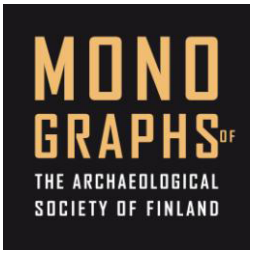

Archaeological Grey Reports – Current Issues and Their Potential for the Future

Author(s): Teija Oikarinen

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Archaeological Grey Reports – Current Issues and Their Potential for the Future

Teija Oikarinen

ABSTRACT **The outcome of an archaeological field study is a report, which often becomes and remains a part of the unpublished grey literature. The report is a necessary prerequisite for future research, but such reports are often disregarded in scientific archaeological discussion. The reports function as access points to the data recorded during fieldwork. Since these documents are products of unique processes including pre-planning, fieldwork, and the post-excavation phase, their degree of complexity varies greatly. These reports form a rich but heterogeneous collection consisting of diverse kinds of data. Grey reports have traditionally been archived as printed documents, but ongoing development related to data integration, sharing, and digitalisation, as well as the evolution of digital infrastructures, will have an impact on the future format of the reports.**

KEYWORDS

excavation, grey report, digitalisation, digital infrastructure, requirement

Introduction

The term 'grey literature' (GL) refers in general to unpublished information resources, such as reports, that are difficult to access and identify (Luzi 2000:110). It is widely recognised that archaeological fieldwork reports are often inaccessible and that they suffer from a lack of dissemination. This has become a source of increasing concern for archaeologists (e.g. Bradley 2006; Aitchison 2009; Gibbs & Colley 2012). The above general definition of GL specifies, to a certain extent, the nature of grey documents of various disciplines, but it fails to accurately describe the discipline-specific complexities of grey reports. Within archaeology, these complexities (e.g. Dunn 2009:209–211) originate from the specific needs and traditions of archaeological research and its country-specific contexts (Snow *et al.* 2006). The degree of diversity in the content of archaeological GL (e.g. Oikarinen & Kortelainen 2013) will also challenge the understanding and usage of reports in the future.

However, during recent years, there have been increasing expectations of better access to unpublished reports using the latest computer-based technologies for data combination, data sharing, and communication (Snow *et al.* 2006; Dunn 2009; Kansa *et al.* 2010; 2011; Vlachidis *et al.* 2010; Richards *et al.* 2011). The past decade has seen the emergence of new demands for archaeology due to substantial changes in discipline-related research and in archiving practices; in the past, reports were stored in archives of printed material, but this practice has gradually been changing into the parallel use of digital archives (e.g. Hughes 2010:200). These digital libraries provide online access to the unpublished resources, of which there is often a remarkably large amount, and the developers of the libraries must also develop digital practices (e.g. Gibbs & Colley 2012; ADS 2013; tDAR 2013).

Huggett and Ross (2004) describe how, due to the increasing use of modern technologies, the require-

ments for the transparency of archaeological research practices and analyses have increased. This change also stresses easier and longer-term access to data, and it emphasises the need to consider the implications of information use (Huggett & Ross 2004). Moreover, an increased interest has been displayed in the effects of technologies beyond the traditional tools used (Huggett 2012), for example, in research and communication (Kansa 2011:2).

The aim of this article is to examine these emerging global requirements for archaeological reports; the objective is to define the nature of an archaeological grey report and its 'greyness', its role in the archaeological discipline, and its potential for the future. This article begins by discussing the nature of and challenges related to the archaeological reports described in archaeological scientific literature. The article seeks to briefly review changes in archaeological research due to the new technologies and to describe recent efforts exploiting those technologies to achieve increased access to the archaeological reports. The approach is international and generic, and it is complemented by interdisciplinary remarks during the course of the article and especially at the end. Therefore, it is beyond the scope of this article to examine country-specific variations, for example, in archaeological standardisation, and some relevant technical details (e.g. explicit file formats for preservation) in reporting practices. The purpose is to summarise the possibilities, solutions, and strategies related to the reports.

It is anticipated that both the increasing amount of digital data throughout society and the development of networked computers using high-speed connections will enable data sharing and open new possibilities for interdisciplinary and collaborative research in digital environments. These factors form the basis of eScience (Ribes & Lee 2010:231–233; in archaeology, e.g. Hughes 2010). Notions related to eScience, such as 'information system research' and its 'socio-technical research approach', and the concepts of 'digitalisation' and 'digital infrastructures', are used in this article (Tilson *et al*. 2010). This approach has its origin in science and technology studies (STS) (e.g. Star & Ruhdeler 1996; Edwards *et al*. 2007).

The Nature and Current Problems of Archaeological Grey Reports

The archaeological report, as a final product of a field study, presents the research process and the recorded, organised, and preliminarily interpreted data. To some extent, the report describes the progress of the field study and its results. The challenge in using an archaeological report lies in its complexity as an assemblage of various types and amounts of data. For example, an archaeological excavation report consists of multiple individual documents, such as written descriptions of the progress of the field and laboratory studies and numerous appendices such as catalogues, maps, images, illustrations, and matrices. They are filled with processed information about the archaeological site, its remains and strata, and the artefacts collected and interpreted. Thus, a report is the result of a continuum, including several interrelated and overlapping phases of preplanning, field study, and data processing. The requirements for the content of the archaeological reports vary from one country to another and from one authority to another (e.g. Snow *et al*. 2006:958–959).

According to Kansa and Whitcher Kansa (2011:87), especially in the past, the 'grey format' hid the fieldwork data and results from the archaeological community, and therefore the data was in danger of being forgotten and lost in archives if it was not published in scientific journals. Archaeological reports were formerly produced for a limited audience, primarily the archaeologists who had access to them. The production was more informal in nature, as was the validation, archiving, and maintenance, as Kansa and Whitcher Kansa (2011:87) have described. This served the original purpose of the reports, which was to mediate information for research and to operate as access points to the data recorded during the field study. But at present, the multitude of varying research practices and the lack of standards are now viewed as a problem in archaeology; this also relates to the fact that archaeology is not separated from the ongoing process of globalisation, for which standardisation is a premise (Zubrow 2010:2).

The diversity in archaeological research practices is challenging from the viewpoints of sustainability, wide-scope understanding, and data interoperability (Kansa & Whitcher Kansa 2011:57–58). Traditionally, archaeologists have been located in disparate institutions following different research traditions. These traditions have created customised research practices, which complicate the understanding, reuse, systemisation, and management of the archaeological data. Further, a major challenge in archaeology is information overload. The sheer amount of data and customised work practices present a challenge to the utilisation of technologies, each of which has its specific requirements. For example, increasing access to the data by adding metadata (i.e., descriptions of the data content and its relation to other data) to the databases is complicated because of the extent of data and also because of the varying criteria for the data (Kansa & Whitcher Kansa 2011:58).

The growing use of technologies escalates the amount of digital data. On the other hand, emerging technologies create possibilities for sharing and utilising data using modern media. It is worth asking how the aforementioned changes will affect the nature of archaeological field study, that is, documentation and data representation and analysis (Kansa & Whitcher Kansa 2011:87). Snow *et al.* (2006:958–959) have presented a simplified view according to the main types of primary data, which are difficult to access simultaneously: textual, visual, and numerical data. Problems also stem from such issues as temporal and inconsistent terminology and data classifications. These factors and the inaccessibility of the reports can affect the utilisation and understanding of archaeological documents. Old customs support traditional ways and individualistic needs in archaeological research, but complicate the synthesis of archaeological material from a wide variety of sources (Snow *et al*. 2006:958–959).

Besides the challenge of providing digital access to the reports and related data collection, another challenge – even in the era of the Internet – is becoming aware of their existence and gaining access to the documents, either in printed or digital form (e.g. Bradley 2006:8). The reports, even those that are published, are available in diverse kinds of publications, which can be difficult to discover (Jones *et al.* 2001). The users of the reports, such as academic archaeologists and contract archaeologists, have different kinds of needs and contextual requirements (Bradley 2006; user needs are studied especially by Jones *et al.* 2001). These user groups, which Bradley (2006) calls cultures, have specialised knowledge of literature sources, and their user needs might have an impact on the valuation and utilisation of the reports; for example, the naming of the reports as 'grey' has sometimes been viewed as a diminishing concept (e.g. Seymour 2010:234–235, 238). But together with these reports' original purpose – to service the needs of planners, authorities, and archaeological researchers, which influences the reports' communication styles and objectives – the reports are seen as valuable particularly in the synthesis and re-interpretation of extensive cultural or geographical areas (Bradley 2006:8–11). This process could be enhanced by increased access via emerging technologies.

The richness or the heterogeneity of archaeological data challenges the formulation of guidelines for digital procedures for archaeological research practices and unpublished resources. In this article, 'digital procedures' are understood as written policies and instructions related to digital data that are targeted at humans (see also Watts 2011). When procedures such as data collection techniques and data analysis are formulated, they should be reflected and transparent (e.g. Huggett & Ross 2004). The challenge associated with this demand is that archaeological research practices are interpretative in nature. Reports hide the non-verbalised traditions of research and the local traditions of research and education. Consequently, unpublished resources and scientific research are more transparent to some users than others. This implicit 'knowledge management system', whether it involves individual or shared knowledge, cannot be reached by reading reports; it should be verbalised and reflected instead (Kansa & Whitcher Kansa 2011:83–86).

These archaeological challenges and possibilities are common in other 'small or young sciences' in which there are no shared repositories, controls, or agreements on data description (Borgman 2007:28–29; Kansa *et al.* 2010:308–309). In small-scale fieldwork-based disciplines, 'meta-analysis', meaning the

comparative study between the data collections of different projects, is recognised as a common issue (Kansa & Whitcher Kansa 2011:64). However, the amount of rich unpublished data can also be viewed as a strength for archaeological research, because the value of original and detailed data has been underestimated as compared to ready-made disseminations (Kansa *et al.* 2010:308). As Kansa *et al.* (2010:308) put it, 'If one measures the value of raw data by the number of publications it spawns, then sharing this set of raw data made it at least ten times more valuable than it would have been without dissemination. Nevertheless, a tool for understanding, retrieving and decoding the unpublished material is needed, and this tool is the use of metadata' (Kansa *et al.* 2010:309).

In archaeology, metadata is used for data documentation, and standardised metadata increases data interoperability (Richards 2009:27–30). Standards are also needed for archaeological practices, such as data recording and content production, and moreover, for technical solutions, such as hardware and software (Richards 2009:27–30). The cooperation of the UK's Archaeological Data Service (ADS 2013) and the US's Center of Digital Antiquity has resulted in a digital procedure, *'Caring for Digital Data in Archaeology: A Guide to Good Practice'* (tDAR 2013). But country-specific contexts for these efforts vary. For example, in the UK, both commercial practices and standards have been established in archaeological fieldwork (Aitchison 2009). By comparison, because of the recent change to the tendering of archaeological fieldwork projects in Finland, quality guidelines have been released by the National Board of Antiquities (NBA 2013a). Online access to reports is also partly provided (NBA 2013b). Regarding other Nordic countries, in Sweden, for example, the digitising of reports (i.e., the conversion of paper-based documents into digital file formats) is currently being executed by the Swedish National Heritage Board (RAÄ 2012), and a project named ARKDIS, coordinated by Uppsala University (ARKDIS 2013), focuses on archaeological information in the digital society. Moreover, the Norwegian Institute of Cultural Heritage (NIKU 2011) aims to improve the policies and practices of heritage management.

The Contribution of the Emerging Technologies to Archaeological Research

In the past, it was possible to compile a synthesis of the applications and technologies used in archaeology (Richards 1998) and the computational practices in archaeology (e.g. Lock 2003). Today, archaeological projects, which rely heavily on modern technologies, are numerous and widely presented in technologically-oriented archaeological conferences such as Computer Applications in Archaeology (CAA 2013) and Cultural Heritage and New Technologies (CHNT 2013). During these conferences, unpublished reports have also been discussed. However, the hybridisation of technological and traditional techniques and methods within archaeological research is still an ongoing trend.

Within archaeological research, there are already research areas specialised in different technologies, such as virtual archaeology and cyber-archaeology (e.g. Forte 2010; see also Hughes 2010). The examination of communication and data sharing that utilises new, easy, cost-effective, and interactive Web 2.0 services is increasing (e.g. Kansa *et al.* 2010; Dunn 2011; Kansa 2011), as is scepticism about the potential of Web 2.0 especially for data preservation (Eiteljorg 2011), but to examine these issues in detail is beyond the scope of the article. Projects related to data interoperability issues, such as Semantic Web technologies, conceptualisation, and ontologies, have also increased (Kansa *et al.* 2010; Vlachidis *et al.* 2010; Richards *et al.* 2011), providing particular examples of how combinations of data can be enhanced. Another new research topic is the preservation of archaeological data in digital archives and the lifecycle of digital data, that is, digital curation and the creation of archaeological infrastructures (Blanke *et al.* 2009; Benardou *et al.* 2010). Moreover, discussion is ongoing about the effects of technologies on archaeological research (e.g. Huggett 2012).

The development trends described above form the basis of and provide possibilities for understanding the change due to technologies that is ongoing in archaeology. This change will enhance archaeological research by providing answers to existing research

questions as well as by giving rise to new questions resulting from the use of the emerging technologies (e.g. Hughes 2010:193). Besides the issues of access to and dissemination of the reports, according to Eiteljorg (2011:263), the increasing amount of digital data will give rise to the critical question of its preservation and whether data collections should be stored both in their original digital formats (as in the archives of printed documents) and in their migrated (e.g. web-accessible) formats.

Limp (2011:274) claims that especially in the past, one reason for underrating the dissemination of archaeological reports was that the time invested in the reports would reduce the resources for the 'actual' archaeological research. But he reminds us that to gain cost-effectiveness, to increase research possibilities, and to serve society, there are profound reasons to put effort into the dissemination of the reports.

The digital future of archaeological reports is a complicated issue. It is related to the interdisciplinary notion of the progress of digitalisation and to the development of digital infrastructures (DIs), which comprise both the social and technological contexts of the use of technologies and the effects of the usage as mechanisms for the future (Tilson *et al.* 2010:748–749). Digitalisation is expected to change the utilisation of technologies and electronic environments to be more established and infrastructural in nature (Tilson *et al.* 2010:749). The progress of digitalisation (Tilson *et al.* 2010:748–758) requires the formation of sustainable principles, such as customised standards and technologies, that are situated, tailored, and flexible and that take into consideration their socio-technical contexts; therefore, the process of digitalisation covers both the developers and the end users of the technologies (Star & Ruhdeler 1996:112; for questions of sustainability and interoperability in archaeological DIs, see Limp 2011:275–279). Institutional and cultural barriers should also be solved (Edwards *et al.* 2007:ii). Also in archaeology, digitalisation requires mechanisms and flexible technologies to achieve interoperability between diverse archaeological data collections. These mechanisms should also preserve the local nuances of archaeological data and offer flexibility for the users (Kansa *et al.* 2010:309–312).

Across disciplines, these principles and policies of the future are already associated with the development of shared 'memory practices' between institutions (Bowker 2006). To develop the shared memory practices and to achieve the goals of accessibility and long-term preservation of the data, a continuous change of discipline-specific practices, goals, and technologies is needed in order to promote shared 'knowledge management' (Bowker 2006:cited by Ribes & Finholt 2009:379). The process of digitalisation also requires collaboration and shared strategies and technologies – necessities that did not exist in the past. Archaeologists are already creating solutions for these needs, which are discussed in the next section.

Diminishing the Greyness of Archaeological Reports

The latest technological solutions have already been proposed (Snow *et al.* 1996) and used to disseminate and preserve archaeological data and to incorporate it into websites or portals that offer services for archaeologists. These include sites such as the Open Context project, which utilises web-based technologies (Kansa *et al.* 2010), or the Archaeotools project, which relies on artificial intelligence technologies and ontologies (Richards *et al.* 2011). In general, open access to data, as in the Open Context project (Kansa *et al.* 2010; in archaeology, see also e.g. Xia 2011), refers to unrestricted (and often free licensed) data sharing via the Internet. The data can be remoulded or just downloaded for later use. A challenge for these projects is that reaching the turning point that increases the use of the technologies requires experimental projects and reliable results in order for the technologies to be established in archaeological research.

Standardised methods for combining data are needed to enable large, interoperable, web-based datasets. This topic is too extensive to be discussed in detail in this article, but a brief summary can be presented by exploring the work of Richards *et al.* (2011) and Vlachidis *et al.* (2010). By enriching data with ontologies and by using the related technologies of the Semantic Web, data can be linked and published via the Web. Ontologies are defined as conceptual frameworks for organising information. The ontologies used must be

standardised in a cooperative effort by archaeologists to provide general and shared understanding about the data. Ontologies can be machine-generated from textual sources or from controlled vocabularies. These ontologies can also be modified by the users or semantically enriched by user-generated tags, which are keywords and terms that are created to describe the data in the Web (Richards *et al.* 2011:31–54). Another way to gain access, besides the Semantic Web, is to utilise static, indefinitely unchanged Web links to Internet resources (URLs). These links, referred to as permalinks, grant access to the original, unchanged datasets. User-generated tagging is also used in connection with permalinks for resource description, that is, creating metadata (see URLs and user-generated tagging, e.g. Kansa & Whitcher Kansa 2011:63–66).

Varying technical developments lead to different kinds of strategies for disseminating digital data, which has also resulted in digital heritage projects. A good example of this is Europeana (2012), a portal and interface for digitised cultural heritage data, integrated from various European museums and cultural heritage institutions. Europeana illustrates the principles of combining data and offers the metadata produced as linked data for free reuse, including commercial use. Another effort already carried out but yet to achieve influence is the European Network of Excellence in Open Culture Heritage (EPOCH 2008), which has also developed a basis for infrastructure, quality, and effectiveness in archaeologists' use of information technologies.

Despite the projects discussed above, there are still numerous discipline-specific goals and challenges related to research practices and digital data. A potential conflict of interest, due to the constraints and possibilities of the technologies, is the tension between the researchers who emphasise detailed descriptions and narratives and those who emphasise data interoperability, the importance of semantics, and standardisation (Kansa 2011:20–24). These should not be viewed as opposing standpoints, however. Instead, it would be beneficial to merge these goals by combining and utilising the positive features of both viewpoints, and researchers should be rewarded for organising and sharing their data (Xia 2006).

Xia (2006) has described challenges related to electronic publication in archaeology, such as financial constraints, the need for technological expertise in electronic publication, and, in addition, the need for collaboration with information technology specialists to produce data that is informative and usable for publication. There is an increasing need for, among other things, technically aware archaeologists (see Kansa & Whitcher Kansa 2011:88). In the future there might even be a demand for infrastructure designers from the eScience perspective.

Interdisciplinary Future of Archaeological Grey Reports

eScience is a scientific research area that utilises digital information technologies to increase cooperation, to distribute data, and to disseminate the research outcomes between disciplines via digital networks (Ribes & Lee 2010:231–233). Further, eScience (known as cyberinfrastructure in the US) is defined as 'the layer of information, expertise, standards, policies, tools, and services that are shared broadly across communities of inquiry but developed for specific scholarly purposes' (ACLS 2006:1). Digital infrastructure (DI) has emerged as a new conceptualisation for this research area in the field of socio-technical information system research (Tilson *et al.* 2010). This originates from the studies of information infrastructures (Star & Ruhleder 1996:112–114) in science and technology studies.

Infrastructures such as transportation networks enable a society to be functional (Star & Ruhleder 1996:112; Tilson *et al.* 2010:748). With the added notion of information, an infrastructure can be broadly defined as a large-scale, layered, and complex structure, in which the use of technologies is more a situated practice (Star & Ruhleder 1996:112–114) than an actual 'thing' (Bateson 1978:cited by Star & Ruhleder 1996:112). Archaeological reports relate both to field studies and research practices. Field study, as a preliminary stage of digital data production, interpretation, and further knowledge creation, and with its technological and social characteristics, has the potential to become a part of the DI. This notion could be more deeply analysed by focusing on the relational properties of the information infrastructures (described in

Star & Ruhdeler 1996:112–114) of the archaeological discipline. However, not much research has yet been carried out regarding the conceptualisation and synthesis of fieldwork practices and of digital data produced from a local to a global level, for example, in the study of archaeological reports as components of DIs. Instead, projects that involve experimental technologies and services needed for the direction of the digital infrastructure are discussed by such authors as Dunn (2011), Kansa and Whitcher Kansa (2011), Snow *et al.* (2006), and Richards *et al.* (2011). However, from the viewpoint of archaeological research traditions, these research perspectives are undertakings on the interdisciplinary edge, and this field of research extends from archaeology to digital humanities (Borgman 2007:219–224). In archaeology, the production of reports at a local level and the understanding of these reports as part of a continuum that is to be standardised globally are affected by the local and discipline-specific contexts and traditions. These contexts must be taken into consideration in developing the procedures for archaeological digital practices and digital data. It is also worth noting that an infrastructure cannot ever be 'changed from above' or changed instantly; instead, this must be done in 'modular increments' (Star 1999:382). This fact has been acknowledged when it comes to archaeology (Dunn 2011).

A New Design Strategy for Archaeological Grey Reports

Inspiration for discussing archaeological grey reports from the design perspective originates from 'design strategy', which combines both technical and human components (Snow *et al.* 2006:959). This way of thinking also exists in socio-technical eScience, in which the combination of the evolution, development, and use of technologies is understood as a socially embedded practice (Star & Ruhdeler 1996:112–113). Discussing this issue here is a preliminary attempt to try to verbalise and conceptualise what this strategy could include from an interdisciplinary viewpoint. The discussion examines the development of design principles from the point of view of information technology and is based on the idea of digital infrastructures (Tilson *et al.* 2010). Although there is currently no wide agreement about standards for digital data in archaeology, efforts are being made in this direction (e.g. tDAR 2013).

In the discussion about design strategy, from the human component's perspective, the archaeological site is the primary data source for an archaeologist. Not all researchers have access to the field study phase, and in addition to the original collected data archive, the synthesised report, including the archived data (image and artefact collection, etc.), becomes a primary data source for later research. This explains the remarkable value of the report. Often, the original data sheets, notes, and other material are not available for those who use the synthesised report. The data that is collected and analysed is influenced both explicitly and implicitly by several social and technical factors. Therefore, in its processed and interpreted format, all this collected data, even the so-called primary data, is actually secondary information; the data in the report has been fragmented, interpreted, and organised into a report document (Jones 2002:40–62).

Archaeological information is also subjected to valuation. The archaeological process of documentation, interpretation and knowledge creation can be described by applying the concept of the 'information value chain' (e.g. Porter 1985:cited by Borgman 2007:116; Sarvary 2012:71–90). At the preliminary stage, the collected archaeological primary data – originally 'observed and uninterpreted symbols' (Aamodt & Nygård 1995:8) – are, or can be, organised and interpreted as information. Knowledge, however, is defined as a deeper and learned understanding of the information (Aamodt & Nygård 1995:6–7). Further, wisdom means an evaluated and more stabilised understanding (Bellinger *et al.* 2004). These phases of the chain can occur as a continuum, in which data gets 'elevated' and value-added (Aamodt & Nygård 1995:13–14), although the raw data is particularly significant for archaeological research. Therefore, since the archaeological report as a knowledge resource is a synthesis of phases of the information value chain, it has plenty of potential for later research and reasoning (see also Aamodt & Nygård 1995:6–14).

From the technological component's viewpoint, a report contains data or symbols about the original

data resource, the site. This data is both descriptive and semiorganised, but not in a structured format. For the structuring, the data needs to be described using metadata. Further, the metadata must be specified by metacontent, which is the data about the content of metadata (e.g. Greenberg 2009:3610–3615).

In the archaeological context, metadata can be used to characterise archaeological remains, the content of the report, and the processes related to the research practices. Alternatively, it can be used as a technological design strategy to produce archaeological digital data. The production of procedures for digital data means actually working at the metadata level of the report when policies for the organisation of digital data are designed. Witmore (2004:135–159) has defined the archaeological field study as 'multiple fields' of archaeology, referring to the complexity of its contexts. Witmore's 'multiple fields' resembles the concept of 'socio-technical worlds' in Tilson *et al*. (2010:749), citing Star & Ruhdeler (1996). The metadata should acknowledge all these contexts of archaeological research.

The challenge of defining the design policies lies in the fact that interpretation is always present in archaeological research and the produced data. Interpretation is related to the theoretical archaeological discussion, which analyses archaeological data, its representations, and its value, as well as the exploitation of this data in research. According to Hacigüzeller (2012:254–256), the main concern is the adequacy of the archaeological representations produced by technologies, that is, the technological capability to model and preserve the detailed features of the original data source. Thus, the effects of the technologies used should be closely examined when digital procedures for using archaeological data are designed.

The needs of archaeological research are different from those in the field of museum research (Xia 2006). Therefore, there is a need for specific policies of work practice and technological specifications that fit the archaeological research requirements; the importance of this was acknowledged during the preparations for the DARIAH project, which aims at synthesising the research practices and research requirements of the humanities, including archaeological research (Benardou *et al*. 2010). Since then, the ARIADNE project (2013) for integrating existing European archaeological research data infrastructures has been launched.

The lack of digital procedures has also been acknowledged by the internal stakeholders of museums in the US (Watts 2011). Among many relevant questions, there is a recently awakened need to examine how information systems are designed and how they will support the new types of digital heritage data (Häyrinen 2012:111–112). There are as yet no ready-made principles, methods, or 'off-the-shelf' technological solutions that could be applied to the evolving DIs and would also be suitable for unpublished resources. Instead, there are many reflective resources available from information-oriented disciplines, as described by Edwards *et al*. (2007), Ribes and Lee (2010) and Tilson *et al*. (2010).

As a consequence of the above issues, there is no self-explanatory method of analysing or producing archaeological digital data, including grey reports, in the multiple socio-technical contexts of local archaeological research and at the same time as components of global DIs. Infrastructure-related projects in the humanities (ARIADNE 2013; Benardou *et al*. 2010) may fulfil this need in the future. A design theory of DIs has also recently been synthesised by analysing the evolution of the Internet (Hanseth & Lyytinen 2010); the collected lessons related to DIs will henceforth contribute to the design (Edwards *et al*. 2007).

Conclusion

The future of archaeological digital data and grey reports can be associated with strategies and visions, shared practices and practitioners, and further with the preservation, sharing, and reuse of data. Moreover, there is a need for the development of customisable digital standards and practices covering requirements related to the technical, content and metadata issues of the data collections. Several emerging technologies, such as Semantic Web, are explored to reach these visionary goals. Semantic Web shows a promise of rich, semantic indexing of reports, which, however, requires a conceptual framework, which in turn is provided by utilising framework ontologies and knowledge re-

sources such as vocabularies (Vlachidis *et al*. 2009). In this effort, both humans and machines are valuable in giving explanations for the contents of documents and in developing ontologies (Vlachidis *et al*. 2009:473).

Archaeological data and reports can also be analysed from the point of view of information systems and databases or from a broader interdisciplinary perspective. The standpoint of evolving multi-institutional and multinational socio-technical digital infrastructures and of eScience seems useful because it deals with extensive socio-technological questions. Archaeological research practices are undergoing continuous change, and digital environments may well be the future work environment also for archaeologists. However simplified it may sound, the basis of this work is a 'digital report', one component of a large source of data, which has the potential to become a component of a digital infrastructure – a virtual research environment that includes relevant digital data collections and publications. An example of an emerging digital publication procedure, mainly used in the sciences, is 'data publication', which means providing access (e.g. via linking) to the original research data collection for the audience of the peer-reviewed scholarly article (see e.g. Reilly *et al*. 2011). This kind of practice may perhaps also be applied to the dissemination and sharing of archaeological reports as data collections and publications.

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