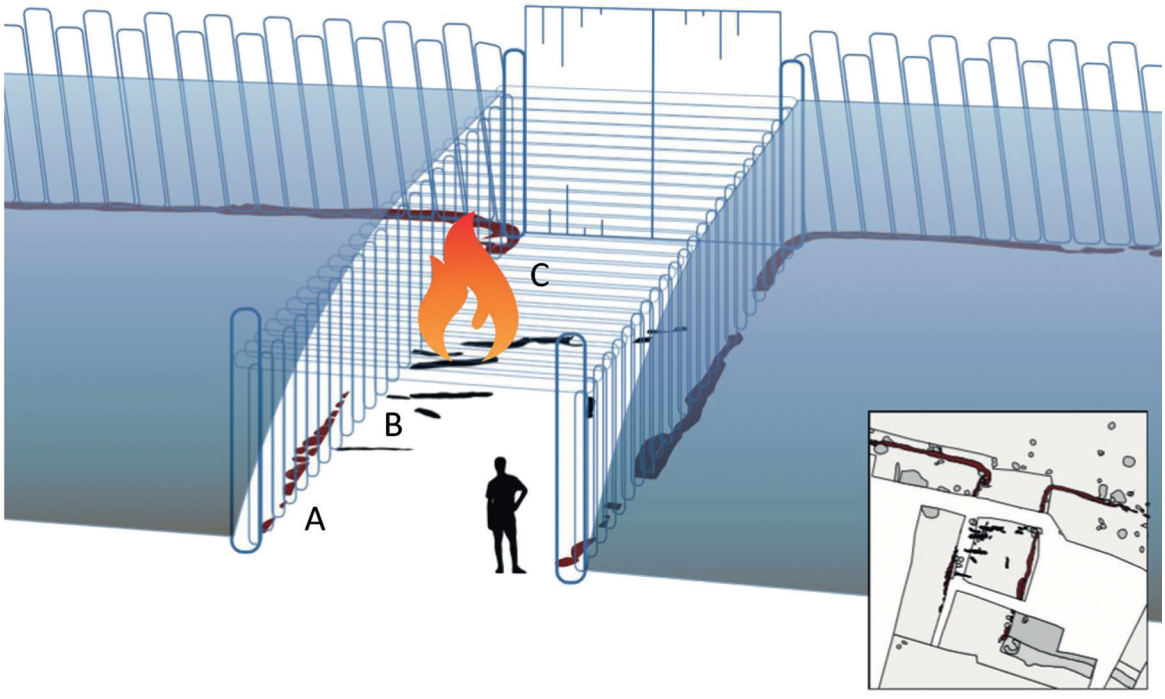

Figure 9. Visualisation of interpretation. The situation in area A is uncertain. Posts in B are burned all way round and leaning. Area C has vertical posts, which are not damaged by fire on the side facing the rampart (Drawing: Ea Rasmussen).

After the uncontrolled fire, the east gate was refurbished with a new floor of clay covering the charred traces. On this floor a new – controlled – fire left its mark in the form of a definite reddish colouring of the clay in the middle of the gateway, probably indicating a fireplace. Sherds from Early Glazed Ware retrieved close to the fireplace indicate a date in the very late tenth century or early eleventh century. The sequence of these events caused considerable problems during excavation, but were also clarified as a result of the fire investigation. This shows that the charred structures only collapsed after an indeterminate period of time, during which the new clay floor and the fireplace were in use. The burial of the tool box may have happened before the collapse.

The application of scientific methods of fire investigation have significantly augmented observation and interpretation of archaeological traces at the Borgring sites, leading to a revised reconstruction of the Viking Age ring fortress and its history. The study thus emphasises a further potential of fire investigation in archaeological sites

From the point of view of the fire investigators the collaboration has also shown that common archaeological methods have a general application in fire investigations. These include methods of three-dimensional spatial documentation and visualisation, and methods for controlling the sequence of depositions through the use of consistent stratigraphic modes of excavation and recording. Archaeological knowledge of taphonomic processes in the burial environment, together with geoarchaeological methods such as soil and sediment micromorphology also deserve wider application in specific forensic cases. This pilot study thus opens a field with far-reaching perspectives for further interdisciplinary collaborations.

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This article is one of more contributions discussing targeted aspects of the results of the Borgring Project 2016–18 published in Danish Journal of Archaeology. Language has been revised by Taylor Grace Fitzgerald

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