From Analogue to Digital

A Study of Documentation Methods during an Excavation of the Neolithic Flint Mines at Pilbladet, Sweden

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Abstract

The 'digital turn' in archaeology has resulted in documentation, analysis, visualization and repository requirements becoming increasingly digital in recent years. However, we are only at the beginning of understanding how the shift from analogue to digital affects archaeological interpretation, as attention has mainly been directed towards technological aspects. However, how archaeology is executed influences the production of archaeological knowledge, and additional research into digital practices and their consequences is needed. During the latest excavation in 2014 of the Neolithic flint mines of Södra Sallerup, in Malmö in southern Sweden, several recording methods were used to document the remains in plan, including hand drawing, digital mapping with GPS and digital photography using a camera mounted on a pole. The records were used to create both digital plans and georeferenced orthophotos from a 3D model and from photomosaic. The aim was to produce a record comparable to previous documentation from decades of archaeological excavations of the flint mines in the area, as well as one that is up-to-date with today's digital standards. The methods are described and their consequences for the archaeological results are discussed.

Keywords: digital turn, archaeological theory, digital archaeology, documentation methods, hand drawing, photogrammetry, digital mapping, GIS, contract archaeology

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Introduction

The introduction of digital tools into the archaeological toolkit has transformed, and is still transforming, archaeological practices, as technical development is in a phase of rapid change. This development and its impact on archaeology has been called a 'digital turn' (Costopoulos 2016) and has had a profound impact on archaeological work and archaeological information processes, altering the subject in ways we have hardly begun to imagine (Huvila 2014, 2018). The digital turn in archaeology has come to encompass all aspects of archaeological work, including recording, analysis, dissemination and storage of archaeological information, wherever digital tools are used in archaeology. It started with data processing and statistical analyses as computers became common in the 1960s and 1970s (Zubrow 2006), continued with digital mapping with total stations during the 1990s, as well as the use of GIS software for analysis and visualization of the collected data, to the situation of rapid development today, which has also been characterized as a 'digital leap', rather than a digital turn (Gunnarsson 2018).

However, the digital turn is more than the increasing use of digital tools. The change of practices caused by the switch to digital methods also leads to a change of processes of interpretation and analysis. This is in essence a change of perspective that leads to the possibility of asking new questions and achieving new knowledge.

The focus of this study is the documentation methods used in the 2014 excavations at Pilbladet in Södra Sallerup, south-west Scania (Berggren et al. 2016; Berggren 2018), and in particular the change there from analogue to digital recording. Södra Sallerup is the only known location of Neolithic flint mines in Sweden. Due to extraction of chalk and other activities in the area, the mines have been known since the beginning of the twentieth century and have been systematically excavated in various phases beginning in the 1960s (Holst 1906; Schnittger 1910; Althin 1951; Salomonsson 1971:127–129; Seitzer Olausson et al. 1980; Rudebeck 1986, 1987, 1994, 1998; Nielsen & Rudebeck 1991; Rosberg & Sarnäs 1995, 1997; Nilsson & Onsten-Molander 2004; Kishonti 2006).

The latest excavations at the site of Pilbladet in 2014 introduced a number of digital documentation tools, which are the basis of this study, in which the new digital methods are analyzed to determine whether they resulted in new knowledge. Storage, archiving and reuse of data are equally relevant and important, but lie beyond the scope of this article. In this study we aim to unravel and follow the links between method and interpretation as closely as possible in relation to documentation practices at the Pilbladet excavation.

The digital turn

Prior to the examination of the documentation of the flint mines in Södra Sallerup, a review of previous discussions of the impact of various documentation methods on analysis and the process of interpretation is needed. Documentation methods have been debated since the beginning of archaeology (Morgan 2016; Olsen 2012). The focus here, however, is on the methods involved in recent developments, as the shift from analogue to digital has been realized. In this discussion we find the foundations of our reasoning as well as our position.

THE DIGITAL TURN: A TECHNOLOGICAL AFFAIR

Digital archaeology has been regarded as a largely methodological issue (Huvila 2014; Huggett 2015), in which archaeological development is determined by technological development.

Digital archaeology has in some ways developed into a separate field within archaeology, with university courses, conferences, organizations, publications and journals devoted solely to the field of digital archaeology. But as archaeology has taken such a comprehensive digital turn, the term 'digital archaeology' may be regarded as superfluous (Morgan & Eve 2012; Costopoulos 2016; Huvila 2018). After all, some of the issues discussed as problematic in digital archaeology, such as standardization as well as awareness of how choice of methods or technology influence the outcome, are not specific to digital archaeology, but relevant to archaeology as a whole. It has been suggested that we should stop discussing the definition of digital archaeology and change the question from 'what is digital archaeology?' to 'what do we want from digital archaeology?' (Huggett 2015).

So, what do we want from digital archaeology? One common argument for the use of a digital method is that it is time efficient and saves money. It is less often argued that it can give new perspectives and create new knowledge, even though this has been put forward in recent years (Perry & Taylor 2018). One way of realizing the potential of digital archaeology is to change how digital tools are regarded, or 'to think beyond the tool', i.e. to visualize the underlying theoretical considerations, wider implications, constraints, effects and impacts of these tools (Huggett 2012). However, this has been difficult to achieve, as seen for example in the many sessions at conferences on digital archaeology. There are often many examples of applications, but few critical discussions on how the tools may have influenced the results. In fact, this focus on technology may be regarded as a form of 'neo-processualism' (Perry & Taylor 2018).

A critical discussion is needed, as technology is not neutral. Technology is socially charged, connected to control, power and structure, which in turn influences how archaeological knowledge is created, represented and manipulated (Huggett 2012:204). We need to know how archaeology is impacted by digital methods. It has been suggested that we need to reach a consensus on the range of archaeological practices before we can understand how the digital context influences archaeological knowledge and fieldwork. This means that there is a need for more research to understand the links between practices, tools, material and their consequences (Huvila & Huggett 2018:90). Generally, there has been very little research on how this gradual shift to digital technology affects archaeological interpretation processes (Huggett 2015). This lack of focus may be explained by the technological driving forces behind the digital turn. It has left archaeologists mainly concerned with tools, methods and data (Huvila 2014:48, 2015:4, 6; Huggett 2015).

It is clear that this has been a technology-driven, rather than research- or question-driven, development in archaeology, but this is changing. A few years ago Jeremy Huggett (2015:88) put forward an outline for a critically engaged and reflexive digital archaeology, and recently Sara Perry and James Taylor (2018) summarized some of the efforts that have actually realized a new, albeit incoherent, critical digital archaeology, and suggested some steps that may be taken to achieve a coherent reflexive model for digital archaeological practice. In this study we frame the documentation practices at Pilbladet with a critical and reflexive approach.

THE THEORY OF THE DIGITAL TURN

It has been argued that technological developments have not been matched with corresponding developments in archaeological theory. Kristian Kristiansen (2014) refers to a demise of post-processual theory and the collapse of a mainstream theoretical framework within archaeology during the early 2000s. In fact, it has been suggested that post-processual theory and digital technology are incompatible (Zubrow 2006). But perhaps the theoretical development has just been slow to catch up. Today the theoretical situation is regarded as more fragmented, as both processual and post-processual approaches are reformulated (Kristiansen 2014).

The introduction of digital methods has had an impact on archaeological practices overall, but so far this appropriation of digital techniques has been relatively atheoretical, even though there were early exceptions (e.g. Evans & Daly eds. 2006). There is a need for further studies of the new technologies and an understanding of how they change existing archaeological practices (Huvila & Huggett 2018:90–91). It becomes especially clear when new technology is introduced in a long-term project where the new and the old practices collide and impact each other with fruitful, as well as negative, results as has been studied in the City Tunnel Project in

Sweden (Berggren 2009), and the Çatalhöyük research project in Turkey (Berggren & Nilsson 2014; Berggren et al. 2015; Taylor et al. 2018). Other studies have critically engaged with various aspects of the impact of digital methods, including issues such as visualization, gaming, interface design, big data, 3D printing, virtual worlds, online teaching and learning and social media (Perry & Taylor 2018:15 with references).

While there have been calls for a theorizing of the digital turn (Huggett 2015; Berggren et al. 2015; Taylor et al. 2018; Perry & Taylor 2018), it has been pointed out that archaeologists are already theorizing about the use of digital methods, but also that these efforts have not impacted the archaeological discipline as a whole (Perry & Taylor 2018). There is a need to bring these efforts together to form a more coherent theoretical framework for digital methods. There are calls for a more reflexive framework that considers not only the impact on archaeological practice, but which also accounts for the impact of digital archaeology in society (Perry & Taylor 2018; Huvila 2018; Gunnarsson 2018). Our study focuses on the impact of digital methods on fieldwork and post-excavation work.

Impact of digital documentation methods

The one-sided focus on technology in digital archaeology has not been without problematic consequences. In some cases, it may lead to an overconfidence in, or over reliance on, the digital solutions, and the results are seen as automatically correct (Morgan & Wright 2018:149). For example, Huvila points out that computers 'support a false sense of accuracy even with technically inaccurate data' (Huvila 2014:7), or as Morgan and Wright puts it: 'garbage in, garbage out' (Morgan & Wright 2018:149). One example of the former is the three-digit accuracy of digital plans of archaeological features in some software. This level of accuracy does not correlate with how precisely remains are documented, but may give this impression to someone unfamiliar with field practice. There is often a gap in the information process between data and interpretation, and this can be bridged by source criticism and an acknowledgement that the results need to be situated and interpreted in context (Huvila 2014). A critical discussion of methods and how they influence the results should be a part of every site report to increase transparency of the interpretation process. In the Pilbladet case we have tried to be as transparent as possible regarding the various steps of documentation, however, details of these are published here rather than in the site report.

One way to achieve a more transparent and open interpretation process could be to embrace the ambiguity of the remains and the uncertainty of the interpretation process, and let this follow the data through the process, even if it means shifting from certain and unambiguous statements to acknowledging the uncertain character of the interpretation process (Gero 2007). In the words of Perry and Taylor (2018:15) we need 'systems that embrace complexity (rather than systems that work to standardize), valuing data's specificity rather than trying to wash over specifics in the hopes of generalizing'. In the case of the Pilbladet project we chose to use categories for features and soil composition that had already been used in previous excavations in the area, which left little room for experimentation and recategorizing of the remains.

It has been argued that digital data is more efficient and accurate than other data (Roosevelt et al. 2015). This may be the case in some respects, but it is problematic when digital data is regarded as objective and not tested for subjective filters. How digital data is contained, structured and represented is not neutral; data is never 'raw' (Huvila & Huggett 2018:92; Huggett 2015:90; Llobera 2011). Data is formed to answer certain research questions and to fit into the digital structure of a database, for example, and this may be problematic, especially with large datasets that are compiled from several sources, if the contextual circumstances of this data are lost, as it turns out that they often are (Huggett 2012, 2015). We should study 'the derivation of data and information systems themselves, their temporal and relational qualities, their histories of production and circulation' (Perry & Taylor 2018:15). It is vital to include provenance metadata in a database from an individual excavation as a means of documenting the underlying theory-laden, purpose-laden and process-laden character of the data (Huggett 2012) to ensure that the data will be understood within its context. In a case where several documentation methods are used and the records are merged, as they were in the Pilbladet case, it may be advisable to document which data is acquired and by what method.

The consequences of digital technology in archaeology are quantitative and qualitative in character. The quantitative impact, for example, concerns the size of datasets and the speed of acquisition and analysis. Affected by the increased speed of the analyses, as well as the push for more efficiency and time saving procedures, digital workflows have been identified as having a negative impact on the process of interpretation. To address this, the call for workflows which allow a more reflexive interpretation process, or a 'slow archaeology', has been heard (e.g. Caraher 2016; Perry & Taylor 2018:15). For economic and other reasons, opportunities for 'slow' reflection and thought processes will not be realized without being systematized and carefully planned and integrated into existing workflows.

Qualitative consequences for the interpretation process are linked to the quantitative. One qualitative aspect is the conception of space. The impact of the digital on spatial analysis in archaeology cannot be overstated, for example, the impact of GIS on landscape archaeology. However, theoretically critical approaches to GIS have been rare in archaeology (Hacıgüzeller 2012) but are now seen in the creation and study of maps (Gillings et al. 2018), for example, as well as in a critical approach to the temporal aspect of space by digitally visualizing the stratigraphic sequence in spatiotemporal models (Taylor 2016).

That the conception of space may be changing with digitalization (Zubrow 2006:20) has also been discussed in connection with documentation in the field. Digital recording has been criticized for adding a layer of distance between the finder and the objects recorded, unlike manual techniques, which are said to create a more intimate relationship with the recorded object (Huggett 2015:89–90). However, increased distance is not necessarily a problem, but is rather a question of scale and remoteness that can be used in the archaeological process (Huggett 2015:93). It may also be argued that, in some respects, the distance created by digital techniques may not be that different from the distance created by printed matter, for example (Huggett 2015:93). In fact, a digital screen does not create distance, but rather constitutes a new interface. Screen work can be as hands-on and embodied a practice as physical excavation, and not detached and disengaged (Edgeworth 2014). The interface, or the digital device, may be regarded as having its own agency (Pickering 1995), and thus may influence the recording process and its outcome. For example, it is problematic if a structure of a database or the capacity of a recording device restricts what is being recorded and how. Predefined categories and a rigid structure may constrain the creative process of interpretation, characterized by uncertainty and fluidity. This way the rigorous structure built into the documentation system influences how the recorded object is regarded and interpreted. A careful balance between the flexibility needed for the interpretation process, and the strict, codified approach needed for data to be searchable and functional, is essential but not easily achieved. There may also be already established categorizations to take into account which are the result of years of previous excavations. This was the case at Pilbladet, where we used the terminology already established for flint mine types.

PHOTOGRAPHY: ANALOGUE VS DIGITAL

Photography has been used in archaeology since the first half of the nineteenth century as an alternative to hand drawing/painting. In 1839 Dominique François Jean Arago argued that photographs ‘excel the works of the most accomplished painters, in fidelity of detail and true reproduction of the local atmosphere’ (citation from Morgan 2016). In the 1980s, photography became more or less standardized with elements such as a scale bar and an arrow indicating north visible in the photograph, and artefacts isolated from the background. This standardization came with the growing professionalization due, at least in part, to the increase of contract archaeology, where excavations have tight deadlines and budgets, making the speed of photography more attractive than drawing (Morgan 2016).

The shift from analogue to digital photography in archaeology took place about two decades ago and has brought many changes and opportunities. During this time the digital camera has rapidly improved in quality (higher resolution) and is available at a lower cost. Quantitatively, the number of photographs has increased enormously. Qualitatively, among other things, the materiality of photography has changed. As a result, digital photography is said to dissolve boundaries both between mediums and between people, between the photographer and the photographed. As the photograph can be viewed instantly on the camera's LCD screen, there is instant feedback for the photographer to reconsider and take a new photograph, perhaps in consultation with a person in the photograph, in reality creating a co-authorship (Morgan 2016). This is an example of how digital technology can break down boundaries, depending on how it is used, and can lead to a more fluid workflow than photography undertaken with analogue cameras.

At the beginning of this transition digital photography was skeuomorphic, but since the adoption of photogrammetry, for example, the archaeological visualization has changed (Morgan & Wright 2018:136–137). Even though orthophotos were created from analogue photographs (by setting a grid over the area to be documented and using a sky-lift or a photo-tower), the digital transition made this process easier. Whether using a photo-pole or a drone, the photographs can be directly transferred from the camera into GIS-software, or by creating a 3D model and then exporting it as an orthophoto (see also Mitchell 1992:7; Morgan 2016).

The inclusion of digital interfaces into the process of interpretation has also caused archaeologists to rethink the notion of discovery, from a strictly field-focused issue to something more fluid and multi-sited. It has changed the rhythms and tempos of archaeological work (Edgeworth 2014) and 3D documentation has added a volumetric dimension to the record (Dell'Unto 2016, 2018; Roosevelt et al. 2015). There are also possibilities that aid the interpretation process, for example by visualizing connections that were not visible during fieldwork. Partial remains might be excavated and recorded on separate occasions and then be digitally joined together in a 3D model, and from there exported as an orthophoto for a greater understanding of the whole (Wilhelmsson & Dell'Unto 2015; Ohlsson & Pettersson 2018; Johansson 2019), or an orthophoto might be used to create a digital plan or section drawing (Gutehall 2016; Arbin 2017; Ohlsson & Ohlsson 2019).

HAND DRAWING: PENCIL AND PAPER VS. STYLUS AND TABLET

Hand drawing with pencil on a paper has been used for documenting archaeological remains from the beginning of archaeology itself, and for a long time it was the primary documentation method for field drawing (plan drawing, section drawing and landscape drawing). Looking back, field drawing has changed dramatically in style, in what information the illustrator wants to convey and in the relative importance placed on communication through illustration. These changes reveal disciplinary shifts in how the archaeological record was understood, how aesthetic considerations influenced the archaeologist's inhabited visual culture and how the illustrator perceived (or did not perceive) the archaeological record (Morgan & Wright 2018:139).

In recent years, the stylus and tablet have been implemented in excavations as a replacement for the 'traditional' pencil and graph paper, although much recording (section-drawing and so forth) is still executed by hand (Berggren et al. 2015:442–443; Morgan & Wright 2018:136; Museiarkeologi sydost n.d.). Colleen Morgan and Holly Wright (2018:136) argue that the term 'by hand' can be problematic since the use of a stylus and tablet may also qualify as being drawn 'by hand'. Here we use the term 'hand drawing' for drawing with pencil on 1mm square graph paper.

There are some major differences in the actual documentation techniques which have significant impact on the interpretation. When drawing by hand, we start with a graph paper and work with the aid of drawing frames, measuring tapes and compasses, and we interpret the archaeological features directly before drawing on the graph paper. This requires not only skill in drawing, but also skill in recognizing, interpreting and transforming the feature to be recorded. When using a stylus and tablet, we seldom draw on a blank screen, but instead more often on an orthophoto (created from digital photographs), which in turn postpones interpretation (see below). Some argue that this leads to a more accurate drawing since there are more 'tracing lines' than in free drawing, while others argue that our engagement with the archaeological record is changed (Berggren et al. 2015:444–445; Morgan & White 2018:137 and references).

The final digital vector-based record created from hand drawing compared with a stylus and tablet is visually more or less equal. The hand drawing can be scanned and then imported and georeferenced in GIS-software such as ArcGIS (used in this study). By tracing all the features in the drawing, one by one, we create a digital data record consisting of points, lines and polygons (all tied to x- and y-coordinates) and these are given unique IDs as well as brief descriptions.

The digital vector-based information that is created using a stylus and tablet is considered primary data (born digital), while the digital vector-based information created when digitizing hand drawings is considered secondary data, as the hand drawing itself is the primary data (Morgan & Wright 2018:142–143). To achieve the same digital record with hand drawing as with a stylus and tablet we therefore add one additional step, or as observed by Morgan and Wright (2018:136): 'The physical entity is seen, understood, and interpreted through many different eyes, and then inscribed through the actions of many hands, into disparate two-dimensional records.' Therefore, when transforming the hand drawing (primary data) into digital vector-based information (secondary data) we add one additional translation process, which increases our distance from the actual objects documented (Morgan & Wright 2018:143).

FULLY DIGITAL WORKFLOWS

As documentation in archaeology has developed from partly digital to fully digital documentation systems, the roles of tablets and smartphones have been discussed. They may be used both for in-field visualization and for recording in special apps or software. A tablet may facilitate accessibility of a range of different types of data during fieldwork; this is information which directly informs and influences the decisions and interpretations that take place during excavation (Taylor et al. 2018; Poehler 2016; Uildriks 2016). Tablets enable fully digital workflows and are said to make recording quicker and the data quality better (Ellis 2016), and the seamlessness of the workflow makes possible instant evaluation of the process (Uildriks 2016). However, 'by eliminating the physicality of graphical recording we actually hammer a digital wedge into the interpretive process' (Taylor et al. 2018). This wedge consists of the delay or disruption of the interpretation process that occurs when the documentation takes place at a distance from the remains, for example away from the edge of the trench or the site, at a later time. This fosters a physical detachment from the remains which is problematic (Taylor et al. 2018). However, the instant accessibility and availability of data is not only used by and for archaeologists in the field, it also involves other groups. Museiarkeologi sydost in Kalmar, Sweden, has developed a fully digital workflow (IDA – Instant field Documentation system and Availability) for gathering field data on a smartphone or a tablet, and this can be used for instant analysis in the field as well as for real-time communication with researchers and the public, as well as online story maps (Museiarkeologi sydost n.d.; pers. comm. Gunnarsson; pers. comm. Nilsson).

DIGITAL DOCUMENTATION AND THE ARCHAEOLOGICAL WORK

There have been calls for further problematizing the ways in which digital methods and techniques influence archaeological work and results. To do this it is important to discuss workflows and archaeological practices that include the digital (Huvila & Huggett 2018; Taylor et al. 2018; Ni Chiobhain Enqvist 2018). Huggett argues it is time 'to examine the ways in which digital technologies may have changed what we do, how we do it, how we represent what we do, how we communicate what we do, how we understand what we do, and how others understand what we do' (Huggett 2015:88). In this study we would like to contribute to this work by examining what we did and how we did it at the excavation at Pilbladet.

The excavations at the flint mines in Södra Sallerup span the last half of the twentieth century, during which time archaeological documentation methods changed radically from a manual to digital enterprise. In this way it serves as an illustrative example of the development of documentation technology in archaeology and a basis for a discussion of the methods used.

Previous documentation of the flint mines in Södra Sallerup

During the early investigations in the 1960s and 1970s, the flint mines were documented in plan by hand drawing in scale 1:50. After careful topsoil stripping by machine excavators was introduced in 1981 – a more precise method than that used previously – the number of remains to be documented increased. Documentation by hand became more time consuming and some experiments with method development were conducted in order to speed up the process of recording. In 1983 stereometric aerial photographs taken from an airplane were used as a basis for hand drawing. The results were compared to the conventional 1:50 hand drawings and showed that the stereometric drawing identified most, but not all, of the flint mines, but smaller features were not identified. It was concluded that the conventional manual drawings were unmatched regarding detail, and the drawings made from aerial photography were too crude (Rudebeck 1994:25–26).

During the 1990s documentation by total station was introduced in Swedish contract archaeology. During excavations of the flint mines it was noted that the complex character of the remains – with layers resembling fills in plans that do not always correspond to cuts underneath, and some cuts discovered only in sections – was not always easily recorded with the strictly codified system of the total station (Nilsson & Onsten-Molander 2004:50–55). This points to the need for a flexible recording method that can be adjusted to various circumstances, and for fully thought-through preparations when planning the coding system of digital mapping.

An experiment with recording by magnetic prospecting was carried out in 2000. An area of previously documented and preserved flint mines was prospected by magnetometer, as a means to discover features under the topsoil. A comparison with previous hand drawings showed that this magnetic prospecting method was too crude, as it detected some mines while others were overlooked (Rudebeck 2010). This corresponds to the results of other experiments with magnetometers at other flint mine sites (Bostyn et al. 2008:82).

The recording methods used to document the flint mines at Södra Sallerup have thus followed the general technical development of methods in archaeology. The special character of the remains coupled with time constraints have challenged the archaeologists to experiment with new techniques in order to speed up the recording process. Awareness of which methods were used when, and how these methods may have affected the outcome, is of importance, especially as this means that not all excavated areas with flint mines in Södra Sallerup are directly comparable. Documentation, interpretation and accessibility of the material are all affected by how the material was recorded.

Documentation methods at Pilbladet 2014

Turning to the latest excavation of the unique remains of the flint mines of Södra Sallerup at Pilbladet, we had the previous investigations to learn from as we planned this project. We decided to duplicate parts of the previous documentation methods so that the records might be comparable. We included hand drawing in the research plan as an addition to the standard digital mapping with GPS. Pole photography was not a part of the original research design but was implemented in an ad hoc fashion once we were in the field as possibilities and opportunities arose. The documentation methods are presented in figure 1 in the order of the workflow: pole photography, digital mapping and hand drawing. The technical details of the workflow for each of the methods are described in appendix 1. The output of the hand drawing, digital mapping and pole photography is seen in figure 2. Recording by each method was performed by a designated person to ensure consistency. The documented area discussed here is limited to the part of the excavation where the Neolithic flint mines were located, about 1800m^2. The following is a descriptive account of how the methods were implemented at Pilbladet, and the discussion of their impacts will follow below.

POLE PHOTOGRAPHY

The first step of the recording was digital photography with a GoPro camera mounted on a pole. As the cleaning of the surface took time, the area was

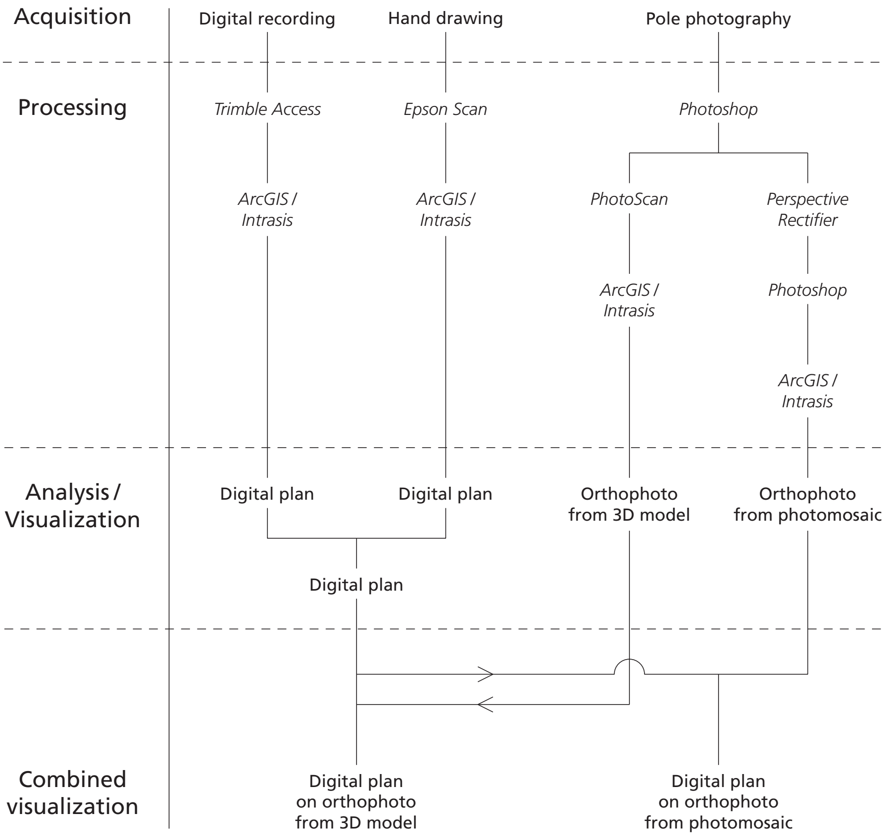
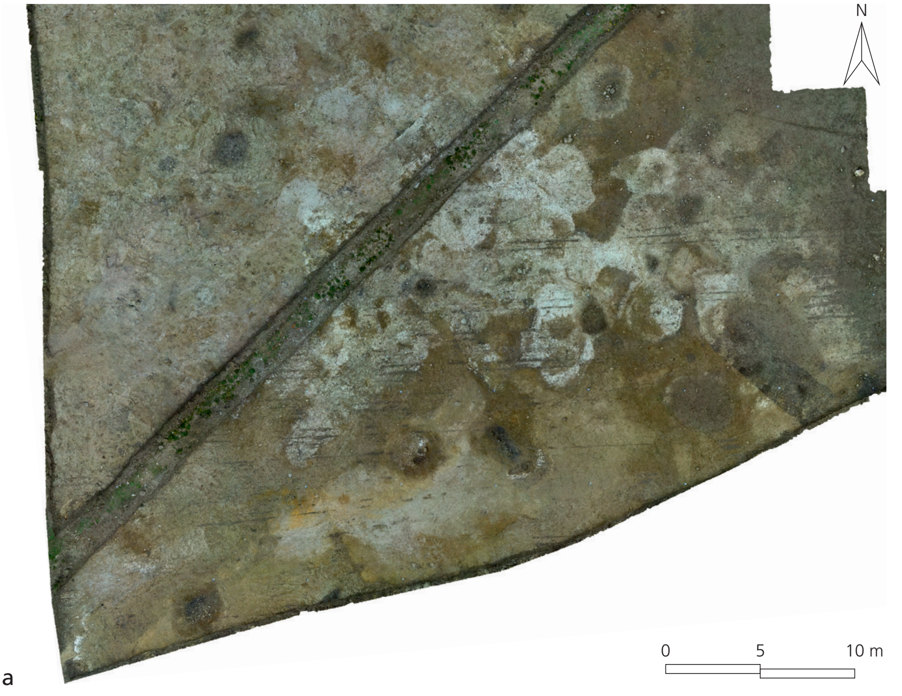


Figure 1. The documentation methods presented in the four steps of the workflow, including software information.

photographed on two separate occasions, using a 5x5m grid. The photographs were used to create orthophotos by two different methods: by exporting an orthophoto from a 3D model created in PhotoScan, and by creating an orthophoto from a photomosaic by georeferencing each photograph in ArcGIS.

The more detailed orthophoto from photomosaic became very useful as it was imported and used as a background to the digital record (the digital mapping and the digitized hand drawings combined, see below) in both Intrasis and ArcGIS. It was not completed until near the end of the fieldwork (since it was not part of the original research design), but would have been useful as excavation work progressed had it been available. Instead, it was mainly used during post-excavation analysis. It was especially beneficial in the open-cast mining area, as the interpretation of the remains on the surface sometimes differed from what could be seen once trenches were



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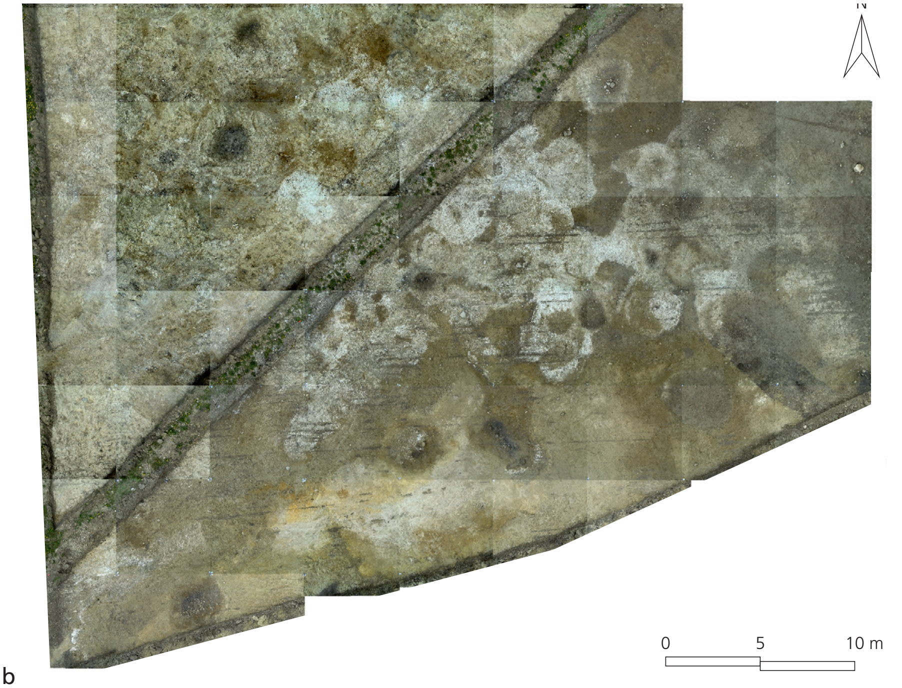

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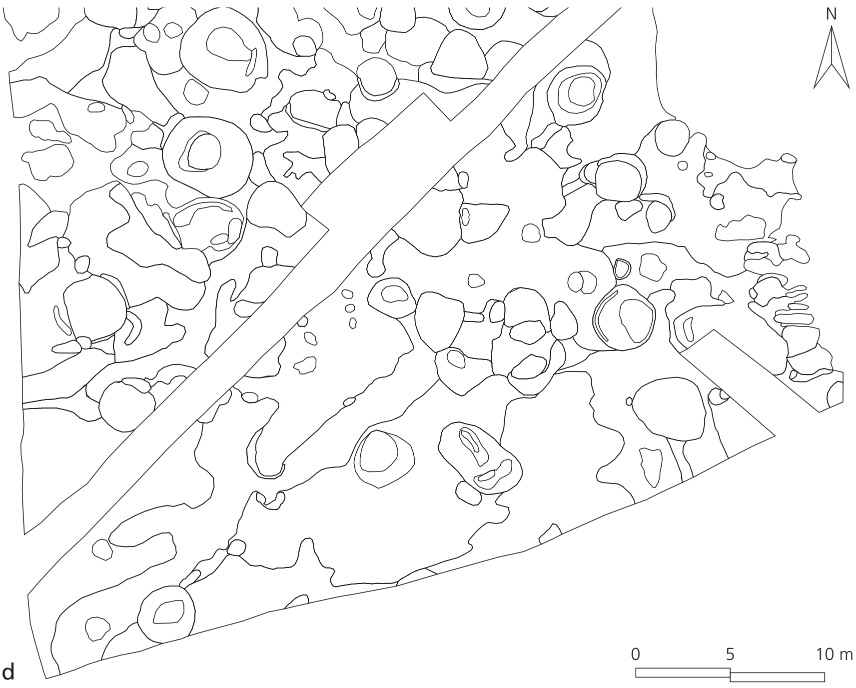

d

Figure 2. Outputs resulting from a. orthophoto from 3D model, b. orthophoto from photo mosaic, c. digital mapping, d. digitized hand drawing. Photo: Anders Gutehall.

opened up to expose sections through the features. The orthophoto with the digital record enabled backtracking to what was seen on the surface and how it was initially interpreted. This was helpful during post-excavation both to understand the interpretation process as well as in presenting re-interpretations. The orthophoto from the photomosaic was best suited for this process, even though the photos were not harmonized, which meant that they formed a mosaic of different exposures (due to the limitation in the GoPro's settings). Having the option to go back and forth from surface to section, and to backtrack through the interpretation process, made this transparent and understandable.

In cases where a less detailed overview was relevant, it was preferable to use the orthophoto created from photographs with harmonized exposures (from the 3D model), which made the exposures seamless. Other than creating an orthophoto, the 3D model was not used. It showed the topography of the area, for example the plateau in the west part where the mining area was concentrated and the slope that had led to the erosion of soil, which could also be visualized by contours in plan.

DIGITAL MAPPING

After additional cleaning, digital mapping with GPS was carried out. The remains were coded according to feature types such as flint mine, pit and

Figure 3. Plan showing the digital mapping with parts of polygons categorized as 'cut' (thicker lines).

posthole, which were already entered into the Intrasis project. In addition, the spatial relationships between the remains were coded as 'cutting' or 'cut by' (figure 3). In this way it was possible to directly record an interpretation of a sequences of events, or the order in which some pits were dug. As most of the surface in the mining area was covered by mines and open-cast pits as well as layers of soil from the mines, this recording turned out to be a painstaking task.

Initially, the plan was to record only the outlines of the features digitally and use this result as an aid during the hand drawing of the details of the features. But as work progressed more and more details were recorded digitally, and in the last area to be documented almost all details were recorded with the GPS (figure 4). This was due to the complex character of the remains and the difficulty of discerning outlines of features from the other multiple layers in the area.

The digital record became available in Intrasis and ArcGIS but was not used for analysis on its own at this stage in the process since it mostly consisted of outlines to be used as a background for the hand drawings.

HAND DRAWING

Additional cleaning was needed before the hand drawing. The remains were drawn in 1:50 scale with prints of the digitally planned outlines as a background. The hand drawing focused on recording the shifts and nuances between layers, similar to the hand drawings of the previous excavations of the flint mining area of Södra Sallerup. Rather than categorizing features, several categories of soil were used, ranging from solid chalk to solid morainic clay, with variations of combinations of the two, so that it might be comparable to the previous record in which similar categories were used.

The hand drawings were digitized in ArcGIS and coded according to eleven categories of the hand drawing (figure 2d) and the data was then imported into Intrasis.

As the digitized hand drawings were used to complement the digital record, it was possible to produce a more detailed image of the remains including stratigraphic information once the two graphic records were merged (figure 4). The two records combined – digital outlines and digitized detailed hand drawings – provided an overview of features such as mines and open-cast pits, and a detailed image of the various layers, which enabled interpretations of sequences of backfilling of specific mines as well as of the occurrence of soil deposited next to the mines.

As the interpretations changed several times, starting during the excavation, this record was not fixed. A feature may have been coded as one category when it was viewed in plan, and later changed to another category once it was excavated and seen in section. The difficulty of detecting cuts in

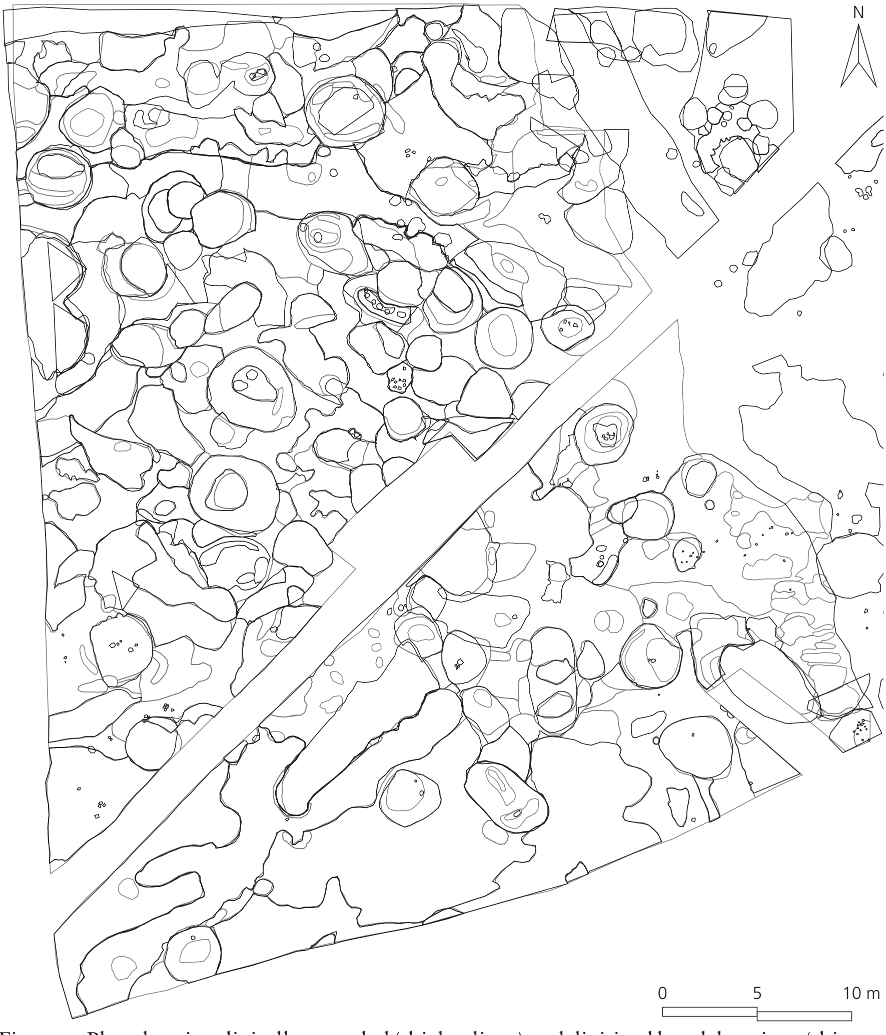

Figure 4. Plan showing digitally recorded (thicker lines) and digitized hand drawings (thinner lines) respectively. Note how the digitized hand drawings coincide more closely with the digital record in the north-western part of the area, as this was recorded last, and more details were recorded with digital mapping.

the area with many open-cast pits contributed to several recategorizations and reinterpretations. This process continued during post-excavation work.

This digitized record was the foundation of the spatial analyses as well as temporal analyses, such as regarding sequences of flint extraction cuts. However, when sections were compared some of the initial interpretation of which feature cut which turned out to be incorrect. Without the additional information deduced from sections, the interpretations made solely from visual assessment in the plan were not always reliable.

During post-excavation analysis the digital record was used as a whole, and not separated into the two categories depending on how they were acquired. However, it was useful that the whole area had been categorized into the soil categories on the hand drawings, even if the layers were not included in the fill of a digitally outlined feature. This circumstance was used on several occasions as a way to reinterpret the extent of a feature which in section was shown to be larger than initially recorded in plan. Layers that were documented on the hand drawings with their own unique number in Intrasis could be included in the fill of a feature. As a result, the fills of some mines consist of layers that are managed differently in the database.

Impact of the documentation methods on workflow and interpretation

The excavations at Södra Sallerup span a period of decades which coincide with great changes in archaeological recording methods. At a general level, the changes can be explained by the technical developments in society as a whole. Other changes are more specific to archaeology. The initial experiments with recording method development conducted at Södra Sallerup generally had a main objective of increased efficiency. This can be explained by the circumstances of contract archaeology, especially economic restraints in combination with the painstaking and time-consuming task of recording the heavily truncated ground surface of the mining area. There is a balance to consider between the demand for a speedy recording and the need for keeping a qualitatively adequate record. The initial experiments with stereometric aerial photography and magnetic prospecting were not successful as the gain in speed did not match the desirable quality of the record. It could not compare to the results of the more time-consuming hand drawing, even though quite a large proportion of the remains were actually detected and recorded. Neither of these two methods were used again at this site after the experiments were conducted.

As stated above, much of the development of digital methods in archaeology has been technologically driven rather than generated by research questions. The Pilbladet investigation is no exception. In the research plan one objective was balancing the need to keep a record that is comparable over time and in tune with contemporary standards. This was achieved by the combination of digital mapping and hand drawing, and the other methods were added largely depending on opportunity and curiosity, mostly for comparison. The experiments conducted at Pilbladet were thus not explicitly research-driven. Subsequently, the experiments gave us the opportunity to compare and discuss the methods.

Even as initially planned, the workflow of recording the remains in plan both digitally and by hand was rather cumbersome and the added methods meant even more elements had to be included. It led to time-consuming extra work and created unwanted gaps in the process of interpretation.

DIGITAL MAPPING

The combination of digital mapping and hand drawing created some unintended double work. Even though the digital mapping by GPS was initially said to cover only the outlines of the features, to be filled in with the more detailed hand drawing, the digital mapping became more detailed over time, and the documentation completed using the two methods partially overlapped. As an increasing number of the remains were recorded by GPS, the hand drawing became more and more redundant, as it only filled in the details of what was already recorded by the GPS. As the two records were merged, there is a slight difference where they overlap, only visible in fine detail. This may be attributed to varying degrees of accuracy or the fact that some parts of the surface had to be cleaned again between the digital recording and the hand drawing. Here the different kinds of acquisitions of the data are visible in the digital plan and need the accompanying explanation of how they were acquired to be correctly understood.

The categories we used during the digital mapping and the hand drawing were not the same – the GPS coded feature types and the hand drawing described soil types of various layers. This difference turned out to be very useful, as the descriptions of the soil were used as a means to understanding and reinterpreting the limits of features in cases where plan and section documentation did not match, which occurred frequently. The detailed hand drawing served a valuable complementary purpose in these cases.

Unexpected gaps in the process were caused by the fact that the GPS does not allow a direct overview of what has been recorded, as the map view only shows the recorded points without the lines between them. In this case, with very complex remains, it was easy to lose track of what had been recorded, which caused interruptions when printouts were needed, and this led to interruptions in the interpretation process. This was not the case with the hand drawing that provided an instant overview, which led to a better flow of the interpretation process.

There is a potential difference in how the remains are regarded and interpreted, depending on the method of documentation. This is connected to the characteristics particular to the recording method, that is, to hand drawing and digital mapping. The structure of recording influences the flow of the interpretation process, and in the end the interpretation itself. On the one hand, digital mapping may be said to force interpretation to be logical (the logic of the digital recording device). A part of the recording process is to decide how features and layers are related to each other and how they are defined, so the recorded points can be transferred into polygons, in the Intrasis software in this case. This forces the archaeologist to make decisions and interpretations at the moment of recording. It cannot be postponed until later, as the software of the machine will object to inconsistencies. In the case of hand drawing it is possible to postpone these decisions, as it is possible to draw unconnected lines and inconsistent relations. On the other hand, instead of the positive influence of the digital recording, which forces the archaeologist to always make decisions and have an idea of the recorded object, the codified structure may also limit the interpretation process. In this case the predefined categories, which do not allow uncertainty, resulted in a large number of features being categorized as flint mines that were, at various stages during post-excavation work, changed into other categories, such as layers or open-cast pits. This is not a problem in itself, but there may be a tendency for initial categories to stick, as there may be a hesitation to change a previous decision. Here the fixed structure of the digital recording system and the connected database overshadowed the need for flexibility in the initial interpretation.

Also, we encountered the problem with cuts discovered in section that had not been detected on the surface, and as in the 1990s, this created irregularities in the database, as we had features with no cut and no geo-object in the database. We solved this by recording a schematic triangle to show the location of the cut, both to visualize the feature and to handle it in the database. This is partly an adjustment to the technology, which was not needed with a hand drawn record.

The experience of combining digital mapping and hand drawing at Pilbladet was both positive and negative. It was time-consuming and the workflow was not optimal as gaps in the interpretation process occurred. However, the different methods resulted in data of different character that played a complementary role in the interpretations. The explanation of why they partially overlapped is kept with the data in the database, as are the various stages of interpretation and reinterpretations.

DIGITAL PLANS COMBINED WITH ORTHOPHOTO

The photographic record resulting in orthophotos was an extra bonus in this case, as it was not planned from the start of the project. In itself it does not contain any interpretations apart from the embedded conditions resulting from decisions on how to clean the area, resolution and framing of the photographs, and so forth. These conditions make the photographs subjective. However, without the digital plans containing coded information, the photographic record became difficult to 'read'. But the combination of

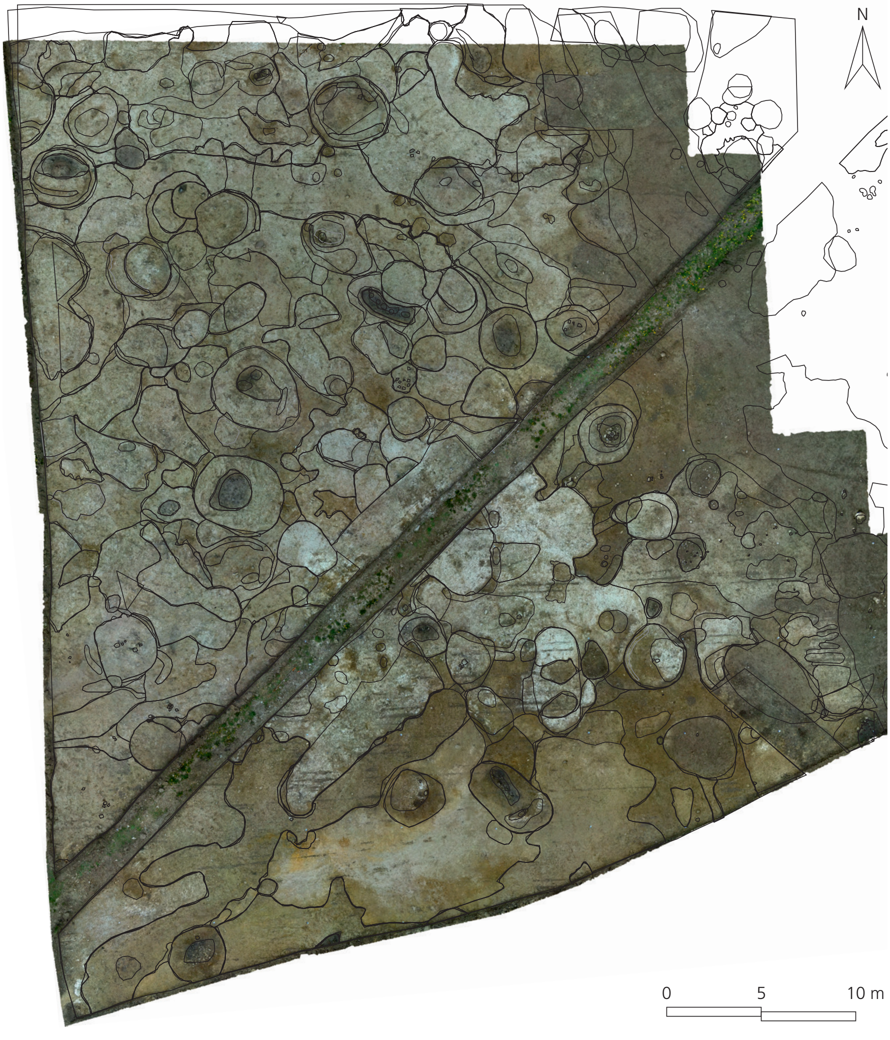

Figure 5. Combination of digitized hand drawings and digital plans visualized on the orthophoto. Photo: Anders Gutehall

the orthophotos and the digital plans (figure 5) became a synthetic interpretation of the remains, and as such it was very useful.

There was a rather long time gap between the acquisition of the record with the various methods and the final combined record. Before it was possible to analyze this combined record with the digital plans on the orthophoto in a GIS project, some time had passed, and it was near the end of the fieldwork phase of the project that this record became available. As a result, it was used mainly during the post-excavation process. As it was in part an unbudgeted experiment we had to rely on ad hoc solutions and volunteered overtime, which caused the delay, or the 'digital wedge', of this project. Had this record been available earlier it might have had a bigger influence on the work progress during the excavation, where this kind of record has great potential. We surmise that it would have been especially useful as the remains were interpreted in section while the sections were drawn. So, even if the digital photos could be seen instantly as a separate record, they were most useful when combined with the added digital plans, outlining the interpretations of the features.

It should be noted here that it would have been possible to use the rectified orthophoto as a background image in ArcGIS and draw directly on it, using a stylus and a tablet. This would omit the stage of digital mapping with GPS and hand drawing, and would allow access to the combined record of drawing and photo, without a delay. However, we did not have access to tablets in this project.

In the post-excavation phase, in combination with section drawings, the combined photographs and plans also shed light on the changing process of interpretation. As some interpretations changed when features were seen in section, it was possible to revisit the conditions in the plan, when the initial interpretation was made. In this way it was possible to understand every step of the interpretation process.

However, there was an issue of balance between the level of resolution of the orthophoto and the size of the file. If the file size of the orthophoto was too large, the project in ArcGIS or Intrasis became slow to work with. If the file size was too small, the resolution of the orthophoto was too low for a close-up study. The interpretation process had to be adjusted to the limitations in hard- and software, but the orthophotos created had sufficient resolution for detailed analysis (table 3b). Of course, by using another camera with higher resolution, the result would be better. The photomosaic of relatively high resolution orthophotos was most useful in the process of post-excavation analysis, as it was the detail that often needed clarification. The orthophoto from the 3D model with harmonized exposures and lower resolution was more useful when an overview was needed, such as in publications and public presentations, and was not used in the analysis to the same extent.

The 'low tech' solution with the GoPro camera on a pole proved sufficient for the needs of this project. It was quick and the equipment was relatively cheap (the software not included). In hindsight, it may have been better to use a drone that could take photographs at a lower elevation, equivalent to the 5m pole with GoPro camera. It could have resulted in a similar high-resolution result (depending on the camera), but would have been executed somewhat faster than the GoPro solution. However, in this case it would have been difficult to use a low flying drone due to trees with branches overarching part of the area. Even though drones are becoming more affordable, the inexpensive alternative with a pole and GoPro camera may be preferable to most projects with a limited budget, as this option is not overly time-consuming. A technically sophisticated solution is not automatically better. It is preferable to adjust the method to the task at hand, as different methods are relevant for different tasks. A drone can cover a large area relatively quickly and is a better choice for the recording of large excavations sites or extended trial trenches.

The 3D component of the record was not necessary in this case (aside from being used to create an orthophoto), as the remains were not visible above ground, and they were not possible to record as negative features in the ground. The topography is possible to visualize using a 3D model; however, this can be done with sufficient accuracy with LIDAR data or contours with low equidistance.

Discussion

To rephrase the question of Huggett (2015), we may ask: 'what did we want from digital archaeology in this case?' The answer is connected to the complex character of the remains and our concern with recording them thoroughly in plan prior to excavation. The main concern was comparability over time and resulted in the addition of hand drawing to the digital. Digital mapping was included as a current practice and the addition of a combination with an orthophoto can be explained by methodological and technological curiosity.

So, the answer to the question is: the partly digital workflow was formed by both research considerations and a technological interest. As the plan to compare and discuss the different documentation methods formed at an early stage, one may say we did not 'think beyond the tool' (Huggett 2012), or rather 'method' in this case, as the focus was on implementing these different methods. We saw the documentation as an experiment that would hopefully be a contribution towards a best practice workflow which might be applicable beyond this project.

As stated above, digitalization has changed the very essence of archaeological knowledge production (Huvila 2014, 2018). In Swedish contract archaeology this change has been gradual, and it is only recently that fully digital recording systems are being put into practice (see Gunnarsson 2018 for a review). During this excavation digital orthophoto was added to a workflow based on standard practice in contemporary commercial archaeology, which at the time consisted of a combination of digital and analogue methods. This means that when we discuss the digital components of this workflow, we include both the established practice of digital mapping (with GPS) and the addition of the orthophoto.

The problematic separation of digital archaeology described above (Costopoulos 2016; Morgan & Eve 2012) may no longer be relevant as digital tools are ubiquitous in archaeology today (Huvila 2018). Digital practices such as digital mapping, databases and GIS analyses are well-integrated in the workflows of contract archaeology, and do not consist of a separate field. However, regarding more recent digital developments there is still a tendency to rely on colleagues with a particular interest in the new technology. This was also the case in this study, as the addition of the orthophotos was the initiative of one person, and this person also created the orthophotos, including photography and processing. Today – a few years later – this kind of documentation is more commonly used. At the time, Pilbladet was one of many excavations where digital experiments took place (Gunnarsson 2018), and it is clear a digital specialist played a crucial role. This illuminates the persistence of the special character of the digital in archaeology and points to the importance of personal agency in this gradual shift of practice. In this way the record is not neutral – and data not 'raw' – but is clearly dependent on personal interests and previous experiences and knowledge of the project members.

Personal experience also played a role during acquisition of the data. In this case two persons, both with many years of experience in archaeological fieldwork, were involved in the recording of the remains in plan (orthophoto, hand drawing and digital mapping), while section drawing by hand was performed by almost all project members (nine persons in total) with varying degrees of experience. Having said this, it should be mentioned that only one person had previous experience of the flint mines, while the rest of us were new to this kind of remains. Taking the general experience into consideration, the digital record in plan and the section drawings were produced under different circumstances. However, this is a typical situation in archaeology and the results are often harmonized through the quality-checking systems of an excavation. This was also done in this case, which made sure no mistakes were made, but for each person the individual perception of the remains is still part of the record. The comparison between plan and section documentation was an important part of the analysis in the post-excavation phase, in particular when reinterpreting layers. As it was possible to go back through the process of interpretation in the plan record, but not in the sections (as they were only hand drawn), the latter more often had to be taken at face value and were more difficult to reinterpret. This may have resulted in more reinterpretations in the plan record than in the sections. Contrary to the fear that the use of digital methods may lead to an over-reliance on the technology, this situation facilitated the re-evaluation of the digitally obtained plans, while we had to rely on the hand drawn sections to a greater extent. It would have been better to have the same kind of documentation in both cases, making it possible to judge and analyze the documentation on the same terms.

As stated above, we need to know more about how archaeological practices work by studying the links between what we do and the tools we use (Huvila & Huggett 2018). We have noted that personal agency played a part in this case, and it is also clear that technology was not neutral. There are constraints and possibilities – a material agency – built into the methods which have to be taken into account. In our case, the characteristics of the technology impacted the workflow. This is not restricted to the digital methods, but also concerns the hand drawing, and includes issues of duration, timing, efficiency and space, all of which not only impacted the workflow during recording, but also affected the process of interpretation and created a new interface and point of discovery, as discussed below.

In this case, it can be concluded that the duration of work changed with the shift from analogue to digital. Hand drawing required a short preparation time, but a long acquisition time, and conversely, photography entailed an increase of preparation time due to cleaning, and a decrease of the acquisition time. There is a significant amount of time to save if the relevant methods are combined (see also Morgan & Wright 2018:147–148 for a discussion about a hybrid methodology). The cleaning before the photographs for an orthophoto is taken cannot be reduced, but a coded digital record combined with a high resolution orthophoto can be achieved efficiently if the workflow is adjusted. A speedy output is important as it may prove helpful in the ongoing excavation and influence the interpretation process.

As mentioned above, digital methods are sometimes said to create distance (Huggett 2015). In this case the distance, or 'digital wedge' (Taylor et al. 2018), can be said to consist of the delayed access to the combined record of orthophotos and digital plans, but also the gaps and interruptions in the workflow caused by double recording and waiting for extra cleaning. However, some of these tasks cannot be avoided, for example cleaning between the different steps of the documentation, and this should not be rushed, as it is an opportunity to get close to the remains and start the process of interpreting them. A workflow that avoids inserting this 'digital wedge' in the process and allows this output to be fed back to the excavation is thus important. Drawing digitally directly on the orthophoto would be a quick solution, as it would save time transferring the data between devices, as was done in this case.

Time efficiency is an important motivator for implementing new methods, especially in a contract archaeology situation, as the earlier tests of recording methods at Södra Sallerup showed. The experiments in this project did not qualify for best practice standards from a time-effective point of view, as testing different methods was time consuming. We did not achieve the seamlessness in the workflow and interpretation process that digital methods may enable, and did not benefit from the possibility of direct digital access to information and legacy data, as we did not bring tablets to the field. Nevertheless, we believe the ingredients are in place to build a better workflow, and that time efficiency can be achieved without compromising the quality of the record. And, more importantly, timing is crucial for the flow of the interpretation process, and thus influences the interpretations. Ideally, the workflow should allow time for reflection, or the 'slow archaeology' (Caraher 2016) mentioned above, with information being fed back to the excavation, without this being perceived as interruptions and delays.

During this project it became obvious that the various recording methods resulted in different decision-making and interpretation processes. During hand drawing and digital mapping with GPS, assessment and interpretation of the recorded object occur at the moment of recording, while photography does not necessarily include this detailed decision-making process at the time of acquisition. However, at the time of cleaning, many such decisions may be made. In this case no interpretations were caused by photography alone. Instead, this process was delayed until the photographs were merged with the digital data. This shift in timing of decisions may influence the possibility for making informed interpretations, especially if one relies on photography as the sole documentation, and the remains are removed before the photographs are examined. If that is the case, there can be no second look at the remains, which is often necessary. If the plan is to first make a sufficient orthophoto and use it as background for the digital recording on a tablet, the time between the acquisition of the photographs and the start of the digital recording should be very brief.

Once the combined record of plans and orthophotos at Pilbladet was in place it allowed detailed analysis and a chance to go back through the interpretation process. The new combination of digital components clearly changed the way we worked and how we reached our interpretations. In this way, the combined record resulted in a new perspective that impacted the interpretation process. It may be compared to the new interface or new point of discovery as discussed by Edgeworth (2014). Instead of adding distance to the remains, this record created a new closeness to the surface, and not just a changed conception of space, as mentioned by Zubrow (2006), but also a change in the relation to time, as the unexcavated surface interpretations could also be revisited after the excavation. In the post-excavation phase this was especially important as it created opportunities for reinterpretations of the surface of the remains. These 'delayed discoveries' were a bonus that would not have been possible without the combined record. Thus, it created a possibility, rather than distance or a 'digital wedge'. This means that our experiences are in agreement with previous statements about the qualitative characteristics of the digital; that is, that it changes the conception of space, and especially that it changes the rhythms and tempos of interpretation as stated by Edgeworth (2014).

There are calls for the recording of qualitative spatial data (Perry & Taylor 2018), and in this case we used the function of the Intrasis system to record in plan whether a polygon was interpreted as cutting or cut by another polygon. These interpretations were later changed in many cases, especially during excavation when the stratigraphy became clearer. This information was still perceived as valuable, as it showed the initial perception of the stratigraphy and made it possible to follow the process of interpretation, which would not have been the case without this qualitative data included in the initial record. This is enabled by a multi-layer record, a sort of palimpsest, of digital documentation which keeps the older versions in the database.

Also, the different acquisition methods (hand drawing and digital mapping with GPS) of the digitized record meant that the data varied slightly. It was valuable to be able to tell these records apart and understand the various ways these data were created when interpreting the details of various features. The different methods resulted in different kinds of categories in the database. This way the creation of each polygon or line in the digital record could be studied and understood. The variations in the data, caused by the documentation methods, are kept in the record, which is in line with calls to keep the provenance of the data in the database (Huggett 2012).

Despite the meticulous documentation and interpretation there is always an element of standardization and homogenization of data. The full extent of the complex character of the remains cannot be documented. However, having the possibility of going back to the image of the unexcavated surface and the various stages of interpretation allowed for reassessments and reinterpretations. This gave the interpretation process a flexibility regarding both space and time, which may not be a solution to the challenge of recording the ambiguity and uncertainty of the remains (Gero 2007; Perry & Taylor 2018), but is a step in the right direction. It consists of a flexible view of the remains, with a new interface for interpretation, providing a new point of discovery.

In this case the new perspective and interface of discovery in the form of the combined record did not immediately result in new research questions. However, the potential to trace in great detail the sequences of actions of digging, refilling, dumping and moving soil in the complex open-cast areas of the flint mines comes to mind, and may be explored in the future.

The hand drawings detailed the variations of layers on the surface in the same way hand drawings of the flint mining area from previous excavations do. This way our record is comparable to the bulk of documentation of the mines. However, this record could have been achieved by digital methods, such as digital mapping or drawing with stylus on a tablet. It was not the documentation method that ensured the comparability, but rather the adherence to the same categorization of the soil that was used previously. A combination of soil categories and feature categories could have been recorded digitally.

Conclusions and suggestions

To yet again rephrase the question asked by Huggett (2015): 'what did we gain from the digital component of our documentation in this case?' It can be concluded that the digital documentation proved most useful as a combination of digital plans and orthophotos, as it provided a new perspective on the remains that was also available after the excavation, which influenced interpretations. Having the opportunity to track the interpretation process also provided transparency and a better understanding of the interpretations. This flexible record can be said to consist of a new perspective. As it was not anticipated, and the research design was set before the excavation, it did not result in new questions in this case, but rather gave more nuanced interpretations of the remains as it provided a chance to rethink the interpretations of the surface layers after they were excavated. However, the same kind of documentation of the sections may result in an even more flexible record and better understanding of the sequences, which may lead to new questions in the future.

The combination of several recording methods caused delays and interruptions to the interpretation process in this case, which in part was a result of our experimentation, but points to the importance of carefully planned workflows. An ideal workflow is flexible and accommodating of the interpretation process, and not the other way around (see also Morgan & Wright 2018:147–148). Timing and flexibility are key factors. The material agency of the digital tools must be understood and taken into account as plans are made. Regarding the shift from hand drawing to digital mapping there is a certain loss of fluidity and flexibility at the moment of acquisition (see also Morgan & Wright 2018:147–148). However, there is also a gain of a greater flexibility and transparency of the formation of the record, as the digital data can include several steps of the interpretation process which are available through the process. With the various digital records, the flow of work changed and resulted in a different process of integration in this case.

The consequences of the position taken in this paper – that the documentation methods and tools used have an impact on the course of the work and on the end result – can crudely be summed up in one sentence: it is crucial to think ahead and know exactly what we want from the documentation, and to choose the relevant methods to achieve this. This may seem banal and self-evident. It also presupposes a familiarity with the various documentation methods and the impact analysis and interpretation. This is far from commonly addressed.

For future projects we would like to stress the importance of careful planning of the documentation strategy and every step of the workflow early in the process of writing the research design. To think beyond the tool – or the method – would in this case mean to think ahead and examine what various documentation methods mean for the analysis and interpretation, and plan the recording strategy according to what the research questions are and how to best answer them. The methods chosen not only impact the interpretation but may provide a different perspective and enable different questions to be asked of the material. The careful planning of the workflow is also crucial for the flow of interpretation. If delays and interruptions of the recording process can be anticipated at the planning stage, and thus avoided, it will mean an uninterrupted process of interpretation. The timing of the various stages of documentation is of the essence. A speedy output of the record is important as it may add a new perspective and influence the ongoing excavation and the interpretation process.

The documentation strategy varies with every project and every research plan, as the remains vary as well as the aims of the projects. It was suggested that we need to reach a consensus of the extent of the archaeological practices in order to have a better understanding of the impact of the methods (Huvila & Huggett 2018). In this case we have limited the studied practices to the fieldwork situation and the post-excavation analysis immediately after. Our findings are only relevant in these phases of the archaeological work. We have not included long term issues such as archiving and processes of reuse in our discussion; these are activities that are also a part of archaeological practices which are equally impacted by the choice of documentation methods. These issues also have to be taken into account in the planning of a documentation strategy for it to be thorough and fully relevant.

At a more detailed level, our study shows that a combination of digital plans and orthophotography provided a flexible basis for interpretation and reinterpretation. The way we reached this combined record was cumbersome, and a replication of this particular documentation workflow is not recommended. However, digital mapping or hand drawing on a tablet combined with an orthophoto is sufficient. In the first case the plans will have to be added to the orthophoto after the recording is done, while the drawing on a tablet can be done directly on the orthophoto. The latter scenario seems to be able to facilitate a quicker feed back to the excavation while it is happening. Hand drawing with pen and paper may easily be replaced with hand drawing with digital tools. This shift adds the flexibility of a combined record and the possibility of adding changes in the interpretation to the record. Also, if possible, the combined record should be achieved both regarding plan and section, as a difference in records may cause an imbalance in the possibilities for reinterpretation.

With the shift from analogue to digital recording in archaeology, the conditions of archaeological interpretation and knowledge have changed. These changes are both positive and negative, but generally there are great advantages which archaeology stands to gain in this digital development. Awareness and transparency in the interpretation processes and how they are affected by the methods are, however, necessary. Even though we did not achieve a best practice documentation system in this case, we believe the preoccupation with efficiency in contemporary developer-funded archaeology may be successfully merged with carefully planned workflows which make use of digital developments and enable a digital archaeology that is both effective and reflexive.

Acknowledgments

The authors wish to thank The Ebbe Kock Foundation and The Gyllenstierna Krapperup Foundation for providing funds that allowed time to write this article, and to Sydsvensk Arkeologi for funds for language revision and additional time. Thank you also to all the excavators at Pilbladet, who with great patience participated in the recording experiments, as well as to Elisabeth Rudebeck, who shared her expertise of the Södra Sallerup Neolithic flint mines and supported our work. We would also like to thank Sophie Bergerbrant, Alison Klevnäs (editors of *Current Swedish Archaeology*) and the anonymous reviewers who helped improve this text, and Kristin Bornholdt Collins for the English revision.

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PERSONAL COMMUNICATION

Gunnarsson, F. Department of Museum Archaeology at Kalmar County Museum, email, 9 April 2019.

Nilsson, N. Department of Museum Archaeology at Kalmar County Museum, email, 9 April 2019.

Appendix 1: Description detailing the acquisition and processing of the documentation methods used at Pilbladet in 2014

The documentation methods are presented in chronological order of the recording: pole photography, digital mapping, and hand drawing, in the following two steps (the equipment and software used are listed in table 1):

The acquisition: how the features were documented: preparation, equipment, acquisition, time and sources of error.

The processing: which software was used, the method and sources of error.

POLE PHOTOGRAPHY

The acquisition

Regarding photography, more preparation prior to the recording is needed than with digital mapping and hand drawing. Since the camera records everything that it sees, the area must be thoroughly cleaned and tools and people must be removed (since we first only planned to create an orthophoto from photomosaic, we only removed objects in the 5x5m squares). The south-east part of the excavation area was the first to be cleaned and photographed, and since the cleaning was time-consuming it took two weeks before the north-west part could be photographed. As a result, the exposures were not identical during the two occasions of acquisition due to slight changes in light and weather conditions.

Table 1. The equipment and software used in this study. Due to the time between the excavation (2014) and the publishing of this article (2019), some of the processes have been repeated with newer computers and software.

Equipment	Software
GPS (GNSS) Trimble GeoExplorer 6000 Series GeoXR	Trimble Access
Epson A3 scanner GT-15000	Epson Scan v3.04A
GoPro Hero3 Black Edition 12MP 2.8mm fisheye lens	Firmware version HD3.03.03.00
Dell Latitude E6540 Intel Core i7-4810MQ 2.80GHz CPU 8GB RAM	Windows 7 Esri ArcGis 10.2 Intrasis 3.1.0
Lenovo ThinkPad T460p Intel Core i7-6820HQ 2.70GHz CPU 32GB RAM	Windows 10 Pro Adobe Photoshop CC 2018 Perspective Rectifier 3.5 Agisoft PhotoScan Professional 1.4.3 Esri ArcGis 10.6
iPhone 4s	iOS 6.1.6

The GoPro camera was mounted on a 5m long rod and controlled via Wi-Fi from a GoPro app installed on an iPhone 4s. This enabled control of the camera's settings and display of the motif (with a 1–2 second delay). During the acquisition, two photographs (in jpg format) were taken of each of the 87 5x5m squares in the grid (if one photograph was blurred, there would be a back up), and the identity of each photograph was marked on the grid.

The processing

The photographs were then used to create an orthophoto by two different methods: by exporting an orthophoto from a 3D model created in PhotoScan, and by creating an orthophoto from a photomosaic by independently georeferencing each photograph in ArcGIS.

Preparing the photographs

The GoPro lens has a high distortion at the edges of the image. Therefore, each photograph was undistorted in Photoshop by the software's predefined setting for lens correction of the GoPro camera and lens (this action can be automated). But since each photograph covered approximate 13x10m and only the centre 5x5m area in the photograph was used, the most distorted parts in the photographs were to be cropped when the orthophoto from photomosaic was created. When the orthophoto from the 3D model was created, the lens correction had enough undistorted the photographs to make a relatively correct orthophoto.

The photographs were copied into two sets, one for the 3D model and one for the photomosaic. In the set of photographs used for the 3D model, details such as tools and people outside the 5x5m square were masked (see above). Following this, the photographs were saved in tiff format with lzw compression (the irreversible compression used by jpg may noticeably reduce the image quality) and the masks were saved in the photograph's alpha-channel. The photographs used for the photomosaic were slightly adjusted in Photoshop to achieve a more accurate colour balance and contrast, and were saved in tiff format with lzw compression.

Creating an orthophoto from a 3D model

The first set of photographs were imported with their masks into PhotoScan (see table 2a for the steps and settings and table 2b for resolution and size). After the sparse cloud was created, it would have been possible to set markers in the photographs – that is to use the x-, y-, and z-value from the grid – and that way directly have the 3D model/orthophoto georeferenced and also optimize the camera positions. Since this is time-consuming, and because the goal was to export an orthophoto to ArcGIS where it is faster to

Table 2a. The steps and settings used to create an orthophoto in PhotoScan.

Step	Import	Align photos	Build dense cloud	Build mesh	Build texture	Build orthophoto
Setting	Photos Masks	High accuracy Calibrate cameras	High quality Aggressive depth filtering	High	Enable colour correction Hole filling	Current view

Table 2b. The image resolution from the camera and the size in each step during processing of the 3D model in PhotoScan.

From camera		In PhotoScan			
Number of photographs	Resolution (px)	Sparse cloud (points)	Dense cloud (points)	Mesh (faces)	(vertices)
87	4000x3000	119,010	41,865,557	8,367,827	4,187,206

do the georeferencing, we chose not to do this. Instead we ran the 'optimize camera alignment' function in order to achieve a higher accuracy in calculating parameters external and internal to the camera and to correct possible distortion, and the bounding box was set to cover the excavation area.

The dense cloud created was thoroughly cleaned in order to delete all points that were outside of the excavation area. By using the high setting in face count when creating the mesh, a large model is achieved, which is not always useful. However, since the aim was to create a high resolution orthophoto in order to see small features (and to compare the two orthophotos), we chose this option. The geometry was then edited by removing faces and closing holes.

Then, the texture was built by using orthophoto in mapping mode, and finally the orthophoto was created by manually adjusting the bounding box and choosing current view as the projection; the image was then exported in tiff format with lzw compression.

The orthophoto was then merged into one layer in Photoshop (which decreases the size of the file) and adjusted slightly for more accurate colour balance and contrast.

Creating an orthophoto from a photomosaic

The second set of photographs was rectified and scaled according to the 5x5m grid using Perspective Rectifier and saved in tiff format. Perspective Rectifier has the option of setting coordinates directly in the photographs, but since they were to be cropped according to the 5x5m grid in Photoshop before importing them to ArcGIS (see below) this option was not used.

After cropping the photographs manually in Photoshop, they were saved in tiff format with lzw compression. The process of rectifying, scaling and cropping was the most time-consuming part of this method.

Table 3. Comparison between the resolution and image size of the orthophotos in this study.

Method	Resolution (px)	Image size (MB)
From photomosaic	15.500x17.050	606.4
From 3D model	14.519x13.613	572.4

Georeferencing the orthophotos

The 5x5m grid coordinates from the digital mapping were imported in ArcGIS. The orthophoto created from the first set was imported into ArcGIS and georeferenced according to the same grid as the grid markers visible on the orthophoto. When creating an orthophoto from a 3D model, PhotoScan adjusted the colour, which creates a harmonized exposure (albeit not necessarily true) (see figure 2a).

The photographs from the second set were imported into ArcGIS and georeferenced one by one to the grid. Since the camera did not have a setting to give all photographs the same exposure, the colour differed slightly from photograph to photograph (see figure 2b).

As shown in table 3, the orthophoto from the 3D model and the orthophoto from the photomosaic did not differ much in resolution and image size.

DIGITAL MAPPING

The acquisition

During the recording with GPS, additional cleaning was performed, and notes taken to further aid the interpretations. When documenting such a complex area, it can be difficult to see what features have already been documented, and occasionally a printed plan was needed to keep track of the documentation. The digital mapping took place while already documented parts of the area were being excavated, which was unproblematic.

The remains were coded as type of feature, such as flint mine, pit, post hole, according to the interpretation of the archaeologist doing the recording. In addition, the spatial relationship between the remains were coded as ‘cutting’ or ‘cut by’, also according to the initial interpretation of the recording archaeologist (see figure 3). Only the part of a pit that was cut by or which was cutting another pit was coded as such, not the whole feature; that is, a part of a polygon was coded as cut by or cutting another named feature. In this way it was possible to directly record an interpretation of a sequence of events, or the order in which some pits were dug. As most of the surface in the mining area was covered by mines and opencast pits as well as layers of soil from the mines, this recording turned out to be a painstaking task.

Initially, the plan was to record only the larger outlines of the features digitally and use this result as an aid during the hand drawing of the details of the features. But, as work progressed, more and more details were recorded digitally and in the north-west area almost all details were recorded with the GPS. This was due to the soil conditions when the previous cleaning of the surface was conducted. As the soil had dried when the north-west area was cleaned, the shift in the soil and outlines of the features were not very clear. As a result, preparations, including additional cleaning for the digital mapping, had to be more thorough here.

The processing

The digital recordings were imported in ArcGIS as well as Intrasis and cleaned from errors made during the recording (see figure 2c).

HAND DRAWING

The acquisition

A rough cleaning of the area is needed before the hand drawing. It is a time-consuming technique, and the digital mapping had to be executed first according to the research plan. This led to the hand drawing of an area taking place a few days or up to a week after the digital mapping was completed. This, in combination with shifts in the weather, meant the area had to be cleaned several times (when it was sunny the soil became brighter and the variations not so distinct, when it was rainy the soil became darker, and when it was windy loose sediments scattered and covered the area). This is not a favourable situation, as repeated cleaning effects the remains, but it was necessary in this case. Nevertheless, this had a negative impact on the result.

The hand drawing was executed in 1:50 scale on A2mm graph film and prints of the digital recordings were used as background images to aid the hand drawing. A 1x1m drawing frame with a 0.1m grid was placed on the ground using the 5x5m grid as well as measuring tapes as reference. During drawing additional cleaning was conducted to facilitate examination of details and unclear relations.

The hand drawing focused on recording the shifts and nuances between layers, which was similar to how hand drawing had been conducted during the previous excavations of the flint mining area of Södra Sallerup. Several categories of soil description were used, ranging from solid chalk to solid morainic clay, with variations of combinations of the two, making it comparable to the previous record in which similar categories were used.

The processing

The hand drawings were scanned with an Epson A3 scanner with a resolution of 600 ppi, and then imported into ArcGIS where they were georeferenced against the 5x5m grid coordinates. In ArcGIS the drawings were digitized and coded according to eleven categories of the hand drawing (figure 2d) and the data was imported into Intrasis.