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Thesis for the Degree of
Philosophiae Doctor
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A study of the status, role and potential of geophysical methods in Norwegian archaeological research and cultural heritage management

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SUMMARY

The main aim of this thesis was to examine the role, function, status and impact geophysical methods have had on archaeological research and the cultural heritage management in Norway, and the identification and investigation of important methodical and empirical research areas for a more integrated use of geophysical methods for Norwegian archaeology in general. This was done by reviewing the way geophysical methods have been used on Norwegian archaeological sites. In addition, by examining and analysing statements from various documents, communications, guidelines, directives and initiatives by actors within archaeological research and cultural heritage management, it was possible to gain a deeper understanding on the acceptance geophysical methods have in Norway, what role, function and status the actors assign to geophysical methods, and how geophysical methods have influenced the archaeological practice. The theoretical framework of actor-network theory was used as an analytics tool for this analysis. By identifying and performing methodical and empirical research using geophysical methods on archaeological sites, it was also possible to present, examine and analyse the cultural historical knowledge gained and how these results could influence or alter decision makers, decision-making processes, and practice within the cultural heritage management. The idea of geophysical surveys as something new in Norwegian archaeology is not correct, but there have been a significant increase the last decade. There is no correlation between the amount of archaeological registrations performed in each county and the amount of geophysical surveys conducted in these counties. Statistics also show that the geophysical surveys performed in relation to archaeological registrations is increasing, as well as surveys performed for management purposes in general. The typical role envisioned for geophysical methods are as non-destructive tools for cultural heritage management and in relation to planning permissions, and as a registration method. The main focus is different from the various institutions involved within archaeological registrations, cultural heritage management, and archaeological research. An increased focus on geophysical methods is observed in the various documents analysed, indicating increased awareness. Still, geophysical methods are not used on a regular basis and has not been accepted as a well known tool for registration purposes. For research applications and management concerns not initiated by a developer, the acceptance for including geophysical methods is higher. The empirical and methodical analysis show possibilities and limitations in using geophysical methods for both research and management purposes. This reveals both instances where the application of geophysical methods revealed important and interesting archaeological observations, but also highlights some of the pitfalls and limitations that one need to take into consideration when commissioning surveys. This relates especially to aspects involving geological conditions, modern influence, ground conditions and field methodical aspects such as resolution and choice of geophysical survey methods. While methodical choices can be tailored to the challenge at hand and increase the possibilities for positive identification of archaeology, it remains that some factors are out of the surveyors hands. The amount of geophysical contrasts of an archaeological feature will vary depending on size and type of the archaeological feature, deposition processes, climatic factors and modern disturbance. A professional judgement relating to what archaeological method that are to be used must take these factors into consideration when assessing the potential gain of suggesting the application of geophysical methods against costs, cultural historical value and other factors. While these uncertainties has to be acknowledged, there are positive benefits of viewing the application of geophysical, non-intrusive methods as part of a longer planning process, as any results revealed in early stages can influence decisions and decision-making processes in later stages. This could be a contribution that reduces bureaucracy, improves budget accuracy, targeted excavations, and an overall better management of the archaeological heritage. Knowledge dissemination, support for training and experience should be encouraged.

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1 INTRODUCTION

Archaeology as a discipline has always taken the advantage of scientific methods and knowledge from other disciplines that can contribute to the understanding of the past in some way or form. Archaeology is in many ways multidisciplinary. Multidisciplinary is by Youngblood (2007:2) defined as "*what happens when members of two or more disciplines cooperate, using the tools and knowledge of their disciplines in new ways to consider multifaceted problems that have at least one tentacle in another area of study*". In practice, the multidisciplinarity of archaeology involves for example the use of ^{14}C-method for archaeological dating, the use of isotopes to study changes of diet in the past, pollen analysis in vegetation history, DNA-analysis, marine side scan sonars and underwater technology, GIS-systems or any other scientific method to help us in our pursuit to study prehistory (Conolly and Lake 2006; Pollard et al. 2007; Cannell 2012; Lidén and Eriksson 2013; Tuddenham 2015). While the archaeologist may not understand the scientific principles behind each scientific method, the method or practice can still have a general acceptance. Interdisciplinary, on the other hand, is something different from multidisciplinary. Interdisciplinary is defined as "*what happens when researchers go beyond establishing a common meeting place to developing new method and theory crafted to transcend the disciplines in order to solve problems*" (Youngblood 2007:2), and this is can be seen as a more ideal way of integrating new fields of research and gain even more knowledge. In this lies a larger form of collaboration and mutual understanding between the researchers, and a deeper knowledge of each others' field of research – a truly interdisciplinary understanding that can give rise to a new practice of archaeology. This does not need to be a one way influence from science to archaeology. Ideas from and requirements of archaeological application might need rethinking methodical and scientific practices, the questions asked, and ultimately lead to an advancement and refinement of the scientific discipline as well. The journal *"Natural Science in Archaeology"s* standpoint is that *"Interdisciplinary collaboration requires multidisciplinary background",* a statement which the journal finds uncontroversial, but also implies that it is only by collaboration in the form of interdisciplinary work that it is possible to fully utilize scientific methods to study archaeological material. While interdisciplinarity might be more fruitful, it still becomes more and more difficult to grasp the whole field of for instance Archaeometry, as it involves so many specializations and techniques (Lidén and Eriksson 2013:11; Natural Science in Archaeology 2016). Still, there are some challenges when being faced with scientific methods in action. Lidén and Eriksson (2013) describe how they as archaeological scientists, often encounter something they call a "filter", where other collaborators put up what the authors call a mental shield that prevents good communication. They believe that this is triggered by one out of two factors, either that the archaeologist has decided that he or she does not understand "these natural science things", so the archaeologist do not need to listen. The other reason they propose is an attitude that spawns out of a notion that the archaeological scientist do not understand archaeology, so the archaeologist do not need to listen to what the scientist has to say (Lidén and Eriksson 2013:12). Lidén and Eriksson (2013:18) has asked for better communication and suggested that an increased effort from both parties involved is a necessary condition for ensuring a genuine collaboration. The problem is that this can be difficult to achieve in practice. Whenever a new method or technology is introduced, the spokespersons and scientists promoting the methods need to prove the methods' possibilities and be able to explain and demonstrate how the methods can be used in practice. This might not be a straight forward process, but a good and constructive dialogue, mutual efforts, sound skepticism, testing and publications can contribute to prove the applicability or dismiss a method as fruitful for archaeological purposes. A survey done in 2008 indicates that there is a wish for additional training and increased competence in the use of new technologies within employees in the cultural heritage management sector. What new technology represents in this survey is not defined, but could include GIS and practical methods for documentation and registration methods etc. (Jacobsen et al. 2008). The important thing is that it reveals both a wish for, but also a need for additional training and competence, and that the issue of introducing new methods and sciences into archaeology is more complex than just introducing and demonstrating the applicability. There is also the issue of how this fits into the regulations, established practices, economic, and managemental framework of archaeology.

Developments in field methodology also influence the archaeological practice in a similar manner as scientific methods. The introduction of mechanical soil stripping as an archaeological field method can serve as a good example. In Norway, the introduction of soil stripping in the 1990s led to a whole new empirical data material, and revolutionized the knowledge of prehistoric settlements (Høgestøl et al. 2005). In the museum district of the NTNU University Museum in Trondheim, the amount of known Iron Age settlements increased proportionally with the use of mechanical soil stripping . In the years 2000-2004, the use of mechanical soil stripping was the dominant excavation method (NTNU University Museum 2005). The introduction of mechanical soil stripping is a good example of a field method that received some skepticism when introduced in Norway. It took over a decade until mechanical soil stripping became nationally accepted within the heritage management, proving to be efficient and provide new and important knowledge. Skepticism may lead to a constructive discussion on the use of any method, and the process involved refinements, publications, academic publications and presentations before mechanical soil stripping become generally accepted (Løken et al. 1996:8-12). Although the applicability of mechanical soil stripping was demonstrated by being able to locate new types of archaeological sites and features, there still was a general reluctance in getting acceptance of soil stripping. This was mainly due to a lack of insight and knowledge of the potential of the method, demands of effectivity and qualitative good results, costs for the developer following the judicial framework and the reigning archaeological practice at the time. A lack of possibilities or will within Norwegian archaeology for a professional reorientation in their daily practice has also been described (Løken et al. 1996:8-12). All of these factors are typical hindrances that any other introduction of field practice or scientific method will have to face to become accepted as a natural part of archaeological practice.

As with mechanical soil stripping, geophysical approaches have been met with skepticism. Geophysical methods are a range of non-intrusive methods to detect features in the subsoil. It becomes a possibility to detect, delimit and understand archaeology features in a completely different way than with conventional methods. Geophysical methods of prospection for archaeological purposes have been defined by Gaffney and Gater (2003:12) as *"The examination of the Earth's physical properties using non-intrusive ground survey techniques to reveal buried archaeological features, sites and landscapes".* The non-destructive nature of geophysical surveys makes it possible to identify and protect sites without damaging them and learn more of sites and features that should not be disturbed. Geophysical approaches also represent a way of gathering information that is examinable and retestable, in contrast with the destructive nature of excavations. Geophysical methods have been used for archaeological purposes for several decades in many European countries such as England, France, Austria, Germany and Italy, where archaeological sites have been identified and investigated with good results. In England, for instance, is geophysical to a large degree integrated in the planning and archaeological evaluation process (Clark 1996; Doneus et al. 2001; Gaffney and Gater 2003; Gaffney 2008; Piro 2009; Viberg et al. 2011; Viberg 2012; Bonsall and Gaffney 2014; Bonsall et al. 2014). A widespread and regular use of geophysical methods can be claimed to be less in Norway than in the countries mentioned above. In the recent years, new initiatives and collaborations have led to a rise in the amount of geophysical surveys in Norway, with an increasing body of geophysical survey reports and articles (Gustavsen and Stamnes 2012), and there is a noticeable increased in the interest and attention of the geophysical methods. This development is similar to what is observed in Sweden (Viberg et al. 2011; Viberg 2012). There is still a reluctance towards the application of geophysical methods, as observed with mechanical soil stripping. This reluctance is especially towards the gain of using geophysical methods, what can be detected and located by geophysical methods, and an uncertainty in how it can contribute within archaeological evaluations in relation to planning applications. It is also uncertain how much this increased attention have influenced the archaeological community, both in regards to archaeological research and cultural heritage management.

Being from an academic background in traditional archaeology, but with an additional education in archaeological prospection, with a particular emphasis on near-surface geophysics (University of Bradford 2016), I am often faced with dealing with questions relating to the applicability of geophysical methods. When discussing geophysical methods and their applicability with my colleagues, they are often very interested in the potential and fascinated by the possibilities that geophysical methods have in investigating and understanding archaeological sites, features and landscapes. How can the methods be used? What can we find? How much time does it take, and what does it cost to perform a survey? Another typical question is why should we do a geophysical survey when test-trenching usually gives us the answers we need? When answering such frequently asked questions, I have several times felt that there is a gap – an inherent difficulty, in explaining the geophysical principles of the various prospection methods to archaeologists with a non-technical background. I feel like an interdisciplinary actor who becomes a multidisciplinary collaborator. I am not claiming that my colleagues do not understand or do not wish to understand. The Jacobsen et al. (2008) study indeed demonstrates that there is both a wish and a need for additional training and increased competence in the use of new technologies within employees in the cultural heritage management sector. In relation to geophysical methods, the understanding of technical requirements, possibilities and limitations of the geophysical methods, and the inherent difficulties in moving from a geophysical anomaly to an archaeological interpretation of the geophysical data, becomes lost in translation and can be difficult to grasp properly without additional training. Sometimes the expectations other actors have of the potential of geophysical methods is over-optimistic, and has in the past led to disappointments and an impression that the geophysical methods "do not work" (Gustavsen and Stamnes 2012). My colleagues' inherent understanding of the role and potential of the methods is different from my own, and so is their impression of the role and status of geophysical methods. Still, it is not that archaeologists do not wish to learn more and update their knowledge on the possibilities of new technologies. It is also possible to ask if geophysical methods really should be regarded as "new" tools any more, although it once must have been.

As Lidén and Eriksson (2013) indicated, there is a need for better communication. Having both a "traditional" and technical background, I can help present aspects seen both from "traditional" archaeology and from the viewpoint of archaeological geophysics. I enjoy bridging gaps between "traditional" archaeology and the use of tools for data gathering, processing and analysis, and have a particular interest in studying how technology can be used for archaeological purposes and be of gain within both archaeological research and cultural heritage management. In this thesis, I use the term cultural heritage management (CHM) as a description of a body of laws, regulations, standards, practices, institutions and practitioners (usually referred to as actors) that in one way or other are related to the management of archaeological heritage, its preservation and land planning. In Norway, the Cultural Heritage Act of 9 June 1978 defines all sites, monuments, features and objects older than 1537 as automatically protected by law. The cultural heritage act also opens up for protection of sites and monuments from other periods, depending on age and circumstances (Cultural Heritage Act 1978). The term archaeological research involves all actors involved in research related to archaeology in all forms, involving methods, practices, institutions and technologies. I define an actor as something or someone that is the source of an action, and use the term both on human and non-human actors (Tuddenham 2015:v).

Researching how the introduction of a new method has influenced the archaeological practice within the networks of archaeological research and CHM can also be seen as a contribution to the field of cultural heritage management research (No: kulturminnevernforskning). CHM research is defined as *"research with the purpose of producing knowledge that is seen as necessary as foundation for decision-making processes within the cultural heritage management"* and further that *"Cultural heritage management research also includes research on the practice of the cultural heritage management, amongst others as a foundation for the evaluation for cultural heritage management measures" (NFR 1994:15, this author's translation).* Such research should contribute with source material for the cultural heritage management and contribute to dissemination from this research to CHM. In this way, CHM research can contribute to bridging the gaps between the cultural heritage management and research upon the cultural heritage (NFR 1994; Holm 2008). This can be both research on and research for the CHM (Holm 2008). By operating with aims and objectives that to a certain degree are directed towards current practice and oriented towards consequences to the future, such research would produce knowledge that is relevant for the society and purvey premises for politicians, planners, directorates, and ministries (Holm 2008:53; Museum of Archaeology 2012:125). More knowledge on the role of various actors within cultural heritage, how the actors perform their functions and how they directly and indirectly contribute to preserve cultural heritage sites and monuments have also been asked for. This is especially in regards to how the various actors operate and interact in relation to each other, and to the cultural heritage management in general. Systematic knowledge on the consequences of the release of guidelines from the public administration, and the results of such guidelines have also been requested. In addition to this is the wish for a continuing development of knowledge that can contribute to exploit the possibilities that new technologies provide (Ministry of Environment 2010). Holm (2008:59) notes how CHM has moved from being a contributor of cultural historical data within the universities to becoming an area of politics within environmental protection. By being an employee with the CHM, there also exist an expectation of loyalty to your employer and the administrative and political signals conveyed. This does not open up for critical questions. It is therefore especially important that the university museums perform research that focuses on the politics of CHM, and ask critical questions that the employees with the CHM to a lesser degree can ask themselves (Holm 2008:59).

To be able to bridge the gap between geophysical practitioner and archaeologists, and increase the possibilities for mutual collaboration and understanding, it is important to gain a deeper knowledge of how the actors within the archaeological community define the role, function and status of geophysical methods within their field of responsibility and interests. This includes how geophysical methods have influenced the practice of archaeological research and cultural heritage management, and what acceptance geophysical methods have within the actors involved in Norwegian archaeology. The framework of Actor-Network theory (ANT) is very useful to study how technology has influenced society and research, and the process of how technologies become accepted or fails to become so (Latour 1987; Tuddenham 2015). This process of getting acceptance can be seen as moving from assertions or assumptions into facts, and is within ANT described as the process of *translation.* It is by Brattli and Brendalsmo (2016:61) defined as *"a process that regulates the relations of different actors in* ***networks****. These networks are the contexts in which some statements attain status as correct and* *true"*. The actors' statements define how the actors ascribe the role, function, purpose, acceptance, and views on the geophysical methods, and it is therefore important to performing an examination and analysis of these statements.

It is also necessary to identify important areas of research that can improve the understanding of the possibilities and limitations of the various geophysical methods, and indicate how they can contribute to whatever role and purpose envisioned for the geophysical methods. In this way, new knowledge can be gained and lead to a better understanding of the potential that geophysical methods have within current and future archaeological practice in Norway. The investigation of the identified areas of research will contribute in assessing the potential the geophysical methods have as an actor within archaeological research and cultural heritage management.

It is within this framework that this thesis is situated, intending to provide research both for but also on CHM practices as well as contribute with empirical and methodical research and new cultural historical knowledge.

1.1 AIM AND OBJECTIVES

The main aim of this thesis is as follows:

To examine the role, function, and status geophysical methods have within Norwegian archaeological research and cultural heritage management. Such an analysis will lead to a deeper understanding on the impact the introduction of geophysical methods have had on the archaeological practice in Norway.

A deeper understanding of the role, function, status and impact geophysical methods have within Norwegian archaeology can be used to identify important research areas for a more integrated use of geophysical methods within Norwegian archaeological research and cultural heritage management. The identification and investigation of methodical and empirical research areas will lead to a new view of the potential of geophysical methods within Norwegian archaeological research and cultural heritage management, and in turn be an important contribution to archaeological practice in general.

The aim stated above will be accomplished by reaching the following objectives (the sections and articles in this thesis that answers to these objectives are in parentheses):

1. Review the way geophysical methods have been used within Norwegian archaeological research and cultural heritage management (article one, chapter 2 and 7)
2. Identify the role, function and status geophysical methods have in Norway by examining statements from actors within the Norwegian archaeological community and aspects relating to field archaeological practices, judicial concerns and professional judgement (article one, chapter 5 and 7)
3. Examine and analyze how the introduction of geophysical methods have influenced the archaeological practice and the actors involved in archaeology in Norway, both in regards to archaeological research and cultural heritage management (article one, chapter 3, 4, 5 and 7)
4. Compare statements from and intentions of actors within Norwegian archaeological research and management concerning geophysical methods against their actual practice as revealed through objectives 1-3 (article one, chapter 5 and 7)
5. Identify important research areas and perform methodical and empirical research that can give a deeper understanding of the potential, possibilities and limitations of geophysical

methods in investigating archaeological sites, monuments and features in Norway (article one and section 7.5 for identification, article two, three and four and section 7.6 presents methodical and empirical results)

6. Examine and present cultural-historical knowledge gained from methodical and empirical investigations, and evaluate how these results can contribute to archaeological research (article two, three and four, and section 7.7 in particular)
7. Examine and analyze how the results from the methodical and empirical investigations may alter or influence decision makers, decision-making processes, and practice within the cultural heritage management (article two, three and four, and section 7.9 in particular)
8. Examine and discuss controversies and disagreements between the viewpoints and statements made by actors involved within archaeological research and cultural heritage management, and the knowledge and experience gained from reviewing the use of geophysical methods in Norway and the results from performing methodical and empirical research (all articles and section 7.8 and 7.10 in particular)

1.2 THESIS OUTLINE – A READER'S GUIDE

This thesis consists of four articles and a synthesis (often called a summary article). Summaries of the articles and declarations of contributions are presented in chapter 6.

The articles are as follows:

Article one: "Archaeological Use of Geophysical Methods in Norwegian Cultural Heritage Management – a Review"

Co-authored with Lars Gustavsen, NIKU in Oslo. Published in Kamermans, Hans, Martin Gojda and Axel G. Posluschny (eds.) 2014: *A Sense of the Past- Studies in current archaeological applications of remote sensing and non-invasive prospection methods.* BAR International Series 2588, Archaeopress, Oxford, England. Pages 17-31.

Article two: "Geofysiske undersøkelser av kirkegårder, kirketufter og svartjord på Veøya i Romsdal».

Co-authored with the main author, professor Brit Solli at KHM in Oslo. Published in *Viking* 2013. Norsk arkeologisk årbok bind LXXVI (76). Pages 181-202.

Article three: "Geophysical Surveys at Avaldsnes"

Co-authored with Egil Lindhart Bauer, KHM in Oslo. Now employed at NIKU, Oslo.

Stamnes, Arne Anderson and Egil Lindhart Bauer (in press): Geophysical Surveys at Avaldsnes. In Skre, Dagfinn (ed.): *Avaldsnes: A Sea-King's Seat at the Island of Kormt*. De Gruyter. Berlin, New York.

In press peer-reviewed manuscript for a book chapter, which is to be published in a book on "The Avaldnes Royal Manor Project" edited by Professor Dagfinn Skre at the Museum of Cultural History, University of Oslo. He is also in charge of The Avaldsnes Royal Manor Project. The book will be published by De Gruyter Publishers on academic level two in the Norwegian Centre for Research Data ranking of publication channels.

Article four: "Magnetic Geophysical Mapping of Prehistoric Iron Production Sites in Mid-Norway".

Co-authors: Professor Lars Stenvik at the department of archaeology and cultural history, NTNU University museum and Dr. Chris Gaffney, head of the archaeological sciences division at the University of Bradford, England.

Submitted manuscript for an anthology to be published by The Royal Norwegian Society of Sciences and Letters (Det Norske Videnskabers Selskab - DKNVS) – which is at academic level one in the Norwegian Centre for Research Data ranking of publication channels. This publication will be a collection of contributions from participants at a workshop/seminar arranged by the NTNU University Museum in March 2015 on the usage of LiDAR and geophysical methods in registering and investigating prehistoric iron production sites in Norway.

1.2.1 Synthesis overview – the road to reaching the aims of the thesis

This section is presented to give the reader an overview of the main elements of this thesis, and an understanding on the relationships and underlying structure of the work presented.

The aim of this thesis is to examine the roles, function and status geophysical methods have within Norwegian archaeological research and cultural heritage management, and to identify and investigate important empirical and methodical research areas on the application of geophysical method within Norwegian archaeological research and cultural heritage management.

To achieve this, it is necessary to give the readers that are unfamiliar with geophysical methods a short introduction to geophysical methods and how they function, as well as how they have been used in Norway until now. This is done in chapter 2, which also will contain an extended historical overview compared to what is presented in article one.

It is also necessary to introduce the organization of cultural heritage management and archaeological research in Norway, which the readers an overview of actors within the heritage management and archaeological research, knowledge of these actors' intended roles and functions, background knowledge on judicial aspects and how archaeology often is performed in practice. This is done in chapter 4. Chapter 2 and 4 constitute of a major part of the research context of this thesis, together with article one. It is important that the theoretical framework is presented and understood before the organization of archaeological research and heritage management in Norway is presented. This is why the theoretical tools and perspectives will be placed as chapter 3.

To perform the analysis and examining the roles, functions and status of geophysical methods in Norway, it is necessary with a theoretical framework for how to approach this aim. The analytical approach that will be used in thesis is Actor-Network theory (ANT), which will be presented in chapter 3. To perform such an analysis, it will also be necessary to present statements where the various actors mention geophysical methods, which can clarify their understanding and attitude towards geophysical methods. This material has been too large to fit in any of the articles and the presentation of strategic documents, communications and initiatives have therefore been given a separate chapter (chapter 5). The material presented in this chapter will be an important data source for the fulfillment of the objectives of this thesis, and will be analyzed in comparison with information from article one and through the theoretical framework of ANT.

A summary of the main aims and contributions from the articles will be presented in chapter 6. The articles will be found in the appendix.

Chapter 7 will be the discussion, where the statements presented by the various actors on archaeological geophysics will be examined and analyzed. This section will highlight specific statements, and see them in comparison with the intentions, interests and practice of the various actors within Norwegian archaeological research and cultural heritage management. In this chapter, the perceived roles and functions of geophysical methods will be presented, along with the entitlements and descriptions of geophysical methods within Norwegian archaeology. Chapter 7 will be the major synthesis of this thesis, binding the research context, statements and the investigation of the actual practice of geophysical methods into a larger analysis and discussion.

The analyses performed will also, together with the results from article one, lead to the identification of important research areas for more integrated use of geophysical methods within Norwegian archaeological research and cultural heritage management. This is part of the main aim of this thesis. The identification and investigation of methodical and empirical research areas, will be presented in article two, three and four, as well as in chapter 7.

Results from articles two, three and four will be highlighted, and will lead to a presentation and analysis of how the methodical and empirical research performed will contribute to both archaeological research (section 7.7) and cultural heritage management (section 7.9).

The methodical and empirical results will also lead to a discussion on a series of controversies identified on the use of geophysical methods within Norwegian archaeological research and cultural heritage management (section 7.8 in particular). The discussion of the controversies will clarify how geophysical methods can contribute to research projects and within cultural heritage management in Norway, and will put a new perspective on the potential of geophysical methods within Norwegian archaeology in general.

The main conclusions of the presented work will be presented in chapter 8, and will sum up the results of reaching the objectives presented in section 1.1 and how the main conclusions answer to the aim set for this thesis.

The preceding description show how the thesis consist of three main parts. The first the presentation of the research context, theoretical background and the presentation of important statements from documents, communications and initiatives released by actors involved in archaeological research and cultural heritage management in Norway. The main results from the articles becomes the second part. The third part combines the analysis, examination and discussion of the presented documents and statements with the main results of the articles, and becomes the turning point where the results of this work becomes drawn into a larger discussion. This is the main synthesis, and where all the lines and results from the presented material becomes connected and analyzed as a whole.

2 GEOPHYSICAL METHODS IN ARCHAEOLOGY

2.1 GEOPHYSICAL METHODS – A SHORT INTRODUCTION

2.1.1 A short history of archaeological geophysical prospection

The first documented use of a geophysical method within archaeology was at Williamsburg in USA in 1938 (Bevan 2000), followed by the first survey in Europe performed at Dorchester-on-Thames in England in 1946 (Clark 1996:12-13). Some early experimentation followed in the years up towards the 1980s. In the 1980s and 1990s the subject of archaeological geophysics were in a stage of experimentation, but with a wider range of geophysical experimentation and professionalization – largely in Great Britain. This professionalization was largely due to a restructuring of the practice of archaeology within the cultural heritage management. As excavations to a larger degree was paid for by private developers, the use of geophysical method as a cost-effective site evaluation method led to increased use of geophysical methods. Archaeological geophysics became a separate subject at university level, firms producing specialized equipment emerged, and influential textbooks and academic journals led to more academic publications on the subject became available (Scollar et al. 1990; Gaffney and Gater 2003; Lockhart and Green 2006; Gaffney 2008; Ernenwein and Hargrave 2009; Gustavsen and Stamnes 2012). From the 2000s and onwards computers became more powerful and cheaper, and a continuous development of specialized and advanced software packages and geophysical instrumentation improved the possibilities of analyzing and presenting the geophysical data collected. A development that has to a large degree continued, and is steadily improving the capabilities of geophysical prospection in archaeology – both in regards to accuracy, resolution, and effectiveness, but also in regards to the applicability within cultural heritage management and archaeological research. GPS-positioning, multi-antenna arrays and instrumentation towed by vehicles have to a large degree revolutionized the possibilities to investigate not only sites and features, but also archaeological landscapes (Gaffney 2008; NIKU 2011b; Gaffney et al. 2012; Gustavsen and Stamnes 2012; Gustavsen et al. 2013b; Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology 2013a; Schneidhofer et al. 2016).

Meanwhile in Scandinavia there is an observed shift, without the same attention and inclusion of geophysical methods at the same scale as in Great Britain. The first known archaeogeophysical survey known in Sweden was performed in 1977, and between then and 2008 the total number of known geophysical surveys conducted on archaeological targets was 280. 137 of these were conducted between 2005 and 2008, following a clear rise in the amount of geophysical surveys from early 2000s and onwards (Viberg 2012). Complete statistics for the following years are not available, but several interesting research projects involving archaeological geophysics are known, involving the Ludwig Boltzmann Institute (LBI ArchPro) from Vienna in collaboration with the National Historical Museums in Sweden (Statens historiska museer SHMM, Arkeologi UV – formerly UV teknik at the Swedish National Heritage Board). The SHMM collaboration with LBI ArchPro has undertaken large scale multi-method surveys of for instance the Viking Age site of Birka-Hovgården (Trinks et al. 2010b; Trinks et al. 2014), Uppåkra (Gabler et al. 2013; Larsson et al. 2015) and Gamla Uppsala (Trinks and Biwall 2011). The Archaeological Research Laboratory at The Stockholm University are also involved in a research project on Iron Age fortifications at the island of Öland (Viberg 2015).

There has not been published a review of the usage of geophysical methods within Danish archaeology, in the same manner as for Sweden (Viberg et al. 2011; Viberg 2012) and Norway (Gustavsen and Stamnes 2012; Stamnes and Gustavsen 2014- article one). An estimation of the total amount of geophysical surveys focusing on archaeological sites in Denmark is therefore not available, and a compilation of such a database is outside the scope of this PhD. There are, however, a series of notable surveys. Since the early 1990s Tatyana Smekalova, representing Moesgaard Museum in Århus, conducted a wide range of surveys over various site types including iron production sites, barrows, settlements from various periods, pithouses, castles, abbeys, flint mines, Neolithic palisades at Rispebjerg on Bornholm and others (Smekalova and Voss 2001; Abrahamsen et al. 2003; Smekalova et al. 2005; Smekalova et al. 2008). Within the last 10 years, initiatives involving geophysical prospection methods show very promising results. This include mapping of pit houses (sunken featured buildings) in Ribe Amt in Jutland (Feveile and Stoumann 2006), Neolithic enclosures (Klassen and Klein 2014), iron- and Viking age farmsteads (Nau et al. 2015), medieval castles and mansions (Larsen and Hjermind 2010), as well as Viking age central sites (Greve and Nørgård 2009; Jørgensen 2009; Stümpel 2010), harbors (Loveluck and Salmon 2011) and ringforts (Sindbæk et al. 2012; Brown et al. 2014) and the discovery of a new ringfort of the same type as Aggerborg and Trelleborg at Vallø close to Køge in Sealand (Ammitzbøll 2014). The overview presented on geophysical surveys in Denmark is not to be considered as a complete, but demonstrates a rather large activity of geophysical prospection on archaeological sites.

Although showing positive results and an increase in the total amount of geophysical surveys on archaeological sites, geophysical method is still not considered a standard tool for documentation, evaluation and investigations. The reasons for this is mainly due to costs for already stretched budgets, limited possibilities for investments in equipment and personnel, lack of knowledge of the potentials and pitfalls of geophysical methods, as well as some disappointments in the early days of introducing geophysical methods (Viberg et al. 2011; Gustavsen and Stamnes 2012; Viberg 2012; Brown et al. 2014; Stamnes and Gustavsen 2014- article one).

2.1.2 Geophysical methods of survey

There is a whole range of various geophysical survey methods, and this section is intended as a general introduction to the geophysical principles of the main methods of survey used within archaeology.

2.1.2.1 Magnetic susceptibility

Topsoil Magnetic susceptibility mapping is a way of locating and delimiting activity sites by measuring how much a sample will be magnetized in the presence of an external magnetic field. The method is explained in more detail in article four, page 2 and article two page 190-191. A magnetic contrast can be generated through anthropogenic activity such as burning, the biological decomposition and redox-processes (heating and cooling) which alter the magnetic properties in iron minerals in the ground. In addition, deposition of refuse materials such as ceramics, metal working refuse or similar increase the magnetic susceptibility response. The effect of anthropogenic activity on the geophysical contrast is dependent on the length of the activity in time, the initial amount of iron minerals present in the soil, deposition and creation of magnetic material, as well as geological processes (Clark 1996; Dearing 1999; Gaffney and Gater 2003; Linderholm 2007; Dalan 2008). Depending on the sample spacing used, areas of several hectares can be surveyed in a day.

The initial content of iron minerals in the soil may vary, creating situations where different soil types create different response. This might in turn create a situation where it becomes problematic to clearly distinguish anthropogenic enhancement. Also, any enhancement detected might be from any time period. There are also limitations to depth penetration and resolution, which are necessary to be aware of when considering performing topsoil magnetic susceptibility mapping. Leeching of iron minerals through waterlogging or in areas often exposed to heavy rainfall will also contribute to moving iron minerals down in the soil horizons and contribute to erasing the magnetic contrast measurable from the anthropogenic activity (Evans and Heller 2003:95-96). Additional magnetic analysis of soil samples can remove inclusions of non-anthropogenic origin and identify additional information of the causes of magnetic enhancements. This includes the analysis of mass susceptibility and frequency dependency (χ_{fd}) (Clark 1996; Dearing 1999; Dalan 2008), fractional conversion-analysis (χ_{max}) (Clark 1996; Crowther 2003; Evans and Heller 2003; Dalan 2008), the analysis of the soils anhysteretic remanent magnetization (ARM) or ratio of ARM/X (Dalan and Banerjee 1996; Dalan 2008), where X is the mass suceptibility, as well as the ratio of mass magnetic susceptibility divided by its saturation magnetization (X/J_s) (Marmet et al. 1999).

2.1.2.2 Magnetometer surveys

A feature can be regarded as a buried magnet with a differing magnetic orientation than the earths magnetic field, and can be distinguished by different magnetic properties than its surroundings. Magnetometers can detect very small changes caused by such tiny variations in the ground. A gradiometer is a combination of two magnetometers, aligning two sensors over each other vertically. The top sensor measure mainly the diurnal variations of the earth's magnetic field, while the bottom sensor measure both these variations and any effects caused by features in the ground. By surveying an area systematically with a magnetometer, it is possible to create maps over the magnetic variation in the subsoil. Typically, features backfilled with more magnetic material with higher magnetic susceptibility (ditches, pits etc.) or features subjected to burning and heating are more likely to be visible in this type of dataset. The method is explained more in detail in article two, page 191-192, and article four page 2-4. See also the Aspinall et al. (2009) book *"Magnetometry for Archaeologists"* for more in-depth information.

Technical setup (i.e. amount of sensors in an array and capabilities for GPS-based data recording), and survey parameters (resolution and probe spacing) does to a large degree govern the area coverage possible to survey in a day. In average, one operator measuring transects at every 0.5m with a hand carried dual sensor instrument can measure up to 0.9-1.2 hectares a day depending on site layout. With vehicle towed multisensory-arrays can measure over 20 hectares a day (Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology 2013b). Survey parameters (i.e resolution), background geology, size of archaeological features expected, and the inherent magnetic contrast of these features to a large degree govern the applicability of magnetometer surveys.

2.1.2.3 Electric methods of survey

Archaeological features might consist of changes in material, porosity and/or water retentiveness. By using instrumentation that measure changes in the electrical resistivity or conductivity in the ground, such variations can be mapped systematically, and be investigated and interpreted for the purpose of archaeological prospection. Such investigations can also reveal information of site formation processes seen from a geoarchaeological point of view. Hard packed surfaces and features built up of stones will typically have a high resistivity, while pits and ditches have a low resistivity contrast. This way of mapping the underground are relatively easy to interpret, but have a low data collection speed and resolution. By having a long series of electrodes evenly spaced along a transect, it is also possible to collect information on changes in the earth resistivity to quite large depths. This is called Earth Resistivity Imaging (ERI) or Earth Resistivity Tomography. Such transects can be arranged systematically and sliced at certain depths to make depth slices over changes in the earth resistivity over a larger area in plan view. Electrical methods of survey are complementary to other geophysical methods, as they measure different geophysical parameters than for instance magnetometers or ground penetrating radar. The relative detectability of geophysical contrasts with electrical methods of survey are to certain degree dependent on the relative moisture in the ground. This means that the relative success of a survey can be dependent on seasonal rainfall. If the subsoil is waterlogged, it might be difficult to detect a geophysical contrast, while such a contrast might be present after the ground have been left to dry out in periods without rain (Clark 1996; Gaffney and Gater 2003; Schmidt 2009, 2013). Electromagnetic instrumentation, electromagnetic induction, can measure the apparent electrical conductivity without the use of probes, which can speed up the data gathering speed**.**

2.1.2.4 Electromagnetic methods of survey (ground penetrating radar and electromagnetic induction)

The most used electromagnetic measurement techniques in archaeology includes electromagnetic induction (EMI) and ground penetrating radars (GPR). Ground penetrating radar functions on the principle of transmitting electromagnetic energy into the ground, and measure the time it takes for some of this energy to be reflected back to a receiver, as well as the strength of the reflected energy. The property that governs if the energy is reflected, is mainly contrasts in the electrical conductivity and to some degree the magnetic properties. Contrast in electrical conductivity is mainly caused by variations of the soil moisture (Conyers 2012; Conyers 2013, 2016). The method is explained more in detail in article two, page 192. Each pass create a profile of the subsoil, mapping and visualizing the reflections with depth along a transect. Such profiles are called radargrams, and are often referred to as GPR sections or profiles. By slicing a series of closely spaced radargrams at a set depth, it is possible to create maps of all reflections over an area at a given depth. Such slices are usually called depth slices or time slices. GPR can provide very detailed maps of the subsoil, and also provide important geoarchaeological information on site formation processes and landscape characteristics (Conyers 2016; Schneidhofer et al. 2016). GPR provide high-detailed information on both depth and geophysical characteristics of features in the subsoil. Modern instrumentation can gather large datasets of up to 2-7 hectares a day (Trinks et al. 2010b; Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology 2013b; Trinks et al. 2014). For a more in-depth knowledge on GPR for archaeological purposes, I will refer to the books “Ground Penetrating Radar for Archaeology” (Conyers 2013), “Interpreting Ground-Penetrating Radar for archaeology” (Conyers 2012) or “GPR remote sensing for archaeology” (Goodman and Piro 2013). The archaeological interpretation of GPR data can be difficult (see section 7.6.7 for a case study). While GPR provides high-detailed information on features and layers in the subsoil, it is not always a straight-forward process to translate the observation of a geophysical anomaly into an archaeological interpretation. First of all, what generates the geophysical contrast in GPR data is to a high degree differences in the soil moisture content. Therefore, variations in rainfall influence the soil water content, which in turn influence the geophysical contrast. Layers and features not visible to the naked eye might still trap moisture and create a geophysical contrast detectable in GPR, and visible in depth slices and GPR profiles. The presence of highly conductive soils, such as marine clay, might attenuate much of, or all, of the electromagnetic energy, which in turn yields no energy return and subsequently no additional information on subsoil conditions (Conyers 2012; Conyers 2013; Goodman and Piro 2013).

Electromagnetic induction is a method where it is possible to measure both the apparent magnetic susceptibility and apparent conductivity simultaneously without direct soil contact. Depending on the instrument configuration, it is also possible to acquire datasets from several depths from both geophysical properties. By magnetizing a volume of soil by generating an electromagnetic field, this creates an effect in the ground creating secondary electromagnetic fields due to the presence of electrical conductors or magnetic features in the ground. These effects are recorded by a secondary receiver coil, where the in-phase components is found to respond mostly to changes in the magnetic susceptibility, while the quadrature (or out of phase) response is mostly due the electrical conductivity.

Modern instrumentation are capable of gathering several datasets at multiple depths simultaneously. The method can be a good alternative to both earth resistance, GPR and magnetometer-surveys, and have shown to provide good data from sites where magnetometer-surveys were less informative due to strongly magnetic bedrock. Relatively large areas can be covered with GPS guided, towed arrays. Coverage up to 6 hectares is known, depending on survey resolution (Bonsall et al. 2013a; Bonsall et al. 2013b; De Smedt 2013; De Smedt et al. 2013; Bonsall et al. 2014). Electromagnetic induction (EMI) sensors can be very prone to drift, where readings over the same spot can change due to changes in temperature and electronic drift. Also, electromagnetic induction is strongly influenced by the presence of metallic objects and external electromagnetic fields (such as powerlines, electrical wires, etc.). The electrical conductivity must be ≤100 mS/m, which equals to very saline conditions and very conductive clays. In very conductive environments, the measurement of the apparent magnetic susceptibility (the in phase, or IP part of the signal), might be influenced by the electrical conductivity of the soil. This creates a situation where it is difficult to distinguish exactly what kind of physical properties it is you are measuring (Clark 1996; Clay 2006; Callegary et al. 2007; Beamish 2011; De Smedt 2013; Delefortrie et al. 2014; Meirvenne 2015). For additional information, please consult (Scollar et al. 1990; Clark 1996; Simpson 2009; De Smedt 2013; Meirvenne 2015).

In this thesis will metal detecting not be discussed. Although a metal detector is an electromagnetic geophysical instrument, their main use is on locating artifacts and not archaeological features as such (Schmidt et al. 2016). While the distribution pattern of archaeological objects is a way to locate and identify archaeological sites and monuments, which in itself is highly interesting application of geophysical instrumentation, this field of research will not be given any additional focus in this thesis.

2.2 GEOPHYSICAL SURVEYS IN NORWEGIAN ARCHAEOLOGY

Since 1968, at least 293 geophysical surveys have been conducted as part of 237 different archaeological projects spread around the country of Norway. The number of surveys performed has increased within the last four decades, and especially within the last decade. Close to half of all surveys and projects were conducted within the last five years- 139 surveys as part of 119 projects. This corresponds well with two significant processes: the main data gathering phase of the Norwegian part of the LBI ArchPro project which started in 2010, as well as the beginning of the PhD-work for this thesis. The latter commenced in autumn 2011. These figures, as well as the data presented figure 1, are updated figures until the end of 2015 compared to the figures presented in article one. The following section are, together with article one, related to objective one (see section 1.1 - “Aim and Objectives”).

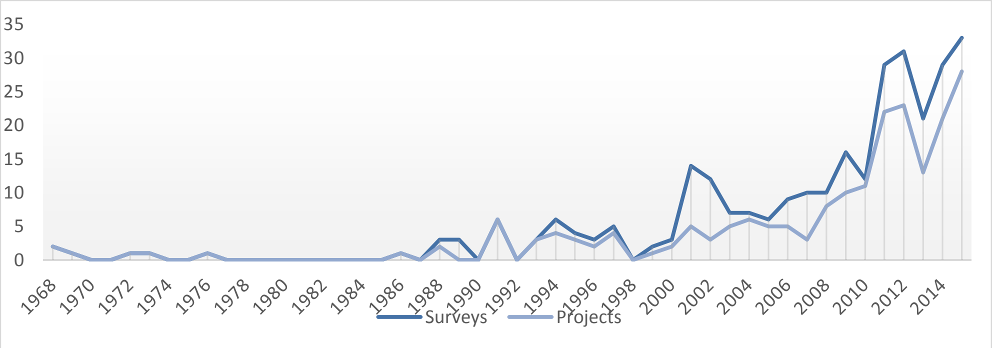


Figure 1: The number of geophysical surveys and projects in Norwegian Archaeology by 01.01.2016. Total number of surveys is 293, and the number of projects they are involved in is 237. These figures are updated since the printing of article one.

The increase in the total amount of surveys mirror a comparable development in Sweden within the last decade Viberg et al. (2011:95-96); (Gustavsen and Stamnes 2012; Viberg 2012). The following presentation will not go through each and every known survey, but will focus on examples that is considered representative for the development and use of archaeological geophysics in Norway. Several of these examples have earlier been discussed in Gustavsen and Stamnes (2012) and Stamnes and Gustavsen (2014, article one), where the latter acts as a quantitative analysis and review of the geophysical surveys conducted on archaeological sites, monuments and landscapes in Norway. Both articles are based upon information from the same database. Please note that the numbers presented in the beginning of this paragraph differ from the numbers presented in the articles mentioned. This is mainly due to more surveys being performed since the publication of these articles, as well as additional examples of earlier surveys have been identified in various archives and publications. The database, named "AGIN - **A**rkeologisk **g**eofysikk **i** **N**orge" (**A**rchaeological **g**eophysics **i**n **N**orway, my translation), has been compiled and is managed by Lars Gustavsen at NIKU and the author of this thesis, Arne Anderson Stamnes at the NTNU University Museum in Trondheim. It is currently a shared database between the two institutions, and is at present publicly available on request.

Two of the earliest known geophysical surveys are from 1968. In April 1968 the archaeologist Asbjørn Herteig included what he calls conductometric measurements as part of an investigation of an early medieval market place in Kinsarvik in Hordaland. It is unclear what kind of technical hardware this represents, but it seems to imply some form of electromagnetic conductivity measurement or earth resistance survey. The surveys indicated two significant anomalies, where subsequent excavations proved one to be modern pieces of metal buried within a medieval wall construction, while the other anomaly was proven to be of greater archaeological significance- originating from burnt material, concentrations of soapstone and a wall foundation of stone found during subsequent excavations (Herteig 1968). The other survey conducted the same year was in relation to an archaeological excavation at Stødleterassen in Etne Municipality in Hordaland. Here, the archaeologist Bjørn Myhre performed a magnetometer-survey on a flat terrace between two burial mounds and found two cooking pits (Myhre 1968). Another early example of successful application of a geophysical method was the proton magnetometer mapping of an iron production site from the early Iron Age at Hoset, Stjørdal Municipality in Nord-Trøndelag. The survey successfully delineated a slag heap, and indicated the location of the associated shaft furnace remains on site (Farbregd 1973, 1977).

The period from 1976 to 1986 have no known surveys, until an investigation took place in relation to the excavations of Borg in Vestvågøy in Nordland county. This site has until this date still the longest and largest known Iron Age house discovered in Scandinavia, where the excavations revealed the remains of a house later rebuilt to become 83 meters long and 9.5 meters wide. The geophysical part of this investigation was a 3000 m² magnetometer investigation, with the intentions of gathering detailed information on the settlement site before commencing with the excavations of the complex. The interpretation soon proved to be problematic, as there was a large amount of metal refuse in the topsoil, as well as large magnetic variations from the bedrock on site. When the site was later excavated, they found some correlation between some of the excavated features and geophysical observations. However, the magnetometer investigation was not detailed enough, both in regards to data gathering and presentation, to be used to say anything additional concerning the character and delineation of the settlement area. In addition to the magnetometer survey, they collected soil samples for analysis of phosphates as well as magnetic susceptibility. The analysis of the magnetic susceptibility of the collected soil samples indicated an area of burning interpreted as either the use of burning possibly relating to clearing the area of vegetation before erecting the oldest settlement structures found on site, or a burning of an older settlement structure before constructing the buildings found during the excavations. The analysis of magnetic susceptibility therefore gave additional information to the discussion of site formation at Borg (Arrhenius and Freij 2003).

In the years 1988 and 1989, The *Borre project,* a research project led by the Museum of Cultural History (KHM) in Oslo, initiated the geophysical investigation of three burial mounds in the Borre park, Horten municipality in Vestfold. The goal of the investigations was to localize and investigate a ploughed out burial mound which exact location was not known, called "Skipshaugen" *(Eng. The ship mound, this author's translation).* In addition to this, they wanted to learn more of the inner construction of two existing large burial mounds within the park in a non-intrusive manner. The ship mound site was investigated by a magnetometer which was performed by the company Geomap, and ground penetrating radar (GPR) survey performed by the company Noteby A/S, which indicated physical contrasts in the ground related to the presence of a burial mound. As the case at Borg, the results was not perceived as good enough to indicate much of the site's character, while later excavations proved partly a correlation between geophysical anomalies and archaeological observations. The ground penetrating radar sections through the two mounds, on the other hand, proved more informative, and indicated the remains of earlier intrusions in the mound as well as other construction details of the inner construction of the mounds (Myhre 2004, 2015:39-41).

During the decade between 1990 and 1999 over 71% off all surveys in time period (20 out of 28 recorded surveys) was performed by the geologist Richard Binns – using a magnetometer on several sites all over the country. Binns investigated, among other sites, the courtyard sites of Værem, Grong municipality in Nord-Trøndelag and Mo in Brønnøy municipality in Nordland (Binns 1993; Binns 2000:16-18). The general tendency from the earliest surveys during this century is dot-density plots and relatively poor spatial resolution and tie-in information compared to modern standards. While the data might be good, the technical possibilities for georeferencing and data presentation was still limited, which reduced the archaeological applicability of the gathered data. Still, the surveys could yield interesting archaeological information, such as cooking pits and the geophysical response from house foundations and burial mounds at Tilrem and Mo (Binns 2000). At Frosta, in the area where the famous Frosta Thing were held annually for several hundreds of years, Kari Støren-Binns and Richard Binns gathered a large amount of data from several areas – covering 48 000 m² in total. The recordings were hand-logged manually, pushing a button for every reading, making this time consuming. Some of the archaeological results from this survey includes a burial mound as well as traces of an area of charred stone (NO: koksteinslag). The area of charred stone was dated to the 13th century AD, and is probably remnants of a Viking-age or early medieval farmstead, making this observation one of the first observation in Norway of this phenomenon with geophysical methods. While encountering several interesting observations, the actual location of the thingstead was not found following their investigations (Binns 1997).

In 1997 a ground-penetrating radar (GPR) survey was performed on the burial mound Halvdanshaugen at Stein, Hole municipality in Buskerud. This is one of the largest burial mounds in Norway, measuring 55m in diameter and is over 5.5m tall. The survey was initiated after it was observed that the central parts of the mound might be about to collapse. This was interpreted as an indication that parts of the mounds interior or construction elements might have rotted away or collapsed. The surveys indicated geophysical anomalies within the mound which could be interpreted as forming the shape of a boat or ship, which led to speculations that the mound might contain a ship burial which was about to deteriorate. A more systematic investigation in 1999 registered additional anomalies. While several of these anomalies seemed to be in relation to each other, it was difficult to understand what they represented. The somewhat unclear results was explained by the subsoil of clay, which made the interpretation of the survey results difficult by attenuating the electromagnetic signals, leading to a lack of penetration into the mound (Larsen and Rolfsen 2004:58; Pedersen 2004)

Challenging geological conditions were also encountered at the Kaupang-investigations in Larvik municipality in Vestfold, which focused on a Viking age early urban settlement, which also had other functions with likeness to other Scandinavian "central places", such as trade, craftwork and the centrality of power (Skre 2007). In 2000 Richard Binns performed a magnetometer-investigation covering approximately 20 000 m². Initially, parts of the area was surveyed with a relatively low resolution (1m traverse interval, 0.5m in line spacing). The initial survey was followed by a more detailed investigation of areas which gave interesting information. The surveys identified pits, areas of slags and a possible earlier beachline, but background noise from the igneous monzonite or quartz-monzonite bedrock made it difficult to properly identify clearly archaeological features in the data. Three years later, the survey was followed up by a 6100 m² GPR survey over three different areas. One area in particular revealed interesting anomalies and observations which was confirmed as archaeological of origin – indicating the potential of combining GPR and archaeological evidence to gain additional archaeological information of the extents of cultural deposits (Pilø 2007:149-151).

In 2003 The Museum of Cultural History (KHM) in Oslo initiated a magnetometer and GPR survey in connection with an archaeological excavation of an iron age burial site at Gulli in Tønsberg municipality in Vestfold. The bedrock in the area is Rhomb Porphyry – which is of volcanic and magmatic origin. Sadly, few of the archaeological features known before the excavation commenced, as well as archaeological observations from the excavation, correlated with the geophysical results. This was explained by a rocky subsoil, which made it difficult to perform a uniform interpretation of the geophysical data. Therefore, illustrations from the geophysical investigations was not included in the final report (Gjerpe 2005). Knowing that the bedrock is magmatic rocks of volcanic origin help explain the problems with the magnetometer survey, but it is surprising that the GPR-investigation did not reveal any cuts from ring ditches that had surrounded the burial mounds or grave cuts from ships. The report mentions issues with (sometimes extreme) unevenness of the field, leading to problems analyzing the top 30cm of the dataset. As a consequence, the process of creating meaningful anomaly correlation with neighboring GPR profiles was considered virtually impossible. The dataset and GPR processing was not correlated for topographical effects (Lorra 2003), so this help explain the lack of response observed in the GPR-data. These datasets have not been re-examined and re-evaluated after the excavation.

Close to the burial ground at Gulli, another burial mound was investigated in the same municipality in the same field season of 2003- at the farm Rom Vestre. The survey was initiated by KHM and Vestfold County Authority, and performed by the company Allied Associates Ltd. in collaboration with the Institute of Geoscience at the University of Kiel. The bedrock in this area is also Rhomb Porphyric lava. The geophysical investigation involved both magnetometer and GPR instruments. The survey revealed traces of a ring-ditch as well as a central cairn, indicating the presence of a ploughed out burial mound where the ring ditch was close to 30 meters in diameter and the central cairn approximately 15 meters across (Lorra 2003; Martens 2003, 2009). While the geological conditions at Gulli gave geophysical responses that reduced the archaeological interpretability, the thermoremanent geophysical response from stones in the central cairn at Rom Vestre helped locate, delineate and identify this archaeological feature – showing that the magnetic response from rocks and stones sometimes can help in the cultural historical understanding of a site or monument (see figure 12).

At Gråfjell in Hedmark county, The Norwegian Institute for Cultural Heritage Research (NIKU) and The Museum of Cultural History in Oslo (KHM) performed a wide range of archaeological registrations and excavations in relation to the establishment of a new regional army firing range. NIKU was in charge of the culture historical registrations, while KHM performed the excavations in relation to the cultural heritage management part of the project. NIKU engaged the geophysicist Tatiana Smekalova from the Physical Institute of St.Petersburg in Russia (and later employed at the Moesgaard Museum in Århus, Denmark) to perform magnetometer surveys over 18 different sites between 2000 and 2002, and KHM engaged her in 2004 and 2005 for additional surveys. The surveys were a combination of scanning (or "free search") and detailed area surveys. Scanning is turning on the sensor and noting a change in the audio signal strength or observing changes in the readings on the instrument panel without recording the strength or position of the readings. The "free search" surveys helped locating roasting sites for iron ore, as well as delineating main activity areas of iron production. Not all investigated sites had the presence of interesting anomalies, which were taken as proof of the absence of iron production. The sites subjected to detailed investigations showed a good correlation between anomalies interpreted as roasting sites, slag heaps and furnaces, and the subsequent ground observations (Risbøl and Smekalova 2001; Risbøl et al. 2001; Risbøl et al. 2002a; Risbøl et al. 2002b; Smekalova and Voss 2002; Rundberget 2007:279-308; Larsen 2009:206, 221-223). See article four in this thesis for additional details.

In the later years, NIKU and The NTNU University museum in Norway have had a focus on the application of geophysical methods within archaeology, performing both research and taking on external projects in collaboration with other archaeological institutions. From 2010 NIKU joined the research collaboration called the Ludwig Boltzmann institute for Archaeological Prospection and Virtual Archaeology (*LBI ArchPro*), which is an ongoing project for the development of new technological and non-intrusive methods for documenting and identifying archaeological sites, monuments and landscapes. The methods applied during these projects involves both geophysical methods, as well as other remote sensing techniques such as aerial LiDAR scanning, terrestrial laser scanning and satellite imagery. This collaboration has led to large-scale geophysical investigations-mainly focused in Vestfold county. The county authority of Vestfold is also a partner in LBI ArchPro. Between 2010-2014 the project collected 327 (3.27 km²) hectares of GPR data, and 460 hectares (4.6 km²) of magnetometer-data, with more data collected during their 2015 campaign. The surveys involve additional surveys of the Kaupang area mentioned earlier, the identification of a collection of over 900 cooking pits at the farm Lunde on Tjøllingvollen close to Kaupang. The project also identified a Viking-age trading site at Heimdal – close to the Gokstad mound famous for the Gokstad Viking ship excavated in 1880 and the identification of settlements and a harbor area close to Borre, as well as other investigations at Tjøllingvollen and Slagendalen. In addition to the archaeological sites mentioned, several burial mounds and settlement traces was located within the surveyed areas, giving important methodical experience and archaeological knowledge. The project is still ongoing by the end of 2015, mainly focusing on the data processing and publication-phase of the project(NIKU 2011b; Bill et al. 2013; Bill and Rødsrud 2013; Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology 2013a; NIKU 2013b; Draganits et al. 2015; Schneidhofer et al. 2016). Two separate PhD-projects will focus on data gathered for the Vestfold case study through the LBI ArchPro collaboration.

NIKU has also invested in their own motorized geophysical equipment and trained personnel, and have conducted a range of surveys on sites all over the country. They have also collaborated with the Directorate for Cultural Heritage (Later refered to as "DCH", NO: Rikantikvaren) with investigating and assessing the preservation conditions of medieval ruins using geophysical methods on sites such as the monasteries at Halsnøy in Kvinnherad municipality in Hordaland county, Rein in Rissa Municipality in Sør-Trøndelag and Verne in Rygge municipality in Østfold county. In addition to these monasteries, the medieval ruins at Giske in Giske municipality in Møre- og Romsdal county and Kongsgården in Tønsberg municipality in Vestfold county have also been subjected to geophysical investigations (Meyer et al. 2014; NIKU 2014b; Directorate for Cultural Heritage 2015d).

The NTNU University Museum in Trondheim has had a research interest in the application of geophysical methods since the middle of the first decade of the 2000s. In 2005 the monastery of Munkeby was subjected to a geophysical investigation (Foosnæs 2009)In 2007 the museum initiated a collaboration with the company Earthsound Associates from Ireland. This led to several geophysical investigations in Mid-Norway, such as a multi-method survey of a large cropmark at Haug in Verdal municipality in Nord-Trøndelag (Barton et al. 2009), the 2nd world war prisoner of war camp in Falstad, Levanger municipality in Nord-Trøndelag (Stamnes 2012) and at the Iron Age centre of power and wealth at Avaldsnes, Karmøy municipality in Hordaland county (Barton 2010 as well as Stamnes and Bauer (article three in this thesis)). In 2009 the museum invested in their own geophysical equipment-involving magnetic, electric and electromagnetic methods, which was supplemented by a multi-antenna GPR system and an device for the measurements electromagnetic induction in 2015. The NTNU University museum also takes on archaeological geophysical survey assignments for other actors in the Norwegian cultural heritage management system, as well as act as a partner in research collaborations. In 2010 the museum performed a multi-method investigation of a ploughed out burial site and prehistoric boat houses at Gustad, Levanger municipality in Nord-Trøndelag. This work was a MSc project in collaboration with the University of Bradford, and showed how different geophysical methods could be combined to identify different geophysical properties of archaeological features in the subsoil. Certain features was visible in the data from all methods applied, but was also evident that one method alone would only reveal limited archaeological knowledge of the sites' constituent cultural historical features. By combining several methods, a more complete overview of the site was gained and therefore a combination of methods proved to be beneficial (Stamnes 2010a). The NTNU University initiated the first PhD project focusing on the application of geophysical methods within archaeology in Norway, which started in November 2011. This thesis is the result of this initiative.

3 THEORETICAL TOOLS AND PERSPECTIVES

To understand the current role, status and position of geophysical methods within Norwegian archaeology, Bruno Latours thoughts on *Actor-Network theory* (ANT) can provide us with a vocabulary and a theoretical background. ANT is an analytical approach that is applicable to study society's relationship to technology and other nonhuman actors (actants), and study the processes in which inventions or technology come into acceptance, or fails to be accepted (Latour 1987). If a new method or technology is to be accepted as usable and credible, then the methods have to "prove their worth". This process of getting acceptance can be seen as a moving from assertions or assumptions into facts, and is within ANT described as the process of *translation.* The process of translation is by Brattli and Brendalsmo (2016:61) defined as *"a process that regulates the relations of different actors in* ***networks****. These networks are the contexts in which some statements attain status as correct and true"*. These networks are a series of actors and actants that interact to support or denounce views and viewpoints in some way or form. It is possible to see the geophysical methods as a "new" actant within a knowledge constituting system – where the geophysical survey results might influence both the archaeological research as a network and the daily practice of cultural heritage management as another network (figure 2). By analyzing and understanding the associations, connections and the way geophysical methods have been entered into the networks of archaeological research and cultural heritage management, it is possible to gain new insight and knowledge of the actors understanding of the applicability of the methods as well as the actors acceptance of- and the role and function the actors designate to, the geophysical methods. The various networks therefore becomes important to investigate, along with the components they are made up of.

ANT is as a method that provides a useful insight and vocabulary, which is helpful to gain additional insight in the statements, documents, actions and viewpoints observed in the material presented in this thesis. Analyzing this information with this theoretical fundament also acts as a way to increase the viability of the presented results. This fits well with the aims of this thesis, and objectives one to four and eight especially (see 1.1. – "Aim and Objectives").

3.1 ACTOR-NETWORK THEORY (ANT) AND THE SOCIOLOGY OF TRANSLATION

Latour (1996) himself uses both the terms actor and actant for someone or something that is a source of an action, no matter if it is human or non-human entity. Latour stressed that he introduced the term *actant* to avoid the term actor as being understood as only human actors of influence (Latour 1996). In the book "Science in Action" he proposes to use the word actant to represent *"whoever or whatever is represented"* by a spokesperson. Another important aspect is that when an actant creates a change, it becomes a *mediator* (Nielsen 2011:7). By using these terms a county archaeologist is an actor, while a trowel, a GPR or the Norwegian Cultural Heritage Act become actants (i.e. nonhuman actors). I will, in the course of the following analysis, use the term *actor* instead of actant to denote both human and non-human sources of actions as well as participants within the networks to avoid unnecessary confusion of multiple terms. The term actant will be referenced to when it is used by other authors in their work.

The current organization of the cultural heritage management in Norway can be seen as a discursive network that applies knowledge from a wide range of scientific disciplines, each individually involving theories, methods, institutions, legislation, regulations, empirical knowledge and technology. Each part of the knowledge involved can again be seen as an actor that is understood and accepted as credible, and that is related to the other actors in one way or another. The size and relevance to each actor does not necessarily have to be equal in these two discourses, and one does not need to distinguish between human and non-human actors. It is not given who becomes an actor, neither is the properties they hold, but they become actors by being the reason or source of something happening. The Directorate for cultural heritage becomes an actor within the cultural heritage management network when issuing budgeting guidelines. The county archaeologist become an actor when handling a planning permission or performing an archaeological registration. The limits and extent of each discourse will to a certain degree be conservative, and the arrival of new theories, methods and technologies have to prove its relevance to be accepted in such a network. The theoretical framework that ANT provides can therefore be applied to investigate the various associations and connections that exists between different elements that together make up the phenomenon we want to study, and this phenomenon came to be through a compilation of these elements (Latour 1987; Schaanning 1996:77; Asdal et al. 2001; Brattli 2006; Brede 2011; Tuddenham 2015).

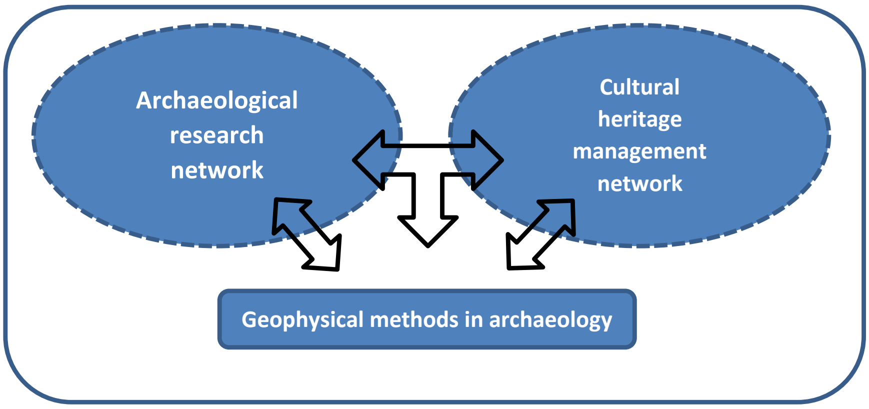


Figure 2: The networks of archaeological research and cultural heritage management

If we want to study the role and expressive force the use of geophysical methods have within the cultural heritage management system and archaeological research in Norway, it makes sense to investigate the roles of various actors within this discursive network. Any statements from these actors on the use of geophysical methods, says something about whether the methods have been understood and accepted by the same actors. To understand these statements, we can study them through the *sociology of translation*- which is a way in which a way of understanding the genesis and constitution of components that are considered as credible. This then becomes a process in which something or someone is ascribed properties, competence, vigor and position based on the networks they are a part of. This process is viewed by Bruno Latour (1987, Schaaning 1996:77, Brattli 2006:40-41) as a set of steps of claims, or statement modalities (NO: utsagnsmodaliteter) listed in table 1.

Table 1: List of statement modalities

Statement modality level	**Type of statement**	**Example of statement**
1	Speculations and guesswork	”Maybe X should be…”
2	Uncertain claims	“It is claimed that X…”
3	Assumptions	“It is usual to assume that X…”
4	Facts	“X is as known…”
5	Un-themed assumptions	“We used X to…”

According to Latour (1987), the goal of science is to move claims from type 1 to type 4 or 5 by getting them accepted in an uncontested manner. This process is called "translation". A statement modality on level five then becomes a *black box*, a statement, attitude, method, instrument or practice so stable and accepted that it becomes difficult to challenge (Latour 1987:2-3; Tuddenham 2015:25). No-one challenges the use of the ^{14}C to date organic material or the possibility to stream a movie on your phone anymore. The technology behind that makes these feats possible is hidden and no longer questioned, or "black boxed" in the process. When something has become a black box, it is being tied together of a range of actors who hold the statement together. If there are fewer controversies, then the box becomes even more black and in turn becomes even harder to open (Latour 1987:2-3; Tuddenham 2015:26).

Callon (1986:202-211) has listed 4 passing points in which the translation process moves through to get claims accepted:

Table 2: Levels of translation, after Callon 1986 and Brattli 2006:44-48

Type	**Process**	**Key points**
1.	The problematisation or how to become indispensable	Define aims and objectives, positioning in the network, establishing obligatory passing points
2.	The devices of "interessement" or how allies are locked into place	Fitting obligatory passing points with the networks interests. Positioning, increase influence, getting acceptance for claims/legitimacy, inclusion of actors in management
3.	How to define and coordinate the roles: enrolement	Building institutions, stabilization, eliminate opposite claims, and getting acceptance and increased legitimacy, strategy
4	The mobilization of allies: are the spokespersons representative?	Mobilization of resources and recruiting new participants to the network

The process of translation can in short be described as moving from defining relevant aims and objectives and position one selves within the network, and later fit the interests of actors in the networks to each other, and in this way successfully get acceptance for the inclusion of a new actor. These passing points should not be seen as a chronological movement from type 1 to type 4, but will be a more floating state moving through and between the passing points (Callon 1986; Latour 1987; Brattli 2006:44-48). An *obligatory passing point* is an actor that forms a privileged position in the network. The Directorate for Cultural Heritage, for instance, have a privileged position within the network of cultural heritage management in Norway by having been granted the authority to decide which sites and monuments are most valuable, the costs and expenses of budgets for archaeological investigations, distribution of funds. The Directorate also serve as a disseminator of knowledge, professional advice and practices (see chapter 4 and table 3). They can be said to be a *centre of calculation,* a point within a network where inscriptions are gathered and connected to other inscriptions (Latour 1987:232-257; Tuddenham 2015:29). An article or published work can similarly be considered as a *centre of calculation.*

Science works by confirming results, and these are being adjusted and adapted through influence from the research community and its surrounding environments (Callon 1986; Latour 1987:12; Svestad 2003:32). The process of getting the scientific results or a new method or piece of technology accepted can also be studied in the same manner. This makes it interesting and worthwhile to study how the introduction of the actor of archaeological geophysics, with its associated results and knowledge, might change or influence the two networks of archaeological research and cultural heritage management in Norway (see figure 2), as well as studying how the two networks influence each other. The benefits, possibilities and restrictions can be understood from both the geophysical results and the relationships to other actors in the network, which opens up for a discussion of the consequences of introducing geophysical methods within these networks.

3.2 TRACING NETWORKS, AND THE ROLE OF DOCUMENTS

One way of using ANT is *"to describe, to be attentive to the concrete state of affairs, to find the uniquely adequate account of a given situation"* (Latour 2005:144; Nielsen 2011:5). By giving an exact account of any given situation, you can start tracing associations between various actors. In this lies information on how the actors relate to one another- their inherent associations and how actors are aligned, transformed or mobilized. Latour (2005:109) also point out that learning ANT is *"nothing more than to become sensitive to the differences in the literary, scientific, moral, political, and empirical dimensions"* of two types of accounts.

Latour describes an actant as constructed by a network of associations. An actant therefore becomes defined by what is being said about it, and what it is associated with in connection with other actants (Latour 2005:222). In line with this chain of thought, then geophysical methods in archaeology as an actor, is defined by what others say about them and how they are associated with other actors with the networks of cultural heritage management and archaeological research. It is therefore of interest to trace these connections and associations with other actors. In this study, this involves analyzing how actors within the two networks of archaeological research and cultural heritage management define the role, potential and possible usage of geophysical methods. Which networks are associated with others, and how are these connected are questions that is important to document. As Latour puts it: *"…to explain (..) consists in connecting entities with other entities, that is, in tracing a network"* (Latour 2005:103). Such an analysis will also reveal statements where definitions, roles and potential are envisioned differently.

In this lies several *controversies* and controversies are good sources of information. A controversy can be seen as something, a viewpoint, a bit of science, or method not yet stabilized – where actors disagree (Venturini 2010). The presence of multiple disciplines, or multiple understandings of an actors' role and function, can create boundaries, or *controversies,* used by the different systems of narrative constructions (Khazraee 2013). Nielsen (2011:7-8) considers a controversy as present as soon as someone decides to question or investigate the representatives of another actor-network, or within the same network. The fact that I in this thesis decide to investigate or question claims set forth by other institutions, is in itself a controversy seen from this viewpoint. It is possible to gain additional insight by tracing differences in the perceived role of geophysical methods by identifying and investigating such tensions, or *controversies.*

The concept of *modalities* is important for how statements are constructed, and to understand statements from an analytical point of view. I have earlier shown how statement modalities can help to categorize a statement in several steps from speculation and guesswork to un-themed assumptions. *Modalities* is defined by Latour (1987:23) as sentences that modify or qualify another sentence. Seen in relation to levels of statement modalities (table 1), a statement on level 3 compared to a statement on level 5 is not totally stabilized, and supports themselves to other claims. For example a statement such as *" as we saw at the Tromsdalen site, possible iron roasting sites at Storbekken 1 could be* *indicated with magnetometers as strong positive anomalies of at least 50nT",* a claim on level three , is very much different from *"we used magnetometers to locate the iron roasting site at Storbekken 1"* – a claim on level 5. Latour (1987:23) define "***positive modalities** as sentences that lead a statement away from its conditions of production, making it solid enough to render some other consequence necessary"* and **negative modalities** as *"those sentences that lead a statement in the other direction towards its conditions of production and that explain in detail why it is solid or weak instead of using it to render some other consequences more necessary".* In our example above, the claim on level 5 that the reason for magnetometers as applicable for locating iron roasting sites are not mentioned, moving the statement away from its condition of production. This is therefore classifiable as a positive modality. The claim on level 3 refers to an observation in data from another site, which is used to support the claim, and can therefore be classified as a negative modality. The status of a sentence is therefore related to how it is placed in relation to other sentences, and that a sentence on its own is neither fact or fiction, but is made to either fact or fiction by others later (Latour 1987:22-28; Brattli 2006:40).

The various documents mentioned in chapter 5 ("Strategic Documents, Communications and Initiatives") are vital sources of information, as they contain information on how these actors relate and ascribe function to geophysical methods (statement modalities - table 1), and their acceptance of such methods (level of translation - table 2). As it is inherent in the ANT method that it is necessary to relate to associations already made, it follows that this part of my investigation is tied to the contents of these documents. As Nielsen (2013:142) has pointed out- all text, including governance policy documents, convey meaning and opinions, and store and transmit information. By storing information, documents can become active and mediating parts in social life. The documents contains inscriptions, and the documents in turn becomes actants in the networks where the documents might play a role (Latour 2005; Nielsen 2013). Also, documents and academic sources can act as means of attaching strength in arguments and function themselves as actors in ongoing scientific debates, i.e. they can be as a device of interessement and enrolement for getting acceptance for a claim and increase the legitimacy of it (see table 2). There is strength in a well-presented and sound argument, a strength that can be advanced and activated by being put forth by a public agency or in peer-reviewed international journal (Schaanning 1996). Published survey reports and peer-reviewed articles therefore act as important empirical reference material, and add additional support for any opinions and suggestions made by actors.

3.3 NORWEGIAN CULTURAL HERITAGE MANAGEMENT AS A NETWORK AND *THE CULTURAL HERITAGE RESOURCE*

The practice of cultural heritage management in Norway is a system involving a range of various actors, each with their own role, position, intuitional affiliation, scholarly and professional interest and responsibility. The most important actors and their role and responsibility are of The MoCE, The DCH, The county authorities, the Sámi parliament, the Regional Archaeological Museums, municipal authorities and NIKU (see table 3). In addition, various developers, local museums and others with a specific interests, can also become actors with opinions related to cultural heritage issues and its management. The latter could for example be politicians, various media or private individuals. The main actors, their role and responsibility, as well as means and political instruments for influencing the cultural heritage management is summed up in table 3 presented in chapter 4 (see also Article one, pages 19-21). There is a range of institutions that become actors in the two networks of cultural heritage management and archaeological research. The university museums have been given a role within the Norwegian cultural heritage management network and within archaeological research – being responsible for all archaeological excavations, as it is seen as important that to have a close connection between research environments and the executive management role to ensure a knowledge-based heritage management. The university museums also teach archaeology at a university level and performs and publishes archaeological research (NOU 2006:64; Proposition to the Storting 2007-2008:39; Directorate for Cultural Heritage 2011:2,16; Trøim and Johansen 2011; Holm and Myrvold 2012:12, 99-102; Proposition to the Storting 2012-2013a:36,41). NIKU also functions as a national center of competence in issues relating to cultural heritage management, and provides archaeological research as a private and independent institution. The various county councils are sometimes involved in research activities, but it is not defined as their main role (Ministry of Climate and Environment 1979; Gaukstad and Holme 2001; Directorate for Cultural Heritage 2015c). The network of cultural heritage management involves the government, the directorate for cultural heritage, all county councils, the archaeological museums, actors involved with development (private and public), land owners etc. In addition to this, the list of potential actors in both the networks of archaeological research and cultural heritage management quickly becomes quite long, and involves also statements, documents, monuments, sites, features, private individuals, published material, instruments and tools etc. In other words, the potential actors, human and non-human, can quickly become exhaustive.

Brattli (2006) argues that what the cultural heritage management is managing, *"the cultural resource"*, can be understood as a construction, a quasiobject defined as a mixed product of associations between various actants/partners (NO: *medspiller*) (Tuddenham 2015:iv and v). *"The cultural resource"* was created out of a notion of something from the past as inherently different from the contemporary as well as cultural something different from natural, and therefore considered valuable and worthy of a legal protection. Cultural heritage therefore appears as a consequence of these dichotomies, the sorting and differences between nature/culture and past/present (Brattli 2006, 2013; Tuddenham 2015:52). Brattli (2006) demonstrated through his analysis how *"the cultural resource"* underwent a transition from an object of knowledge to a non-renewable environmental resource. This transition was connected to a the introduction of the principle of sustainability as a basis for the cultural heritage management (Tuddenham 2015:30). *"The cultural resource"* can therefore be understood as several things: a symbol of identity, as a limited or non-renewable resource in the same manner as endangered species or oil, as a scientific research material and sources of knowledge on various aspects of past societies, as well as sources of valuable experiences and means of value creation. Sometimes it is only understood as material culture from the past (Brattli 2013:28).

This also means that the object being managed, *the cultural resource,* might not be limited to past material culture. Sources such as judicial sources, institutions, economy, politics and technological means, all become actors which influence what it is that the cultural heritage management, as a sum total of cultural heritage narrative, values and wants to protect.

The various institutions have a series of responsibilities, roles, experience, research and scholarly interest and institutional organization. The institutions also have different possibilities to explore scholarly interests and participate in debates. The presence of various institutions and their inherent interest and possibilities creates boundaries which can influence the way the cultural heritage management is being performed. While each actor perform their function and manage their responsibility within the limits they are constricted by, they also become a part of the greater cultural heritage management as a whole. What is perceived as important at one management level, might not that easily be implemented in practice at other levels. The way in which guidelines, directives and instructions are created and presented, does not necessarily represent the interests of other actors on another level or position. An example could be that expression and professional opinions in a circular response might not end up altering and changing the final outcome. Another example could be that an advice stated in a scientific evaluation programme might not end up altering the archaeological field practice. This could therefore create tension between the different actors as they try to integrate their practice and opinions into the way the cultural heritage management is being performed (Khazraee 2013). The final cultural heritage management narrative is therefore not only a sum total of the individual functions as stated in strategic documents and communications. The end result is the total narrative of their actual practice and the way the actors within the cultural heritage management perform their functions and responsibilities. The overall management outcome from interactions between the actors involved can therefore be different from the original intentions, advice and goals set by the government or the actors themselves. This also involves the integration of new research and field methodical knowledge, as well as the way actors within the cultural heritage management system chose to react to and implement strategic documents and communications, and how the actors perform their function and responsibilities.

3.3.1 The creation of new inscriptions – geophysical data, spokespersons and the translation process of archaeological interpretations.

If geophysical methods are to be recognized as useful, trustworthy, time saving or economically justifiable, then decision makers (actors) within the heritage management system and archaeological community need to accept these methods and their contribution as viable for whatever purpose the archaeological community envision. Put in simple terms, the methods needs to prove that they can contribute with cultural historical information that can be trusted and used within the reigning archaeological practice.

As presented in Article one, the use of geophysical methods within Norwegian archaeology has clearly increased within the last decades, and the archaeological community is faced with new sources of information in an increasing degree. It is therefore interesting to ask if phenomena within the heritage sector are about to created- phenomena which the cultural heritage management have not had to deal with in the same manner before. As it is possible with geophysical prospection methods to visualize and present physical properties in the ground, new objects are being created that can be interpreted as cultural historically important, or relate to cultural historical activity of some sort. Schaanning (1996:79) notes that nature, here understood as what is being detected by the instruments, is not something that is just lying around waiting to be detected, but rather something that is being constructed through the discourse it has as an object. The networks then also has a role of creating such objects. The information needs to be *translated* from geophysical data to sources of cultural historical information. As what is mapped is variations in the geophysical contrast in the subsoil, these variations in the geophysical properties do not gain a cultural historical value until someone interprets them as being important from an archaeological perspective. As Myklebust (2003:9) presents it: "*no object is a cultural heritage object until it is sensed and interpreted as such*". To use Latour's vocabulary: the researcher or operator takes into use *instruments,* which is used in an archaeological laboratory – the archaeological site, monument or landscape under investigation. Here, these *instruments* collect geophysical data, and the one that presents these data in a report becomes a *spokesperson* speaking on behalf of the geophysical data, and create *inscriptions* in the form of maps and illustrations over new objects that previously have been inaccessible or unattainable (Latour 1987:63-100). Also, the geophysical instruments themselves can also appear as a *black box,* where the use of advanced, and for many incomprehensible, technologies makes it difficult to evaluate the quality of the collected data and the validity of the *inscriptions* derived from this data. This validity is therefore segregated and moved away from anyone which wants to contest the inscriptions (Schaanning 1996:77). This point of segregating and making the possibility to verify the validity away from the actor is good reason why it is recommended standard practice to present raw data plots and summary statistics in geophysical reports (David et al. 2008; Schmidt et al. 2016). By presenting the raw data, others can inspect and validate any interpretations made. Access to raw data or the possibility of redo a survey makes it possible to examine and reevaluate any archaeological interpretations made by geophysical data gathering due to their non-intrusive nature, in contrast to regular excavations and destructive ways of archaeological documentation.

The creation of *inscriptions* and the role of the *spokesperson* is therefore important when evaluating the value of a statement and the final acceptance of the result. Who makes the statement, and with what background knowledge, experience, professional training and understanding of the geophysical principles are they operating? Is the person making the statements capable of providing a trustworthy step from moving the collected from geophysical information to the indication and detection of archaeological features, observations and constructions? The value of such statements and the acceptance of the interpretation given by the *spokesperson* who speaks on behalf of the geophysical data, can have judicial, economical and/or managemental consequences. For instance: if a geophysical contractor interpret a geophysical anomaly as being the response from an Iron Age longhouse or ploughed out burial mound, this can create a legal protection as a cultural historical site if accepted by the cultural heritage authorities. The step that is made in translating the information from geophysical to archaeological information, and creating the inscriptions that do so, is therefore important. Being the spokesperson becomes a way in which a researcher can place himself in a position in the translation process as described by Callon in table 2 earlier in this text. Objects and observable phenomena are created through the use of technology. During this process, it is possible that the material preconditions for creating the following inscriptions in the form of maps, illustrations, interpretations, graphs or similar, with all the inherent controversies and uncertainties related to the creation of these inscriptions, are being pushed aside and ignored when the inscription is printed and presented (Latour 1987:79; Schaanning 1996; Myklebust 1997). It is therefore a great responsibility in the production and presentation of such inscriptions.

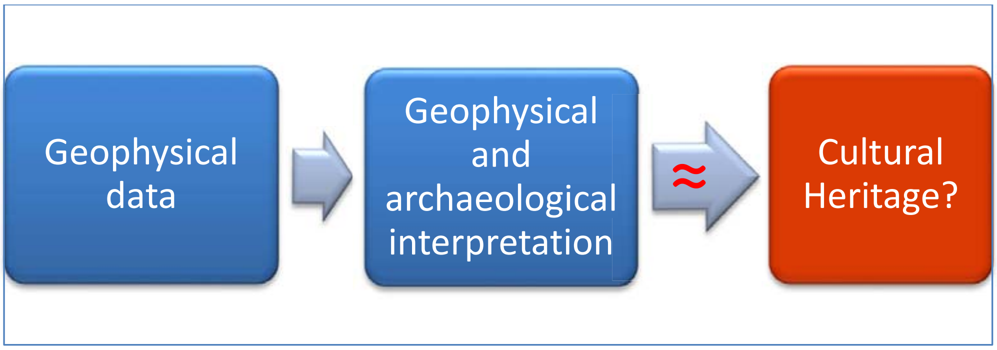


Figure 3: The transformation from geophysical data to cultural heritage.

Many controversies can be hidden within this process. The *spokesperson,* which makes a statement on behalf of the geophysical data or on the applicability of geophysical methods, becomes a central character in the process of *translation.* By taking part in this process, the *spokesperson* will also be in a position where he or she can position oneself within the existing networks, and try to fit the interests of other actors towards mutual goals or interests of the inherent research project or the importance of the results derived from the geophysical data. This could for instance be NIKU stating that "*these* *are methods that* ***will give*** *very good results for the registration of archaeological sites and monuments both on and under ground*” (NIKU 2008:6 this author's translation and highlighting). The same way of positioning can be claimed when article four concludes that magnetic geophysical methods are ideal for delineation and characterization of iron production sites (see article four). Being able to identify knowledge gaps, perform geophysical investigations, publish articles and participate in public fora are additional ways of participating in such networks. The *spokesperson* can establish *obligatory passing points* in the network (see table 2), and try to relate the spokesperson’s own interests towards the interests to others actors within the network. Being the one identifying and presenting potential future research areas can be a way of establishing obligatory passing points.

3.4 THE ROLE, FUNCTION AND STATUS OF GEOPHYSICAL METHODS

Objective two of this thesis is to investigate the role and status of geophysical methods within the cultural heritage management and archaeological research in Norway. This involves investigating the way in which geophysical methods have been described in the various documents presented in chapter 5, both in regards to statement modalities (table 1) and levels of translation (table 2). This will reveal how the role, function and status of geophysical methods is envisioned, and in this way becomes part of defining what geophysical methods as they are perceived in these documents, communications and initiatives.

The role, function and status of geophysical methods as envisioned within the actor-networks of archaeological research and cultural heritage management is traceable through analyzing how the methods are ascribed properties, competence, vigor and position in various statements in the analyzed documents. Also, following the construction of *the cultural resource* as potentially being perceived differently by various actors, the use of geophysical methods to indicate objects of research might not be the same as using geophysical methods for indicating of objects of management. The perceived role, function and status is therefore related to the success of which such methods could be used in this manner.

4 THE ORGANIZATION OF CULTURAL HERITAGE MANAGEMENT AND ARCHAEOLOGICAL RESEARCH IN NORWAY

4.1 THE NORWEGIAN CULTURAL HERITAGE MANAGEMENT SYSTEM

The present cultural heritage management system in Norway is a stately regulated. Archaeological practice is monopolized by the state, and a series of institutions have been given certain responsibilities following the Norwegian Cultural Heritage Act (NCHA) (Cultural Heritage Act 1978). The management of cultural heritage is based on an idea of sustainable management of important resources, where cultural heritage is seen as a limited resource to knowledge, vales of identity, experience and use, and esthetical values (Holme 2001). The general principle is the “polluter pays” principle, where whoever wants to excavate or destroy a protected site, monument or feature has to cover any expenses for the proper documentation by record. Certain exemptions apply, which is described in section 4.2. The NCHA states that all monuments, sites and features older than AD 1537 are automatically protected by law. This implies that all traces of human activity older than AD 1537 are automatically protected, no matter if the monument, site or feature have been discovered or not. This also has the implication that any unknown sites and monuments in the landscape still have a legal protection (i.e. site not yet to be identified). For underwater shipwrecks, and remnants from the indigenous Sámi populations, all sites and monuments older than 100 years are protected. For standing buildings, the legislation gives an automatic legal protection for all standing buildings older than 1650 (Cultural Heritage Act 1978). There is a set goal that the loss of protected sites, monuments and features should be minimized, and should by 2020 not be more than 0.5 percent annually. A representative selection should also be under legal protection by 2020 (Proposition to the Storting 2012-2013a:11). This goal has later been redefined so that the loss of cultural heritage sites, monuments and features should be minimized, without a quantitative percentage goal (Ministry of Climate and Environment 2016:20) The NCHA designates legal responsibilities to a series of administrative agencies. The cultural heritage management in Norway is performed through a collaboration between various institutions, which each has a role defined through the legislation and official documents (table 3). The judicial aspects will be outlined in section 4.2. The presentation and understanding of the roles, functions of, and judicial aspects relation to, these actors is important for the fulfillment of objective two (see section 1.1 - “Aim and Objectives”). Table 3 summarizes and explains the role and position of various actors within the Norwegian cultural heritage management System:

Table 3: Main actors in the Norwegian cultural heritage management, with their role, responsibility, means of influence and political instruments

Actor	Roles and responsibilities	Means and political instruments
Ministry of Climate and Environment (MoCE) (NO: Miljøvern-departementet, MD)	Overarching responsibility for the Norwegian Cultural Heritage Management. Enunciates political goals and instruments based on the Government's expressed politics. Ensures that the governmental offices and agencies follows the goals and strategies passed by the Government.	Delegation of responsibility and authority, and acts as a complaints' board for any decisions made by the heritage management. Give general statements on the cultural heritage act and the planning and building act. Release propositions to the Storting (NO: Stortingsmelding), organize , as well as circulars and guidance documents related to relevant judicial sources, as well as an annual letter of assignation with the responsibilities and economical framework for the Directorate for Cultural Heritage, Can influence the preparation of laws, circulars and preparatory work, as well as politics and heritage philosophy.
Directorate for Cultural Heritage (DCH) **(NO: Riksantikvaren, RA)**	Professional secretariat and the executive head of the cultural heritage management in Norway. Advisory functions to the Ministry of Climate and Environment, and is set to administer and execute the politics the Norwegian parliament (Stortinget) and Norwegian government has decided. Shall also procure and distribute knowledge on cultural historical monuments and buildings, as well as heritage environments, applicable methods and tools.	Make decisions on conditions for the protection orders of sites and monuments. Influence and approve budgets concerning investigating and securing/safeguarding of sites and monuments, as well as project plans. Developing budget guidelines for the county authorities and regional archaeological museums. Decide on terms for granting of exemptions to the cultural heritage act. Develop strategies and priority areas, and disseminate research- and development funds or wishes and needs from other actors. Input to the county authorities on general expectations and prioritizations through their annual letter of expectation/prioritization. Delegate funds and support for research initiatives.
The County Authorities	Norway is divided into 19 counties. Oslo is regarded as both a county and a municipality, and performs the same cultural heritage functions as a county authority. Responsible for regional-political planning, has the responsibility for the handling planning permissions and the coordination of the economic, social and cultural activity in the counties based on information from the state, the counties and the local municipalities. Has delegated responsibility according to the Norwegian Cultural Heritage Act and is the regional administrative organ. Is the first-line contact and information source for further treatment in the Norwegian administrative system. Perform any archaeological registrations following the NCHA §9	Register and document cultural heritage sites and monuments. Raise objections to any planning decisions made. Can influence how they choose to perform their responsibilities through strategic and professional choices.. This is also valid in relation to the choice of registration and archaeological field methods. The county authorities often participate in dissemination projects in collaboration with private individuals, land owners or other institutions. Give professional feedback to the Directorate through responses to circulars

The Sámi parliament	The Sámi parliament has the same responsibility as the county authorities for cultural heritage monuments, sites and landscapes defined as Sámi of origin, and which are older than 100 years. They employ their own cultural heritage offices, which represents the interests of the indigenous people. They are based in four regional offices in Norway.	This is the same as for the county authorities as stated above.
The Regional archaeological museums	There are five regional archaeological museums, each managing their own region. Perform archaeological excavations in their region following the granting of exemptions from the NCHA §8. They also have possibilities to perform additional archaeological research investigations, including excavations of archaeological monuments. The museums also manage cultural historical collections, perform research and dissemination. Give statements concerning the quality of documentation as performed by the county authorities. By being closely linked to the universities, education and research becomes central for the university museums. Should have an active role in following up the reigning cultural heritage politics.	The museums can propose methodical and procedural choices for documentation of cultural heritage sites and monuments. The participation of research programs and projects contribute to an increased knowledge base and professional development. The museums can influence the directorate and the county authorities through statements, hearings, circulars and research results. They can also conduct their own archaeological research investigations.
Municipal authorities	The local municipalities have no authority or direct responsibility according to the cultural heritage act, but are central collaborators through caretaking, protecting and managing sites and monuments. This can be through their treatment of development plans. They have a responsibility to ensure the care of cultural heritage sites and monuments in relation to planning decisions.	The local municipalities can be active collaborators and participants in research, dissemination and management projects. Cultural heritage sites can be a local resource for tourism and business. Active part of the planning of the land-use part of the municipal master plan.
Norwegian Institute for Cultural Heritage Research **(Norsk Institutt for Kulturminne-forskning - NIKU)**	NIKU is a separate and independent institute for research- and development relating to cultural heritage. NIKU acts as a national centre for competence in issues regarding cultural heritage management, including conservation, technology and methodology. It acts as a consultancy to any cultural heritage management body. It is a private institution, but manages, through license from the DCH, medieval monuments in the major medieval towns and cities, as well as clerical buildings and monuments from this period.	Performing and publish research, participating in local- regional and international research collaborations and disseminate results from research on priority areas. Develop research programmes and strategic programmes. Through their development and evaluation of theoretical and practical knowledge on archaeological issues, NIKU acts as an important contributor to research on cultural heritage management, conservation technology and methodology.

Content in the table is based upon Ministry of Climate and Environment (1979), Gaukstad and Holme (2001) and Directorate for Cultural Heritage (2015c).

4.2 THE JUDICIAL ASPECTS OF GEOPHYSICAL SURVEY RESULTS - IMPLICATION FOR THE CULTURAL HERITAGE MANAGEMENT IN NORWAY

It is important to clarify the legal and judicial implications geophysical survey results have, as well as which administrative agency have the responsibility of assessing and including the geophysical survey results in any part of their cultural heritage management. It is also of interest to clarify to what extent the Norwegian legislation open up for the inclusion of non-intrusive methods as part of the daily cultural heritage management relating to the process of administering archaeological registrations as part of the handling of any planning applications.

4.2.1 Cultural Heritage Management Legislation in Norway

The Norwegian Cultural Heritage Act (NCHA) of 1978 (§4, subsection 2) states that all monuments and sites older than AD 1537 are automatically protected, and further that this the term "archaeological and historical monuments and sites" is defined as all traces of human activity in our physical environment, including places associated with historical events, beliefs and tradition (§2, section 1) (Cultural Heritage Act 1978). This implies that all archaeological monuments, sites and features are automatically protected no matter if they still remain unknown and have not yet been recognized or discovered.

The NCHA § 3, first paragraph contains a prohibition against disturbing monuments and sites. When a public or large project is being planned, the developer or person in charge of the project has a duty to ensure that it will not affect an automatically protected monument or site, and does so by sending the plan for the project to the appointed authority, which will be the relevant county authority or the Sami parliament (Cultural Heritage Act 1978: §3). Who the appointed authority is stated in Circular H-2/14 from the Ministry of Local Government and Modernisation, part 2.2.1. If national values are threatened, and the county authority or Sami parliament does not raise an objection to the plan, then the Directorate for Cultural Heritage (DCH) can do so (Ministry of Local Government and Modernisation 2014).

The NCHA §8 concerns the granting of permissions to proceed with a development when they are in a conflict with automatically protected archaeological sites and monuments. This is done by applying for such an exempt from the law to the correct governmental body. It is the DCH which has the overall responsibility, but it is the county authority, the Sámi parliament, NIKU by appointment from the DCH or the police who initially are to receive the application. The regional archaeological museum also issues a letter of professional advice, and a project proposal and a budget for an archaeological excavation. Based upon the received information the DCH can issue a permission for an exempt of the NCHA §3, and the terms under which such an exempt will be granted. This could be for instance the permission to remove an automatically protected site or monument after an archaeological investigation has taken place or a dispensation has been granted without any terms and conditions for excavations (Cultural Heritage Act 1978; Ministry of Climate and Environment 1979). The NCHA §8 section 2 concerns the course of action when an automatically protected archaeological site or monument appears as part of ongoing development, and states that all work should be stopped and a notice should be sent immediately to the correct governmental body (Cultural Heritage Act 1978: §8, section 2). This has practical implications for the developer in case of any unsuspected halts in the progression of the development, and therefore illustrates the potential outcome if cultural heritage sites, monuments or features are missed during the evaluation process of the planning permission.

The NCHA §9 states that the administrative agency in charge has a duty to investigate if a development plan would influence any automatically protected site or monument in any way. It is not stated how the monuments and sites are to be identified, delimited or investigated, although some indications exists. According to the preparatory work for the NCHA entitled "Om lov om kulturminner" (Ministry of Climate and Environment 1977-1978) it is stated that the administrative agency responsible for an assessment can charge the developer for any expenses related to necessary controls, inspections, samples of the subsoil and archaeological excavations (Kahn 2007:199). How any controls, inspections, samples of the subsoil and archaeological excavations are to be undertaken, is up to the county authority to decide, following a professional judgement as stated by the NCHA §4. The decision by the administrative agency of whether a monument or a site is to be seen as automatically protected is decisive, unless "*evidence is submitted to the contrary*" (Cultural Heritage Act 1978:§4, section four). It does say, however, in the Public Administration Act state that "*The administrative agency shall ensure that the case is clarified as thoroughly as possible before any administrative decision is made*" (my underlining) (Ministry of Justice and Public Security 1967:§ 17). What the phrase "as thoroughly as possible" implies is a question of professional judgement. Any actions taken to find a solution that is sound and gives the necessary information must be weighed against other factors when clarifying a case. Such factors can be the cultural historical, scientific and social value of the monument, the preservation condition of the monument and the cultural historical landscape, as well as the societal use or need of the proposed development, its size and other economic concerns (Kahn 2007:178-185). For additional discussions on professional judgement as part of the cultural heritage management, see section 4.2.3.

§10 of the NCHA concerns the expenses involved in investigating automatically protected monuments or sites or in implementing special protective measures. Any expenses should be borne by the initiator of the project if they are considered more extensive following the polluter pays principle. Expenses for less extensive private projects can all or in parts be met by the state, if they are unreasonably heavy for the initiator of the project (Cultural Heritage Act 1978: §10). It should be a close link between the expenses related to any archaeological work and the planned activity. There should also be a close relation between the size of the expenses and the extent of the planned development (Guribye and Holme 2001:92-93; Kahn 2007:199 and 200). The circular "Dekning av utgifter til arkeologiske arbeider ved mindre, private tiltak" defines what kind of developments that should be considered less extensive private projects. A general principle is that the development should only influence one or a limited amount of users or properties within normal standards for that type of development to be considered a less extensive private project. If the purpose of the development is primarily of commercial character for rent or sale, and not own use, then it is likely to be considered a more extensive, and should be covered by the developer. When it comes to the clearing of new land for cultivation, any size of newly cleared land under 15 decare (0.15 hectare) is considered a less extensive private development. Laying out new farm roads or maintaining existing farm roads can count as a less extensive private development if they do not exceed road lengths of three kilometres over a time period of five years. The same applies to drainage work on agricultural land being less than 10 hectares (Ministry of Climate and Environment 2007).

The NCHA § 11, section 1, letter a, says that the competent authority can, after notifying the landowner "*search for, record, take pictures of, maintain, restore, reconstruct, move or enclose an automatically protected monument or site and take the necessary steps to look after it or display it, including clearing the surrounding area*" (Cultural Heritage Act 1978).

The preparatory act concerning the division of responsibilities according to the NCHA kap 2 §9, state that the regional archaeological museums is to give their recommendation to any decision made by the county authorities related to the permission granted to any exempts from the NCHA. They are also to give a statement related to the quality of the source material and documentation used as a basis for the decisions made (Ministry of Climate and Environment 1979). As (Kahn 2007:202-203) notes, the developer must trust that any investigations performed as part of the initial assessment following the NCHA §9 is performed thorough enough for budgeting an excavation of an archaeological site or monument to avoid unexpected expenses. In practice, it then follows that the initial archaeological investigation performed by the county authorities following the NCHA §9 should be thorough enough so that the regional archaeological museums can plan an investigation based on the county authorities' assessment. This is important, as any work undertaken by the county authorities, i.e. archaeological registrations following the NCHA §9, has implications for other actors within the cultural heritage management system and the processing of the planning permission at a later stage. The regional archaeological museums assessment of the quality of the source material and documentation therefore acts as an additional quality control of the work undertaken. In case there are any disagreements if a registered site or monument is regarded as automatically protected, or any issues related to costs and sizes of budgets, this responsibility has been delegated to the DCH by the Ministry of Climate and Environment (MoCE) (Ministry of Climate and Environment 1979:chapter 2, § 9 and chapter 3 § 12, section 11 and 14).The developer can only be charged for the actual costs of performing archaeological registrations or excavations (Ministry of Climate and Environment 2011; Directorate for Cultural Heritage 2015e).

4.2.2 Conventions, treaties and charters – formal advice and implications

Norway has ratified several charters, treaties and conventions which are relevant for the way Cultural Heritage Management is being performed in Norway. With regard to their encouragement of using non-intrusive methods, the ICOMOS charter (ICOMOS 1990) and the Valetta Convention are of particular interest (Council of Europe 1992a).

The International Council on Monuments and Sites (ICOMOS) Charter for the Protection and Management of the Archaeological Heritage states in its Article 5 that "*it must be an overriding principle that the gathering of information about the archaeological heritage should not destroy any more archaeological evidence than is necessary for the protectional or scientific objectives of the investigation. Non-Destructive techniques, aerial or ground survey, and sampling should therefore be encouraged wherever possible, in preference to total excavation*" (ICOMOS 1990). The icomos charter refer specifically to archaeological excavations, and not preventive archaeology in regards to archaeological registrations (for instance following the NCHA §9) to identify and limit the conflict between a planned development and any archaeological sites, monuments or features present.

In 1992, the Convention on the Protection of the Archaeological Heritage was released by the Council of Europe. This convention is also known as the Valetta Convention, and has later been ratified by 41 countries (Council of Europe 1992a). Accompanying the convention is an "Explanatory Report" – a supporting document which can be regarded as a point of reference which can help clarify the meaning of any points in the convention and help to a uniform application (Council of Europe 1992b). In the convention, Article 3, paragraph i, letter b, it is stated that *"non-destructive methods of investigations are applied wherever possible" (Council of Europe 1992a).* The explanatory report explains that the article 3 of the convention is there to limit any damage to the archaeological heritage to that which provides scientific evidence. This article also emphasizes that *"excavation is to be regarded as the ultimate step in seeking information – not the normal method. Non-destructive methods are to be used wherever possible".* The latter part of this is something already stated in the ICOMOS charter *(Council of Europe 1992b).* The convention was created as a response to the increased threat to the archaeological heritage, imposed by growing large-scale development and illegal or undocumented excavations. Central to the development of the charter was two ideas: firstly, that archaeology should be part of the planning process – recognizing the importance of the archaeology at an early stage so that it can be communicated and preferably preserved. Secondly, the general introduction of a developer pays principle. These ideas were already rooted in Scandinavia at this time (Willems 2007). In my opinion, it is still uncertain how to interpret the section on non-destructive method, as it can be understood as valid as advice for cases where the alternative is to leave any archaeology untouched – i.e. research excavations where there is no development pressing forth some form of action. On other hand, the convention was created as a response to an increased threat to archaeological heritage through large-scale development and undocumented excavations. The convention can therefore be used to promote an increased use of non-destructive techniques, which can involve, and are not limited to, chemical prospection, satellite and aerial imagery, mapping schemes of standing monuments and geophysical methods etc. A question that arises here, is if this is in some way limited to certain activities – be they general planning and landscape development, information gathering and research investigations, or other activities that might impose a threat to the cultural heritage. The Chair of the initial group which drafted the convention was Dr. Gustav Trotzig, at this time employed at The Swedish Heritage Board and who later become a professor at the Archaeological Research Laboratory at the University of Stockholm in Sweden. He has said the following on Article 3 in an article following the announcement of the Convention: "*A new idea is that in the examination of monuments and sites non-destructive techniques must be used as far as possible, rather than excavation. This provision is rarely, if ever applicable to rescue excavations but it is a word of warning to over-zealous scholars*" (Trotzig 1993:414-415). This opinion that the provision is rarely, if ever applicable to rescue excavations, and indeed restriction to the understanding of the convention, has not been presented in the explanatory report for the convention (Council of Europe 1992b), and therefore has no legal implication as it is the wording, and not the intention, that has been ratified. Trotzig's comment also regards rescue excavation, but not the initial archaeological registrations process following the treatment of planning permissions. In my opinion, it is still uncertain if this is to be understood so that the article is only valid until, within the current Norwegian Cultural Heritage Act, an exemption to the law is granted for the excavation and removal of an archaeological site as the ultimate step in seeking information. If so, then all archaeological evaluations leading to the identification and delineation of a site should be as non-intrusive as possible. On the other hand, if the convention is to be understood so that this article is mostly valid as an advice for research investigations where the archaeology is not really in any danger from imminent development, as well as to avoid unscientific investigations and treasure hunting, then the convention is less relevant for archaeological evaluations and rescue excavations. The latter argument disregards the initial rationale behind drafting the convention in the first place, i.e. as a tool for view archaeology as part of a planning process. These conventions support the use of non-intrusive methods within the Norwegian cultural heritage management, but regular archaeological evaluations involving digging test-pits or performing test trenching is not necessarily in conflict with the ICOMOS and Valletta convention. By seeing archaeological evaluations as preventive archaeology to clarify and limit the conflict between a planned development and the potential archaeology present, i.e. archaeological registrations following the NCHA §9, this is a practice that is following the Valetta convention. In preventive archaeology, the main question one should ask as part of the professional judgement is which method will be the best balance between accurately locating and delimiting a site, monument or feature, and the intrusiveness of the method. Seen in this way, test trenching – while still being an intrusive method, may still not be in opposition to the Valetta convention if the results from test trenching is seen as the best option for clarifying any conflicts.

In regard to the Norwegian legal system, Charters are political statements which are not legally binding, but still ensured that the country agree on a political obligation. Signing the ratification of a convention, on the other hand, commits a country to include its content within the domestic legal system. A convention is considered as international law, which cannot be used directly on its own as a law in Norway, but can be included or transformed into Norwegian laws by the government. Ratified conventions, as international law, can be used as a legal source when there are doubts in how a law should be interpreted. If there is a dispute between international and national law, the dualistic principle practiced in Norway will in most instances lead to a situation where an advantage is given to Norwegian Law over international agreements, treaties and conventions. The Dualistic principle is a principle that ensures that the international legal sources and legislations are separated from national law. While the national laws sets obligations to the citizens of Norway, the international law does so for the state of Norway. International law is therefore not directly valid for Norwegian citizens unless legal paragraphs and intentions are integrated into Norwegian law directly (Kahn 2007:21). Another principle is the presumption principle, which assumes that Norwegian law to be conclusive with international obligations. If the wording of an international obligation disputes Norwegian law, then it follows that Norwegian legal practice should be careful to directly pursue the content these international obligations uncritically (Kahn 2007, 2011).

Seen in relation to this, articles in the Valletta-convention can be used as arguments in the daily archaeological practice as long as their contents are in agreement with current legislation. As mentioned earlier, the current Norwegian legislation does not define how the monuments and sites are to be identified and taken into practice. The archaeological practice is therefore related to the professional judgement of the administrative agency responsible for the daily cultural heritage management- for instance the county authorities, the Sámi parliament or the DCH. The professional judgement on choice of archaeological registration methods must be a balance between the effectiveness of the chosen method and other priorities such as cultural historical, scientific and social value, aims and objectives of the survey, increased prognosis for archaeology being present etc. The archaeologist handling such issues *can* refer to the Valetta convention as an argument for increased inclusion of non-intrusive methods. At the same time, the choice of other, and indeed more intrusive methods, is not in opposition to the convention if they are used within a general preventive archaeological practice, which is the rationale behind the NCHA §9.

4.2.3 Professional judgement in relation to archaeological assessments as followed by the Norwegian Cultural Heritage Act

There are a range of legislative decisions which are being performed not based on a definitive fact, but on the professional judgement of the administrative agency. This means that the power to decide on a planning permission raised by a citizen or a company is performed by an official appointed by the administrative agency to manage the cultural heritage on society's behalf. In this lies a huge responsibility. The official, in cultural heritage cases usually an archaeologist, decide whether or not a planning permission needs an archaeological evaluation, how to search for, locate and delimit archaeological sites and monuments in case they decide that an evaluation is needed. They also decide the extent and size of such evaluations, and when a case has been clarified *"as thoroughly as possible"*. Such archaeological judgements should, ideally, take into account all parties involved and their needs in a case, including the archaeology, the society and the developer (Nerbø 2008). Any administrative agency has by law the possibility to judge if and when they should use their authority, and what their decision should include (Kahn 2007:123). Nerbø (2008:23) had defined professional archaeological judgements as *"value based decisions taken based on professional and personal knowledge and experience, within the framework set by laws and official guidance documents"* (this author's translation). The professional knowledge includes judgements based on knowledge, competence and experiences based on education and through professional work. This can also envelope routines, where one would choose to continue to apply a method, if this method earlier have shown to give good results. Personal experiences can for instance be how to deal with parties involved in a planning permission, how to deal with unexpected factors not mentioned in laws or guidance documents, personal interests or physical factors (Nerbø 2008:20-22).

This means that even though laws and guidance documents to a certain degree governs how the government official should make his or her decisions, there are still a large room left for professional archaeological judgements, which is rooted in each government official individual experience, knowledge and interests.

In regards to the legal implications of the results of geophysical surveys: it is not really stated whether the geophysical signature from traces of human activity is enough for a site to be legally protected or not. §2, section 1 in the NCHA defines the term «*archaeological and historical monuments and sites*» as *"all traces of human activity in our physical environment, including places associated with historical events, beliefs and traditions*" (Cultural Heritage Act 1978). As Myklebust (2003:9) eloquently puts it: "*no object is a cultural heritage object until it is sensed and interpreted as such*". Such a geophysical signature does not need to be visible and identifiable to the naked eye. If a county archaeologist orders or make use of a geophysical survey contractor or specialist in relation to a planning permission, the specialist would in most instances provide a report with geophysical data and archaeological interpretation of these. There are no Norwegian guidelines on what such a report should include, but the English heritage guidelines for geophysical surveys in archaeological field evaluations (David et al. 2008) or the newly released European Archaeologicla Councils newly released "EAC Guidelines for the use of geophysics in archaeology: Questions to ask and points to concider" (Schmidt et al. 2016) could be suggested as a model.

If the specialist interprets an anomaly or a combination of anomalies as potentially anthropogenic or archaeological in origin, who is then to decide if this should be recognized as an archaeological site or monument automatically protected by law according to the NCHA? The answer to this is the governmental official who is responsible for the archaeological evaluation of the case in question, as detailed above. If the county official (in most cases the county archaeologist) brings the decision into doubt, or that it is uncertain if the observation should be considered an automatically protected site or monument, they could chose to perform additional archaeological investigations to verify the archaeological interpretations. If there is still uncertainty to whether or not the anomaly, site or monument in question should be regarded as automatically protected, it is the MoCE who has the final decision. This responsibility, as mentioned earlier, has been delegated to the Directorate of Cultural Heritage (Ministry of Climate and Environment 1979: chapter 3, §12, nr.11). Kahn (2007:142) recommends that if the DCH should made such a decision after the NCHA § 4, section 5, it should rest on their own investigations, and not just statements from the county council and regional archaeological museum. In this way, the decision is ensured a treatment in a higher administrative body.

This means that the appointed county archaeologist have the option of deciding in what manner an archaeological evaluation should be performed, including choice of most appropriate archaeological field methods to apply. When provided with geophysical data collected by others, the county archaeologist have a choice of either trusting the interpretation provided to them by a specialist. Alternatively, and more ideally, the county archaeologist should have knowledge and understanding of the potential, limitations and geophysical responses derived from geophysical surveys be able to properly assess if the geophysical results represents (i.e. can be interpreted and understood as) an automatically protected monument. An increased level of knowledge and understanding should be considered necessary for a better integration and application of such methods within the Norwegian cultural heritage management system.

4.3 FIELD ARCHAEOLOGY IN NORWEGIAN CULTURAL HERITAGE MANAGEMENT

4.3.1 Archaeological field practice relating to archaeological registrations

As described previously the responsibility to perform field archaeological evaluations of planning permissions and rezoning (NO: omregulering) are usually handled by the various county authorities, the Sámi parliament and the maritime museums. Norway is divided into 19 different counties, where each county has a duty to employ official civil servants responsible for cultural heritage conservation. These officers handle planning permissions, advice the county administration and the public on everything related to cultural heritage management, conservation and dissemination. The way each county authority has organized and financed this part of their work is different, as the political organization and public administration varies from county to county. This influences the way the cultural heritage management is performed. The DCH can choose to delegate the responsibility for searching for and recording automatically recorded monuments from the county authorities over to NIKU or the regional archaeological museums. NIKU has been delegated responsibility for the archaeological investigation of medieval monuments in the major medieval towns and cities, as well as clerical buildings and monuments from this period. NIKU can also be delegated the responsibilities for archaeological registrations for medieval towns, cities, clerical buildings and monuments from these periods following the NCHA §11 (Cultural Heritage Act 1978; Ministry of Climate and Environment 1979; Gaukstad and Holme 2001; Ibenholt et al. 2012:8; Stamnes and Gustavsen 2014).

The way in which such archaeological evaluations are performed in the field is very much dependent on the situation and the archaeological circumstances the planning permission is related to. Desk based assessments could involve the analysis of known archaeological finds and monuments in the area, maps and landscape context, topographical studies using LiDAR-datasets, as well as known historical and written sources. How any controls, inspections, samples of the subsoil and archaeological excavations or registrations are to be undertaken, is up to the county authority to decide.

A typical archaeological registration usually involves either visual inspection for monuments and sites visible above ground, or intrusive methods such as the digging of test pits or mechanical soil stripping for evaluation purposes. In certain instances, other archaeological registration methods can be used dependent on the situation, such as geophysical or soil chemical prospection schemes, field walking, aerial photography or other non-intrusive methods (Karlberg and Jerkø 2009). The DCH has released a guidance document related to budgeting directives for archaeological registrations following the NCHA §9 c.f. §10, which states that "*as a main rule, well known methods, such as visual inspection, test pitting and test trenching, should be used when performing the field work*" (Directorate for Cultural Heritage 2015e:8, this author's translation). According to this document, the use of various forms of remote sensing such as LIDAR or non-intrusive geophysical methods, can be included after agreement with the developer (Directorate for Cultural Heritage 2015e:8).This sentence is not unproblematic, and will be discussed later. It is important to stress that the quality of the documentation at this level in the planning process should provide sufficient information for the budgeting for an excavation (as mentioned earlier), and that any archaeological information provided can be used as part of research schemes. Often the archaeological assessments will be the only source of information on a site or a monument, as the planned development might not be commissioned. The representability and quality of the information is therefore not only important for archaeological assessment reasons relating to the planning permissions, but also as data sources for further archaeological research (Bjørgo 1988).

4.3.2 Archaeological field practice relating to excavations

As part of the development of a scientific evaluation programme for the NTNU University Museum in Trondheim, the museum compiled an overview of all excavations performed during the years 1980-2004, 353 in all. This document also includes an overview of excavation methods used, which was divided into five categories: Traditional excavations with of gridded box pits and layers, mechanical soil stripping, test pitting and test trenching, visual inspection, and surveillance of development work. The statistics show a massive increase in soil stripping excavations: a very few investigations in 1980-1984, none between 1985-1989, a few between 1990-1994, an increase in 1995-1999, while becoming the dominant method for the years 2000-2004. As the amount of soil stripping excavations increase, so does the amount of known iron-age settlement sites in the region. It is also interesting to note that the total number of research excavations decreases from 1980 to 2004 from approximately 22% to only 3.5% of the total number of investigations (Birgisdottir 2005; NTNU University Museum 2005). Much the same excavation and investigation methods are used by Tromsø Museum, with the additions of collection of surface scatter material of archaeological origin, the mechanical removal of turf and geophysical investigations. The use of mechanical soil stripping has been much more scarce in the northern part of the country. The statistics from Tromsø does not reveal any chronological information on the development of management versus research investigations, but until 2009 Tromsø University Museum had performed 128 management investigations and 150 research investigations. The research investigations were of varying size and extent (Tromsø University Museum 2009). The scientific evaluation programme for the Museum of Archaeology in Stavanger has a much more multidisciplinary and interdisciplinary focus, with separate sections presenting and discussing natural scientific methods. The relationship between research and management initiated archaeological investigations are not presented in the same manner as in Tromsø and Trondheim. At Museum of Archaeology in Stavanger, they present a graph of different investigations in the low-lying landscapes from 1979-1997, where a total of 63 investigations were management-initiated and 27 were research initiated (Museum of Archaeology 2012). The Museum of Cultural History in Oslo has until now provided two very detailed scientific evaluation programmes, instead of focusing on a single scientific programme as an overview for all monument types, time periods or landscapes. Extracting a general statistical overview is therefore difficult (Glørstad 2006; Larsen 2009)

One of the intentions of the following work, is to gain an overview of how geophysical methods have been included in archaeological research as well as used as a tool in relation to archaeological excavation projects.

4.3.3 Knowledge-based management and the role of scientific evaluation programmes

It is a clear attitude from the Norwegian Government that the cultural heritage management, and the way it is performed, should be based on and defined by knowledge and research. The handling of questions of dispensation and exemptions from the cultural heritage act should be routed in scientific objectives and based upon knowledge on cultural heritage sites and monuments. The term usually used is knowledge-based management (NO: *kunnskapsstyrt/kunnskapsbasert/forskningsstyrt forvaltning*) (NOU 2006:64; Proposition to the Storting 2007-2008:39; Directorate for Cultural Heritage 2011:2,16; Trøim and Johansen 2011; Holm and Myrvold 2012:12, 99-102; Proposition to the Storting 2012-2013a:36,41). This involves, on a museum level, the involvement of the museums' knowledge on documentation, conservation, research and dissemination (NOU 2002:108), and the university museum has been assigned a key role in generating and making accessible the necessary foundation for an knowledge-based management (Proposition to the Storting 2007-2008:39). Between 2003-2010 the DCH, channeled funds to the archaeological museums for them to write scientific evaluation programs (NO: faglig program) that should serve as a scientific basis for future heritage management, presenting, assessing and prioritizing focus areas, which is based upon a status overview of the presented work. Each regional archaeological museum was encouraged and stimulated to write scientific evaluation programs for their own activity. The DCH has also financed three cross-regional programs: One for the medieval archaeology of cities, towns, sacral places and fortifications and two for the investigation of watercourses, which must be understood in relation to the periodical renewal of concessions to extract water energy from these watercourses (Trøim and Johansen 2011).

A knowledge-based management has been stressed by several researchers and research institutions as a very important aspect of the Norwegian system of archaeological heritage management. Glørstad and Kallhovd (2013:26) argues that "*by using the universities as the context for rescue excavations, chances for creating viable and meaningful results are significantly improved than by separating the large research environments at the universities from the process of generating new data"*. Another point that they stress, is that a state-based monopoly has an advantage when it comes to easy integration of data from developer-led excavations into a wider framework of knowledge production (Glørstad and Kallhovd 2013:25). An independent report emphasize this fact as a large strength and positive effect of the Norwegian system, as the University museums also receives basic financing from the Ministry of Education, which also could be channeled into research projects (Holm and Myrvold 2012:9,12,120). While this sounds all good and well, several authors have indicated a paradox between the reluctance to open up for research financed by the contractor, while at the same time having an intention of a research- and knowledge-based archaeological heritage management. The public funding for the latter is perceived as not generous enough to finance the expected research (Glørstad and Kallhovd 2011; Glørstad 2013; Petersson 2013; Primitive tider 2013; Ringstad 2013).

A Supreme Court order determined that regional archaeological museums can not impose a developer to cover any expenses for method development or research upon the excavated material if this would lead to additional costs for the developer, unless the developer agrees to do so. The regional archaeological museumscan only charge for direct expenses related to securing the record (Norwegian Supreme Court 2007; Glørstad and Kallhovd 2011; Ministry of Climate and Environment 2011; Glørstad and Kallhovd 2013:21-22; Directorate for Cultural Heritage 2015e; Ministry of Climate and Environment 2015). While this practice secures a reasonable, equal, fair and transparent treatment of developers, it still remains a fact that it can be hard to distinguish management from research sometimes, as report writing always contains aspects of interpretation, the constitution of new knowledge, comparisons to known or comparable archaeological material etc. (Petersson 2013). The inclusion of various forms for scientific analysis can add to new archaeological knowledge, but there are not always any available examples of the application of scientific methods or "new" ways of gaining additional knowledge from investigations performed on a Norwegian material. Therefore, it can be hard to decide for whomever writes the excavation plan and budget, or the one that have to approve the budgets, which methods are feasible and necessary for the appropriate documentation of a site. From an ANT perspective, such inclusions can be a stage where an actor can chose to mobilize and enrole a method (as another actor) into the daily practice and the networks they constitute.

Between 2003-2010, the DCH channeled funds to the university museums to write scientific evaluation programs (NO: faglig program), which should serve as a scientific basis for future heritage management, and present, assess and prioritize focus areas based on current status overviews. Such programs should ensure that the handling of questions of dispensation and exemptions from the cultural heritage act could be routed in scientific objectives and based upon knowledge on cultural heritage sites and monuments. The activation of such scientific evaluation programs in management decisions could ensure that cultural historical knowledge gaps could be investigated further. They should also function as background information for the advice and recommendations the museums and the county authorities (including the Sámi parliament) provide to the DCH in regards to questions of dispensations from the NCHA (Trøim and Johansen 2011). While these scientific evaluation programs are important documents for the formation and renewing of archaeological knowledge, I see potential problems in incorporating such programs into the regional archaeological heritage management on a county level. First of all could an emphasis on potentially investigating "new" landscape types or areas with little or no known archaeology potentially lead to a range of archaeological registrations giving "negative" results – in the form of no archaeology present. While negative results are also important from a knowledge perspective, it can be argued that it might be unfair for a developer to have to pay for archaeological investigations with, in lack of a better expression, less than ordinary archaeological prognosis. At the same time, it can also be a challenge for the university museums to involve the archaeologists on a county level in the formation and execution of such scientific evaluation programs. There are known cases where the county archaeologists felt that the scientific evaluation programme had little relevance for their daily practice, or that they did not have the opportunity to contribute to the formation of such programmes (Åstveit 2013:127-128). It is also seen as important that the county archaeologists can contribute to such collaborations, as they have detailed local knowledge and networks that can be included in the development of scientific evaluation plans (Ringstad 2013). With regards to this thesis, such scientific evaluation programmes also function as an overview of the knowledge as well as research results gained at the university museums. The evaluation programmes can also provide an evaluation of various documentation methods. The programmes also have a function as a communication link between the university museums, county authorities and the DCH. As a communication link, the programmes provide background knowledge to any advice and recommendations the university museums and the county authorities (including the Sámi parliament) gives to the DCH regarding issues concerning dispensations to the NCHA. They are also intended to be central in the knowledge production at the university museums (Trøim and Johansen 2011; Glørstad 2012; Gundersen 2015).

Often, the archaeologists on a county level gain important local knowledge, experiences and networks that can be hard for the archaeologists at the university museums to attain. This can be used as an argument for a need of a better collaboration of all actors within the cultural heritage management framework. Also, the local knowledge of positive archaeological registrations that does not lead to an archaeological excavation, can be very archaeologically important, but might easily be lost to researchers at the university museums while the archaeologists at a county level rarely have time, funds or the institutional goodwill to perform archaeological research on this material (Ringstad 2013). At the same time, a quantitative analysis of archaeological sources used in Norwegian Archaeological Journals show that, although dominated by excavation reports from larger excavations, unpublished grey literature deriving from archaeological registrations are to some extent included in published articles. This proves that the archaeological registrations do contribute with information that is of high value for archaeological research (Gundersen 2015). The relationship between archaeological research and archaeological heritage management has been the focus for several academic discussions and articles. This relationship is the main discussion topic in two separate issues of the Norwegian archaeological journal "Primitive tider" in 1999 and 2013, with contributions from 13 different authors with various institutional affiliations (Boaz 1998; Primitive tider 1999; Glørstad and Kallhovd 2013; Primitive tider 2013).

The involvement in various natural scientific methods such as macrofossil analysis, pollen, wood analysis as well as geoarchaeological and geochemical approaches have also been highlighted as part of larger excavation projects. Such methods have proven to yield new and important archaeological information – showcasing how other information sources than just the archaeological features themselves tell a story about the past (Skre 2007:249-360; Bjerck et al. 2008; Gjerpe 2008:477-546, 646-659; Cannell 2012; Gjerpe 2013; Linderholm and Wallin 2013). It is in this line of view the inclusion and description of geophysical methods in the scientific evaluation programmes become interesting to study in regards to archaeological registrations and excavations. The inclusion, descriptions and intended role of geophysical methods in these scientific evaluation programmes becomes an interesting insight into the role and status of geophysical methods in line with the aim and objectives of this thesis.

5 STRATEGIC DOCUMENTS, COMMUNICATIONS AND INITIATIVES

All actors listed in table 3 and presented in chapter 4 can in some way or form influence the use of geophysical survey methods within the current cultural heritage management system in Norway. This can be through the approval of budgets and issuing guidelines and directives for budgeting, management or investigations. These actors can also issue strategic plans and prioritization, methodological choices, commission research, scientific evaluation programmes and other academic activity. The following section summarizes the most important sources where the different actors in the cultural heritage management system in Norway have discussed, mentioned or taken the initiative the use of geophysical methods in some way or form. This could be through Propositions to the Storting (NO: Stortingsmelding) – which are the white papers on political strategies for a certain topic presented by the active Government to the Storting, Official Norwegian Reports (NO: Norges offentlige utredninger, usually referred to as NOUs), Strategic plans for research and management on various bureaucratic levels, scientific evaluation programmes, budgeting guidelines and directives, letters of advice, as well as responses to hearings and circulars on drafts of official guidelines and directives. Circulars give a very useful insight in the meaning of opinions of various governmental policies and documents. In the previous account, circulars relating to the DCHs strategic plan for 2011-2020 and the Ministry of Environments budgeting directives for NCHA §9 c.f. §10 cases tell an interesting tale (Directorate for Cultural Heritage 2011; Ministry of Climate and Environment 2015). While documents and communications mention the use of non-intrusive methods or remote sensing in a general sense, others are more specific. I will in my analysis use information gathered from these documents and initiatives to compare and discuss the use of geophysical methods on archaeological sites and monuments in Norway (article one) with the observations made from the claims presented by the various actors in these documents. This would lead to a comparison between what the actors say and claim, versus what they actually do as seen from an Actor Network Theory perspective as presented in chapter 3. This presentation will in combination with article one and the following discussion in chapter 7 contribute to providing answers to the main aims of this thesis, as well as objectives one to four.

5.1 DOCUMENTS AND STATEMENTS FROM THE GOVERNMENT, THE MINISTRY OF CLIMATE AND ENVIRONMENT AND OTHER MINISTRIES

The main task of the Ministry of Climate and Environment (MoCE) is to ensure that the governmental offices and agencies follows the goals and strategies passed by the Government. The MoCE has the overarching responsibility for the cultural heritage management in Norway. The main outline of the political strategies towards cultural heritage management are disseminated to the public through Propositions to the Storting (governmental white papers). These are released by the responsible ministry, and often based on earlier Official Norwegian Reports (NOUs). Such NOUs are written by a commission set down by the government or the relevant ministry. While the NOUs are the product of a group of experts, bureaucrats and politicians asked to form a panel and author a report on a given topic, a Proposition to the Storting presents the Government's own position in the case. The experts views, arguments and votes might not transfer in its entirety into a governmental Proposition. Also, inherent differences of opinions between members of expert panels expressed in NOUs have sometimes not been transferred into the final Proposition – masking the experts opinions and hiding controversies, and in using a familiar term from ANT, become hidden away and masked within a *Black Box* (Nielsen 2013).

In addition to the MoCE, other ministries such as the Ministry of Education and Research, the Ministry of Culture and Church affairs have also contributed with political documents relevant for the Norwegian Cultural Heritage Management. Below is a table showing relevant Propositions to the Storting and NOUs concerning cultural heritage management:

Table 4: List over Propositions to the Storting, NOUs and other important documents released by governmental agencies concerning cultural heritage management. English translations by the author.

Title	Year	Type	Released/Commisioned by or for	Reference
Fortid former Framtid ***(The past forming the future)***	2002	NOU	For the Ministry of Environment	(NOU 2002)
Leve med kulturminner ***(Living with cultural heritage)***	2004-2005	Proposition to the Storting	Ministry of Environment	(Proposition to the Storting 2004-2005)
Kunnskap for fellesskapet ***(Knowledge for the community)***	2006	NOU	For the Ministry of Education and Research	(NOU 2006)
Tingenes tale ***(The things' speech)***	2007-2008	Proposition to the Storting	Ministry of Education and Research	(Proposition to the Storting 2007-2008)
Framtidas museum ***(The museum for the future)***	2008-2009	Proposition to the Storting	Ministry of Culture and Church affairs	(Proposition to the Storting 2008-2009)
Miljøvernforvaltningens prioriterte forskningsbehov 2010-2015 (Prioritized research needs for the Enrironmental management 2010-2015)	2010	Special report	Ministry of Environment	(Ministry of Environment 2010)
Framtid med fotfeste ***(Future with foothold)***	2012-2013	Proposition to the Storting	Ministry of Environment	(Proposition to the Storting 2012-2013b)
Klima- og miljødepartementets prioriterte forskningsbehov (2016-2021) (Prioritized research needs for the Ministry of Climate and Environment)	2016	Special report	Ministry of Climate- and Environment	(Ministry of Climate and Environment 2016)

The NOU "Fortid former Framtid" from 2002 does not mention geophysical or other non-intrusive methods (NOU 2002). The proposition to the Storting "Leve med kulturminner" (which partly builds on the former NOU), however, mention that new methods for registration and investigation makes it more possible than before to investigate and acquire knowledge, even if it does not mention what kind of archaeological registration and investigation methods this refer to (Proposition to the Storting 2004-2005:23-24).

The NOU "Kunnskap for fellesskapet", which was written to assess the obligations and responsibilities for the university museums and analyze the challenges that these museum could face, mentions that a possible relationship between research and development-work and the archaeological museums could be for instance research projects focusing on surveying techniques for field archaeology (NOU 2006:60). One of the recommendations of this report is that the archaeological museums should collaborate with the regional cultural heritage institutions in developing scientific development plans based on knowledge and the development of adequate engineering- , excavation- and documentation methods (NOU 2006:67). Both points from the NOU report "Kunnskap for fellesskapet" was repeated in the Proposition to the Storting called "Tingenes tale" from 2007-2008. Neither the NOU report "Kunnskap for fellesskapet" nor the Proposition "Tingenes tale" or "Framtidas museum" mention geophysical, non-intrusive or remote sensing methods specifically (NOU 2006; Proposition to the Storting 2007-2008, 2008-2009).

The Proposition to the Storting "Framtid med fotfeste" from 2012-2013 mentions how new technical methods, including satellite imagery, laser scanning and geophysical methods, has made it easier to make images and gain an overview which previously was very demanding to create manually. The proposition mention that the methods are still in a testing-phase, but have a large potential when it comes to providing good data for prioritizations and formation of prognosis of the existence of cultural heritage sites and monuments (Proposition to the Storting 2012-2013b:40). This section refer to the strategy plan released by the Directorate for Cultural Heritage (2011), where method development is described as one out of three priority areas for reaching one of the main goals of this strategy plan. This main goal is the safeguarding of archaeological sites, monuments and environments based on a high quality data, unanimous criteria and justifiable methods (Directorate for Cultural Heritage 2011:3, 8-11). This is described in further detail below. One of the measures that the proposition concludes with, is to ensure a continuance of this strategic plan. The proposition also refer to one of the conclusions in a report concerning the responsibilities and roles of the regional archaeological museums and NIKU. This report was commissioned from the Norwegian Institute for Urban and Regional Research (NIBR), and concludes that it is important to maintain a knowledge-based heritage management, and that it is a strength for cultural heritage management to have access to research environments and educational institutions (Holm and Myrvold 2012; Proposition to the Storting 2012-2013b:71). The NIBR-report also highlights the importance of development of new methods for investigations and documentation of cultural heritage. In a section concerning the Ruin Conservation Project, led by the Directorate for Cultural Heritage (2015d), it is clearly stated that the MoCE intend to continue the work this project undertakes in registering and mapping ruins above and below ground, by for instance georadar and airborne scanning methods (Holm and Myrvold 2012; Proposition to the Storting 2012-2013b:34). The Ruin Conservation Project is also mentioned below.

A report on the prioritized research needs for the environmental management, which in Norway also includes the Cultural Heritage Management, was released in 2010. The report asks for a research based- more future oriented way of gathering knowledge, and points towards new technologies as an aid. The report states that the management of cultural heritage and heritage environments depends increasingly on high-technological equipment for documentation and monitoring, and there is a need for a continuous knowledge development which can contribute to the release of the potential that lies within such high-technological equipment (Ministry of Environment 2010:42-43). This report was updated in 2016. In the new report it is stated a central research need for "*methods for cost-effective mapping and surveillance of climate changes and natural- and cultural historical values. This includes the usage of remote sensing data"* (Ministry of Climate and Environment 2016:19). This report also states a need for research and development within surveillance and mapping techniques, where new technology and new methods can make the management capable of measuring new parameters, more parameters simultaneously, with better coverage and increased accuracy (Ministry of Climate and Environment 2016:18)

5.2 THE DIRECTORATE FOR CULTURAL HERITAGE (RIKSANTIKVAREN)

The DCH has the responsibility for the cultural heritage management in Norway, and while they in general do not conduct research of their own, they still have a large influence on what kind of methodical choices they approve of being used in the daily cultural heritage management. This is done by approval of budgets, letters of prioritization and expectations to the county authorities, ordering research evaluations from external collaborators as well as through their general strategies and guidance to the cultural heritage management system. The DCH has also research and development funds (R&D) and funds earmarked for environmental monitoring (MOV) which they can distribute to other actors based on the DCHs strategies and priorities and applications received. Some of these funds have been used and granted to various projects involving non-intrusive methods, including LiDAR, geophysical surveys and analysis of satellite imagery and aerial photos (see section 5.2.2).

The DCH released a strategic plan for the management of archaeological monuments, sites and environments in 2011 valid for the years 2011-2020. The first main goal ("delmål 1") is to ensure the protection of archaeological monuments, sites and environments by having a solid basic data knowledge, uniform criteria and justifiable methods. To reach such goals, the DCH should "*Stimulate to the further development and use of non-intrusive methods in relation to registration and excavation*" (Directorate for Cultural Heritage 2011, this author's translation). As part of this goal, the document mentions how methods such as geophysical prospection and airborne laser scanning limits the physical damage on cultural heritage sites and monuments, and increase the effectivity and accuracy of the documentation. It is interesting to note that the DCH refer to the Valletta-convention in a section on *in-situ* preservation, but do not refer to the convention as part of their section on non-intrusive methods. Also, in a guidance document for the Planning and Building act called "Kulturminner, kulturmiljøer og landskap" (which can be translated to *Cultural heritage monuments, environments and landscapes*), non-destructive methods is presented as one out of several other archaeological registration methods (Directorate for Cultural Heritage 2010d). In this document it is stated that the counties should evaluate the purpose of an archaeological registrations in relation to the type of regulation that is intended for the area in question. In cases where land is to be regulated to for instance agricultural purposes, the purpose of an archaeological registration would be to identify any archaeological sites, monuments and features, and decide whether a zone requiring special consideration should be included into the plan, including protection and conservation measures. In such cases the DCH suggest to either perform a less extensive archaeological registration by traditional methods, or perform registrations by non-destructive methods rather than to perform test-trenching (Directorate for Cultural Heritage 2010d:66). Geophysical methods is also mentioned as one of several non-intrusive archaeological methods in a guidance document for the construction business for archaeologists and archaeology for the construction business which was written as a collaboration between the DCH and independent research organization Sintef Byggforsk (ENG: *Sintef Building and Infrastructure*). In this document, the authors note that one in Norway "*at the moment is more on an experimental stage in the registration phase with regards to the use of such methods*" (Karlberg and Jerkø 2009:121 this author's translation). The guidance document does not discuss any mutual benefits on performing geophysical surveys in collaboration between the construction industry and archaeologists.

In the DCH's annual report for 2014, the DCH mention an assignment received from the MoCE, which was to *"assess the need for, and optionally promote a suggestion to, a demand for an increased use of new technology (for instance airborne laser scanning, georadar), when performing archaeological registrations following the Cultural Heritage Act §9" (Directorate for Cultural Heritage 2014g:58, this* *author's translation).* The reply to the assignment was sent to the MoCE in letter sent in an e-mail dated 27.08.2014. In this e-mail, the DCH states that even though they notice an increased awareness and knowledge concerning the use of "new technology" within the cultural heritage management, they describe the use of such technology as very limited (Directorate for Cultural Heritage 2014f). This letter is one of the sources with the clearest statements and thoughts on the applicability of geophysical methods in relation to archaeological registrations released by the DCH. It is also an unpublished source as such, but will be a vital part of the discussion later in this thesis. The letter also state that:

> *It is a fact that "new technology" only can map certain types of cultural heritage sites and monuments, and that the methods only in very few cases can replace "traditional" registrations methods. It will require additional method development and lower use costs to attain a potential "efficiency reward". This is valid for both typical outfield monuments (by using airborne laser scanning) and in cultivated land (by using georadar or magneomteter. In both cases will there always be necessary to perform control registrations to verify or control the data, and both methods "lose" important types of cultural heritage sites and monuments. The methods also shows large variations related to topographical, geological and vegetational circumstances (Directorate for Cultural Heritage 2014f, this author's translation).*

The DCH therefore conclude that they cannot impose the cultural heritage management to use methods that are not cost-effective, seen in relation to each individual case, as long as the financing remains as it is and the size of the individual archaeological registration is fairly limited. They also state that it is not sensible to increase the use of "new technology" as part of archaeological registrations, when the methods do not replace the use of traditional methods. The additional cost should then either be covered by larger, private or public developers, or by the heritage management themselves (Directorate for Cultural Heritage 2014f).

The DCH has also contributed to the budget directives for any archaeological work relating to planning permissions following the Norwegian Cultural Heritage Act §8 and §9, relating to §10, which was released by the MoCE (Ministry of Climate and Environment 2011, 2015). The directives concerning §9 is related to the budgeting of archaeological registrations and the execution of the duty to investigate if a planning permission might affect an automatically protected monument or site. The directives concerning §8 is related to expenses for the investigation of a site or monument after an exemption from the NCHA has been granted. This is in the UK referred to as documented by record, and is in Norway usually performed by the regional archaeological museums or NIKU. It is especially the budgeting directives relating to NCHA §9, cf. §10, concerning the initial archaeological registration and evaluation of a planning permission, that is interesting in regards to the application of geophysical methods. The directives were developed to ensure equal and predictable budgeting practice for the registration of automatically protected sites and monuments (Directorate for Cultural Heritage 2015e), and they are a result of a longer process of drafts, official hearings and discussion that has been ongoing for several years. In versions of the directives dated to 17th July 2012 and 26th June 2014, the directives included a section mentioning several remote sensing methods and non-intrusive geophysical methods (Directorate for Cultural Heritage 2012c, 2014e). Both these versions stated that the use of such methods could be included in agreement with the developer, and that such use should be founded in professional and/or practical considerations. It is also stated that any registration work should not be used for research on the applicability of various methods, i.e. the developer should not pay for research. This section was removed from the final official version of the §9 budgeting directives released by the MoCE on the 21st of August 2015 (Ministry of Climate and Environment 2015). In this final version, remote sensing and non-intrusive geophysical methods are not mentioned specifically. The directives does, however, mention in section 2.3. a list of what the DCH considers the main methods used in archaeological fieldwork relating to registrations. This list include fieldwalking, test pitting, test trenching, metal detecting, documentation (surveying, photography, drawings etc.) and the extraction of natural scientific samples. This list is not meant as a definite and exhaustive list of all methods applicable or approved, but the fact remains that remote sensing and non-intrusive geophysical methods are not included and highlighted by the DCH. It is also clearly stated that it is the cultural heritage authorities that are professionally and legally responsible for the archaeological registration, and should ensure that the quality of this work is sufficient, even if this work is performed by external consultants (Ministry of Climate and Environment 2015).

The DCH released separate guidelines which is to be considered as instructions to the budgeting directives, and was written to ensure equal treatment, predictability and due process of the law for developers. Additional clarifications are included in this document related to the use of registration methods, where the main rule is that well known registration methods such as visual surveys, test pitting and test trenching should be used. The document also includes remote sensing and geophysical methods as a possible registration method, but they are not listed among the well known registration methods. This section is largely the same as the part removed from the final version of the budgeting directives, and does in the guidance document read as follows:

> "*It may, in agreement with the developer, be appropriate to include various forms of remote sensing (for example aerial photography, LIDAR etc.) or non-intrusive geophysical methods (for example georadar, magnetometer) as part of archaeological registrations. The use of such methods should be justified with references to professional and/or practical considerations. The use of such methods should be specified and be budgeted under "external consultants" if it related to equipment which the institution does not have at their disposal*" (Directorate for Cultural Heritage 2015e:8, this author's translation).

The guidelines also state that it should be clarified if the use of such methods represent an additional costs compared to what they call ordinary methods, and that the registration should not be used for method development if this leads to an additional cost for the developer (Directorate for Cultural Heritage 2015e:8). As the paragraph is phrased now, it creates an uncertainty in regards to the role of the developer, as the paragraph could be misread in a manner stating that the developer now should approve or influence the methodical choices being proposed. As concluded in the section concerning legislation, it is the professional judgement of the cultural heritage management which according to the wording in the legislation is to be trusted when a decision on which method is the most appropriate to be used should be met. A developer might not have the necessary knowledge or intentions to judge which is the most appropriate archaeological method, and if the DCH intends to include the developer as a part in choosing the method and influence the professional judgement of the heritage management, this would be a fundamental change in attitude. I interpret this phrasing in the guidance document as a case of unfortunate wording which hopefully will be altered in later editions of the guidance document. DCHs intentions was to highlight that if the inclusion of non-intrusive or remote sensing methods represents additional costs for the developer, it is these additional costs relating to the archaeological registration phase that the developer should agree upon covering (Jostein Gundersen, Directorate for Cultural Heritage, pers. comm.).

The latest version of the budgeting directives for §8, jf. §10 cases, i.e. relating to expenses for the excavation of archaeological sites and monuments after an exempt from the cultural heritage act has been granted, was released on the 15th April 2011. These directives was also the results of a long process, which started back in 2006 (Jostein Gundersen, Directorate for Cultural Heritage, pers. comm.). The directives were also released to ensure a uniform, clear and lucid practice concerning the budgeting and accountancy from the institutions that undertake the archaeological excavations. At this stage, the size and extent of a site or monument is already investigated in earlier stages of the process, so the potential application of geophysical methods are more related to answering specific questions which is vital for the understanding of the site. Also, it is clearly stated that only the gathering and documentation of archaeological data is covered by the developer, but not research upon the collected data. Any natural scientific sampling scheme should be justified in a project plan and specified in the budget, and should be limited to the range necessary to identify, date and interpret the site and its archaeological features and finds (Ministry of Climate and Environment 2011).

5.2.1 Scientific evaluation programmes

In 2009, the DCH released a scientific evaluation programme for watercourses in the southern part of Norway (Indrelid 2009). Even though fully financed by the DCH, it was written by a researcher at one of the archaeological museum. In this programme, geophysical methods is introduced and explained as together with several other archaeological registration methods in the chapter concerning methods. It is stated that "*In relation to archaeological use of geophysical methods, the methods are still on a stage of experimentation, but in several of the larger projects the geophysical methods have been utilized with very good results*" (Indrelid 2009:134, this author's translation). The section mentions examples of use of geophysical methods, and refers to recent initiatives at the NTNU University museum in Trondheim, and the collaboration between NIKU and UV-Teknik/Riksantikvarämbetet. It is also mentioned how the geophysical methods could be used on ice and in densely fouled and marshy areas, which makes it possible to do archaeological investigations in other times of the year than what archaeologists usually do (Indrelid 2009:133-135). Gustafson (2011) published an evaluation of this scientific evaluation programme, where she is positive to the usage of geophysical and geochemical methods. She believes that these methods probably would represent a progress in relation to archaeological registrations in such terrains, but she is also doubtful if they would be ideal in denuded shorelines along the watercourses (Gustafson 2011:151).

The DCH released their scientific evaluation programme for the medieval archaeology of cities, towns, sacral places and fortifications in 2015 (Riksantikvaren 2015). While geophysical surveys are mentioned several times in the programme in relation to the summary of knowledge status from some of the sites and monuments mentioned, geophysical methods as such is not mentioned or treated specifically in the chapter concerning methods for excavation and documentation. The word non-destructive (NO: ikke-destruktiv) is mentioned twice in the report, once for taking chemical soil samples, and once in a chapter concerning prioritized research areas. The latter as a small part of a section concerning method development and multidisciplinary collaboration, where the authors ask if "*maybe new non-destructive methods for investigation and documentation can be developed, which also can document the preservation conditions and preservation status of cultural layers*" (Riksantikvaren 2015:181, this author's translation). There is a section on methods and documentation in the same chapter, but geophysical or other non-destructive methods such as laser scanning or photogrammetry are not mentioned (Riksantikvaren 2015).

5.2.2 Other initiatives by the Directorate for Cultural Heritage

In addition to the five survey they have commissioned through their own Ruin Conservation program, the DCH has taken initiative to, or financially supported, several other geophysical surveys. In 2006 the DCH initiated and financially supported a pilot program for evaluating the use of geophysical methods in Norway, in collaboration with Vestfold county authority and what was then UV Teknik at the Swedish National Heritage Board (Fossum 2010). The DCH has later given financial support to the research collaboration between the Norwegian Institute for Cultural Heritage Research (NIKU) and the Austrian research initiative LBI ArchPro. (NIKU 2011a). The DCH also provided financial support to a geophysical investigation of the burial mound known as Herlaugshaugen in 2012. This investigation was performed by The NTNU University museum on behalf of Leka municipality and the Nord-Trøndelag county authority (Directorate for Cultural Heritage 2012d; Stamnes 2015b, 2015c). In relation to the start-up of the research project at Avaldsnes, focusing on the function and role of royal manors in the early phases of Norwegian kingdoms, the DCH pointed out that "*it would be natural that such methods would be used and developed further in relation to planned research projects" (Directorate for Cultural Heritage 2009, this author's translation).* "Such methods" relates to non-destructive methods, and later in the letter, geophysical methods are mentioned explicitly. The main point addressed in this letter, is that the DCH asks for additional geophysical surveys in advance of the excavation project, as the DCH'sinitial assessment was that a combination of such non-destructive methods would reduce the amount of physical impact on the archaeology in the area (Directorate for Cultural Heritage 2009). Article three in this thesis presents a comparison of the geophysical prospection data with the archaeological excavation results from Avaldsnes. The DCH has also supported budgets including geophysical documentation methods for emergency excavations of sites and monuments under threat (so called "Post 70" funds for rescue excavations).

5.3 THE COUNTY AUTHORITIES

The county authorities appoint their own archaeologists that handle planning applications, answering questions and give advice to the public, and other related activities. These archaeologists have a role as official civil servants. The cultural heritage management can organized differently within both the political and organizational system in the county administrations. While the countie authorities receive letters of expectations/prioritizations as well as budget guidelines, directives and professional advice, and have to follow the national strategies issued by the DCH, the county authorities can influence how they choose to perform their responsibilities through professional and strategic choices.

5.3.1 Strategic plans for cultural activities, planning and/or cultural heritage management

Most of the county authorities have released their own strategic plan for cultural activities, planning and/or cultural heritage management. These plans are well suited to communicate key challenges the cultural heritage management is faced with, and is a way to develop a common understanding of challenges and possibilities, as well as advocating a uniform way of dealing with tasks such as heritage management, dissemination and use of cultural heritage. Also, the counties own strategic plans for cultural activities can serve as a way of indicating key goals, prioritizations, priority areas and central aims for the heritage management, and often state central objectives that should be reached or aimed for. While the extent in which the county authorities discuss prioritizations, management philosophy and methodological choices in these documents differ in both detail level and focus on cultural heritage management, it is interesting to note how the county authorities address issues of archaeological field methodology and practical heritage management. As both the cultural heritage, cultural and natural landscapes and development activities vary from county to county, it follows that the counties might choose different key issues and focus areas suited to their specific needs.

In the middle of 2012, 13 out of 19 counties had such plans. By November 2015 17 out of 19 counties have developed such plans. 9 county authorities had released new strategic plans or were in a process of releasing plans for official hearings and following approval within the county authorities, compared to the 2012 overview (Ibenholt et al. 2012:60-61). For the purpose of this work, it is interesting to investigate the various counties' attitude towards the use of non-investigative techniques, and especially geophysical survey methods. The strategic plans for cultural activities, planning and/or cultural heritage management function as inscriptions that connect the county authorities to other actors, either as presenting obligatory passing points for their acceptance of a method, a way of showing interest and defining aims and objectives for a field practice, mobilize support and define their own role towards other actors.

Out of these 17 strategic plans, 11 mention new methods and technologies, and eight mention geophysical prospection methods specifically (see table 6, table 7 and table 8 for an overview of entitlements, descriptions, roles and functions as used by the various actors within Norwegian archaeology – both research and management). The other three strategic plans mention "modern technology and tools", "new methods and technology", or "new methods for searching for archaeology in the field", without going into detail on which specific method being discussed. Often have such "new methods" been mentioned together with LiDAR and satellite imagery. While the extent to which these methods are being discussed differ, some general notions can be discerned: Geophysical prospection methods are often perceived as new methods for gathering knowledge and performing archaeological registrations. Some of the plans are followed by up goals for prioritization, plans for action or necessary efforts, which is the case in seven of the plans. These seven plans emphasize the utilization of novel technologies and methods as central points for their work in the years to come. It is interesting to note that the oldest plan which includes geophysical prospection as a goal or special bullet point is from 2009 (Nord-Trøndelag county authority 2009). When geophysical methods are discussed as a goal or a special bullet point, it is with an emphasis on cost effectiveness, or where it serves a purpose for the heritage management as a mean of ensuring a good or cost effective management and handling of planning permissions. It is also emphasized how the methods can be a beneficial addition in cases where the site is easily disturbed or in cases with especially significant cultural heritage (Sør-Trøndelag county authority 2013b; Vestfold county authority 2015).

5.3.2 Hearings and budgeting directives

In relation to the hearing of the NCHA §9 c.f. §10 budgeting directives, all counties except Finnmark, wrote a response to the draft dated 18th july 2012. Out of these, five counties responded on a section concerning method development, which said registration work should not be used for research on the applicability of various methods. The discussion generally regarded whether or not method development in some way or form should be accepted, or seen in a wider sense on who decides on what should be considered method development. Østfold county authority noted that the division of responsibility within the cultural heritage framework implies that actors within the cultural heritage network should have a responsibility for the actors' own method development, where methods are developed and introduced continuously. The directives should therefore take such a development into consideration (Østfold county authority 2012). Telemark is more direct, and say that the county authorities should be able to conduct method development as part of their daily heritage management, as this is important for the quality of their daily tasks (Telemark county authority 2012). Hordaland specifies that it is the professional judgement made by the county official that should define the choice of effective methods and magnitude on a case- to case basis (Hordaland county authority 2012). Sør-Trøndelag on the other hand, agrees that archaeological registrations based on NCHA §9 should not be an arena for method development, but see that in special cases it could be ideal to include for instance geophysical methods. It is therefore important that the directives takes this into account. Of all the comments made by the county authorities to these directives, Vestfold is the most direct, and say that the initial draft to the directives imply that the use of GPR, magnetometers or other high-technological methods is not something that the developer should pay for (Sør-Trøndelag county authority 2012). In Vestfold, they considered these methods as being in an operational phase, in their opinion being equal to any other archaeological field. Vestfold therefore states that it is unreasonable that the developer should approve which method they choose to apply, as the developer does not (usually) have the necessary professional knowledge to judge which archaeological method is the most appropriate. Vestfold county authority also note that the DCH does not promote the use of geophysical methods even though Norway is obligated to include such methods through the Valetta convention. The county archaeologists should therefore decide what methods to use themselves on a case by case basis (Vestfold county authority 2012).

5.3.3 Other initiatives by the county authorities

Nord-Trøndelag county authority also financially supported and collaborated in a research project focusing on the Frosta Thing Site at Frosta Municipality in Nord-Trøndelag. The project was a collaboration between the Frosta Municipality, Nord-Trøndelag county authority, The Assembly Project and their norwegian partner the Museum of Cultural History in Oslo, as well as the NTNU University Museum in Trondheim. The main strategy in this project was to utilize geophysical methods and lidar-analysis to get a new perspective on the archaeological spatial activity in the area surrounding the probable location of the Frosta Thing Assembly in late Viking Age and Medieval periods (Nord-Trøndelag county authority 2012). Nord-Trøndelag also initiated a survey of the Herlaugshaugen burial mound (Stamnes 2015b, 2015c). Vestfold has also been an active partner in the Norwegian part of the LBI ArchPro research initiative, together with the LBI ArchPro institute in Vienna, Austria and NIKU (NIKU 2011b; Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology 2013a). In Oslo, the Agency of Planning and Building services (NO: Plan og bygningsetaten) in collaboration with the DCH initiated a pilot study on the use of geophysical methods for archaeological registrations in densely built-up areas (Oslo Municipality 2015). The geophysical field work was performed by NIKU. The county of Vest-Agder also commissioned several surveys on their own initiative, in collaboration with the Moesgaard Museum in Denmark and geophysicist Tatjana Smekalova.

5.4 ANNUAL LETTERS OF PRIORITIZATIONS FROM THE DIRECTORATE OF CULTURAL HERITAGE TO THE COUNTY AUTHORITIES

Each year, the DCH send out a letter explaining their prioritizations based on the national goals as decided by the Norwegian parliament (No: Storting), and the DCHs wishes, expectations and goals for the cooperation with regional cultural heritage management in the county authorities. These are divided up in two parts, one general part and one specific part with feedback and specific issues related to each county authority individually. Before the DCH send out these letters, they ask each county authority to submit important priority areas and challenges relevant for their county specifically. These letters then act as two-way communication, which in turn help for a mutual understanding and practice. The letters are also used on a political level towards the regional politicians within each county authority. They are therefore interesting, because they both highlight important heritage management issues, and act as a direct response from the DCH on any issues raised. In some cases, as presented below, this also includes technical and methodological choices- including the use of remote sensing and non-intrusive geophysical methods. The following observations was gathered by investigating the prioritization letters for the years 2011-2015. I will highlight important statements and communications, which later will be drawn into a further analysis of the role and status of geophysical methods within the Norwegian Cultural Heritage Management. While the reference in the text usually refer to the DCH for these letters, it is because the letters are sent from the DCH to the county authorities with feedback on specific focus areas and challenges raised by the counties. This means that while these documents might contain issues raised by the counties, and referring to statements and viewpoints deriving from the county authorities, the actual references will refer to the DCH. This is also valid for when these sources are referred to later in the text.

2011:

The DCH notes that one of the national objectives involves limiting the use of intrusive registration methods only to the extent necessary to define and delimit cultural heritage sites and monuments, and clarify any conflict with a planned development (Directorate for Cultural Heritage 2010c). This statement should be seen in connection with critique raised towards county authorities for uncritical practice of test trenching larger areas during archaeological registrations (Museum of Cultural History 2010; Glørstad and Kallhovd 2013). The mentioning of a wish to limit the use of intrusive registration methods could therefore be seen as an encouragement of restricting uncritical field practice during archaeological registrations, as well as an encouragement for using non-intrusive methods as part of the archaeologicla practice. This is part of an overarching goal of limiting the annual decimation of cultural heritage sites and monuments to 0.5% within 2020. While this is a natural extension to the cultural heritage regulation, this is the only year this is stated clearly by the DCH in their prioritization letters (Directorate for Cultural Heritage 2010c). It is, however, repeated in the latest Proposition to the Storting (2012-2013b:11).

This year Buskerud and Vestfold mentions geophysical prospection methods specifically, while Oslo raises the notion of improved development of archaeological methods. Oslo is faced with challenges concerning performing archaeological investigations in an urban context (Directorate for Cultural Heritage 2010b). Buskerud raise the development of *new* non-destructive methods as one of their important challenges for this year. The DCH responds that this is a *central challenge* for the cultural heritage management for the coming years, and point towards the work NIKU is involved with (Directorate for Cultural Heritage 2010a). Vestfold has the implementation of *new* technology as one of their main priority areas this year. Vestfold had by this time joined up with the LBI ArchPro together with NIKU, and the DCH was positive towards Vestfold's experiences with *new* registration and data collection methods – and said that Vestfold was one pioneering counties concerning *testing* of non-destructive methods. The DCH further state that "*use of the new methods is necessary to ensure knowledge in the most effective, not to mention non-intrusive manner. It is* <u>*important*</u> *for the cultural heritage management get proper experience on which way such methods best could be used in heritage management cases"* (Directorate for Cultural Heritage 2010c, this author's translation and underlining).

2012:

The DCH does not explicitly mention limiting the use of intrusive methods this year, although the overarching goal of limiting the annual loss of site and monuments to 0.5% remains the same.

For 2012, the counties Sør-Trøndelag and Vestfold mention *new technologies* in one way or form. Sør-Trøndelag mentioned the need for an emphasis on *new technologies* to investigate automatically protected sites and monuments, as part of central challenges for the county. In addition to this Sør-Trøndelag highlight *early* involvement and the *development* of technological aids as part of their priority areas (Directorate for Cultural Heritage 2012a). It must be mentioned that Sør-Trøndelag county authority had by this time been heavily involved in GIS-based registration systems for visible monuments. The county-archaeologist at Sør-Trøndelag county authority has confirmed that this refered to LIDAR scanning, satellite imagery, and the usage of geophysical methods for archaeological registrations (Rut-Helen Langbrekke Nilsen, Sør-Trøndelag County Authority, personal communication). The DCH does not comment on the technological aids specifically in their response. Vestfold mention their LIDAR scanning as an important priority area. The DCH, in their response, praise the collaboration between Vestfold and LBI ArcPro concerning the *development* of investigation methods, which has given new knowledge of methods, landscapes and cultural heritage sites and monuments in the region. The DCH considers this an important step towards the *integration* of the *high-technological methods* in the daily heritage management, and that these are important results that will have relevance for the cultural heritage management seen as a whole (Directorate for Cultural Heritage 2012b).

2013:

For 2013 the DCH comments on the NCHA §9 c.f. §10, in regards to the duty to investigate if a development plan would influence any automatically protected sites and monuments in any way. The DCH stresses that it is very important that the regular cultural heritage management provide good, professional justification for any decisions made, especially with regard to the extent of any initial archaeological registrations being adapted to the size of a development plan (Directorate for Cultural Heritage 2013a).

In 2013, Sør-Trøndelag has a very similar wording as last year, emphasizing *effective* treatment of the planning permissions as a challenge. Sør-Trøndelag also state the need for early involvement and the *development of technological aids*, and see this as a contribution which can lead to a clear and predictable management of archaeological sites and monuments, which in turn would lead to a limitation of the use of intrusive methods (Directorate for Cultural Heritage 2013a). This letter does not mentioned what type of technological aids they refer to, but Sør-Trøndelag's initial email to the DCH shows that this refer to Sør-Trøndelag county authority's wishes for laser scanning, *research on- and testing of* geophysical registration methods under Norwegian conditions, as well as analysis of satellite-based imagery. They also stress that these are costly methods where the DCH should take the initiative for financing and initiating research and testing (Sør-Trøndelag county authority 2013a). The DCH's response see this as very positive, and that they see *these methods* as giving good results, which contributes to a clear and predictable cultural heritage management. Vestfold also mentioned LIDAR and the use of geophysical methods as *new* registration methods as one of their priority areas this year. The DCH's response praises both the good collaboration with LBI ArchPro and NIKU, as well as good results by the LBI-collaboration between Vestfold, LBI ArchPro and NIKU in the previous year. They do not mention the geophysical methods specifically in their feedback (Directorate for Cultural Heritage 2013b).

2014:

This year the national goal for prevention of loss of cultural heritage sites and monuments has been rephrased away from a specific goal of 0.5% yearly, and now only say that it should be minimized (Directorate for Cultural Heritage 2014a). This is different than the wording in the latest Proposition to the Storting (2012-2013b:11).

For 2014, Hordaland mention *new* technologies as a challenge for dissemination, upkeep and management of cultural heritage sites. It is not defined in the letter what they mean by new technologies in relation to dissemination and warding of cultural heritage sites (Directorate for Cultural Heritage 2014c). Hordaland county authority have through direct contact with the author clarified that the intention was to increasingly use new technologies that they today is not a part of their registration methods, which especially includes LiDAR scanning. The use of GPR was not something they intend to use regularly, but would consider in particular cases (Heidi Handeland, Hordaland county authority pers. comm.). Hedmark mention geophysical methods specifically as one of their priority areas. The previous year Hedmark county authority was partner of an airborne magnetometer test to locate iron production sites together with NIKU, LBI ArchPro and the Austrian company and LBI ArchPro partner Airborne technologies (NIKU 2013a). They now want to continue an effort concerning the use of *effective* and non-destructive *new* methods for archaeological use (Directorate for Cultural Heritage 2014b). The DCH praise this effort. Vestfold has again the use of *high technological methods* through their collaboration with the LBI as a priority area, and want to extend the use of such methods also towards the investigation of monuments newer than 1537. This is praised by the DCH. Sør-Trøndelag indicate that initiated work on geophysical methods is very important, and should be given high priority. The DCH responds that they want to have a *high focus* on the possibilities that *new and high* technological methods can provide for the cultural heritage management.

2015:

The national goal concerning the decimation of cultural heritage sites and monuments was the same as in 2014, worded towards a minimization of the loss of sites and monuments (Directorate for Cultural Heritage 2015a).

In 2015, Sør-Trøndelag reported *research on and testing of* geophysical methods under Norwegian conditions as one of their main priority areas, together with laser scanning and automatic detection in remote sensing data. The aspect of research on and testing of geophysical methods was not commented on by the DCH, who responded to this by pointing out that they prioritize the work on a national topographical height model without commenting on the application of geophysical methods (Directorate for Cultural Heritage 2015a). While Nord-Trøndelag did not submit any comments on non-intrusive methods or remote sensing as such, the DCH highlighted the presentation of geophysical results from the geophysical survey of Herlaugshaugen in their feedback to the county (Directorate for Cultural Heritage 2014d). This work is published in Stamnes (2015b) and Stamnes (2015c). Instead of reporting aspects of archaeological prospection as a goal this year, Vestfold reported a challenge concerning the national goals. Vestfold felt that they were receiving little help from the MoCE in the *development* of non-intrusive methods. Vestfold refer specifically to their response to the budgeting directives for NCHA §9 jf. §10, where the non-intrusive methods are not considered equal to traditional methods of registration by the Ministry and the DCH. The DCH responds to this by saying that the understand that these challenges are demanding for the heritage management, and that it can be a challenge to reach the goals set for 2020 with the means provided by the Ministry. In relation to the comment on the budgeting directives, the DCH emphasize their support to the collaboration between Vestfold, NIKU and the LBI, and their work with *non-intrusive* methods. They also say that they note the comments raised by the county, and will remember them in the coming work with the budgeting directives (Directorate for Cultural Heritage 2015b).

All in all, it is interesting to note that it is much the same counties that raise issues relating to non-destructive/non-intrusive and high technological methods, especially Sør-Trøndelag and Vestfold. Buskerud mentioned work with non-destructive methods in 2011, but not within the last 4 years of this period. Hedmark mentioned it in 2014. It is rarely more than two counties each year that mentions non-destructive methods in their communications with the DCH. While the DCH remains supportive towards the issues and priority areas raised, the mentioning of an increased use of intrusive methods was only raised in 2011, and not again. Also, the way in which non-intrusive methods are being mentioned is interesting, and will be discussed later.

5.5 THE REGIONAL ARCHAEOLOGICAL MUSEUMS

The regional archaeological museums perform the majority of archaeological excavations within their district, apart from the investigations delegated to NIKU or potential research excavations. The regional archaeological museums also perform research on cultural historical aspects they find relevant based on their specific competence, the archaeological material discovered in their region, as well as what is defined as important cultural historical knowledge gaps to investigate further for their specific region. As it has been stressed that the cultural historical management should be research based, a clear communication and understanding between the museums, the Sámi heritage officials and the county authority should be maintained. The regional archaeological museums also have a status as university museums, which gives them a role within higher education. The regional archaeological museums influence the general cultural heritage management through statements, hearings, education of archaeologists and research results. Also, the museums' play a vital role in managing cultural historical collections – a responsibility which have been entitled to them for centuries (Iversen 2012).

5.5.1 University of Oslo – Museum of Cultural History

In the scientific evaluation programme for the investigation of iron production sites from 2009, the Museum of Cultural History (KHM) recommend using geophysical methods- especially magnetometers- for locating and delimiting iron production sites and related activities (Larsen 2009:206). This is based on the good results from the Gråfjell project where the use of magnetometers for locating roasting sites, gave undoubtedly the best results (Smekalova and Voss 2002:206, 221-223; Larsen 2009). Larsen (2009:206) therefore recommends that the use of metal detectors and/or magnetometers should be mandatory when doing field campaigns to locate slag pits or slag tips. This is especially relevant when finding pits from coal production, where any traces of iron production is suspected to be nearby but is difficult to locate. This comment is mentioned in a section of the evaluation programme focusing on locating iron production sites as part of the registration process. It is also noted how the registrations often have a larger focus on the visible features than the invisible features often expected also to be present (Larsen 2009:205-207).

The KHM commented on a series of aspects in their response to the circular for the DCH's strategic plan for 2011-2020. First of all, the museum warned against a strong emphasis on standardizations and a strong regulation of practice, as KHM mean that the CHM always should have a goal to supersede the existing knowledge level, and in this way be able to identify new types of monuments and new aspects of past societies. The discussion relates mainly to dispensation practices, routines relating to procedural treatment of planning permissions, as KHM in the same letter approve of the planned work of developing directives relating to archaeological registration work relating §9 c.f. §10, regulating the extent and costs of archaeological registrations. The museum had noted a wide variety in size, extent and costs, as well choices of sites deemed necessary to archaeologically evaluate planning permissions in the years prior to this hearing (Museum of Cultural History 2010). Later, in 2014, the museum responded to a hearing relating to the NCHA §9 cf. §10 budgeting directives where they said the following "*basically, the museum sees the development of a national standard of practice for the registration of automatically protected heritage sites and monuments as appropriate*...." (Museum of Cultural History 2014, this author's translation). It is therefore unclear if these responses should be read in relation to field methodical choices, as KHM on one hand warn against a strong emphasis on standardizations and strong regulation of practice, while on the other hand also support the development of budget directives and the development of a national standard of practice for archaeological registrations. It depends on how you interpret the word "practice": if this is meant to cover mainly budgeting and the extent of the registration work, but not the standardization of methodical field practice as such. In regards to the discussion in this thesis, these hearing responses are interesting on a principal basis in relation to choices of field methods to be used. They present viewpoints regarding to the museums' attitude towards utilizing new methods and practices (which could include for instance geophysical methods), and the way in which this has been communicated to the DCH. The responses contain conflicting attitudes within the same institution. It is possible that this reflects a different attitude towards potential restrictions to the museums' own work (i.e. mainly excavations) and the way the museum feels that the county authorities perform their registrations work. The response from 2014 should be seen in relation to critique raised from the museum towards county authorities regarding the size and extent of archaeological registrations performed (Museum of Cultural History 2010; Glørstad 2013). This discussion should also be seen in relation to the general discussion on knowledge-based heritage management (see section 4.3.3 and 7.4).

Another part of the hearing of the DCHs strategic plan for 2011-2020 concerns the use of high-technological methods as part of archaeological investigations. Initially, the letter does not distinguish between various high-technological methods, but it does note that the museum has chosen not to build up competence and equipment, although a focus on geophysical investigation and the acquisition of geophysical survey methods had previously been discussed. This choice was made mainly due to the cost of the equipment, as well as the fact that other institutions were at that point in the process of building up such competence and experience. KHM recommends the DCH to focus on a limited number of institutions in regards to specialist knowledge, such as NIKU and NTNU. The KHM would rather, at this time, buy these services when needed. They also point to the possibility of other institutions to participate in Research and Development-projects related to method development, as they considered it very important that knowledge concerning the use of the methods exists in the whole of the cultural heritage management, while the investments and specialist knowledge should be concentrated to a few chosen institutions (Museum of Cultural History 2010).

Later, in the annual plan for 2013-15, the museum mentions an intention of investigating the possibility to plan and initiate an archaeometric laboratory, where geophysical methods is mentioned among a wide range of other scientific methods which could be included in such a lab (Museum of Cultural History 2013). In the following annual plan for 2015-2017, the extent of such an investigation is revised to cover permanent analytical lab for Cultural Heritage, called "SciCult", based on equipment and competence gained through the project called "Saving Oseberg". This project focuses mainly on digital documentation and conservation issues (Museum of Cultural History 2015b, 2015a).

5.5.2 The Museum of Archaeology, University of Stavanger

In their strategic plan for the years 2008-2011, the Museum of Archaeology state further development of the environmental archaeological professional environment as one of their goals. While environmental archaeology also could encompass geophysical methods, the Museum of Archaeology in Stavanger is mainly concerned with botanical, geological and meteorological methods. They also indicate that it is possible for them to gain access to knowledge and equipment which they do not have themselves through collaboration with other external institutions (Museum of Archaeology 2008).

As a response to the DCH strategic plan for 2011-2020 (Directorate for Cultural Heritage 2011), the Archaeological museum in Stavanger stated that they see the development of tools based on available technology as an important supplement for excavation and registrations. Tools for prognosis, environmental archaeology and overviews/statistical analysis should only be a supplement to, and not a replacement for, ordinary registrations and professional assessments (Museum of Archaeology 2010).

The scientific evaluation programme for the museum, released in 2012, has a section on prognosis, planning and registration tools. Geophysical methods are, however, not mentioned at all in this programme (Museum of Archaeology 2012).

5.5.3 The University Museum of Bergen

In their response to the DCH circular of the strategic plan for 2011-2020 (Directorate for Cultural Heritage 2011), the museum sent two different circular responses – one from Cultural History Collections (No: De kulturhistoriske samlinger, DKS), and one from the Section for Cultural Heritage Management (No: Seksjon for ytre kulturminnevern). The Section for Cultural Heritage Management commented at investigations related to heritage management should not be subject to restrictions that limits the use of various field- and documentation methods, and that the choice of method should be dependent on the investigated monument or site, and the aims and objectives of the investigations. The Section for Cultural Heritage Management also note that the archaeological research process discusses how archaeological investigation and the knowledge production is in a dialectic relationship between excavation the archaeological research. A limitation of available or allowed methods during excavation could therefore lead to the loss of important information and weaken the production of knowledge. A standard for documentation should therefore be dynamic and, at least in principle, not limiting to the choice of applied method (University Museum of Bergen 2010a). In the same letter they also claim that "*non-intrusive high-technological methods will never replace ordinary registration- and excavation methods, and will when seen in isolation, not fulfill the demands required for identification, description and interpretation. The use of such methods are, however, an important supplement, both as part of the knowledge basis for decisions on registrations and heritage protection strategies, and as means for improving the efficiency for documentation by registration and excavation*" (University Museum of Bergen 2010a:4, this author's translation).

The Cultural History Collections responded by encouraging the DCH to follow the international development, concerning the development and use of high technological methods. The Cultural History Collections do not discuss further what they mean this development consists of, but point out that it is important that the cultural heritage management do not become set in its ways, but remains dynamic in line with the introduction of new methods (University Museum of Bergen 2010b). As with the hearing responses from the Museum of Cultural History in Oslo, this statement is also interesting on a principal basis – where the Cultural History Collections at the University Museum in Bergen encourages the DCH to keep themselves informed of the development outside of our own national borders, and remain dynamic.

The University Museum released a research-strategic plan in 2013 for the years 2014-2020, where it is stated that the scientific employees at the museum has a right and duty to perform scientific research, and can choose their research projects freely (University Museum of Bergen 2013b). Accompanying the plan is a list of all research projects, initiated or ongoing, at the museum (University Museum of Bergen 2013a). None of descriptions of the archaeological research projects in this document, 28 in all, involves an element of geophysical prospection. This observation is important, as it showcases how geophysical methods are not part of everyday archaeological practice, or are being considered as a natural part of, the archaeological research being conducted by researchers employed at the University Museum in Bergen.

5.5.4 The NTNU University Museum, Trondheim

The NTNU University museum has released a series of strategic plans, research strategic plans, plans for action, and a scientific evaluation programme over the years. The strategic plan for the years 2003-

2010 does not mention archaeological field methods or geophysical methods (NTNU University Museum 2003). Neither does the scientific evaluation programme for heritage management at the museum from 2005, although the document contain a paragraph that calls for innovation regarding methods to search for and locate settlement traces relating to agricultural settlements from the Viking- and medieval times (NTNU University Museum 2005). In 2007, the strategic plan from 2003 was revised. In this version, an aim for the future development of the museum towards 2015 is introduced which says that by 2015 "*The NTNU University Museum has a close collaboration with other technological environments within the Norwegian University of Science and Technology (NTNU) concerning the development of archaeological methods for prognosis, investigation and documentation*" (NTNU University Museum 2007:4, this author's translation). The same document also mentions that the museum should develop a clear research agenda within a prioritized field of study concerning method development for field archaeology (NTNU University Museum 2007:6). The action plan for 2010 clearly states that the department of archaeology and cultural history should strengthen the competence in geophysical prospection techniques in collaboration with national and international research environments; with an ambition of taking a leading role nationally. The department should apply for funding for a PhD scholarship in archaeological geophysics (NTNU University Museum 2010). This was supported in the strategy plan for the years 2011-2016, which states that NTNU should be an active producer of knowledge for a sustainable cultural heritage management on a high international level. This should be reached by developing advanced archaeological prospection- and documentation methods in collaboration with technological environments, where the museum should do research within technology-based monitoring, prospection and heritage management techniques (NTNU University Museum 2011).

In 2014 the Department of Archaeology and Cultural history developed their own research strategy for the years 2014-2019. In this document, one of the four main research themes outlines is concerning technologies and methods for spatial analysis, which is defines as the study of the applicability and consequences of technology-based methods for prospection, analysis and monitoring cultural heritage, which enables us to gain more information within archaeological heritage management and research. Technologies and methods for spatial analysis is defined as including geophysical methods, marine technology, remote sensing, photogrammetry, remotely controlled and autonomous robots, geographical information systems, the development of databases as well as data visualization. The goal is to increase the quality of the data, as well as an increased speed and rationalization of data collection, as an important resource for archaeological heritage management and research. This involves research on the applicability of spatial analytical and non-destructive methods for the identification, documentation and monitoring of cultural heritage sites and monuments under varying conditions and over time. The research should also involve knowledge on how spatial analysis and non-destructive methods influence common archaeological practice within cultural heritage research and management. This research is relevant for the society in general, and also functions as a link between humanistic, technological and natural scientific professional traditions, and unites the research environments at the NTNU University museum and The Norwegian University of Science and Technology (NTNU) (NTNU University Museum 2014).

In regards to the hearing related to the DCHs strategic program for 2011-2020 (Directorate for Cultural Heritage 2011), the museum commented that they have had a focus on geophysical prospection methods over several years. The NTNU University Museum also noted that it would be desirable for a dialogue between the DCH and the museum, in regards to a collaboration concerning the development and implementation of research- and development projects aimed towards the future needs within the cultural heritage management.

5.5.5 Tromsø University Museum

The University Museum in Tromsø released a scientific evaluation programme in 2009, which also presented statistics for various registrations, excavation and documentation methods. Two investigations involved geophysical methods. These related to investigations on land, while the scientific evaluation programme later emphasize a need for increased use of geophysical methods for investigating heritage sites and monuments under water. Terrestrial geophysical mapping is therefore given little attention in this document (Tromsø University Museum 2009).

In regards to the hearing related to the DCHs strategic program for 2011-2020 (Directorate for Cultural Heritage 2011), the response from Tromsø University Museum emphasized that tools for prognosis should not replace traditional registration methods. They considered the development and use of high technological methods as a valuable supplement to other methods. The development of such methods should be performed in collaboration between the institutions, and in this way ensure that the broadest possible competence is included in the collaborations (Tromsø University Museum 2010).

The Tromsø University Museum also released a strategy for the years 2014-2020, which does not mention geophysical methods in particular, but emphasize that the museum should communicate the prespectives, methods, results and effects of the cultural historical research and management. The museum should also increase their competence within archaeological field methods, without discussing this further (Tromsø University Museum 2014).

5.5.6 Regional archaeological museums – a short summary

The regional archaeological museums in Oslo, Bergen and Stavanger all warn against a strong regulation of practice, as a limitation of the available methods could lead to the loss of information and knowledge (Museum of Archaeology 2010; Museum of Cultural History 2010; University Museum of Bergen 2010a, 2010b). These three museums all consider a dynamic approach to the choice of applied method as more ideal. New methods and technologies could help the heritage management to supersede the existing knowledge level. The NTNU University museum in Trondheim is the only university museum which have access to their own geophysical equipment and expertise, and is together with NIKU, the only archaeological institutions that are in this position in Norway. Oslo, Bergen, Stavanger and Tromsø all express an interest in the possibilities of collaborating with other institutions regarding research and development related to method development or access to expertise and equipment. The Museum of Cultural History in Oslo encourage the DCH to focus on a limited number of institutions in regards to specialist knowledge, and points towards the NTNU University museum and NIKU as institutions with specialist knowledge. Stavanger, Bergen and Tromsø see high-technological methods as a good supplement to other methods as provider of additional knowledge and as a means improving the efficiency of archaeological documentation. They also express a view that tools for prognosis and non-intrusive methods should not be considered a replacement for ordinary registration, documentation and professional assessments. The latter can viewed in regards to several methods, including for instance predictive GIS-models, LiDAR scanning and other remote sensing methods- including geophysical prospection.

5.6 THE NORWEGIAN INSTITUTE FOR CULTURAL HERITAGE RESEARCH (NIKU)

NIKU plays a role within the Norwegian Cultural Heritage Management as a national centre for competence in issues regarding cultural heritage management, and acts as a consultancy to the cultural heritage management. NIKU is a commercial private institutions, which also is given responsibilities (by license from the DCH) to perform excavations and archaeological registrations in the major medieval cities, clerical buildings and monuments from these periods following the NCHA §11. NIKU also acts as a commercial service provider in issues relating to conservation, archaeological field methods and technology – including providing geophysical surveys to interested actors. They are also an important collaborator in the LBI ArchPro project. Their position and role within the Norwegian cultural heritage management system is therefore very different than the other actors mentioned in this chapter, as they are a private institutions which has been granted special privileges, while still providing commercial services. Being a collaborator in research projects while at the same time providing a commercial service and undertaking geophysical surveys for other actors, creates a situation where new and valuable experience becomes built-up within the organization and becomes beneficial for the practice of geophysical methods in archaeology within both the cultural heritage management and the archaeological research networks.

In the years 2000-2002 NIKU took involved magnetometer-surveys as part of the initial stages of the archaeological registration part of the Gråfjell-project in Hedmark, where Tatiana Smekalova from the Saint Petersburg State University in Russia and the Moesgård museum in Århus, Denmark, surveyed 18 different sites in total. The focus was particularly on traces of iron production and metalworking (Risbøl and Smekalova 2001; Risbøl et al. 2001; Risbøl et al. 2002b).

NIKUs research strategic plan for the years 2005-2009 did not mention technological, remote sensing methods, such as geophysical methods, lidar, terrestrial laser scanning, photogrammetry or similar non-intrusive methods, specifically. The development of methods related to environmental surveillance of landscapes, monuments, objects and cultural environments was mentioned (NIKU 2005:8), but which methods and techniques this could relate to is not indicated. In their annual reports, NIKU has mentioned important focus areas. The first time of geophysical methods were mention in an annual reports was in 2007, where geophysical methods are mentioned among other advanced technological methods in which NIKU had a focus on this year (NIKU 2007). In the annual report for 2008, NIKU give special attention to their project "Mellom himmel og jord" (Eng. "*Between heaven and earth" this author's translation)*, which represented a clear focus and effort into building competence on high-technological methods such as GIS, geophysical methods and other remote sensing methods such as airborne laser scanning, ground-based laser scanning and satellite imagery. NIKU note that "*these are methods that* ***will give*** *very good results for the registration of archaeological sites and monuments both on and under ground*" (NIKU 2008:6, this author's translation and highlighting). Please note the use of future tense. This effort is also mentioned in 2009, where NIKU's involvement in investigating the potential of high-technological methods for documentation and surveillance has led to both an increased work portfolio as well as participation in international research collaborations. This is the first time that their collaboration with the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (LBI ArchPro) is mentioned (NIKU 2009). This institute and the associated research collaboration was founded in 2010, and NIKUs participation was partly financially supported by the DCH. Other Norwegian partners were Larvik municipality and Vestfold county authority (NIKU 2010, 2011b; Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology 2013a). The strategic institute program "Tekno-SIS", which focuses on the use of advanced technology to map, understand, preserve and manage the cultural heritage, was initiated in 2011 and is set to last to the end of 2015, has a separate work package focusing on advanced non-destructive methods (NIKU 2014b). This research focus is further emphasized in their research strategy for the years 2012-2017, where the development and application of new investigation- and documentation methods is one of the main focus areas. Their research focus is to investigate the possibilities of technology to improve efficiency in solving various tasks, as well as investigating the contribution such technologies has on relevant decisions related to the protection and use of cultural heritage sites- and monuments (NIKU 2012:5). In 2014 NIKU founded a separate department for digital documentation, cultural heritage and landscapes (NIKU 2014a). In NIKU's research strategy for 2015-2020, Technological methods and tools is indicated as one of their central approaches for their research contribution towards heritage management and planning. This involves geophysical methods (NIKU 2015a).

NIKU is also involved in a pilot project led by the Norwegian Public Roads Administration called "Arkeologi i veien" (Archaeology in the way – this author's translation), which was initially a call for a report assessing modern and advanced archaeological registrations methods in advance of larger road-development projects (Gustavsen et al. 2013a), but later became a research and development project. This project's main goal is to assess newer registration methods against more convention methods, and investigate if it is possible to make the archaeological registrations more effective. This is being done by performing large-scale and high-resolution GPR surveys in advance of at least two larger road developments (NIKU 2016; Norwegian Public Roads Administration 2016). This example is interesting, because it demonstrates that a initiatives does not have to enter the networks of archaeological research and cultural heritage management through the institutions usually performing research and development, but as in this case can be initiated by an actor who is also a larger developer.

6 SUMMARY OF ARTICLES

This PhD-project started in November 2011 and lasted until May 2016, a time period with a notable increase in the amount of geophysical surveys undertaken in Norway. To properly estimate the status, limitations and possibilities of geophysical methods within archaeological research and cultural heritage management in Norway, it was necessary to review the ways in which geophysical methods had been used in Norway until now. This was done in article one: "Archaeological Use of Geophysical Methods in Norwegian Cultural Heritage Management – a review". This article also sets the course for the research focus of the following articles. While it is clear that an in-depth study of the geophysical response of archaeological site types from all time periods and various geological conditions is beyond the reach of this study, a series of investigations and analyses has been performed to provide new and important information on research topics proposed in article one. Article two therefore focuses on how geophysical methods can be integrated within an archaeological research project, article three evaluates a range of geophysical methods by comparing them with excavation results, while article four is an investigation on how magnetic geophysical mapping can be used to locate and delimit iron production sites in Mid-Norway. All articles contain aspects of field methodological evaluations, evaluations of the various geophysical responses at the investigated sites, as well as suggestions for future practice. All in all, the presented work can act as reference material for future application and analysis of geophysical methods on archaeological sites.

6.1 ARTICLE ONE: "ARCHAEOLOGICAL USE OF GEOPHYSICAL METHODS IN NORWEGIAN CULTURAL HERITAGE MANAGEMENT – A REVIEW"

Declaration of contribution: AAS and LG initiated and designed the study and compiled the jointly run AGIN-database of known geophysical surveys in Norwegian archaeology. AAS wrote the manuscript draft with contributions and input from LG. Both authors were involved in revising the final manuscript.

The aim of this article was to review the ways geophysical methods have been used in Norway, and gain a better understanding of the role and status of geophysical methods within Norwegian Cultural Heritage Management. The work was performed by reviewing and analyzing the content of a database over all geophysical surveys undertaken within archaeological research and cultural heritage management until February 2013, as well as an analysis of strategic documents, treaties, guidelines, directives and associated correspondence from participants within cultural heritage management in Norway. This article related to objective one and five in particular, as well as objectives two to four. For the fulfillment of objectives two to four should article one be seen in conjunction with chapter 4 and 5 (see section 1.1. – "Aim and Objectives").

By this time, 197 surveys conducted as part of 148 different projects were identified and entered into this database. The review shows that the number of surveys in Norway had increased since the beginning of this millennium, but geophysical surveys are nothing new. 64 % of all surveys were initiated for research purposes and 36 % for management purposes - a number much lower than in England and Ireland (Bonsall and Gaffney 2014). Only 11%, or 22 out of 197 surveys, were performed in relation to archaeological evaluations in advance of all other archaeological stages, and 29 % of all surveys involved more than one geophysical method. There is also no clear relationship between the amount of archaeological work each county conducts in relation to planning permissions, and the number of geophysical surveys performed in Norway. While strategic documents and signed treaties justify the use of geophysical methods, the analysis shows that the application of such methods has yet to be generally accepted within the existing cultural heritage management in Norway. The reasons for this is a combination of lack of resolution and technical limitations of earlier surveys, challenging natural conditions and ephemeral archaeology, combined with a lack of trained personnel and competence. Recent research initiative by domestic institutions related to the application of and research on geophysical methods is considered to be a step toward building up domestic experience and knowledge.

Article one demonstrated that the application of geophysical methods is still not considered as an integrated part of the everyday archaeological practice in Norway despite the content of strategic documents and signed treaties justify an increased use of using non-intrusive. The reasons for this is found in the lack of resolution and technical limitations of earlier surveys, challenging natural conditions and ephemeral archaeology, combined with a lack of trained personnel and competence. The article concludes with a series of suggestions of topics for further study concerning the limitations, possibilities and methodological experiences of the use of geophysical methods. These suggestions include a range of aspects that should be investigated further; such as the applicability of the various geophysical methods under different of natural conditions and archaeological site types. In addition, comparisons of collected geophysical data with archaeological feedback from ground based observations and archaeological excavations would improve the understanding of the applicability of the various geophysical methods, and the dissemination of methodological experiences on how geophysical assessments alter or influence decision-making processes in later planning work and archaeological excavations is considered important.

6.2 ARTICLE TWO: "GEOFYSISKE UNDERSØKELSER AV KIRKEGÅRDER, KIRKETUFTER OG SVARTJORD PÅ VEØYA I ROMSDAL».

Declaration of contribution: BS and AAS initiated and designed the study. BS reviewed the historical documents and research history of the site, and wrote this section of the article. AAS gathered and analyzed the geophysical data, and wrote this part of the article. Both authored contributed to the main conclusions and revising the final manuscript.

The English translation of article two is "Geophysical investigations of churchyards, church foundations and the black soil on Veøy in Romsdalen". The main aims of this article was to delimit and indicate the size of the early medieval churches previously indicated by test trenches on the site, locate and estimate the amount of early Christian graves as well as other archaeological structures and traces of activity. The article also reflect on the applicability of the various geophysical methods applied at the site. This work is an example of how geophysical methods can contribute to the understanding of a site which is protected by law, and where there is no imminent reason for undertaking intrusive archaeological work. This article related to objectives five to eight (see section 1.1. – "Aim and Objectives").

In this case, the survey area was an early medieval market place with the remnants of one of the earliest Christian burial grounds known in Norway as well as known traces of early churches dating back to the 11th or 12th century. The area investigated is situated on metamorphic bedrock. The drift-geology on site was mainly marine deposits, with exposed bedrock or thin deposits on certain places. The site was investigated by topsoil magnetic susceptibility mapping, fluxgate gradiometer survey and GPR.

The geophysical survey results led to a series of observations that gave new and important archaeological knowledge as well as methodological experiences. The topsoil magnetic susceptibility measurements indicated higher readings within the area of black soil known to be outside, but not inside the burial ground. In this way, it was possible to delineate one of the churchyards on the island, as it lacked the prominent stone fence indicating its size and layout on its eastern side (churchyard two). The fluxgate gradiometer-results indicate areas of activity, or increased magnetic variation in the measured response over a larger area- indicating a difference between the inside of churchyard two and the settlement area east of this. A possible building was also indicated. The observed variance in the magnetic response from the site indicated the influences the metamorphic bedrock had on the dataset, obstructing a clear identification of archaeological features. The GPR survey results contributed to the delineation of churchyard number two in the eastward direction. In addition to this, the GPR investigation revealed the presence of three possible buildings, where two buildings were interpreted as the remains of previous churches – where one could be one of the oldest churches erected in Norway. Although several east-west oriented anomalies was identified, a clear and undisputed interpretation of these anomalies as graves was difficult.

The general conclusions in the article is that the geophysical data collected at the site gave very interesting results if applied within a clear framework. At the same time, the surveys conducted highlighted some problems with converting the geophysical data into clear and trustworthy archaeological interpretations, partly due to the effect of the predominant geological survey conditions as well as problems distinguishing the geophysical response from geological sources from important archaeological features. The survey results also indicated some of the inherent limitations associated with the various geophysical survey methods applied here, highlighting the importance of source criticism and knowledge on geophysical factors that might impede clear archaeological interpretations of the geophysical observations.

6.3 ARTICLE THREE: “GEOPHYSICAL SURVEYS AT AVALDSNES”

Declaration of contribution: AAS and ELB initiated and designed the study. AAS compiled, processed, analyzed and compared the geophysical information with excavation results. ELB contributed with archaeological feedback, excavation results and the excavators’ experience of working with the geophysical data sets. AAS wrote the first draft, based on contributions from ELB. Both authors were involved in revising and reviewing the manuscript.

Article three, “Geophysical Surveys at Avaldsnes”, focuses on comparing the geophysical prospection results from Avaldsnes in Western Norway with the excavation results from the same site. The main aim of this article is an evaluation of the applied geophysical method under the prevailing geological and archaeological conditions. A key point in the evaluation was to assess how readily the geophysical data could be made accessible and interpreted by the on-site staff, and how this communication functioned at Avaldsnes. The results of this evaluation is to propose suggestions for good practice in the future. This book chapter contains a brief history of the various geophysical surveys conducted, a short introduction the various geophysical survey methods applied at the site, as well as background information on how data from the excavation were linked together with the geophysical results as part of the evaluation. This article relates to objectives five to eight (see section 1.1. – “Aim and Objectives”).

Generally, the experiences at Avaldsnes show that the GPR dataset was more applicable for use during excavation than magnetometer, magnetic susceptibility and the earth resistance data under the prevailing conditions. This was mainly due to GPR anomalies being more easily comparable to excavated archaeological features. GPR also proved very applicable to locate cooking pits within a thick and homogenous prehistoric cultivation layer. These conditions are site dependent, and it is clear that local geology, thickness and homogeneity of deposits, and past activities at the site, affect the interpretable result. In all areas at Avaldsnes, the gradiometer results were susceptible to background variations of non-anthropogenic origin – mainly magnetic bedrock of volcanic origin. Electromagnetic induction was more successful than magnetometers in delineating sources of firing under these geological conditions. The mass susceptibility samples indicated comprehensively activity areas within the excavated layers. The topsoil magnetic susceptibility, as well as the other datasets, were conflicted by modern disturbances, which made it difficult to distinguish archaeological features and cultural historically important information in the datasets collected. While it was difficult at times to correlate geophysical observations with archaeological observations, each and every method proved to contribute additional archaeological information, demonstrating the advantage of a multi-method approach. Another important observation was that features visible in the geophysical datasets were sometimes overlooked by the field staff as the illustrations in the geophysical report was not presented in at a suitable scale, without an interpretation or description giving the anomaly much notice. It is therefore important for the field staff to have access to georeferenced data plots and interpretations, allowing them to select which slices and data plots appropriate for their current task and investigation area. Some of the methodological choices made at Avaldsnes, does, in hindsight, appear inappropriate. The article argue for supplying the geophysical technicians information on the kind of features to expect, based on survey excavation, written sources and experience. Communication between the provider of the geophysical data and the excavation staff should be maintained throughout the excavation phase and even post-excavation work, when interpretations are tested and revised.

6.4 ARTICLE FOUR: "MAGNETIC GEOPHYSICAL MAPPING OF PREHISTORIC IRON PRODUCTION SITES IN MID-NORWAY".

Declaration of contribution: All authors contributed to the design of the study. LS contributed with historical background and documentation of the archaeological investigations of iron production sites in mind-Norway. CG contributed with background information and concepts of geophysical investigations and the analysis of geophysical results from iron production sites. CG also supervised the data collection. AAS collected, processed and analyzed the geophysical data. AAS drafted the manuscript with contributions from LS and CG. All authors were involved in revising the manuscript.

The aim of this paper is to investigate how magnetic geophysical mapping of iron production sites can be used to locate and delimit prehistoric iron production sites, and help to characterize activity zones and specific archaeological features associated with the iron production tradition in mid-Norway called the Trøndelagsfurnace-tradition. This work was undertaken by investigating four iron production sites in mid-Norway by combining topsoil magnetic susceptibility sampling with detailed fluxgate gradiometer surveys. The survey results were compared with sketches, surface observations and topographic information. The article contains a short description of the geophysical methods used, a short history of the geophysical mapping of iron production sites in Europe and within Norwegian archaeology, as well as a presentation of the survey results and a discussion of the survey results. The results include summary statistics over geophysical contrasts and observations, area covered as well as detailed data plots. This article should be seen in relation to objectives five to eight (see section 1.1. – "Aim and Objectives")

The main conclusions of this work is that the use of magnetic geophysical mapping is ideal for locating, delimiting and characterizing iron production sites. The topsoil magnetic susceptibility measurement revealed a strong contrast between the main production measurements and the natural background measurement values, making it possible to indicate the size of, and zones of enhancements within, the main activity areas. As only one of these sites have been excavated in its entirety, the information of site size is something that has previously been largely unknown. The highest topsoil magnetic susceptibility readings was observed in the areas in the immediate vicinity of the furnaces, but the area of enhancement extended several tens of meters into the flatter terraces behind the furnaces. A close relationship between the thickness of slag and the measured susceptibility values was observed. The fluxgate gradiometer surveys proved ideal for a more detailed mapping of the production sites, but also resulted in a more complicated geophysical response, with a variation in the shape and geophysical contrast for known furnaces. There was a strong magnetic response within the main activity areas- making it easy to distinguish between readings within and outside of the main activity areas of the iron production sites. The archaeological interpretations the collected fluxgate gradiometer data indicated possible roasting sites for iron ore, as well as storage areas for the roasted iron ore. Overall, the work undertaken on these iron production sites created new and valuable cultural-historical knowledge, including details of size, spatial layout and extent- as well as methodological experiences concerning spatial resolution and sample strategies.

Overall, the articles give new and valuable insight in role and status of geophysical methods within the Norwegian cultural heritage management system as well as the applicability of a wide range of geophysical methods over various geological and archaeological site conditions. In addition, methodological experiences contribute to a better future practice of geophysical methods within Norwegian cultural heritage management and archaeological research. The articles demonstrate how site conditions, with regards to geological conditions, modern disturbance and archaeological site types, all influence the relative “success” in being able to identify potential archaeologically relevant information in the collected geophysical data. The acquired knowledge from these articles will be discussed in relation to objectives five to eight in this thesis, and included in a more thorough discussion in chapter 7

7 DISCUSSION

7.1 GEOPHYSICAL METHODS IN CULTURAL HERITAGE – STATEMENTS AND MODALITIES

In chapter 5, I gathered various statements on how geophysical methods have been mentioned in strategic documents and communication by actors in the cultural heritage management and archaeological research in Norway. Following the theoretical and methodical perspectives presented in chapter 3, it is clear that how various actors mention and discuss geophysical methods helps us better understand how these methods are perceived in relation to heritage management and research aspects (objective two). Seen from an ANT perspective, a phenomenon is defined by how it is perceived and understood by other actors. In this instance the object of investigation is a network of associations, where geophysical methods in archaeology is defined by what is being said about the methods by these actors, and what the geophysical methods are associated with. It therefore becomes highly interesting to investigate what these associations are in the documents and statements as described in chapter 5 (objectives two and three). Such a presentation of associations, in this work focusing on the entitlements and descriptions used when describing the geophysical methods, provide a deeper understanding of the perceived and envisioned role and function of geophysical methods by as viewed by the various actors within archaeological research and cultural heritage management. This understanding, in turn, helps us to understand the background to the actors' acceptance for using such methods within their daily work. The actors' acceptance is directly related to the perceived role and function of the geophysical methods (objectives two and three). The task at hand for the following part of the thesis is to investigate how the various actors entitle and describe geophysical methods, as well as evaluate the role and status and intended of geophysical methods in Norwegian archaeology through an analysis inspired and influenced by ANT (see chapter 3) and the concept of statement modalities (table 1) and level of translation (table 2).

7.2 ENTITLEMENT AND DESCRIPTIONS

First of all, a presentation on how the geophysical methods are entitled, or what words are used to introduce them, is necessary. They are not always mentioned as geophysical methods, but with more general entitlement or description. In certain instances, it is unclear which technical method the documents and statements refer to, and might refer to LiDAR scanning, the analysis of satellite imagery, photogrammetry or some other high-technological instrumentation. From an ANT perspective, the entitlements and descriptions stated by the various actors indicate how the actors associate geophysical methods with their own activities and roles, as well as tell us how the methods connect to these actors and the networks the actors and the methods are a part of.

Table 5: Entitlements used in the various documents presented in chapter 5, arranged by institutions. Bold and underlined are the most used expressions per institution type, bold and italic are the second most used. An expression might be presented as a combination of several entitlements in the original statement.

ENTITLEMENT	MINISTRIES	DCH	COUNTY COUNCILS	ARCHAEOLOGICAL MUSEUMS	NIKU	TOTAL
GEOPHYSICAL METHODS	1	**11**	4	**5**	**4**	25
NON-DESTRUCTIVE (NON-INTRUSIVE) METHODS	0	***8***	**7**	1	1	17
NEW TECHNOLOGIES/NEW METHODS	**3**	4	3	0	0	10
HIGH-TECHNOLOGICAL/ADVANCED METHODS	1	1	0	**5**	***3***	10
NEW REGISTRATION METHODS	1	2	***6***	0	0	9
METHOD FOR DOCUMENTATION, INVESTIGATION AND PROGNOSIS	0	0	0	***3***	1	4
SURVEYING TECHNIQUES FOR FIELD ARCHAEOLOGY	***2***	0	0	0	0	2
NATURAL SCIENTIFIC SAMPLING METHOD	0	1	0	0	0	1
TECHNOLOGIES AND METHODS FOR SPATIAL ANALYSIS (INCL. GEOPHYSICAL METHODS)	0	0	0	1	0	1

While the use of the term “geophysical method” is most abundant (see table 5), the word “new” is often used – either in relation to “new methods for registration and investigation”, “new technologies”, or “new methods for documentation”. Most recently, the word “new” was used in a letter from the DCH to the MoCE in 2014, and in the strategic plan for culture in Oppland county in 2015. The word new was also used several times by both the DCH and various county authorities in the annual letters of prioritizations for the years 2011-2014, when discussing geophysical and other non-intrusive methods. Although geophysical methods were discussed in 2015 in these letters, they are not denoted as “new”. NIKU used “new” in their Tekno-sis research strategy from 2012, but not their new research strategy from 2015 – there NIKU mention geophysical methods without this description (see chapter 5 for a presentation of the various documents).

Several actors describe a wish for, or the intention to, developing geophysical methods or describe them as on a development stage or in a testing phase. This can be interpreted in several ways. This can for instance be that the actors feel that the geophysical methods are not entirely adapted or understood- while still having a wish for a better understanding of the methods. Alternatively, the word “development” expresses a wish to investigate and understand the methods better, and in this way positioning one self as a spokesperson speaking on the methods’ behalf. The latter is probably more true for research institutions such as the NTNU University Museum in Trondheim and NIKU. It can also be an indication that the actors do not properly understand the methods and their potential use, as I find it unlikely that for instance county authorities should be directly involved in any hardware development of geophysical instrumentation. I will discuss the entitlement of “new methods under development” specifically later in this chapter. This tendency indicate that some actors place geophysical methods within the network of research (be it archaeological, field methodical or geophysical research), rather than within the cultural heritage management network. This can also be an indication that the methods, to them, seem at a research stage. Other actors, such as argued in article one, mean that this is more a question of the lack of knowledge and insight of the possibilities and limitations the geophysical methods have to offer.

The use of *non-intrusive* and *non-destructive* methods is also common in the communications from the DCH (see table 5). The various county authorities most often mention geophysical methods as non-destructive methods, new registration method or as just "geophysical methods". The application of non-destructive/non-intrusive methods aligns well with pronounced intentions in ratified treaties and conventions (see section 4.2.2), and is a way of interessement and enrolement, where the methods gain increased legitimacy by referring to- and mobilizing allies such as stated strategies, ratified treaties and national goals for the cultural heritage management.

Seen from an ANT perspective, the statements mentioning high-technological (and indeed geophysical) methods are defined and positioned towards the actors main interests and occupations. This visualizes to some degree what type of cultural resource the actors intend to apply such methods on- either as a resource to be registered and managed, or a resource to be documented and recorded for research purposes. The university museums, for instance, often describe these methods as *geophysical methods*, as archaeological methods for documentation, prospection and spatial analysis (see table 5). The description *high-technological methods* is mentioned by all university museums. Several museums emphasize that the methods should be viewed as a supplement to, and not a replacement for, traditional documentation and registration methods. As presented in article one, and with updated statistics in figure 1, the notion of geophysical methods as something new within Norwegian archaeology is not entirely accurate. This will be discussed further as a controversy below.

This variation is interpreted as a representation of the main interests for the various institutions – for instance non-intrusive or non-destructive management of cultural heritage by the DCH, the registration and identification of archaeology and an interest in non-destructive techniques by the counties and documentation by the museums. This can be investigated further by looking at how the various institutions describe the function and role of the methods in the documents.

7.3 THE PERCEIVED ROLE AND FUNCTION OF GEOPHYSICAL METHODS

When investigating the role and function of geophysical methods as perceived by the various actors within archaeological heritage management and research, it becomes clear that these perceptions are not unified and equal, although some elements repeat themselves. The following walk-through involved investigating what role and purpose the various actors envision for the use of geophysical methods. It does not distinguish between an accepted use, or the wish for methods that can help with certain aspects relating to cultural heritage management and research. The descriptions presented in table 6, to some extent overlap in meaning. I.e. investigating, mapping and registering can one and the same purpose, but the table has been organized to show the inherent variation in the statements presented in chapter 5.

Table 6: Summary over roles and functions envisioned for geophysical methods. Bold and underlined are the most used expressions per institution type, bold and italic are the second most used. A statement might contain several intended roles and function within the same statement. In such cases, the statements can be contribute to several counts within different categories.

ROLE AND FUNCTION	MINISTRIES	DCH	COUNTY AUTHORITIES	ARCHAEOLOGICAL MUSEUMS	NIKU	TOTAL	TYPE
INTEGRATION IN CHM/ PLANNING PERMISSIONS		***3***	**9**	**3**	**3**	18	Management
REGISTERING	1	**6**	6	***2***	1	16	Investigation
EFFICIENCY/ COST-EFFECTIVENESS/ SPEED		***3***	***7***	***2***	1	13	Management
DOCUMENTATION METHOD	**4**		2	**3**	***2***	11	Investigation
ACQUIRE KNOWLEDGE	***2***	1	3	***2***	***2***	10	Knowledge
INVESTIGATION	***2***	1		**3**	1	7	Investigation
MAPPING	1	2	3		1	7	Investigation
TOOL FOR PROGNOSIS	1	2		***2***		5	Management
EXCAVATION METHOD	***2***	1		1		4	Investigation
REDUCE PHYSICAL IMPACT		***3***	1			4	Preservation
CLEAR AND PREDICTABLE MANAGEMENT		1	1	1	1	4	Management
NON-INTRUSIVENESS/NON-DESTRUCTIVENESS		***3***				3	Preservation
INTERPRETATION/ IDENTIFICATION				***2***	1	3	Knowledge
MONITORING/ SURVEYLANCE	1			1	1	3	Investigation
LIMIT CONFLICT		1				1	Preservation
ACCURACY		1				1	Investigation/ management
EXPAND FIELD SEASON		1				1	Investigation/ Management
TOOL FOR PRIORITIZATION	1					1	Management
SUSTAINABLE MANAGEMENT			1			1	Management
PROSPECTION				1		1	Investigation
ANALYSIS				1		1	Knowledge
QUALITY				1		1	Management
PRESERVATION					1	1	Preservation

The following table can be presented by ordering the numbers in table 6 by type, based on the main wording and description. Again, the main purpose might overlap, as for instance registering and mapping monuments to some extent might be performed for the purpose of better management and the preservation of monuments. This distinction has still been made to be able to group the statements into main groups of intended purpose for the geophysical methods. This is presented in table 7 and table 8.

Table 7: Ordering of Table 6 by main type of envisioned role and function

TYPE	NUMBER	ROLES AND FUNCTIONS
INVESTIGATION	51	registration, documentation, investigation, excavation, mapping etc.
MANAGEMENT	45	integration in CHM/handling of planning permissions, efficiency/cost-effectiveness/speed, tool for prognosis etc.
KNOWLEDGE	14	knowledge, interpretation and analysis
PRESERVATION	9	non-intrusiveness/non-destructiveness, reduce physical impact, limit conflict

By breaking down the numbers in table 7 even further by institutions, this results in table 8.

Table 8: The role and functions for geophysical methods as stated by the various institutions. Numbers are based on table 6 and table 7.

TYPE	MINISTRIES	DCH	COUNTY COUNCILS	ARCHAEOLOGICAL MUSEUMS	NIKU	TOTAL
INVESTIGATION	**11**	**12**	***11***	**11**	**6**	51
MANAGEMENT	***2***	***11***	**18**	***9***	***5***	45
KNOWLEDGE	***2***	1	3	5	3	14
PRESERVATION	0	7	1	0	1	9

While the MoCE in the earlier years mention the methods as either new methods (Proposition to the Storting 2004-2005), methods involving high technological equipment (Ministry of Environment 2010) while the latest proposition to the Storting (governmental white paper) is the first to mention geophysical methods explicitly (Proposition to the Storting 2012-2013a). The perceived role also changes through time, from *methods of investigation and acquiring knowledge* (Proposition to the Storting 2004-2005), to *geophysical methods as aid to excavation, documentation and monitoring* (NOU 2006; Proposition to the Storting 2007-2008; Ministry of Environment 2010). In the latest Proposition to the Storting the focus is more on the methods' potential for indicating the presence of cultural heritage sites and monuments, i.e. tools for prioritization and the formation of prognosis for use in heritage management (Proposition to the Storting 2012-2013a). See table 6 for a more detailed list of expressions used.

Looking at strategic documents and communication from the DCH, the most mentioned role and purpose of geophysical methods is registration of cultural heritage sites and monuments (see table 6). In this is to be understood the geophysical methods' potential for mapping archaeological features, sites and landscapes. In this lies an element of increasing accuracy of archaeological investigations, by being able to more accurately focus an investigation to targets indicated by the geophysical results

(Indrelid 2009; Karlberg and Jerkø 2009; Directorate for Cultural Heritage 2011, 2014b, 2015a). These are traits of geophysical methods that are relevant for the methods' use in both archaeological research and within heritage management. In relation to archaeological registrations is the potential of limiting conflicts, and increasing the archaeological knowledge both in relation to increased integration in cultural heritage management and within archaeological research (Karlberg and Jerkø 2009; Directorate for Cultural Heritage 2010c, 2011). An understanding of the geophysical methods' potential of increasing efficiency and cost effectiveness, as well as potential to expand the field season has also been mentioned (Indrelid 2009; Directorate for Cultural Heritage 2010c; Museum of Cultural History 2010). There has also been an emphasis of replacing, rather than supplementing, traditional field methods (Directorate for Cultural Heritage 2010d, 2014f), as well as an emphasis on the geophysical methods' non-intrusive nature (Directorate for Cultural Heritage 2009; Karlberg and Jerkø 2009; Directorate for Cultural Heritage 2010d, 2014b). Several actors have earlier expressed concerns with the idea of geophysical methods as a replacement for traditional registration methods (Directorate for Cultural Heritage 2014f; Oslo Municipality 2015, 2016). It becomes interesting to note that several actors try to redefine the aims and objectives of using geophysical methods to becoming a supplement to other methods (see for instance Museum of Archaeology 2010; Tromsø University Museum 2010; University Museum of Bergen 2010a)- an action on level one in the levels of translation (see table 2). The use of geophysical methods as mainly a supplement, and not a replacement, of other geophysical methods very much in line with my own views of the role of geophysical methods, although this does to some degree have to be considered against the initial reasons for performing a survey in the first place. Geophysical methods *can* be used as a replacement, depending on the questions that is asked and the aims and objectives of the investigations. This will be discussed further in section 7.8.3 – on the controversy of replace versus supplement.

The various county authorities have their main emphasis on geophysical methods as methods that can be integrated in cultural heritage management (CHM) and in relation to planning permissions for registration of sites, monuments and archaeological features and increase the efficiency/cost-effectiveness and speed of investigations and planning permissions (see table 6). The overall total focus are on management, followed by investigations (see table 7 and table 8). Vestfold county authority emphasized in their strategic plan for 2011 and 2015 how *new* non-intrusive technology such as geophysical methods could help to provide a clear and predictable cultural heritage management and increase the efficiency in the planning process by introduction non-intrusive methods early in the planning process (Vestfold county authority 2011, 2015). The emphasis on the non-intrusive and non-destructive character of the methods, as well as geophysical methods as a mean of attaining more knowledge, is less evident for the county authorities in general. However, a few exceptions exist. In addition to Vestfold, county authorities such as Hordaland, Oppland and Sør-Trøndelag emphasize the possibilities of a more sustainable and efficient handling of planning permissions by having more knowledge in the early stages of the management process. Since 2011 there has also been an additional interest in the potential of increasing the efficiency in the handling of planning permissions, and how to minimize delays (Vestfold county authority 2011; Sør-Trøndelag county authority 2013b; Buskerud county authority 2015; Hordaland county authority 2015; Oppland county authority 2015; Vestfold county authority 2015).

The various regional archaeological museums have a larger emphasis on geophysical methods as a documentation method (including archaeological registrations) and management aid, which can work as a tool for improving efficiency, prioritization, and rationalization as well as for analysis and interpretation (NTNU University Museum 2007; Larsen 2009; Museum of Cultural History 2010; NTNU University Museum 2010; University Museum of Bergen 2010a; NTNU University Museum 2014). The

NTNU University Museum emphasize geophysical methods in archaeology as a field of research on its own (NTNU University Museum 2007, 2010, 2014). Of all institutions, the university museums also have a larger emphasis on the knowledge aspect compared to the other institutions (see table 8).

NIKU used magnetometers systematically as part of the Gråfjell project in 2000-2002 to map iron production sites and related activity, as part of a larger archaeological registration project (Risbøl and Smekalova 2001; Risbøl et al. 2001; Risbøl et al. 2002a; Risbøl et al. 2002b; Smekalova and Voss 2002). The institute has since then had a focus on the use of geophysical methods within several aspects of cultural heritage management: the geophysical methods' applicability in mapping archaeological features under varying conditions, how the methods can used within cultural heritage management as part of the planning process by contributing to decisions related to protection and use of cultural heritage sites and monuments, as well as how the methods can contribute to increased efficiency and predictability throughout the planning process (table 6). NIKU has a different role than the other actors within archaeological research and cultural heritage management, as they are a private institution that also provide commercial services.

As with the variation on how geophysical methods is described or categorized (table 5 to table 8), there is also variation in the perceived role and function of geophysical methods. While some of these roles and functions are interconnected and related, others have a more specific focus. The most perceived role and function, integration in CHM and for planning permissions, is closely related to the second and third most annotated property: geophysical methods as a tool for registering archaeological sites, monuments and features. The third most annotated property is a focus on how geophysical methods can improve the efficiency and effectivity of heritage planning and therefore contribute to reducing the costs of archaeological registrations. The last was the main focus in the 2014 evaluation letter from the DCH to the MoCE (Directorate for Cultural Heritage 2014f), where the efficiency versus total costs of archaeological registrations was discussed, but then mainly concerning the NCHA §9 c.f. §10, focusing on the stage of archaeological registration. This was also a tailored response to a specific order focusing on the issue of archaeological registrations following the NCHA §9 c.f. §10. The cultural heritage management perspective is also related to the fourth and fifth most annotated property: how geophysical methods can be a documentation method and contribute to cultural historical knowledge. Topics such as improved preservation, integration and expanding the field season has also been mentioned (see table 6).

Also, while the main focus is different from each actor and from the networks of archaeological research versus cultural heritage management, it is also evident that there has been an increased focus on efficiency and effectivity since 2011, especially by the county authorities which are mainly situated within the network of cultural heritage management. All actors have elements of the detection of archaeological features and improved cultural heritage management in regards to planning as the actors' main focus for the role and purpose of geophysical methods. Some aspects vary: the archaeological museums see the methods mainly as tool for rationalization, prioritization and documentation and to acquire knowledge (mainly network of archaeological research), the counties and the DCH have a main emphasis of detecting archaeological features (mainly network of cultural heritage management). Interestingly, the analysis and interpretation-aspect is only focused on by the museums, while it can be argued that this can be seen as a sub-aspect of the more generic expression "knowledge". Preservation-aspects are specifically mentioned by NIKU (see table 6). The results show how the actors' understanding of their role and function within the networks of archaeological research and cultural heritage management influence their main focus when making statements regarding geophysical methods.

In article one, the following main benefits of geophysical methods was listed:

1. The non-intrusive nature of the methods
2. The potential for acquiring more information about archaeological sites without destroying them
3. The fast speed of at which surveys can be conducted
4. The level of accuracy and detail providing useful means of pinpointing the location of interesting anomalies and activity zones

(Article one - Stamnes and Gustavsen (2014:25) with references to Clark (1996), Gaffney and Gater (2003), Lockhart and Green (2006), Gaffney (2008), Ernenwein and Hargrave (2009:9-13), Viberg et al. (2011)). In this lies the possibilities of gathering complementing information beyond the edges of test trenches or outside of any excavation boundaries (Viberg et al. 2011:53).

The topics presented in the list from article one, is to a high degree overlapping with the observations in the statements made by the various actors in the documents presented in chapter 5. It is interesting to note that two of the main aspects presented in article one, i.e. the importance of non-intrusiveness and information potential without destroying the sites, receives less attention when the various actors mention the methods as summarized in table 6. The statements will be presented and discussed in more detail in the following section on statement modalities.

In articles two, three and four, practical examples of archaeological use of geophysical methods demonstrates various roles and functions geophysical methods can have. The articles demonstrate how geophysical methods can be integrated to locate archaeological sites in the landscape, and further how the sites can be further understood by locating and characterizing the geophysical responses in various ways. The geophysical observations was used to plan excavations, understand the spatial layout and extent of sites, monuments and features, and gain new and previously unattainable archaeological knowledge of the sites investigated. This new knowledge can be integrated in cultural heritage management planning, both directly by having new information on size, extent and location, but also as providing important knowledge on typical extent of sites- for instance the size and extention of iron age production sites in mid-norway (see article four). Section 7.6, *Locating archaeological sites, monuments and features with geophysical methods,* discussed the possibilities and limitations observed in more details.

Seen from an ANT perspective, it is interesting to note the purposes the actors within a CHM-network envision for the geophysical methods as stated in the documents presented. These statements can be seen as aims and objectives for the development or adaption of such methods, or as obligatory passing points – interests within the network of which the methods need to prove their applicability. Such statements then serve both as devices of interessement, and as a way to enrole and mobilize both the methods as actors, but also the actors that provide geophysical services. The actor of geophysical methods becomes connected to the various actors within the CHM-network through these statements. The network of archaeological research, for instance research on the applicability of geophysical methods, can in turn, be influenced by wishes and needs from the CHM-network, and provide results that intend to answer some of those needs. In this way, the process described above is way to influence and activate the research-network for the needs of the CHM-network, and it then becomes a way to enrole and coordinate allies and tie them towards mutual goals. The statements of the CHM-network also functions as providing increased legitimacy for research focus and for instance improved impact of research applications for actors involved in research on geophysical methods for

CHM purposes. Section 7.6, “Has geophysical methods proven their worth?”– based on the empirical results from article two-four, should be seen in direct relation to this as a research contribution that addresses issues raised by both the networks of CHM and archaeological research.

7.4 STATEMENT MODALITIES – CURRENT UNDERSTANDING OF APPLICABILITY AND ACCEPTANCE FOR THE USE OF GEOPHYSICAL METHODS

The previous presented and discussed the main roles and function of geophysical methods as understood by various actors within Norwegian archaeological heritage management. The increased understanding and overview gained from presentation and discussion makes it possible to evaluate what confidence level each actor assigns the perceived roles and functions of geophysical methods (table 6, table 7 and table 8) following Latour’s theory on statement modalities (see table 1) (Latour 1987; Schaanning 1996:77; Brattli 2006:40-41). It is also important to understand that the assignment of these roles and functions is not necessarily only an understanding on how the methods are used, but can also imply a suggestion or hope for future application of these methods. In this case this still retains an aspect of perceived potential for application of geophysical methods, and therefore implies a role and function.

One thing is the perceived role of the geophysical methods, another important aspect is the acceptance for use of geophysical methods, which is connected to how well the various actors believe geophysical methods can contribute to fulfilling the role and function the actors designate to them. The understanding of the acceptance of the geophysical methods, should be read in relation to the role and function mentioned for each specific statement. This section investigates the statement modalities (see table 1) of the statements. To properly present and explain the analysis, quoting and repetition of statements, i.e. the contents of the documents presented in chapter 5, is necessary. While this may seem repetitive, such an approach it is necessary to investigate and exemplify the statement modalities contained in the statements.

In the governmental Proposal to the Storting “Leve med kulturminner”, the Ministry note that “*new methods to register and investigate archaeological sites and monuments makes it, in a larger degree than earlier, possible to identify and acquire knowledge of such finds*” (Proposition to the Storting 2004-2005: 23, this author's translation). Although a generic comment, this still represents one of the earliest mentioning of role and potential for geophysical methods although the methods are not mentioned specifically. The statement is difficult to place within a specific statement modality. Later, in 2010, the ministry note that management depends increasingly on high-technological equipment as an aid to gathering knowledge, as well as documentation and monitoring (Ministry of Environment 2010). This is an interesting observation that puts a role and function to high-technological methods within heritage management, but does not really give a clear indication of the acceptance of use of geophysical methods, or indeed if it is geophysical methods and not some other high-technological method that it is they refer to. It is not really until the latest Proposition to the Storting, “Framtid med fotfeste”, that the Ministry give some additional indication of their acceptance of use of geophysical methods. The geophysical methods are still described, along with LiDAR, as *new* technical methods that are “*within a testing phase, but have a large potential when it comes to getting good data as foundation for making prognosis for cultural historical value within an area*” (Proposition to the Storting 2012-2013a: 40, this author's translation). The fact that the methods are described as *new technology being in a testing phase* that have *potential*, places them somewhere between step one and three on the statement modality ladder (see table 1, and chapter 3), i.e. between maybe we could use the methods to an assumption that the methods might give a contribution to the relevant question at hand. Still, the geophysical methods are associated with knowledge production, in alignment with an interest of better prognosis and cultural historical management. The Ministry, when discussing this, refers to a NIKU assessment of advanced archaeological registration methods (Gustavsen et al. 2013a), mobilizing additional actors and their support in to the statement made by the Ministry. The Ministry also clearly state that the DCH will continue using GPR for registering and mapping ruins of stone buildings below ground (Proposition to the Storting 2012-2013a:34; Directorate for Cultural Heritage 2015d). In the latter, the Ministry does not question the applicability of the method for this purpose, GPR and its usability has become a black box on statement modality level four or five (table 1). This is a contrast to the other statement from the same document mentioned above.

In a report written in collaboration with the research organization Sintef, the DCH states that magnetometers *"may map features subjected to heat such as iron production sites, roasting sites of iron ore, tile ovens and places for melting ore"* and *"GPR contributes to measure the depth to features in the subsurface, and is mostly applicable in urban areas and beneath standing buildings".* It is also commented that the use of these methods for the registrations of archaeological sites and monuments in Norway still are on an experimental stage (Karlberg and Jerkø 2009:121). These statements are also conflicting, as the wording concerning GPR is definite and specific, the magnetometer-comment uses the word "may", and the introduction states that the use and development of the methods are still experimental. Experimental indicates, as with the testing-phase comment from the Ministry, a statement modality somewhere between stage one and three, while the specific comment on the methods indicates a more definite acceptance on level four or five. It is also possible to question the statement that GPR is mostly applicable in urban areas and beneath standing buildings. According to Larry B. Conyers, the author on several books on GPR in Archaeology, an urban environment is amongst the most complex of all environments you can survey with GPR, and requires well understood stratigraphical information from excavations or core samples to be properly applied (Conyers 2016:135). Gaffney and Gater (2003:48) also commented on this, saying that it was not necessarily so that GPR works well for urban sites, but rather that GPR worked better than most other geophysical methods in such site conditions. This therefore draws the conclusions and suggestions of Karlberg and Jerkø (2009) into doubt. In the later years, GPR has proven highly beneficial for large-scale archaeological mapping outside of urban areas (Trinks et al. 2010b; Gabler et al. 2013; Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology 2013a; Nau et al. 2015). Three other documents provide more definite statements on the current role of geophysical methods as seen from the DCHs point of view: The strategic plan from 2010 (Directorate for Cultural Heritage 2011), a letter from 2014 to the MoCE (Directorate for Cultural Heritage 2014f), as well as the a guidance document for budgeting for archaeological registration concerning §9 c.f. §10 in the Norwegian Cultural Heritage Act (Directorate for Cultural Heritage 2015e).

The Strategic Plan for management of archaeological sites, monuments and cultural environments from 2011 emphasizes geophysical methods as a method that *"to a large degree limit the physical damage to cultural heritage sites and monuments, and increase the efficiency and precision of the documentation"*. The DCH therefore stated that they wanted to stimulate to the development and use of non-intrusive methods in connection with registration and excavation, as a support to the cultural heritage management, so that DCH can have satisfactory tools for the safeguarding of archaeological sites, monuments and landscapes (Directorate for Cultural Heritage 2011:10-11, this author's translation). The DCH also refer to the Valletta-convention in relation to Norway's obligation to preserve archaeology *in-situ*, which therefore is used to support the DCH's emphasis of contributing to the development of methods for the best possible safeguarding of archaeological sites, monuments and landscapes. It is therefore strange that the DCH refrain from mentioning the Valletta-convention article 3, paragraph I, letter b that states that *"non-destructive methods of investigation are applied wherever possible"* (Council of Europe 1992a) when the DCH states their intention to stimulate to the development and use of non-intrusive methods. Although, as previously discussed in section 4.2.2, the intention of this paragraph in the Valletta convention might be interpreted in several ways. I therefore consider this emphasis as a general acceptance of geophysical methods for limiting physical damage, increasing efficiency and precision of documentation, although some room is left for doubt following the refraining from using the Valletta convention as support in the statements made by the DCH.

This doubt becomes very explicit in a letter to the Ministry of Climate of Environment from 2014, outlining the DCH's assessment in relation to whether or not the cultural heritage management should be asked to increasingly utilize new archaeological methods in relation to archaeological registrations following §9 c.f. §10 in the Norwegian Cultural Heritage Act. In this letter the DCH state that *"it **is a fact** that "new technology" **only can map certain types** of cultural heritage sites and monuments, and that the methods **only in very few cases can replace** "traditional" registrations methods. It will require additional method development and lower **use costs** to attain a potential "efficiency reward". This is valid for both typical outfield monuments (by using airborne laser scanning) and in cultivated land (by using georadar or magnetometer). In both cases will there **always** be necessary to perform control registrations to verify or control the data, and **both methods "lose"** important types of cultural heritage sites and monuments" (Directorate for Cultural Heritage 2014f, this authors' highlighting and translation).* The DCH therefore conclude that they cannot impose the cultural heritage management to use methods that are not cost-effective, seen in relation to each individual case, as long as the financing remains as it is and the size of the individual archaeological registration is fairly limited. In this letter, dated in august 2014, the DCH calculate an average expense of 50-60 000 NOK per archaeological registration. They also state that it is not sensible to increase the use of "new technology" as part of archaeological registrations, when the methods anyways do not replace the use of traditional methods. The additional cost should then either be covered by larger, public developers, or by the heritage management themselves (Directorate for Cultural Heritage 2014f). This letter, in connection to the released guidelines for budgeting for NCHA §9 c.f. 10, clearly states the DCH most recent understanding of geophysical methods and their applicability in relation to archaeological registrations. In the NCHA §9 c.f.10 guidelines for budgeting for archaeological registrations, geophysical methods were not listed as a well known registration methods recommended. The document opens up for inclusion of geophysical methods if the developer agrees to the costs, and the use is justified with references to professional and/or practical considerations. The DCH also see the use of such methods as an additional cost (Directorate for Cultural Heritage 2015e). By clearly stating their impression of geophysical methods as definite as this using wording such as "***never** replace traditional registration methods*", or that there will "***always** be necessary to perform control registrations to verify or control the data*", the DCH acts as a spokesperson speaking on the methods behalf, and the DCH's statements are very much worded as facts without much room for doubt or discussion. A wording as this is on a level four of the statement modality ladder, as stating facts. The content in this letter does, however, present an un-nuanced view of the role, function and potential of geophysical methods within archaeological registrations, and will be the subject for further discussion later. The only reference in this letter is a report relating to experiences with Lidar data in Oppland county, but resources such as article one in this thesis published in January 2014 (Stamnes and Gustavsen 2014), the review-article on archaeological geophysics published in Norwegian in 2012 (Gustavsen and Stamnes 2012), the NIKU report written on behalf of the Norwegian Public Roads Administration on the use of new technological methods in Archaeology (Gustavsen et al. 2013a) were not mobilized. Any other published sources of knowledge of geophysical methods were not referenced to in this letter. This demonstrates how published sources in the network of archaeological research not always directly influence the practice of cultural heritage management (understood as the network of cultural heritage management), even within a knowledge-based management scheme. The published sources are inscriptions and become actors that can be mobilized in the support for a viewpoint or an argument. The actors of published sources do not become part of the networks of which they were intended to contribute to – they become hidden. The letter from the DCH to the MoCE (Directorate for Cultural Heritage 2014f) becomes an example of a *black box* where a spokesperson hides controversies and different viewpoints and opinions in an inscription.

The process of making the budgeting directives for archaeological registrations involved releasing initial drafts as a circular, inviting other actors within the cultural heritage management to comment on the content of initial drafts of these directives. This means that the document released by the Ministry of Climate and Environment (2015) is the result of a longer process, and might hide controversies. As I stated in the theoretical chapter (chapter 3), the release of official document can help hide such controversies, and make a matter seem more undisputed than what initially was the case. Here, Hordaland specified how it is up to the professional judgement of each county authority to decide the choice of effective methods and magnitude of archaeological fieldwork on a case to case basis (Hordaland county authority 2014). Vestfold county authority clearly stated that as being in an operational phase as an integrated part of the daily archaeological management as performed in the county. Vestfold also note that the DCH is not promoting the use of non-intrusive methods, although Vestfold county have the understanding that Norway is obligated to do so through the Valletta-convention (Vestfold county authority 2012; Directorate for Cultural Heritage 2015b). Although not discussing role and function as such, it is clear that Vestfold county authority has a very different opinion on the methods' usability than the DCH, and accepts daily use of geophysical methods as equal to other registration methods. Similarly, any uncertainties and doubts the county authority might have of the geophysical methods becomes hidden in such a statement.

The Vestfold county authority also raised this issue as feedback to the annual letter of prioritization from 2015, where the Vestfold county authority told the DCH that they felt that they were given little support from the MoCE in the development of non-intrusive methods, which is related specifically to the county authority's response to these budgeting directives. The DCH noted the response from Vestfold, and said they will remember the comments in the coming work with the budgeting directives (Directorate for Cultural Heritage 2015b). As the final directives were released in 2015, it is clear that the county's response to the circular *and* from the annual letter of prioritization for 2015, both commenting on the geophysical methods as not considered equal to more traditional archaeological registrations methods, did not alter the DCH's view on the applicability of such methods. An actor and their opinion becomes hidden from the network. Similar, but more general critique, was also raised by other county authorities against a strong regulation of practice, with a special emphasis on how it is the professional judgement in the county authorities that should define which methods is to be considered the most appropriate on a case- by case basis (Hordaland county authority 2012; Vestfold county authority 2012; Østfold county authority 2012; Hordaland county authority 2014; Norsk Maritimt Museum 2014).

Other county authorities that have mentioned geophysical methods in strategic documents, circulars and other communications. Sør-Trøndelag has for instance stated that geophysical methods could *"**in certain cases** find and document cultural heritage sites and monuments under ground, without doing any intrusive investigations",* further mentioning that *"the methods **can be used** in defined areas where one is facing cultural heritages sites and monuments that cannot withstand physical erosion or wear".* Geophysical methods are in this document seen as a supplement to other methods (Sør-

Trøndelag county authority 2013b:35). Sør-Trøndelag county authority also emphasized in the annual letter of prioritization from 2014 that the DCH's work on a registration standard, including the use of geophysical methods, is very important and should be given high priority. The DCH's response to this was that the DCH want to have a high focus on the possibilities that new and high technological methods can provide for the cultural heritage management (Directorate for Cultural Heritage 2014a). The county authority also stated that research on and testing of geophysical methods under Norwegian conditions was one of the main priority areas for 2015 (Directorate for Cultural Heritage 2015a). The oldest strategic plan for culture from any county which included geophysical methods a goal or given specific emphasis is from Nord-Trøndelag county authority (2009), and state that geophysical methods "***can show** features below the ground surface which represents settlement sites or graves".* The plan also mention that the results are different depending on soil conditions and moisture, and continues with stating that *"the methods **are most relevant** when there is already indicated cultural heritage sites and monuments hidden under ground, or for example when areas are to be investigated as part of a planning permission or other activity" (Nord-Trøndelag county authority 2009:20-21, this author's translation).* Both Nord- and Sør-Trøndelag points towards a collaboration with relevant research environments on method development and improved efficiency of this work. Nord-Trøndelag point specifically to the NTNU University museum, which can be seen as a way to mobilize resources and recruiting new participants to the network and lock allies into place, as well as define aims and objectives that might be of mutual interest for several actors (Nord-Trøndelag county authority 2009, 2012; Sør-Trøndelag county authority 2013b). While the wording does not open up for being classified within a specific statement modality, although the choice of wording such as "in certain cases", "can be used" or "can show", indicate some reluctance. Still, the counties indicate potential in geophysical methods by including them in the counties description of potential field methods that can be integrated in the cultural heritage management.

In a circular response to the strategic plan for cultural heritage monuments, sites and environments (Directorate for Cultural Heritage 2011), the Section for Cultural Heritage Management at the University Museum of Bergen state that *"non-intrusive high-technological methods will **never** replace ordinary registration- and excavation methods, and will when seen in isolation **not fulfill** the demands required for identification, description and interpretation. The use of such methods are, however, an important **supplement**, both as part of the knowledge basis for decisions on registrations and heritage protection strategies, and as a mean for improving the efficiency for documentation by registration and excavation" (University Museum of Bergen 2010a, this author's translation).* Again there is a focus on supplementation rather than replacement of methods, the use of the strong adverb "never". The author of this letter does, however, see a potential in geophysical methods and say that such methods *are* (not *can be*) an important supplement for knowledge basis for decision making processes and improving efficiency for documentation by registration and excavation. So, this particular comment's statement modality can be placed at a stage four – presented as a fact.

In the scientific evaluation programme released by the KHM in 2009, it is statement that the use of metal detectors and/or magnetometers should be mandatory when doing field campaigns to locate slag pits or slag tips, and the evaluation programme also state that the undoubtedly best results when trying to locate roasting sites came from the use of magnetometers (Smekalova and Voss 2002; Larsen 2009:206). These statements are presented as uncontested facts on level five on the statement modality ladder (see table 1). Another regional archaeological museum that is central in this presentation, is the NTNU University Museum. The NTNU University museum has had a research emphasis on geophysical methods since 2007, with the acquisition of their own geophysical instruments in 2009 and clearly stated research strategy involving research on the applicability of geophysical methods in archaeology (NTNU University Museum 2007, 2010, 2011, 2014). This research emphasis position the NTNU University Museum, together with the Norwegian Institute of Cultural Heritage Research (NIKU) in a leading role in providing both a service provider to other actors within the Norwegian Cultural Heritage Management, but also as research partners and collaborators locally, nationally and internationally – securing a domestic based research. NIKU has emphasized how the geophysical methods can act as a supplement to traditional methods, increasing the archaeological knowledge in a non-intrusive manner (Gustavsen et al. 2013a; NIKU 2014b).

7.5 HAS GEOPHYSICAL METHODS PROVEN THEIR WORTH?

In the theoretical outline, the methodical approach in looking at statement modalities to indicate if an actor had been accepted, or if a method has proven its worth. The controversies I will focus on in a later section (see section 7.8), indicate that the question is more complicated than that. Actors have different opinions and views on the role, function, purpose and potential of geophysical methods, which in turn influence the actors opinions on the capabilities and their acceptance of geophysical methods as a tool in the archaeological toolbox that the actors can choose to utilize. Nevertheless, the application of geophysical methods have to prove to be beneficial for whatever purpose intended, and this all revolves around whether or not geophysical methods can help in identifying archaeological features, sites and landscapes, and in this way become a useful tool for both archaeological research and within the cultural heritage management. If such methods cannot provide some form of indication of the presence of anthropogenic activity with an appropriate degree of certainty, then it is of limited value as a management aid in planning and as a source of new knowledge to be included in research. The method should be able to provide information for prioritization, rationalization, increased efficiency and accuracy, limiting conflicts, as well as a source for additional cultural-historical knowledge. It is clear from the previous discussion (sections 7.1 to 7.4) that the acceptance of geophysical methods within the current archaeological research and cultural heritage management is limited, with some exceptions. Article one together with the previous discussion, cover objectives one to five in this thesis: reviewing the way geophysical methods have been used and their perceived role, function, purpose and status, as well as identify important research areas and perform methodical and enmpirical researcg to improve the understanding of the applicability of geophysical methods.

Article one presents several reasons for why there is a lack of acceptance of geophysical methods. The first three of these focus on the perceived success of the geophysical surveys performed. The main findings were as follows:

1. A lack of resolution and technical limitations of earlier surveys
2. Challenging natural conditions
3. Ephemeral archaeology difficult to locate by geophysical methods
4. Lack of trained personnel and competence

This conclusion was reached after analyzing who commissioned geophysical surveys, where the surveys were performed, how they were conducted, and on which types of archaeological features and monuments. To be able to improve the knowledge of the applicability of geophysical methods, the article suggested an increased research focus on the following topics:

1. General assessments of geophysical techniques used under varying natural and archaeological conditions
    a. Comparisons with archaeological excavation results (ground based assessments)
    b. Geophysical reason for detectability, or the lack thereof
2. Effectiveness
3. The Impact of geophysical surveys on decision-making processes throughout the whole planning processes, archaeological registrations and archaeological excavations
4. Cost-benefit analysis

Carrying out research on these focus areas is a direct response to, and fulfillment of objective five in this thesis: identifying and investigating important methodical and empirical research areas on geophysical application in Norwegian archaeology as mentioned above. An impression we gained by reviewing earlier projects involving geophysical surveys, was that even the total amount of project initiated within a research context was high (57% - see table 12), this does not necessarily mean an archaeological-geophysical research project. If the initial integration of geophysical methods also had included an element of research on the geophysical data, there would be a potential for an increased knowledge gain both geophysically and archaeologically, by revealing information that could improve our ability to process, analyze and interpret such data (Hargrave 2006; Stamnes and Gustavsen 2014:28, article one). The importance of communicating new knowledge and results through publications, press releases, blogs, conferences, seminars and presentations was also stressed in article one.

I will, in this part of the discussion, focus on how the geophysical results presented in articles two, three and four contribute to our understanding of applicability and limitation of geophysical methods under the prevailing survey- and archaeological conditions faced at the sites investigated. In addition to this, I will emphasize how this knowledge influenced and the potential the results have in influencing decision-making processes in later planning work and archaeological investigations (objective seven – see also the discussion in section 7.9). This will provide a new and updated view on the potential of geophysical methods within Norwegian cultural heritage management and archaeological research, including concerns associated with limitations and possibilities under varying conditions- including archaeological, geological, technical conditions, as well as within archaeological heritage research and management networks. I will also discuss how the results contribute to new cultural-historical knowledge (objective six).

7.6 LOCATING ARCHAEOLOGICAL SITES, MONUMENTS AND FEATURES WITH GEOPHYSICAL METHODS

This section will present examples from the published articles where the geophysical methods contributes in locating and characterizing archaeological sites, monuments and features, and will discuss possibilities and limitations faced at these sites. The articles providing geophysical information focused on the Viking-age and early medieval trading site at Veøy in Romsdalen, the complex settlement- and activity area at Avaldsnes – involving prehistoric, medieval and post-medieval activity as well as iron production sites from the roman iron age. In article one we concluded that settlement sites and burial monuments were the most surveyed archaeological targets (Stamnes and Gustavsen 2014:23, article one). While parts of the Avaldsnes sites revealed settlement- and activity traces in farmed land (Avaldsnes Area 2), as well as iron age houses underneath a parking lot (Area 1) and in a modern day garden (area 5), none of the other surveys presented in the articles focus on typical bronze-and iron age settlements often found during soil stripping investigations in farmed fields. While other geophysical examples from settlement and burial sites in farmed land exist, such as (Stamnes 2010a; Trinks et al. 2010a; Stamnes 2011b; Bill et al. 2013; NIKU 2013b; Akershus county authority 2014), sites of this type were not the main focus of my field investigations in these articles. I will therefore provide a couple of examples of survey results from other investigations of settlement sites and burial mounds surveyed in typical agricultural fields. The representability of the following discussion must therefore be read with this in mind.

The geophysical investigations performed at the sites surveyed in article two, three and four involved various geophysical methods:

Table 9: Overview of the various geophysical methods applied in articles two, three and four

	Fluxgate gradiometer	**GPR**	**Topsoil magnetic Susceptibility**	**Mass magnetic susceptibility**	**Earth Resistance**	**EMI**	**ERI**
Avaldsnes	X	X	X	X	X	X	X
Veøy	X	X	X				
Storbekken 1	X		X				
Tromsdalen	X		X				
Roknesvollen			X				
Mokk	X						

The bottom four sites are all iron production sites. While it could be interesting to utilize for instance Earth Resistivity Imaging (ERI) or GPR to investigate thickness of slag deposits, or compare Electromagnetic induction (EMI) with susceptibility measurements or fluxgate gradiometer plots, this was not performed as part of these investigations. The main reason for this was the aims and objectives of these surveys, time constraints and lack of access to equipment for performing EMI at that time.

7.6.1 Possibilities – topsoil magnetic susceptibility

At Veøy the application of topsoil magnetic susceptibility mapping was used to delineate an early Christian burial ground, with distinct differences in the magnetic contrast between the interior of the burial ground and the settlement outside of it (figure 4). By returning to the site in 2014 and expanding the survey area from 2011 survey, it was also possible to indicate the extent of a smithy area – identified by Asbjørn E.Herteig in 1954 and re-excavated by Solli between 1990-1992, which provided ^{14}C dates to both the 10th and the 14th century (Herteig 1954; Solli 1996:171-177). In the vicinity we noticed large amounts of slags while doing the field survey. The smithy area is approximately 0.4 hectares, which is about 10 % of the overall area of black earth as indicated by Herteig (1954) and Solli (1996:119).

Similar to the results from the metal working area, topsoil magnetic susceptibility measurements provided equally good results from older Iron Age iron production sites in mid-Norway (article four and figure 9 in this thesis). Article four as well as figure 9 and figure 37 shows how such sites could be located and delineated in a similar manner, and provides very useful descriptive statistics on expected contrasts from the surrounding area and the main activity areas of iron production sites of this type.

At Avaldsnes, soil samples taken from deposits undisturbed by modern day activities and analysis of mass specific magnetic susceptibility proved useful in understanding and spatially delimiting past activities. At this site, the topsoil magnetic susceptibility sampling on the ground surface proved less useful in this respect, as will be discussed later.

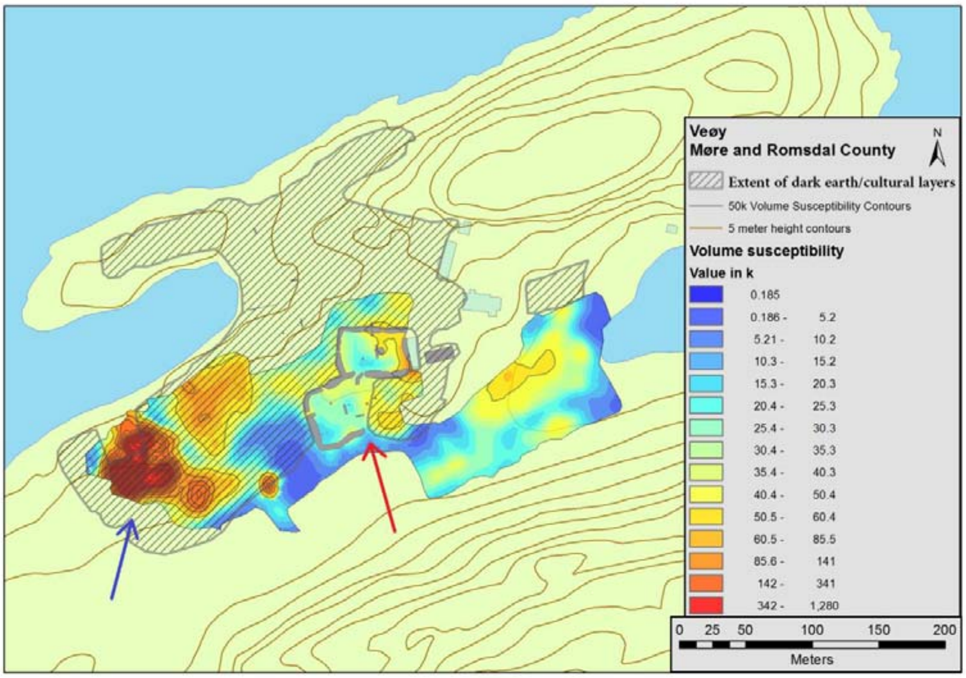


Figure 4: Expanded magnetic susceptibility survey at Veøy. Blue arrow is the area with very strong MS reading delineating the smithy area. The red arrow indicated the break between the inside (west) and outside (east) of the burial ground.

Article two and four demonstrates that using topsoil magnetic susceptibility is a very useful way of locating and delineating industrial activities. At the site of Gustad, topsoil magnetic susceptibility proved to help delineate and characterize an area of activity around prehistoric boat houses (Stamnes 2010a, 2011b). A similar example of delineation of settlement sites is presented from Frosta on figure 5, where several medieval rural farmsteads were delineated in this manner. Gustavsen et al. (2013a) did not recommend using the method on road work projects as the method is better at locating and delineated activity areas rather than specific features. Gustavsen et al. (2013a) also pointed out that the method only measure the top 10-15 centimeters, and that the resolution is often low. While the depth penetration and resolution is low, I disagree with the notion that topsoil magnetic susceptibility (topsoil MS) is not recommendable on larger road work projects. While being able to locate separate archaeological features is important and something that is not possible with sample based topsoil MS, the main benefit is the possibilities of using topsoil MS to delineate settlement- and activity sites – important information for the proper management and archaeological understanding of the sites. There are, however, limitations, especially concerning varying landscape characteristics, soil types and modern disturbance, which I will discuss in the section below.

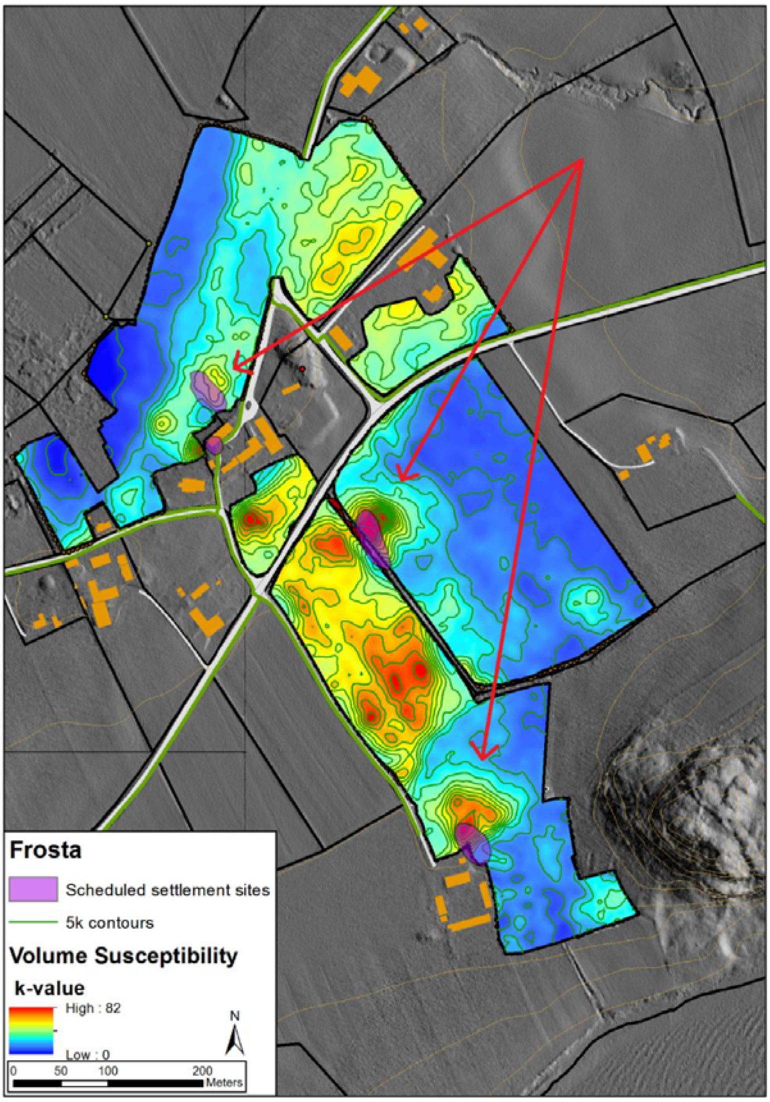


Figure 5: Topsoil magnetic susceptibility surveys at the peninsula of Frosta, around the farms Logtun and Logstein. The arrows indicate several scheduled archaeological settlement sites. The topsoil magnetic susceptibility measurements reveal additional information on the size and extent of these. The site in the centre of the image has been dated to 13th century AD (Binns 1997). The measurements also indicate different areas of potential activity and earlier landscape features. Data gathered and processed by the author.

7.6.2 Limitations – topsoil magnetic susceptibility

At Avaldsnes the topsoil magnetic susceptibility measurements did not prove as applicable in locating and delineating past human activity. Here, elements such as modern refuse and activity, evidence of different agricultural practices in neighboring fields, thick cultivation layers overlaying archaeological features, as well as the influence of highly magnetic bedrock hampered a successful application of topsoil MS for locating and delineating the archaeological activity proved to be present by subsequent excavations (article three and figure 6).

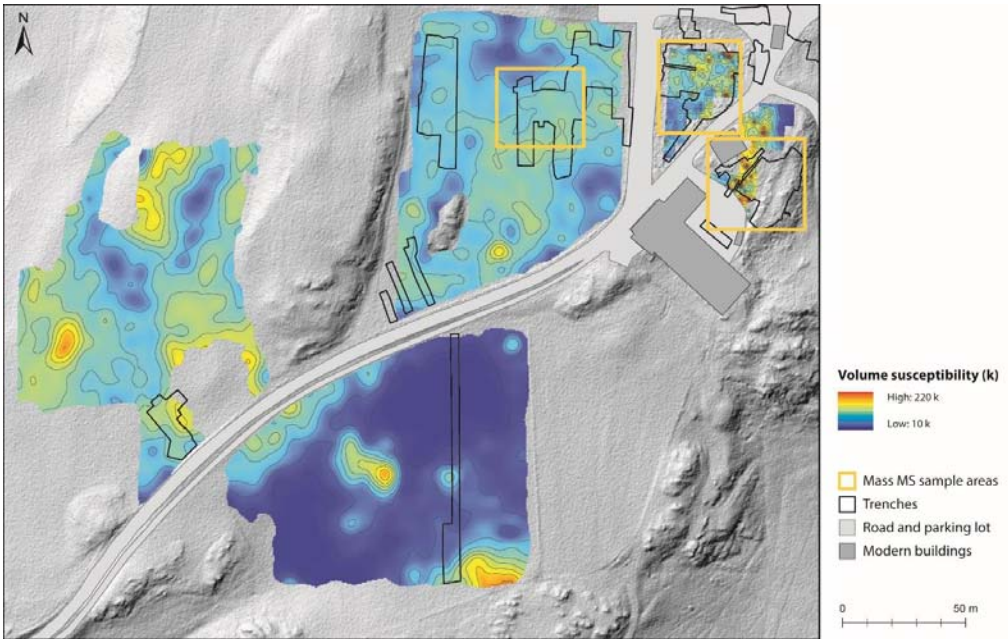


Figure 6: Topsoil magnetic susceptibility survey over the various investigations areas at Avaldsnes (article three)

The sensor used here, a Bartington MS2 with the D-field loop, has a depth penetration of 10-15 centimeters, but 90% of the measured signal derives from the top 6 centimeters (Lecoanet et al. 1999). This means that such measurements used for archaeological purposes is dependent on the thickness and treatment of topsoil (as faced in outfield sites and demonstrated in article four), the movement of anthropogenically influenced deposits upwards in the soil horizon through either ploughing or bioturbation, as well as an even and uniform surface as possible. Leeching of iron minerals through waterlogging or in areas often exposed to heavy rainfall will also contribute to moving iron minerals down in the soil horizons and contribute to erasing the magnetic contrast measurable from the anthropogenic activity (Evans and Heller 2003:95-96). Spacing between measurements is also important, as each measurement is usually spaced in a certain distance from the previous, and the measured value will therefore represent a larger area (see for instance Stamnes (2010a). If you measure every 5th meter, then your measurement is considered a proxy for an average area of 12.5 m². If you were to be so unlucky to come in touch with a piece of ground which happened to have a metal object or intrusions of highly magnetic material close to the sensor, then you will get a reading which is not representative for the average background magnetic susceptibility of the soil. This, in turn, will give erratic values unless you are observant and take another reading uninfluenced by any near-surface intrusions.

Also, a variation of soil types can also influence the readings and introduce differences between neighboring fields (Evans and Heller 2003; Dalan 2006, 2008). In figure 7 the magnetic susceptibility measurements presented in is overlaid over the various WRB (World Reference Base for Soil Resources) classification of the soils in the area downloaded from the website of the Norwegian Institute of Bioeconomy Research (2016). Typically Stagnosols and Gleysoils refer to soils types influenced by water, either by waterlogging (Stagnosols) or through the seeping up of groundwater (Gleysoils). At Logtun, the readings from areas with these soil types are generally low. Anthrosols are soils formed through cultivation over time generally have higher readings, and the same also applies to Arenosols, which are thick, self-drained soils typically of sandy composition. The settlement site in the center of the map is mainly localized on Cambisols, which are classified as young soils with weakly developed soil structure (Nyborg and Solbakken 2003).

At Gustad, presented in figure 11, the topsoil magnetic susceptibility did not reflect the location of the ploughed out burial mounds, but did indicate the size of the activity area (Stamnes 2010a, 2011b).

To overcome uncertainties as to whether or not the variations observed are caused by anthropogenic or natural variations in the magnetic susceptibility values, several authors have suggested to perform analysis of additional magnetic properties of the soil (see section 2.1.2.1). Linderholm and Wallin (2013) did perform a variant of fractional conversion as well as mass susceptibility and phosphate analysis as part of the soil chemical analysis at Avaldsnes (article three), but apart from this investigation, few examples of other types of additional magnetic analysis of soil samples from archaeological investigations in Norway exist.

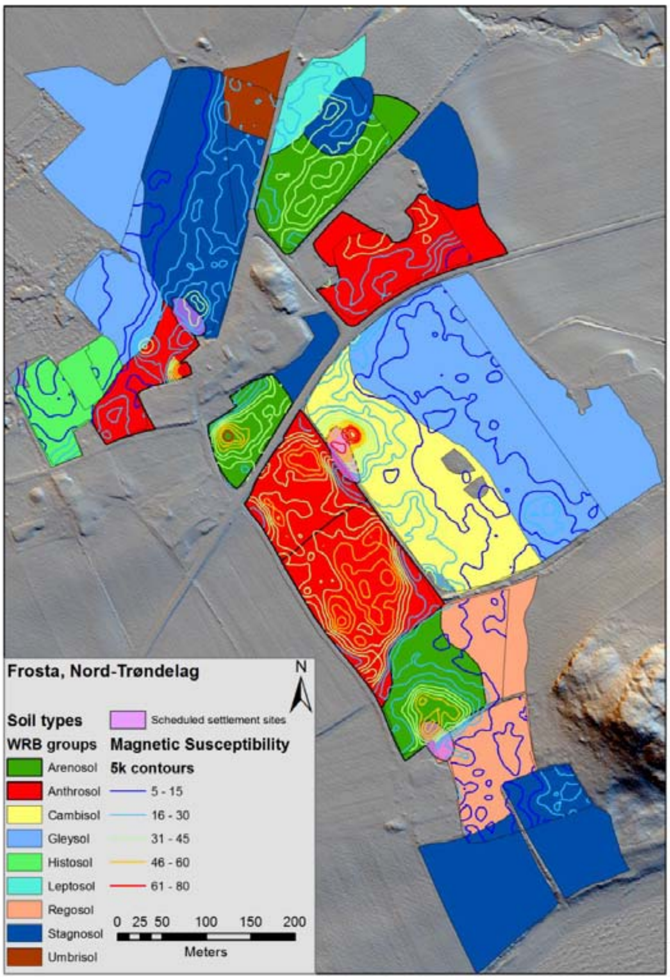


Figure 7: Soil types versus topsoil magnetic susceptibility measurements. Data from www.skogoglandskap.no

7.6.3 Possibilities- magnetometer surveys

At Veøy, the fluxgate gradiometer survey located a possible building at the northern part of churchyard two (letter A), as well as a zone of increased magnetic activity east of churchyard two (letter B), which consist of multiple small positive and negative readings within a relatively delineated zone. This is interpreted as the geophysical response from the black soil/cultural layers we know to be in this area through the investigations performed on the island in 1990-1992 (Solli 1996). Apart from an example from Logtun in Frosta (Binns 1997), this one of few examples of the geophysical response from black earths, which often are interpreted as remnants of settlements consisting of black earth, charcoal, and fire cracked rocks (Solli 1996).

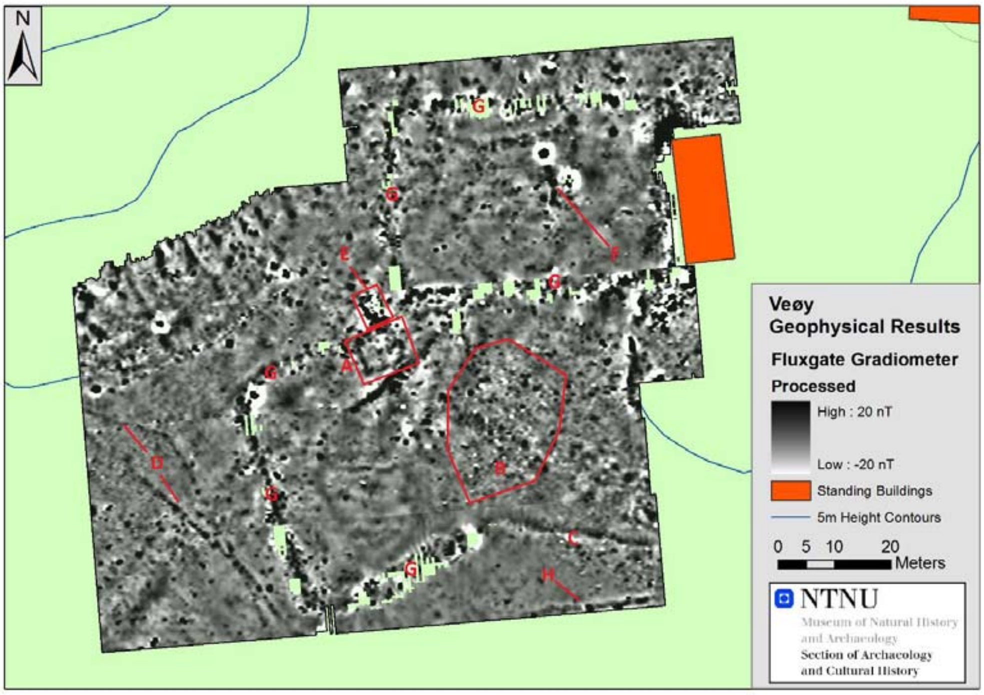


Figure 8: Fluxgate gradiometer data from Veøy, with interpretations A-H. Figure presented in Solli and Stamnes (2013) as figure 12. A was interpreted as a building. Letter B indicates black earth response. C is a lynchet.

The early Iron Age iron production sites showed a very strong and definitive contrast between the main production areas and areas outside of the production zones (figure 9 and 37). The investigation also gave quantitative data on expected strengths of archaeological features such as furnaces, possible roasting sites for iron ore and slag heaps. We also discovered an unexpected and very clearly intentionally constructed oval feature measuring 12x7.5 meters at the site of Storbekken 1. The potential roasting sites for iron ore has also been previously undetected in the vicinity of the main activity areas of iron production sites of this type in mid-Norway. The results from article four shows how various features from iron production sites appear in magnetometer data, and provides important contributions for future application and interpretation of similar data sets. The article can act as a reference for future investigations of similar sites, and illustrates the interpretive process in the knowledge transfer from geophysical information to archaeological information.

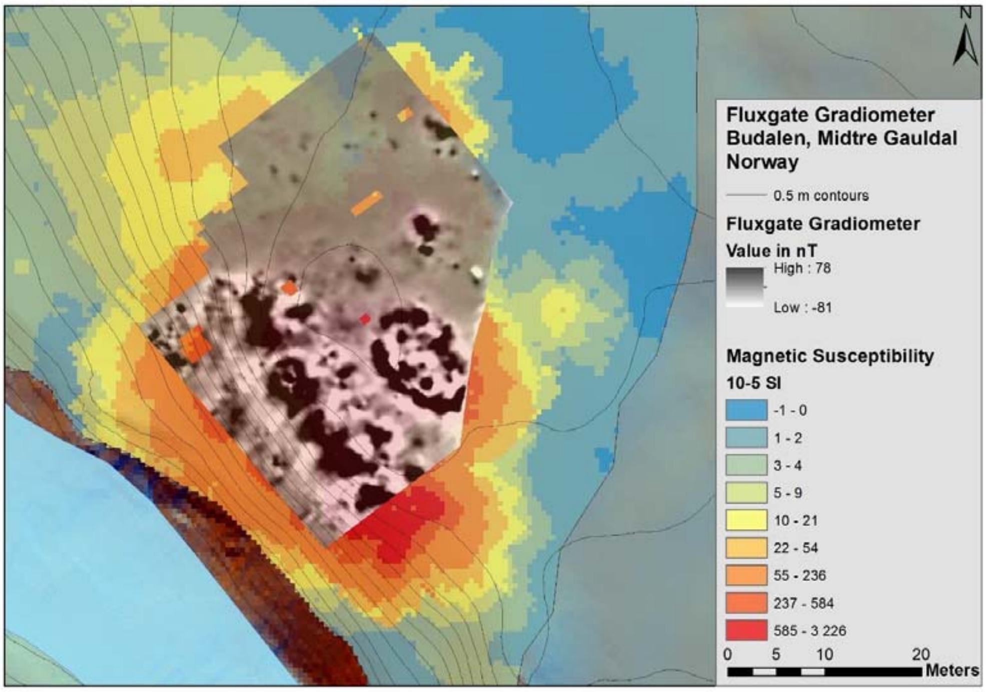


Figure 9: Fluxgate gradiometer survey results from the site of Storbekken 1 in Budalen, overlaid over the topsoil volume MS map. The gradiometer-data is presented at ±1 standard deviation around the mean. This figure is presented as figure 4 in article four.

At the site of Alstad at Frosta (figure 10), the NTNU University museum conducted a short test with a fluxgate gradiometer prior to a soil stripping excavation with a 0.5m crossline and 0.125m inline sampling spacing. The excavation revealed an iron age settlement, with cookings pits and post holes – a fairly typical result from soil stripping excavations in this region (Norderval 2011). 15 out of 25 (60 %) cooking pits within the excavation area gave a detectable magnetic contrast, in this instance presented as 1 standard deviation around the mean (mean 0.13 nT, Standard deviation 2.24 nT). The contrast of these cooking pits vary from a maximum value of 2.4 nT to 33.1 nT, with an average of 8.26 nT, which is 5.89nT stronger than 1 standard deviation above the mean. While the cooking pits had a detectable contrast, it must be pointed out that it is not that easy to distinguish between the anomalies that was confirmed to be cooking pits and other anomalies of the same size, strength and geophysical characteristics which were not confirmed to be of archaeological origin. Performing a more detailed analysis by investigating the shape, size, contrast and other geophysical characteristics following suggestions by Hargrave (2006), can be a good strategy to better separate anthropogenic from natural features if this data set was to be investigated further. In addition, no confirmed postholes yielded a detectable magnetic contrast at this site.

At Gustad, the spatial distribution of magnetic anomalies detected following a fluxgate gradiometer survey had approximately the same spatial distribution as higher readings in the topsoil MS-mapping. This increases the probability that the magnetic anomalies detected are in fact of an archaeological origin (figure 11). Original data from Stamnes (2010, 2011b).

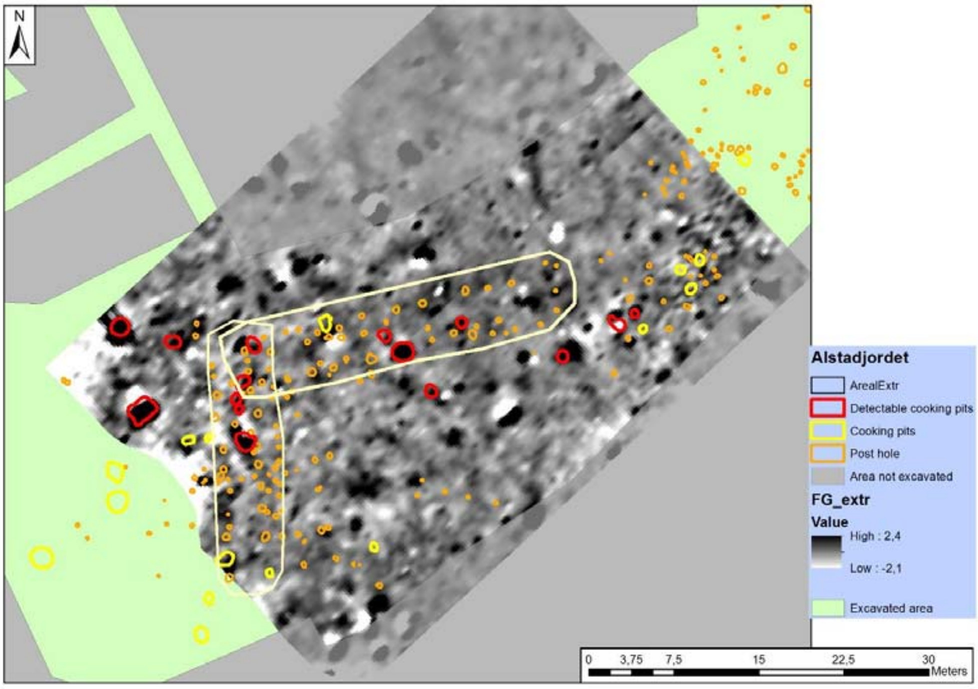


Figure 10: The site of Alstad in Frosta. 15 out of 25 cooking pits had a detectable magnetic contrast. Bright yellow lines indicate prehistoric longhouses.

7.6.4 Limitations- magnetometer surveys

As the Alstad-site on figure 10 demonstrate, ephemeral archaeology such as postholes are difficult to detect with magnetometers, although a few examples exist (see for instance Smekalova et al. (2008; Nau et al. (2015)). As indicated in article one, this is both a question of the initial sample resolution as well as the geophysical contrast of the features expected to be present. At Alstad, the postholes are typically around 0.3-0.35m in diameter, with the smallest around 0.15m in diameter and up to 0.65m. Ideally, a sample resolution ensuring at least two readings over a feature is necessary for it to be possible to distinguish, so with an crossline spacing of 0.5, the proper identification of archaeological features less than 1m in diameter should not be expected (Schmidt and Marshall 1997; David et al. 2008). An increased sampling resolution would improve the chances to detect smaller features, but this is usually also more time demanding. Other geophysical methods, such as high-resolution GPR can be an option to consider (see the section 7.6.5 as well as figure 29).

At the site of Gustad, several ploughed out burial mounds and iron age boat houses were located with a range of geophysical methods. At this site, the magnetometer surveys did not reveal the remnants of the burial mounds, while one of the boat houses and over 600 anomalies were possible to identify. While it was difficult to interpret the anomalies archaeologically, their spatial distribution, as presented in , focused around the identified boat houses – indicating some form of spatial relationship and therefore also mainly an archaeological origin (Stamnes 2010a, 2011b).

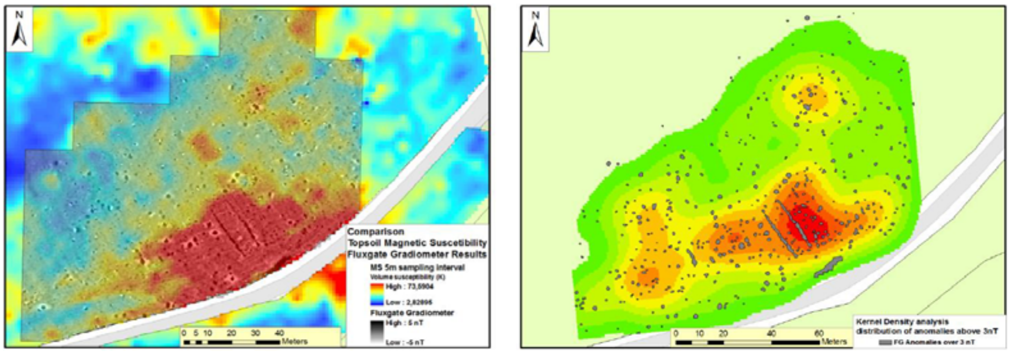


Figure 11: Magnetic susceptibility, fluxgate gradiometer and the spatial distribution of magnetic anomalies. To the left is the gradiometer-data overlain over the topsoil magnetic susceptibility. On the right is a kernel density analysis of the spatial distribution of the magnetic anomalies identified in the fluxgate gradiometer data. Data originally presented in Stamnes (2010a) and Stamnes (2011b).

At both Veøy and Avaldsnes, the geological conditions influenced the possibilities for easy interpretation of separate anomalies. Both sites represented geological bedrock conditions which influenced the data quality for archaeological purposes. As mentioned earlier, the presence of magnetic bedrock influence the readings, and often either masking any geophysical contrast from the archaeology on site – which was the case at Avaldsnes (see figure 13 and figure 14), or creating survey conditions as faced at Veøy (see figure 8), where remanent magnetic bedrock and random magnetic stones made it difficult to distinguish an archaeological feature from random rocks and inclusions present within the survey area. Hargrave (2006) suggested using summary statistics to set appropriate range parameters for visualization and calculating thresholds of magnetic contrast for distinguishing potential archaeological features. As the magnetic variance and background is different for the surveys conditions at each site, such an approach provides interesting legacy data and information of the impact the soil and bedrock conditions have on the data. It is important to keep in mind that the magnetic contrast of a typical archaeological feature, let us say a cooking pit, might be different on other types of soil conditions, due to possibility of varying initial content of iron minerals in the soils. Also, increased distance from the sensors to the feature creating a magnetic contrast, will decrease this contrast (Aspinall et al. 2009). So, while the average response of the identified cooking pits at Alstad was 8.26 nT (see figure 10), this value might be different on another site.

Article four presents an overview of the magnetic variability of available fluxgate gradiometer data. I have here expanded this table to include the Alstad-site, as well as bedrock conditions (table 10). Standard Deviation (St.Dev.) Variance and inter quartile range (IQR) are all statistical parameters for measuring variability, or spread of variables (Isaaks and Srivastava 1989:16-23). The bedrock at Avaldsnes is characterized by metamorphic and igneous geology of volcanic origin, and has by far the highest variability in the presented statistics. Veøy is also situated on metamorphic bedrock, but not from volcanic origin. While the values are much lower, they are still significantly higher than the sites of Gustad and Alstad, which both are situated on sedimentary beach deposits. This table function as a demonstration of the effect of the magnetization of the bedrock on the possibilities for a successful magnetometer-survey result and function as a good reference for future evaluations of the applicability of magnetometer-surveys on various bedrock. If the background variation is stronger than the expected contrast of an archaeological feature, it becomes difficult to do an archaeological interpretation of the dataset. By examining the summary statistics in table 10, it becomes clear that igneous and metamorphic bedrock can represent a problem for easy interpretation, as the background magnetic variation (standard deviation) is very high (for instance at Avaldsnes area 2 with a St.Dev of 27.44 nT) compared to the magnetic response of typical cooking pits at the Alstad example in (8.26 nT in average) discussed earlier. At Veøy, we have several archaeological observations in the dataset, but the Avaldsnes-dataset proved very problematic. At Avaldnes the magnetic fields created by the bedrock was so strong that the general background noise was much greater than the magnetic enhancement of any archaeological features.

Table 10: Summary statistics over magnetic variability over the available fluxgate gradiometer data from Avaldsne, Veøy, Gustad and Aldstad. Original values are in Nanotesla (nT).

SITE	MEAN	ST.DEV	VARIANCE	IQR	GEOLOGY	DRIFT GEOLOGY
AVALDSNES AREA 2	2.59	27.44	753	6,2	Metamorphic greenstone and igneous alkali basalts	Morraine (shallow)
AVALDSNES AREA 3	-1.47	37.42	1400	27,2	Metamorphic greenstone and igneous alkali basalts	Morraine (shallow)
AVALDSNES AREA 4	-1.02	40.38	1631	19,8	Metamorphic greenstone and igneous alkali basalts	Morraine (shallow)
AVALDSNES AREA 5	1.46	27.6	762	10,0	Metamorphic greenstone and igneous alkali basalts	Morraine (shallow)
AVALDSNES AREA 6	-0.28	43.22	1868	34,7	Metamorphic greenstone and igneous alkali basalts	Morraine (shallow)
VEØY	-0.54	13.49	182,0	11,1	Metamorphic dioritic and granitic gneiss and migmatite	Marine deposits
GUSTAD	-0.26	2.04	4,2	1,5	Sedimentary (metasandstone and greywacke)	Raised beach deposits
ALSTAD	-0.13	2.25	5,1	1,64	Sedimentary (phylite slate and sandstone)	Raised beach deposits and morraine

In a report to the National Roads Association in Ireland, Bonsall et al. (2014) discuss the effect of various geologies on geophysical surveys performed for archaeological purposes. Bonsall et al. (2014) discuss both rock types and the influence of various geologies, including Igneous, metamorphic, sedimentary, peat, alluvium and colluvium as well as boulder clays.

Table 11: Idealised performance of magnetometers upon principle Irish geologies. After Bonsall et al. (2014:36). They note that the geophysical response on a particular geology might be better or worse depending on type and depth of overlying surface geology.

Poor	Moderate to Poor	Moderate	Moderate to Good	Good
•Granite •Basalt •Dolerite •Gabbro	•Greywacke •Sandstone	•Siltstone •Rhyolite •Limestone	•Mudstones	•Shale •Slate

Igneous and metamorphic rocks, altered by pressure and heat, can create unfavorable conditions for magnetometer surveys- especially if the soil cover is insufficiently deep to mask the effect of the magnetic fields created by these types of bedrock. When surveying in areas close to the occurrence of these types of bedrock, the occurrence of glacial erratics (i.e. randomly distributed igneous or metamorphic rocks) can create magnetometer plots with thermoremanent anomalies with strong magnetic contrast which can be quite difficult to discern from the magnetic response from made made activities. On sedimentary geology in Ireland, magnetometers generally proved as a favorable technique to identify archaeological features, with a low and uniform magnetic background. This proved both favorable and unfavorable, where cut-earth features sometimes responded poorly to magnetometer surveys, often creating week or no magnetic contrast at all, while burnt features normally responded very well. This situation is comparable to what we observed at Gustad (see figure 11). Shales returned particularly good responses with clear datasets (Bonsall et al. 2014:37-58). While we observed a range of thermoremanent responses at Veøy, which obstructed a clear archaeological identification and interpretation of the anomalies present, we also observe how the thermoremanent response of the standing stone wall encircling the graveyards is visible (see figure 8). Stone constructions of thermoremanent stones can therefore provide an opportunity to actually detect archaeological constructions, even in areas of unfavorable geology. Such an occurrence was observed at Odberg in Vestfold (figure 12), where the central burial cairn in a ploughed out burial mound was detected as a result of a magnetometer survey (Trinks et al. 2010a). Depending on the type of bedrock, the use of magnetometers on exposed bedrock or instances where the bedrock is close to the surface might create difficulties in providing useful archaeological information.

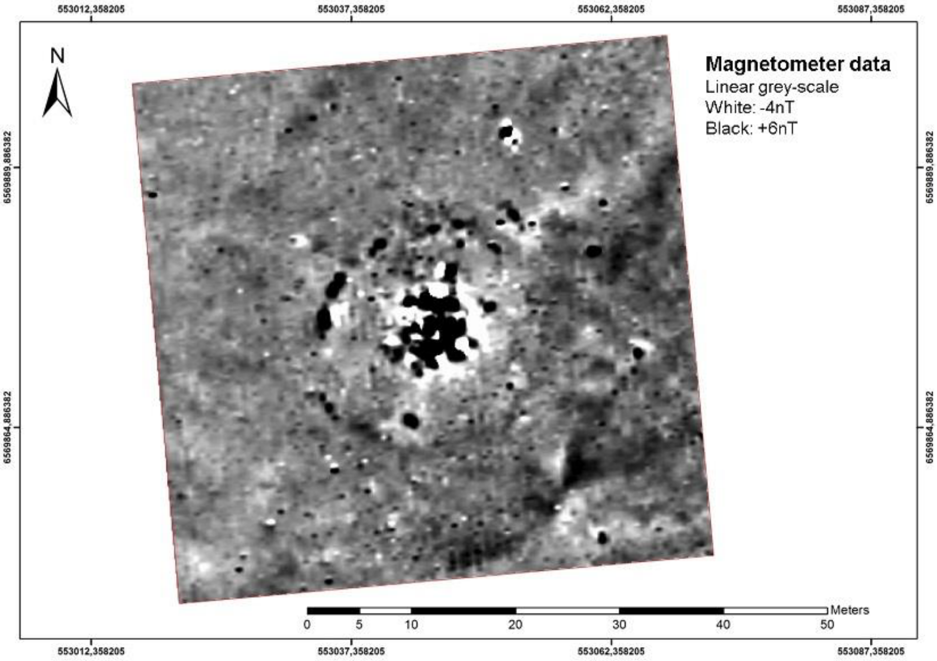


Figure 12: Magnetometer from Odberg in Vestfold, showing the magnetic response of a central cairn of a ploughed-out burial mound. From Trinks et al. (2010a). Used with permission – courtesy of Immo Trinks.

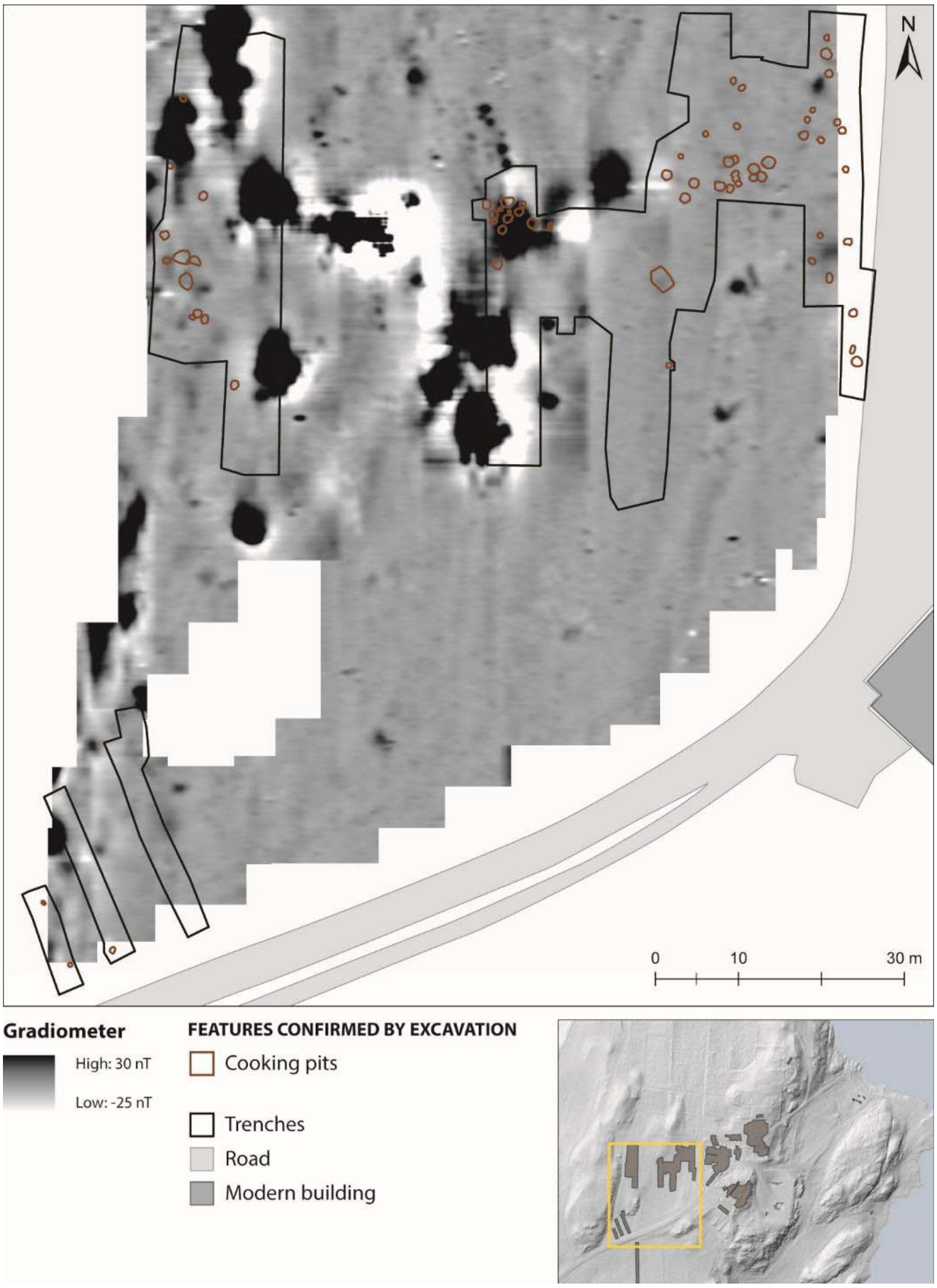


Figure 13: Fluxgate gradiometer survey from Area 2 at Avaldsnes. Data collected by Earthsound Associates, reprocessed by the author and illustrated by Ingvild Tinglum Bøckman.

At Avaldsnes the combination of both unfavorable geology and modern day activity (figure 14) created a highly disturbed and uninterpretable image. In the eastern part of Area 5, excavations reveal an older iron age house, and in the western part of this garden they found an area of cooking pits during excavation. None of these were visible in the fluxgate dataset.

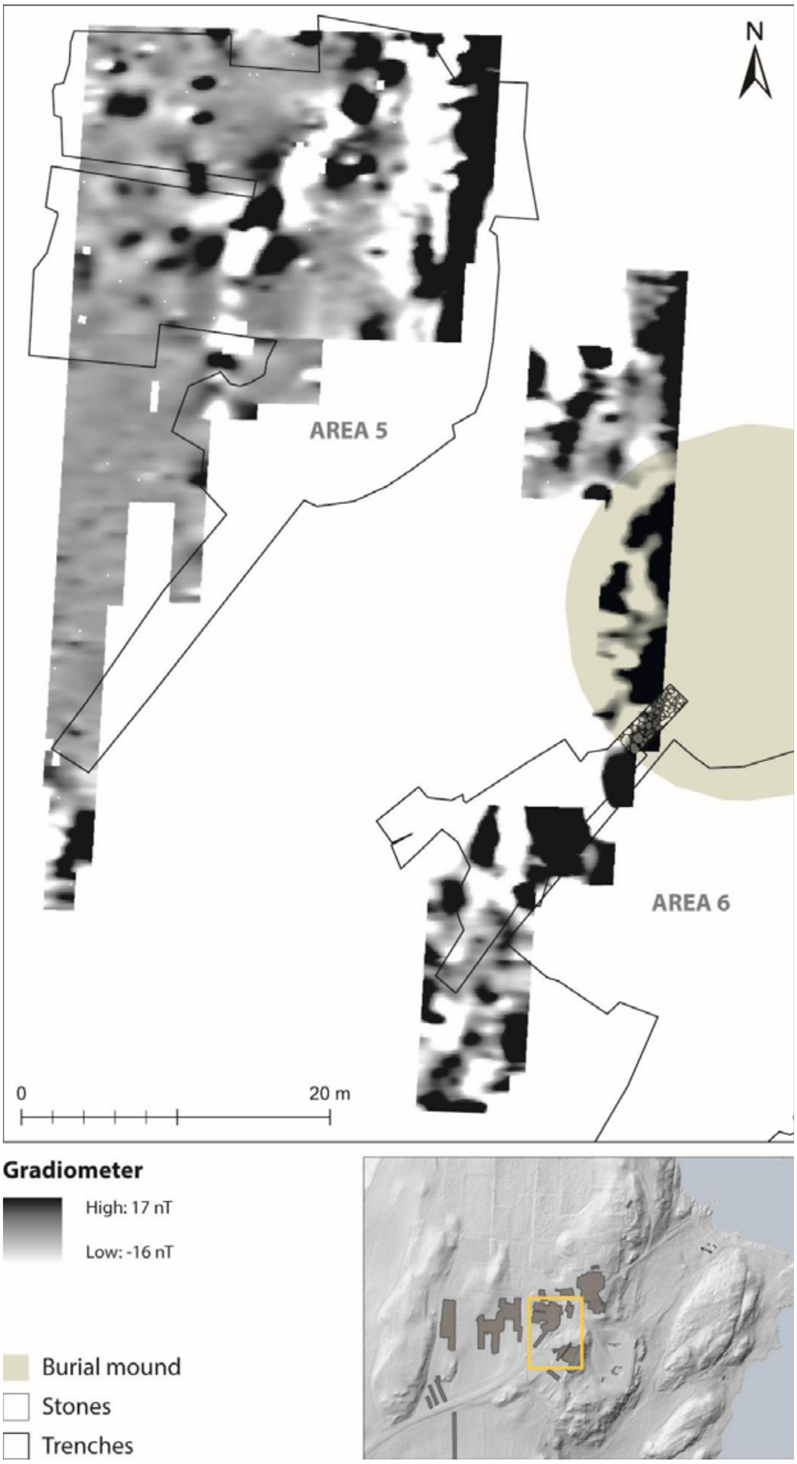


Figure 14: Fluxgate gradiometer survey from Area 5 and 6 at Avaldsnes. Data collected by Earthsound Associates, reprocessed by the author and illustrated by Ingvild Tinglum Bøckman.

7.6.5 Electromagnetic techniques - possibilities

The only site presented in the articles where EMI was involved is Avaldsnes (article three). Two separate EMI investigations were performed by GeoFysica in 2006 (Persson 2006) and Smekalova and Bevan (2009). While these EMI surveys at Avaldsnes only were from smaller, limited areas, some observation of geophysical contrast from archaeological features were visible in these datasets. This also accounts for instances where the magnetometer-surveys were compromised by the influence of magnetic bedrock, demonstrating that EMI can be considered as a useful alternatives where the bedrock is known to be problematic for magnetometer-surveys (see figure 11 and 16 in article three). EMI has been utilized in Archaeology for quite a while (Clark 1996), but has not often been applied in Norway- only at about 2% of all surveys performed (figure 6 and 7 in article one, as well as figure 25 and figure 26 in section 7.6.8 in this thesis). Recent development in equipment capabilities and data processing has led to an increased interest in this prospection method for archaeological purposes in Europe, which have shown potential on soil types and under geological conditions that has been problematic to survey with other methods. EMI is also less hampered with the negative effects of water and clay content in the subsoil, which can be a drawback for GPR surveys (Simpson 2009; Bonsall et al. 2013a; Bonsall et al. 2013b; De Smedt 2013; De Smedt et al. 2013; Bonsall et al. 2014).

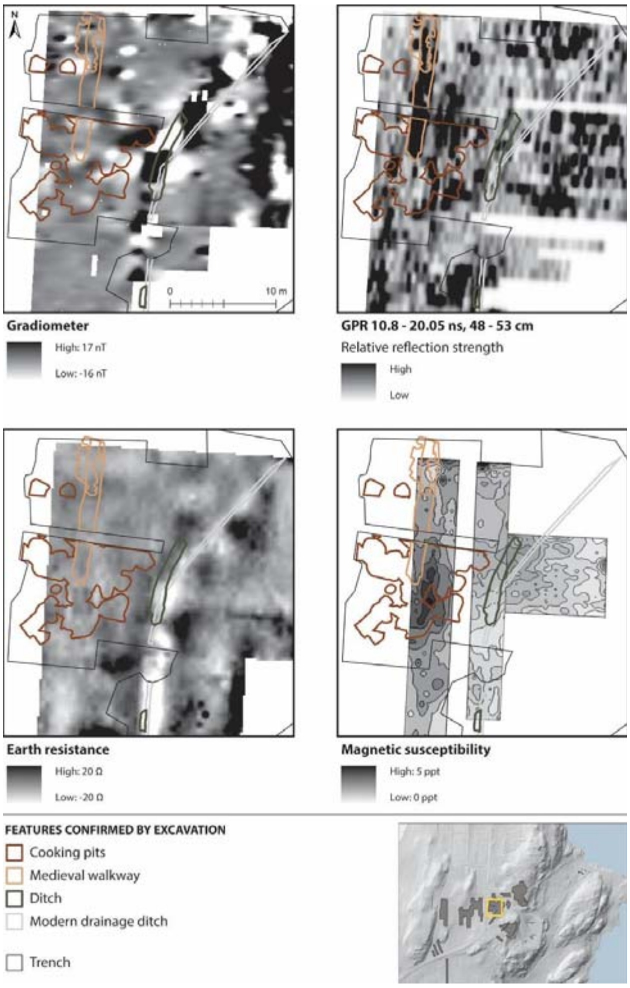


Figure 15: Comparison of geophysical data from Earth Resistance, Gradiometer, GPR and Magnetic Suceptibility (EMI – in-phase). Published as figure 16 in article three. Note how the Magnetic Susceptibilty results indicate an area of cooking pits not located by any other method. Gradiometer, GPR and Earth Resistance data from Earthsound associates, and Magnetic Susceptibility data from Geofysica. Data processing by the author. Illustration by Invild Tinglum Bøckman

The use of GPR gave interesting results at both Veøy and Avaldsnes. In Area 2 at Avaldsnes, a GPR survey initially conducted by the Vienna Institute of Archaeological Science (VIAS), as well as separate GPR sections surveyed by Earthsound Associates (Barton 2010), revealed archaeological information on both site formation processes and archaeological features. The archaeological investigation following these surveys proved several of the anomalies observed in the depth slices to be cooking pits buried at various depths within a thicker homogenous cultivation deposits (figure 16). After performing an interpretation of the available depth slices, we compared the anomalies with the presence of excavated features. Of all anomalies identified within the excavated depth, only 36% of these archaeological features had a geophysical contrast of reflected electromagnetic energy that was recognized and interpreted by the authors in the GPR dataset. Apart from one stone, all of these were cooking pits. 67% of all cooking pits within the homogenous cultivation layer were identifiable, while the cooking pits cutting into the more heterogeneous subsoil were more difficult to discern – with a rate of 19% . Postholes, wall ditches, or the presence of stone were not recognized in the GPR datasets. Local geology, thickness and homogeneity, as well as the type of prehistoric and historic activity, influenced the relative applicability of the method. The analysis and comparison of GPR data and excavated features also showed the presence of a stone-paved walkway, the subterranean passageway as well as modern infrastructure and drainage in the GPR data (see article three).

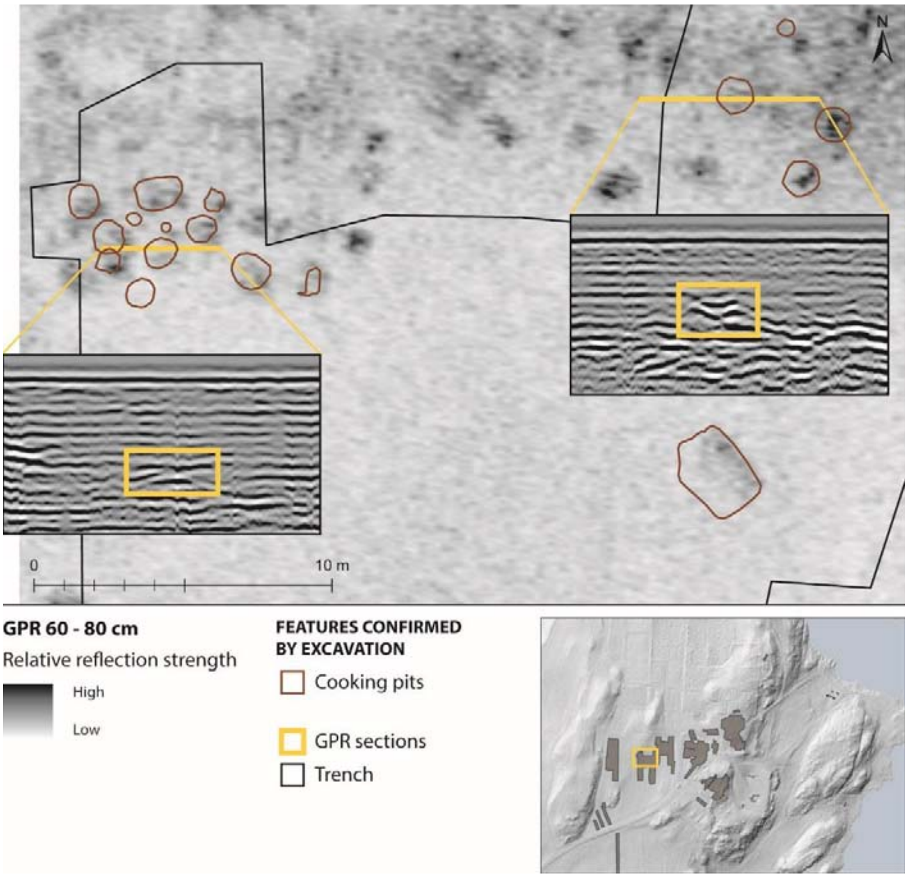


Figure 16: GPR depth slice and cross sections of cooking pits in homogenous surroundings. Depth slice information gathered by VIAS, and GPR profiles by Earthsound Associates. Interpretation of the depth slices, and data processing of the profiles, by the author. Illustration by Ingvild Tinglum Bøckman.

At Veøy, previous archaeological investigations had revealed the presence of graves and the probable remains of three buildings, two of which might very well be indications of some of the earliest clerical buildings located in Norway. In addition, indications of a former eastern wall of the southern graveyard- graveyard two, support the observations made in the magnetic susceptibility dataset (see figure 4 – red arrow). Our GPR survey gave very interesting data, albeit difficult to interpret. I will therefore present selected depth slices and profiles from church yard one to illustrate the interpretability of this dataset:

Figure 17: Interpretation of GPR-data from Churchyard one at Veøy. This figure is printed as figure 14 in article two.

The interpretation of these anomalies are based on separating defined reflections that repeat themselves over several depth slices (usually at least two, but preferably more). Figure 18 present the depth slices from 31-60cm. The process moving from the processed data to an archaeological interpretation based on an understanding of the data collection, data processing and geophysical characteristics, can be experienced and handled differently dependent on experience, professional training and routines. Another operator or archaeological geophysicist might have ended up with a different interpretation than the interpretations presented in an article two in general. This is why access to raw data, clear information on data processing and interpretation procedures are important additions to any geophysical survey reports. This exemplifies the role of the *spokesperson*, as seen from an ANT-perspective, where the trustworthiness of the presented interpretations (*or inscriptions* as described in ANT) and the interpreter, gives additional value to any statements and interpretations made by this *spokesperson.* As controversies and uncertainties are hidden or masked in the process of providing an interpretation, the responsibility of the *spokesperson* providing such interpretations to an untrained audience becomes even more important. This issue will be discussed in futher detail in section 7.6.7.

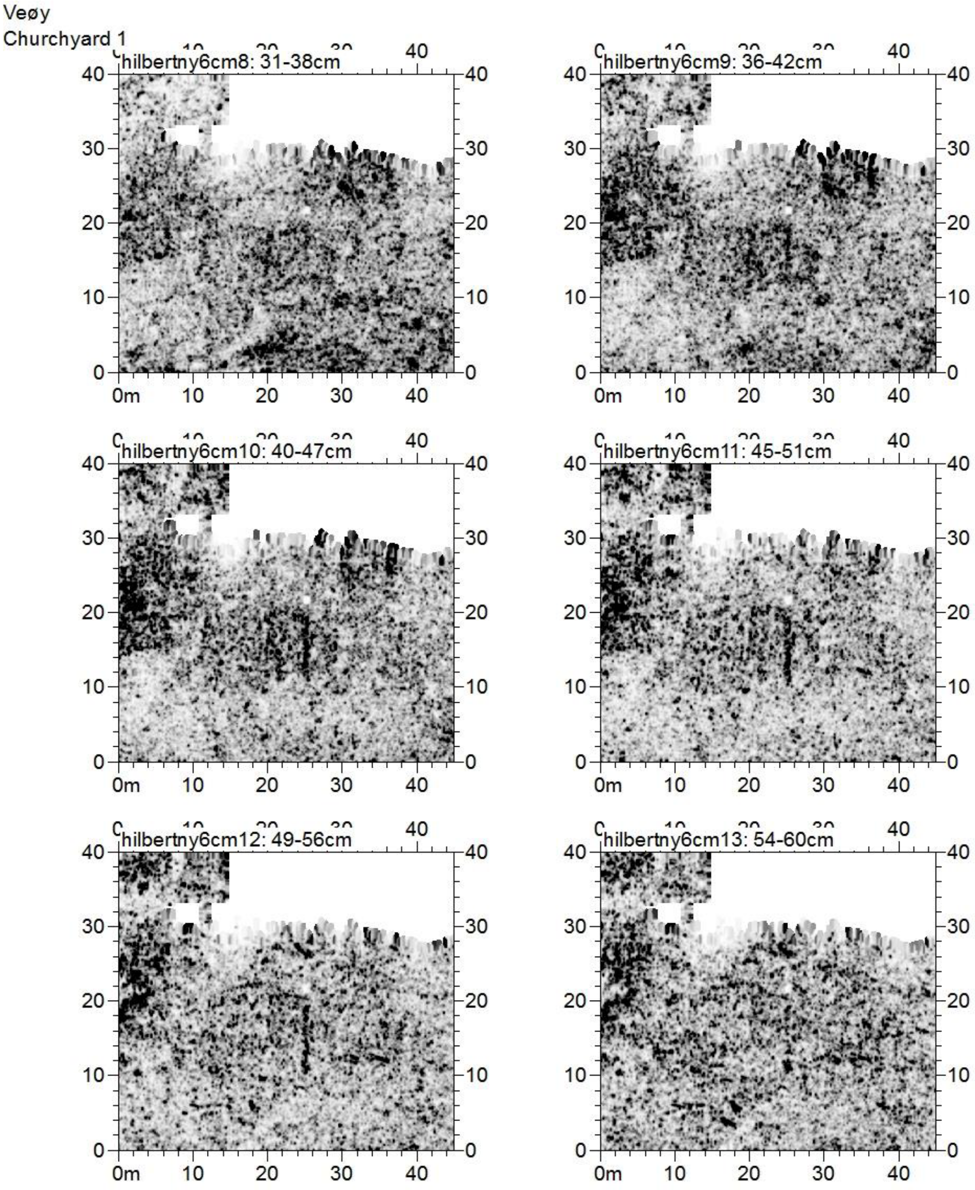


Figure 18: Depth slices of GPR-data from churchyard one at Veøy. This data was not presented in article two (Solli and Stamnes 2013), but were included in the geophysical survey report in color palette. The raw GPR-data has been resampled, bandpassed filtered to 195-735 Mhz, subjected to background removal, migration with a velocity of 0.053 m/ns, and Hilbert transformed before creating depth slices in the software GPR-slice (Stamnes and Solli 2012).

This information provides important archaeological information and new knowledge, which influence both the cultural historical understanding of the site, but also has implications on how the site should be delineated, managed and understood.

7.6.6 Electromagnetic techniques –limitations

At Peter Egges Plass in downtown Trondheim, it is assumed that salt used to prevent dusting and for the removal of ice created a situation where the electromagnetic energy was attenuated by the gravel-surface in a parking lot (Stamnes and Kristiansen 2014). The post-excavation surveys at Avaldsnes Area 8 and Area 1 were conducted in late November, in typically western-Norwegian climatic conditions with a more or less constant downpour all throughout the survey, which is suspected to create less of a contrast and poorer depth penetration of the electromagnetic energy propagated into the ground. It is a possibility that we could have better results if the survey was repeated at another time of the year. In area 1, the post-excavation GPR survey provided data in an area with a known medieval cellar, where the excavations revealed a range of stones, where some were the remains of stone-lined fundaments for buildings. While the GPR data provided geophysical contrasts that matched up spatially with known stones, the sheer number and randomness of the anomalies created difficulties in separation possible wall foundations from the "clutter" created from random stones (see figure 19).

Figure 19: GPR depth slices from Area 1 in Avaldsnes. It is published as figure 10 in article three. Processed by the author and illustrated by Ingvild Tinglum Bøckman.

The relative "easiness" of providing archaeological interpretations is also dependent on the clarity of geophysical contrast, and the presence of recognizable shapes or patterns of archaeological origin. The interpretability is therefore also dependent on the preservation condition of the archaeology, which might be highly variable. The presence of additional archaeological information, such as aerial photos, test-excavation results, soil auguring information or other, might improve the quality and usability of the geophysical information, improving the characterization and interpretation. While it is ideal if such information can be provided without additional data collection, this is not always possible. A good example of an archaeological feature is the wall ditch from an older iron age house at area 1 at

Avaldsnes (figure 20). It was dug into the bedrock, 0.5m wide and 16.5m long, but shallow. The house was not originally observed in the GPR dataset, but found during excavation. After reprocessing the available GPR data, the ditch became visible, but only in the data collected perpendicular to the ditch. Even then, the ditch was only barely visible, and could have easily been missed as an archaeological feature in the interpretation process. The complex combination of deposition processes, soil conditions, activity since deposition, and archaeological complexity can resort in it becoming difficult to provide clear and accurate archaeological interpretations. This is discussed in the next section of this chapter, section 7.6.7, on the process of creating incriptions.

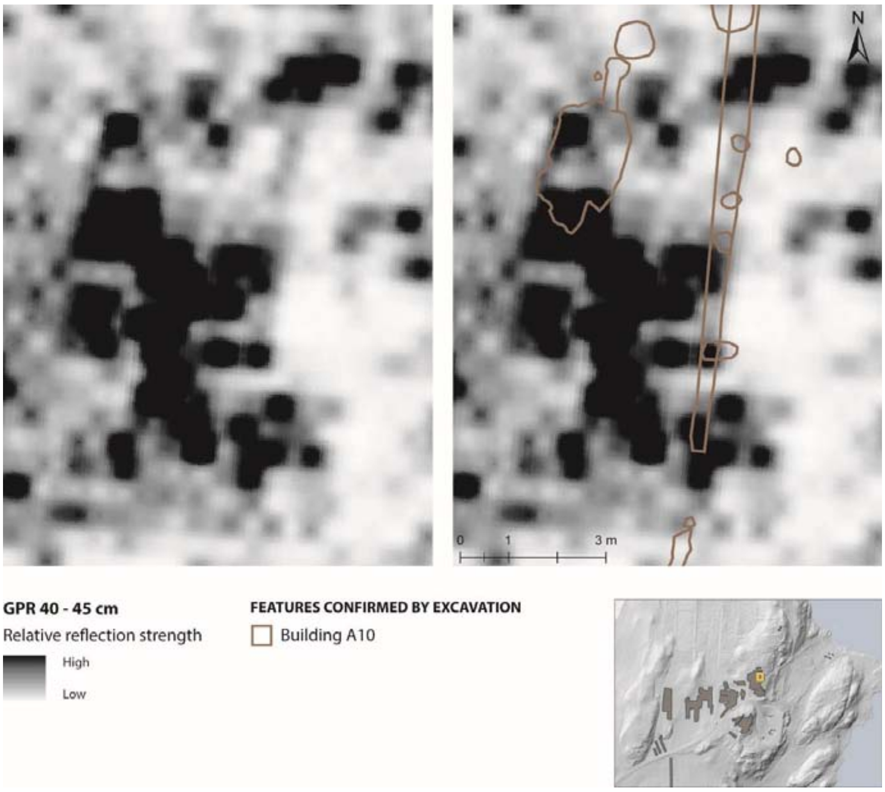


Figure 20: The difficult recognition of the wall ditch of building A10 at Avaldsnes (published as figure 7 in article three). Processed by the author and illustrated by Invild Tinglum Bøckman.

7.6.7 The process of creating inscriptions – controversies, uncertainties and the localization of graves at Veøy

The following section will concentrate on the creation of inscriptions from geophysical data, and will demonstrate how doubts and uncertainties can be hidden in the process of interpreting geophysical data and converting the geophysical data into archaeologically meaningful interpretation (see section 3.3 and figure 3). A good example of uncertainties and limitations of using GPR is the problems in clearly identifying graves at Veøy (article two), which was expected to be present based on earlier excavation results (Solli 1996). It was difficult to provide definitive and conclusive interpretations of graves at Veøy, even though several anomalies had the correct alignment (east-west oriented), shape (typically 1.5-2m in length and 0.5-1m in width) as expected graves. I will therefore provide additional insight into this interpretation process here, using the GPR investigation of potential graves at Veøy to exemplify the difficulties in being the *spokesperson* providing archaeological interpretations of geophysical data. I will use the case of analyzing the GPR data from Veøy for locating graves to demonstrate how inscriptions, i.e. archaeological interpretations from geophysical data, can hide controversies and uncertainties that appear during the interpretation process.

At Veøy the geophysical response from churchyard one varies throughout the area. Solli (1996) reports the subsoil to be of marine clay, which is usually understood as an signal attenuating environment (Conyers 2012; Conyers 2013). The geophysical response of typical graves can be caused by a range of factors (figure 21), as for instance strata breaks, fill scatter or a contrast caused by the burial in the bottom of the dug pit (Bevan 1991). Within buildings, the geophysical response from graves in GPR data can often be caused by air voids (Conyers 2012).

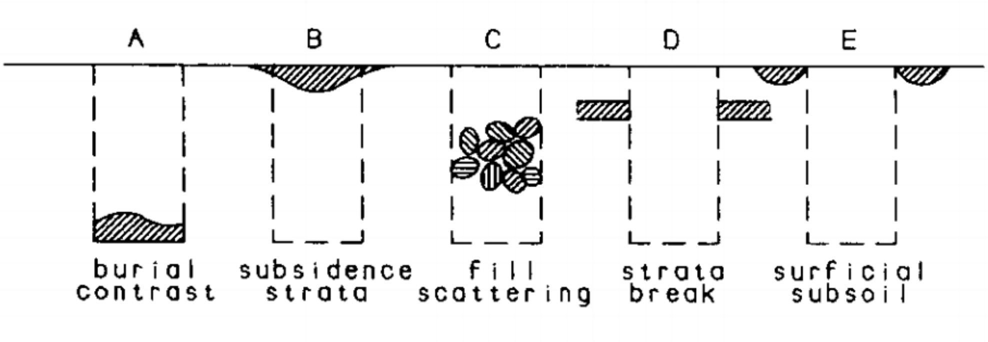


Figure 21: The broken line indicate the cross section of the original burial, while the hachured areas indicate possible soil contrast that could suggest a grave (Bevan 1991). Used with permission.

Bevan (1991) suggests that instance A in figure 21 may be the most common. If the typical instance at Veøy is a break in an attenuating layer, a similar effect with a stronger reflectivity at the bottom of the strata should be visible. The presence of pit-shaped edges in the geophysical data is very much dependent on the archaeological context. It therefore follows that to be properly able to interpret graves with some certainty, you need to factor into account a wide set of processes:

1. Archaeological aspects of burial tradition (depth to feature, construction of graves, intermingling of archaeological features)
2. Post-depositional processes (soil changes, ploughing, decomposition of original deposited material, dissipation of grave)
3. Geological conditions (subsoil type, potential geophysical contrast between archaeological feature and geological context)

As all of these factors may vary, so does also the geophysical expression that a grave might create. For instance, if the subsoil is of clay with a very waterlogged wooden plank in the bottom, you might expect no detectable difference, as wooden planks might dissipate the signal – revealing an absorption of signal strength. If the subsoil is of sand or silt, on the other hand, the depositional structure might be clearer in the geophysical data. Also, you might, or might not, find a strata break with a disturbed horizon. In addition to this, intermingling of grave cuts and other archaeological features crosscutting each other might create a geophysical response which is very hard to interpret.

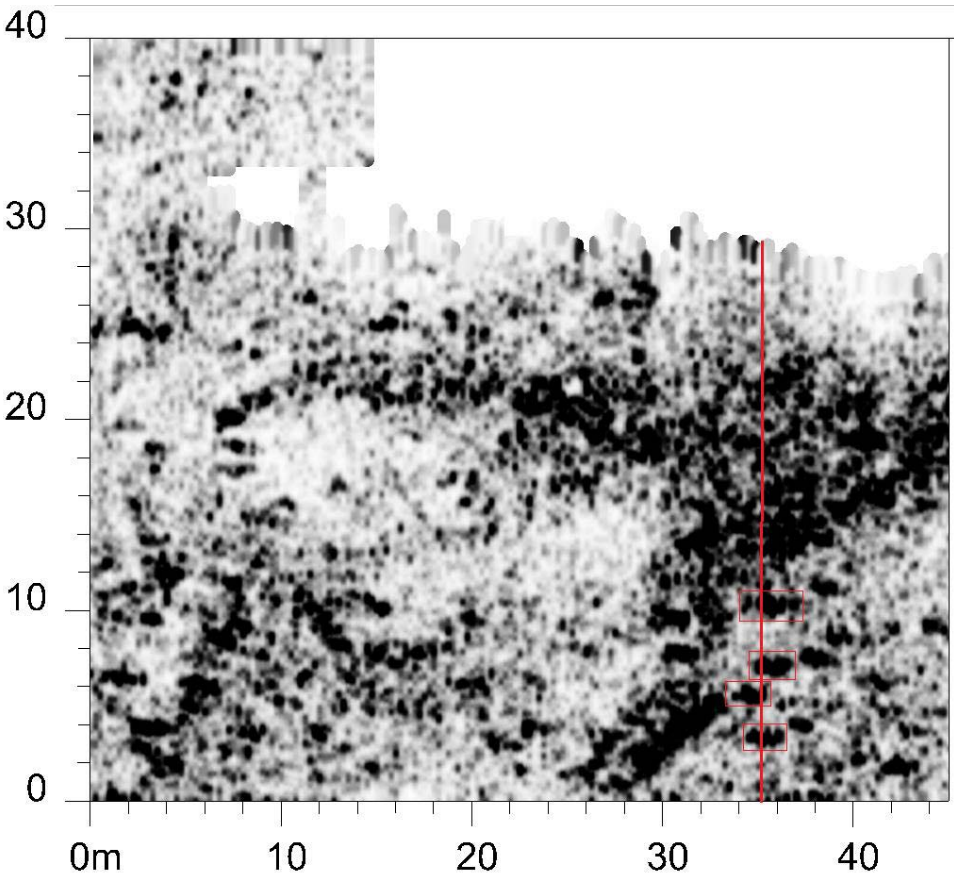


Figure 22: Depth slice from churchyard one in Veøy, at an approximate depth of 1.06m, with several anomalies having an east-west orientation and a size of 1.5-2m long and 0.7-1m wide. Red line indicate position of GPR profiles in figure 23 and figure 24. Boxes indicated possible graves further discussed in figure 23 and figure 24.

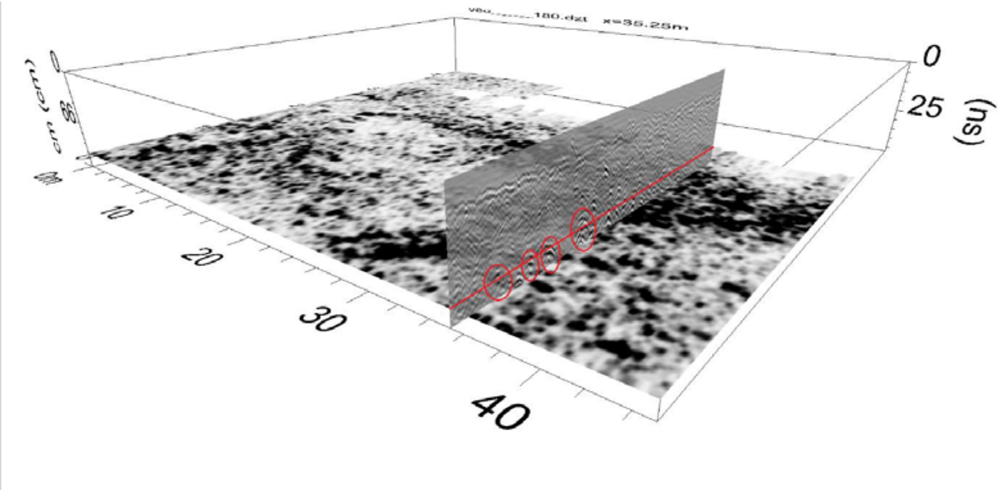


Figure 23: GPR profile overlaid on depth slice from figure 22

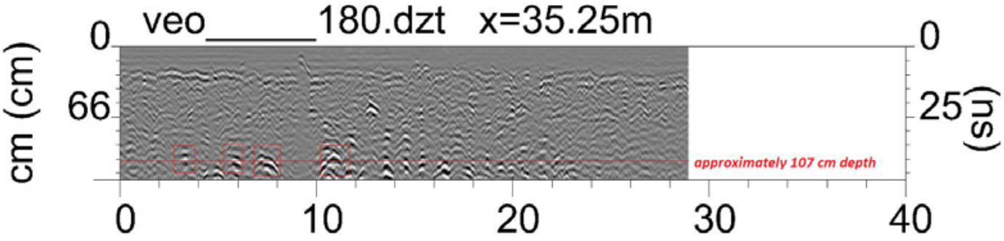


Figure 24: GPR profile indicating position of possible grave cuts as indicated in the depth slice in figure 22 and figure 23.

In article two it was implied that these anomalies could be potential graves, but also noted that such an interpretation was not to be considered certain (see figure 17, figure 18 and figure 22). Considering the discussion above, it could be that what is observed in figure 23 and figure 24 is a situation where the subsoil creates an absorbing situation, and that the grave fill is reflective as presented in letter A in figure 21. This is opposite from expected given the information of the presence of wooden planks in the bottom of several of the graves encountered in this church yard (Solli 1996). It is difficult to observe clear strata breaks, with dipping, pit-shaped sides of a cut.

At Veøy, a roughly North-south measurement direction was chosen to make sure to cover any potential east-west oriented graves in a perpendicular direction. The alignments of graves was proven by earlier excavations (Solli 1996), and a crossline resolution of a GPR section each 0.25m was considered appropriate. Survey direction and resolution is important to consider, as the survey direction can influence the relative "success" of a survey. At Avaldsnes on the other hand, we observe cross-line spacing of 0.25m, 0.5m and 1m. If the intention is to indicate the presence of smaller archaeological features such as postholes and pits, then a cross-line spacing of even 0.25m might be too widely spaced. A typical post-hole is usually somewhere between 0.2-0.5m in diameter. In retrospect, one can therefore conclude that the chosen crossline spacing of 0.5m and higher at Avaldsnes were not ideal for typical Norwegian settlement traces, although some archaeological features were observed even in the 1m crossline spacing dataset (article three – see also the GPR data in figure 15).

The example of graves at Veøy demonstrate the process of creating inscriptions, and how to be the spokesperson speaking on behalf of the geophysical results. The example demonstrates how knowledge of geology, archaeology and the geophysical methods all adjoins and are drawn into the work of interpreting geophysical data and provide archaeological interpretations. Sometimes there must be room left for doubts. The example demonstrate how the perceived and real potential and limitations of the methods all act as actors in the interpretation process, and how this process becomes a network in its own. The example also demonstrate how difficult it can be to be a meeting point between different subjects, and be a mediator who is set to adjoin the information and convert it into a meaningful entity and inscription. The perceived and real potential of the actors in this data analysis-process can both limit and strengthen the position of geophysical methods in archaeological research and heritage management in Norway.

7.6.8 Benefits of combining methods

Article one presents statistics of the use of various geophysical methods on various site types, as well as statistics on the number of geophysical techniques applied at each survey. Below are updated graphs with numbers including 2015 (figure 25, figure 26 and figure 27). As the various geophysical methods measure different geophysical properties in the ground, an inclusion of additional methods will provide an increased amount of information, which increases the confidence level in the final results and interpretations. This was demonstrated in figure 15 (Clark 1996; Gaffney and Gater 2003;

David et al. 2008; Stamnes 2010a; Gustavsen and Stamnes 2012; Gustavsen et al. 2013a; Bonsall et al. 2014; Stamnes and Gustavsen 2014; Schmidt et al. 2016).

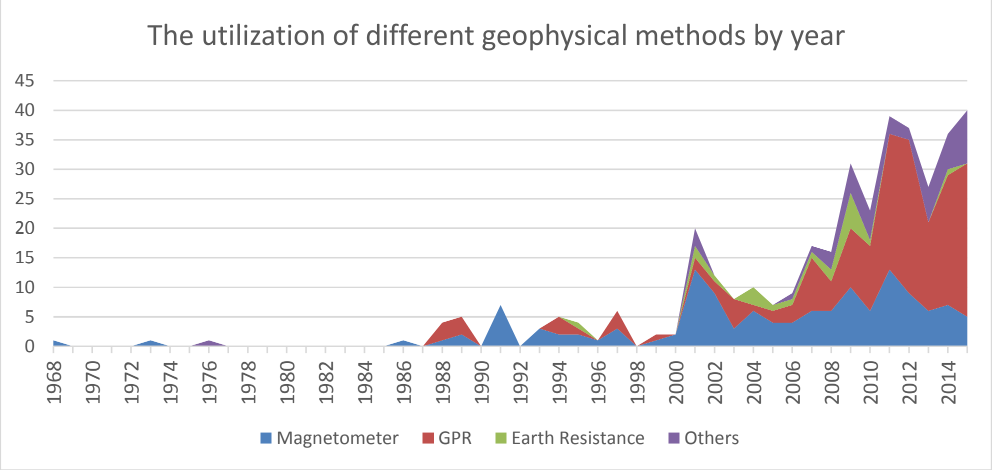


Figure 25: The graph shows the variation in the utilization of different geophysical methods on archaeological sites in Norway by year, from the earliest known surveys in 1968 to 2015."Others" include magnetic susceptibility and electromagnetic induction (EMI).

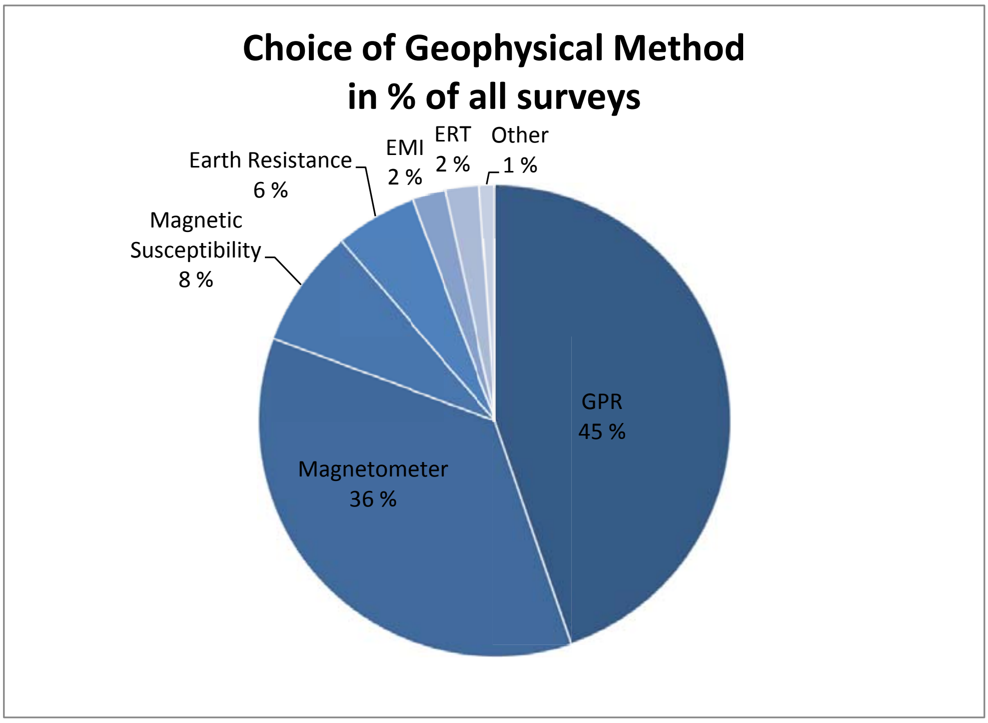


Figure 26: Graph showing the use of each main geophysical technique. Several methods may have been applied at one survey. The precentage is related to the number of surveys involving a technique, and not the size of the surveys.

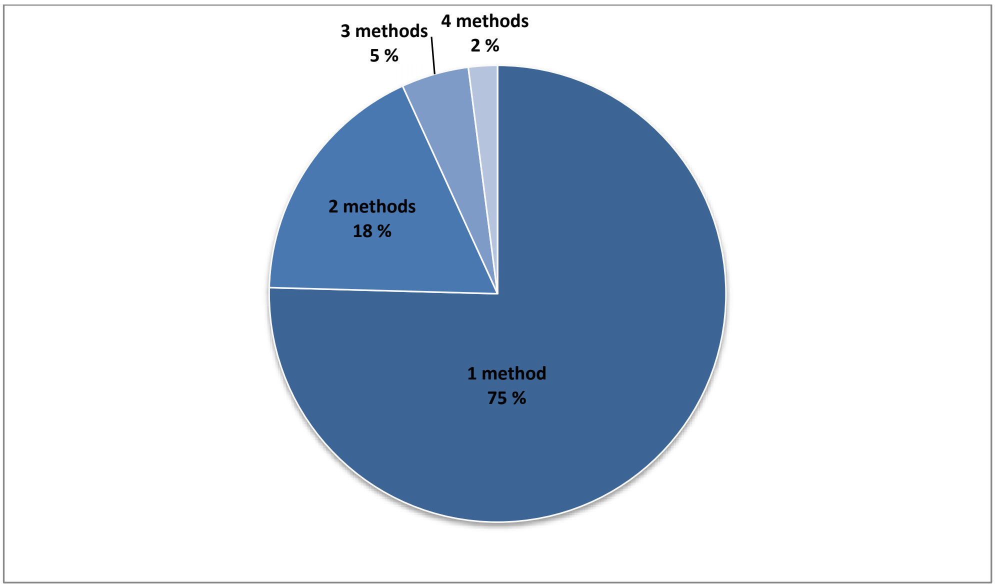


Figure 27: Graph showing the number of different geophysical methods used at each survey

There is an increased use of GPR and "other" methods over time, even compared to the figures presented in article one which is based on numbers until 2013. The total percentage of surveys involving GPR has for instance increased from 42 % in January 2013 (article one) to 45 % by the end of 2015. Earth resistance is seldom used, which can be easily explained by the fact that none of the institutions in Norway performing geophysical surveys own a twin probe earth resistance kit, while we still observe a couple of Earth Resistivity Imaging surveys. The total number involving one method has also increased from 71% (article one, number from January 2013) to 75% by the end of 2015. This is mainly due to the acquisition of instrumentation capable of large-scale GPR by NIKU and the NTNU University museum, the surveys commissioned in relation the the DCHs' Ruin Conservation project as well as a series of GPR investigations revealing good results in Norway (Stamnes 2011b; Bill et al. 2013; Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology 2013a; Meyer and Gustavsen 2013b; Gustavsen 2014; Meyer and Kristiansen 2014; Directorate for Cultural Heritage 2015d; Meyer and Kristiansen 2015).

Although GPR has turned into the main method of geophysical investigation in Norwegian archaeology, the combination of several geophysical data sources can help in characterizing and interpreting the geophysical observations. An example of this could be the additional information gained by combining GPR and magnetometry. This could be illustrated by an example from Rygg, at Frosta municipality in Nord-Trøndelag, where the NTNU University museum have conducted a magnetometer-survey followed up by a GPR survey. The combination of GPR and magnetometer here helped identifying a magnetic anomaly as a pit with magnetic content of a maximum of 32.7 nT (figure 28 and figure 29). This feature have not been excavated, but an archaeological interpretation of this as a cooking pit is suggested due to the pit-shape observed in the GPR data and the magnetic contrast visible in the magnetometer-data. Most of the other strongly magnetic anomalies with a weak negative signal response show similar traits. This small example demonstrates the benefits of combining several geophysical methods.

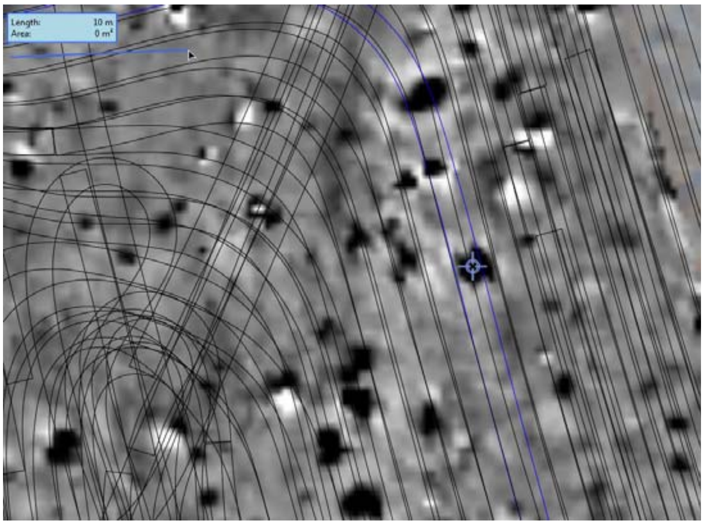
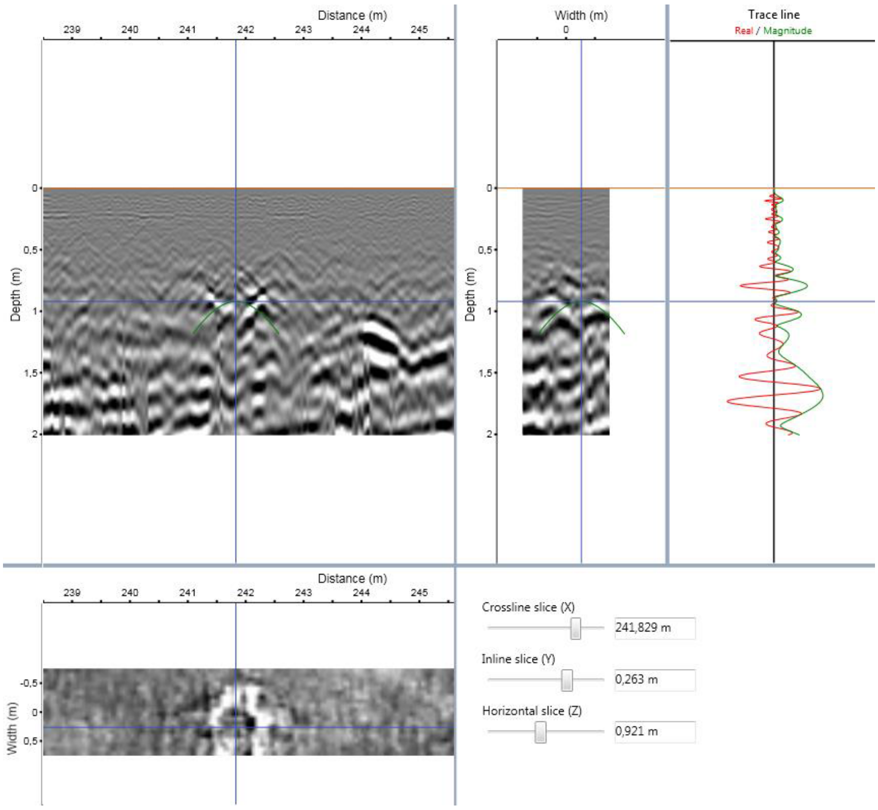


Figure 28: Example of magnetometer plot (black +7.7 nT, White - 7.3 nT). The crosshair indicates a magnetic anomaly of a maximum of +32.7 nT. The parallel black lines represents GPR transects of 1.5m wide swaths of data collected with a ground-coupled, multi-frequency 3d-radar GPR system by the NTNU University Museum. The blue line on top indicates 10m distance. The dataset has a gpr profile for every 7.5 cm.



Crossline slice (X) 241,829 m
Inline slice (Y) 0,263 m
Horizontal slice (Z) 0,921 m

Figure 29: GPR crossline, inline (with trace line) and depth slice of the same anomaly. Notice the pit-shaped cut from either side, and the week reflection response from the topsoil, which eases the identification of cut features into the subsoil.

7.7 CONTRIBUTION TO CULTURAL-HISTORICAL KNOWLEDGE

This section should be seen in direct relation to objective six (see section 1.1. – “Aim and Objectives”), on cultural-historical knowledge gained from the methodical and empirical results of articles two, three and four.

The previous section presents a range of new cultural historical observations which was derived from the geophysical data presented in article two, three and four (with additional information from other surveys). Although the original results derived from research-initiated projects, this information contribute both to the cultural historical understanding of the sites and gives additional information regarding issues of delineation, entries in the national monument registry, and as management aid for future use. The results presented in the articles can also act as reference material for future projects and research.

In article two, the geophysical methods indicated the presence of potential graves and the delineation of an early Christian burial ground at the island of Veøy. The survey results also helped indicate the presence of several buildings, where two of these might very well be the earliest indications of clerical buildings known in Norway. An extension of the topsoil magnetic susceptibility survey presented in the article (see figure 4 in this thesis), led to the delineation of a metal working area that turns out to be approximately 10% of the total area of the known distribution of the black earth deposits. In addition, there is a zone of low topsoil magnetic susceptibility between the industrial area and the black earth immediately to the east, which can be interpreted as an intentional separation between the industrial activity and the rest of the market place (Solli and Stamnes 2013- article two).

At Avaldsnes cooking pits in thick prehistoric cultivation deposits was identified with good confidence (article three and figure 16 in this thesis). This is knowledge which can be expanded to areas outside of the excavation area and add to the total understanding of the archaeological activity in the area. The GPR investigation in area 2 also contributed to the geoarchaeological understanding of the landscape (article three).

The magnetic prospection of iron production sites in article four contributed to a range of new and exciting information. It was possible, for the first time, to properly delineate and indicate the size and layout of the iron production sites of the Trøndelag furnace-tradition- independent on registration method. The size of the three sites delineated varied from approximately 1150 m² (Tromsdalen – figure 37) to 3020 m² (Roknesvollen), and the surveys revealed heightened measurement values of topsoil magnetic susceptibility as far back as 30 m from the terrace edges by which the furnaces at these sites often are located. The results also show how magnetic geophysical prospection methods is applicable to locate and characterize the geophysical responses of furnaces, probable roasting sites for iron ore with very good confidence. In addition to this, the fluxgate gradiometer results help identifying an oval-shaped feature of 12x7.5m at Storbekken 1 in Budalen (see figure 9). This oval feature was interpreted as a storage area of roasted iron ore. These surveys provided quantitative statistics of the geophysical response of typical features such as slag tips, furnaces, storage pits, as well as the possible roasting sites.

In addition to these investigations, there are several other examples of well performed geophysical surveys with good results from Norway. Many of these are mentioned in the historical overview presented in chapter 2. Honorable mentions are for instance the mapping and outlining of iron production sites at Gråfjell (Risbøl and Smekalova 2001; Smekalova and Voss 2002; Smekalova et al. 2008), geophysical survey of prehistoric graves and boat houses at Gustad (Stamnes 2010a, 2011b), the geophysical identification of graves at Odberg (Trinks et al. 2010a), iron age buildings at Borre

(Trinks et al. 2007; Fossum 2010) and the location and characterization of a viking age trading site with house parcels and burial mounds at Heimdal (Bill et al. 2013; Bill and Rødsrud 2013; Schneidhofer et al. 2016).

The results in all of these articles and reports, demonstrate how geophysical surveys can act as a tool in the archaeological toolbox that becomes a source of interesting knowledge in a non-intrusive manner. The results themselves, along with any published reports and articles, become actors themselves that can be mobilized and used as allies for other actors interests. Geophysical methods provide the possibility to investigate sites and monuments that previously have been difficult to investigate further (for instance due to legal protection and cultural historical importance). Within the network of archaeological research, the geophysical methods creates an opportunity to rephrase the questions asked and serve as a provider for new knowledge. Within the network of archaeological research, the funding for surveys comes from the institutions themselves – actors which are not concerned with aspects of balancing costs and priorities against legal concerns in the same manner as what is relevant for a NCHA §9 case initiated by a developer. The application of geophysical methods, and any methodical and survey-parameters, can be tailored towards the research questions that are of interest. It is therefore evident that the acceptance of including geophysical methods into research projects are easier to attain than what the case is within the network of cultural heritage management.

7.8 CONTROVERSIES

7.8.1 New methods under development?

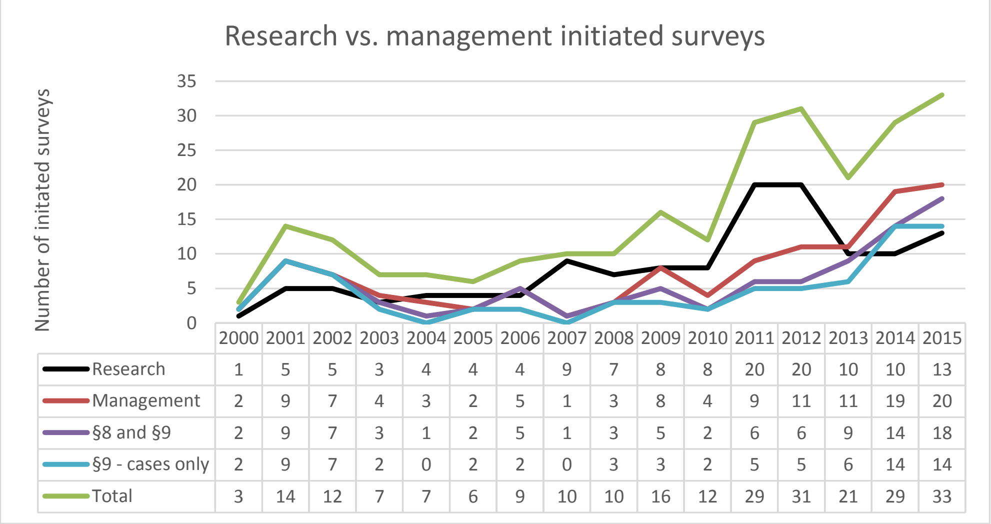
This section related to objectives two, three and eight (see section 1.1. – “Aim and Objectives”).

Geophysical methods were often referenced to as “new”, or under “development”. When actors within the Norwegian cultural heritage management describe these methods as new, I interpret this as a reflection of how the geophysical methods are perceived by them. This could be explained in several ways, for instance reflecting that the actors have not themselves any experience with using the methods or the background knowledge of the possibilities and limitations of such methods, and therefore choose to denote them as “new”. As geophysical prospection in archaeology is not taught as a specialist subject at any archaeological teaching institutions in Norway, but only included as singular lectures of the Field Archaeology course for master students in Archaeology at NTNU the last five years, this has also limited the knowledge available to professional archaeologists throughout their education. This might have, in turn, restricted the knowledge available within different decision making bodies involved in Norwegian archaeology.

Following the descriptive statics from the AGIN database as presented in article one, the understanding of geophysical methods as something new is not correct. In fact, the use of geophysical methods within Norwegian archaeological research and cultural heritage management can be traced as far back as 1968, but not really adding up in numbers of surveys until late 1980s and mid 90s. There has been a large increase in the amount of surveys within the last decade, and especially since 2010 and onwards (see figure 1 and figure 25). 163 geophysical surveys have been performed in Norway since 2007, out of a total of 293 surveys performed until the end of 2015, equal to 56%, have been performed since 2007. Figure 32 shows the development of commissions of geophysical surveys by various county authority. This figure shows that that apart from a couple of surveys in 2002 and 2003, a more geographical widespread in commissioning geophysical surveys did not occur until 2009 and onwards.

What is new is the establishment of domestic competence, as well as easier access to geophysical equipment, tools and providers of archaeological prospection surveys. In addition, there have been improvements in relation to software capacity and efficiency in data collection within the last few years – involving multi-sensor arrays capable of collecting larger amounts of data than before – and with a higher resolution. This speeds up the efficiency of data gathering and can improve the spatial resolution of the data depending on the equipment setup (Stamnes and Gustavsen 2014, article one). The actors are now accessible both within, and for the networks. The flipside to this development is the amount of data that needs to be processed, and the increased post-survey work necessary to provide decent data presentation and interpretation. Although there has been a development in data processing and anomaly extraction, the sheer size and complexity of large datasets now possible to attain requires different approaches to data interpretation such as semi-automated and automated anomaly extraction and characterization (Leckebusch et al. 2008; Conyers and Leckebusch 2010; Pregesbauer et al. 2013; Schmidt and Tsetskhladze 2013; Pregesbauer et al. 2014; Hinterleitner et al. 2015; Johnson et al. 2015). The amount of research and surveys published as reports and articles by actors conducting geophysical surveys on a Norwegian material has also increased in the later years (see for instance Stamnes 2010b, 2010a, 2011b, 2011a; Gustavsen and Stamnes 2012; Stamnes 2012; Stamnes and Solli 2012; Bill et al. 2013; Gustavsen et al. 2013a; Gustavsen et al. 2013b; Meyer and Gustavsen 2013a, 2013b; Modern Arkeologi 2013; Gustavsen 2014; Meyer et al. 2014; Stamnes and Gustavsen 2014; Stamnes and Kristiansen 2014; Draganits et al. 2015; Stamnes 2015d, 2015b, 2015c, 2015a; Schneidhofer et al. 2016).

The analysis in article one made a distinction between surveys commissioned for “research” and “management” purposes respectively. The surveys labeled “management” was surveys either conducted as part of a developer-led planning application or excavation, conducted for special dissemination purposes for an institution within the cultural heritage management system, or to answer specific questions relating to the proper management or investigation of an archaeological site. Surveys conducted for research purposes involved all other aspects of field methodical research as well as investigating and acquiring additional cultural historic knowledge of a site, monument or feature (Stamnes and Gustavsen 2014:21, article one). Also, an overview of the total amount initiated for research vs. management purposes in the last 15 years (figure 30) reveals that the there have been more surveys initiated for management purposes than research purposes in the last three years:



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Research	1	5	5	3	4	4	4	9	7	8	8	20	20	10	10	13
Management	2	9	7	4	3	2	5	1	3	8	4	9	11	11	19	20
§8 and §9	2	9	7	3	1	2	5	1	3	5	2	6	6	9	14	18
§9 - cases only	2	9	7	2	0	2	2	0	3	3	2	5	5	6	14	14
Total	3	14	12	7	7	6	9	10	10	16	12	29	31	21	29	33

Figure 30: The total amount of surveys initiated for research versus management. Numbers are taken from the AGIN-database.

The relatively high numbers in 2000-2002 is mainly due to the Gråfjell-project, where NIKU chose to include magnetometer surveys in locating and delimiting Iron production sites when performing archaeological registrations in the Gråfjell-area in Hedmark (Risbøl et al. 2001; Risbøl et al. 2002a; Risbøl et al. 2002b). This information only tells part of a story, as the large increase in management-initiated surveys can be investigated in more detail. The majority of the management initiated surveys in the last two years are mainly commissioned by Vestfold county authority. The decrease in the total number of surveys in 2013 is related to the end of the field campaigns of the LBI-project, but it is interesting to see how after these field investigations ended, the total number of management surveys started to climb (see Figure 35 and Figure 30 respectively). The total number of research versus management initiated surveys for all 293 surveys performed until the end of 2015 in Norway is 57% research initiated and 43 % management initiated surveys (see table 12). In February 2013 this number was 64% research and 36% management initiated (Stamnes and Gustavsen 2014, article one), and this change is apparent in figure 30 and in table 12.

Table 12: Total distribution between research and management-initiated surveys for all institutions – all geophysical surveys until the end of 2015.

	Research	Management	Total	Total %	Research %	Management %
ARCHAEOLOGICAL MUSEUMS INCL. NORWEGIAN MARITIME MUSEUM	**77**	**25**	**102**	34,8 %	75 %	25 %
NIKU	**39**	**22**	**61**	20,8 %	64 %	36 %
COUNTY AUTHORITIES INCL. THE SÁMI PARLIAMENT AND OSLO MUNICIPALITY	**19**	**62**	**81**	27,6 %	23 %	77 %
DCH	**1**	**7**	**8**	2,7 %	13 %	88 %
MUNICIPALITIES	**2**	**3**	**5**	1,7 %	40 %	60 %
OTHERS	**29**	**7**	**36**	12,3 %	81 %	19 %
TOTAL	**167**	**126**	**293**	100,0 %	57 %	43 %

Table 12 indicates how the various types of actors have used geophysical methods when commissioned. Research dominates at the archaeological museums, NIKU and “Others”. Others include private initiatives, local museum historical societies and similar. Of management initiated surveys, the county authorities dominate – with approximately 77% of all surveys commissioned by counties. This show to a certain extent the connections and alignments that exits between the geophysical methods and the networks of archaeological research and cultural heritage management.

7.8.2 Statements versus practice

This section relates to objectives one, four and eight in particular, but also contributes to fulfilling objective three (see section 1.1. – “Aim and Objectives”).

7.8.2.1 County authorities

The graph below (figure 31) shows the total amount of archaeological field work reported to the Norwegian KOSTRA-database for municipal and county authority activities, compared to the geographical location of all geophysical surveys performed. KOSTRA stands for “Kommune-Stat-Rapportering” (En: Municipality-State-Reporting, this author’s translation), and gathers statistics over activities, resources, priorities and goals reached for municipalities, districts and county authorities.

This includes figures on economy, schools, health, culture, the environment, social services, public housing, technical services, transport and communication (SSB 2016). The numbers are reported by the institutions themselves, and the reporting of cultural heritage management statistics started in 2007. The numbers equal percentage of the total amount of archaeological field work and geophysical surveys respectively.

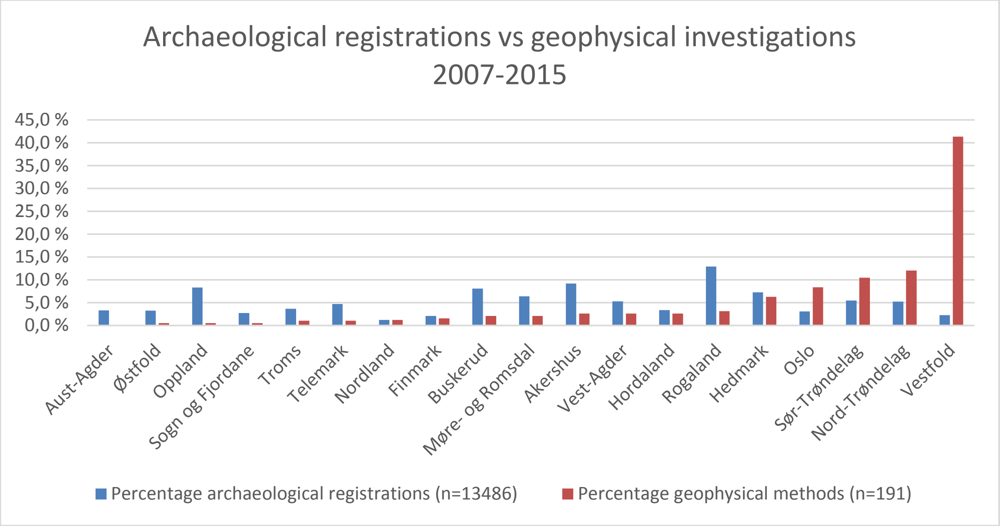
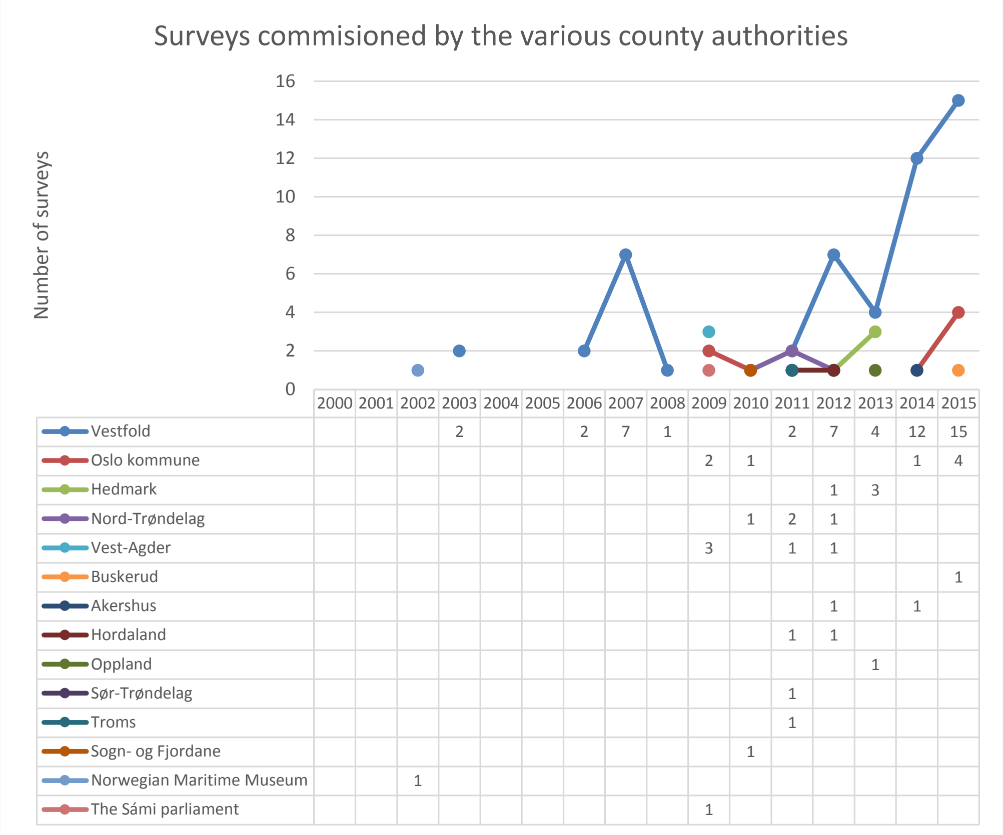


Figure 31: The total amount of archaeological registrations versus geophysical surveys for the years 2007-2015 in Norway. Numbers are in percentages compared to the national total. Please note that these are updated numbers compared to figure 4 in article 1.

This table does not represent who commissions geophysical surveys, but rather where they were commissioned compared to the archaeological registration activity. Figure 32 and figure 35 shows who commissioned the surveys. There is no correlation between the counties performing a large amount of archaeological registrations related to planning permissions and the amount of geophysical surveys conducted within the same county. The rationale behind this interpretation is that research activity conducted in an area will induce an increase knowledge and understanding of the methods for the regional cultural heritage authorities (which is typically the county archaeologists in the respective county authority). Although there are various institutions commissioning the geophysical investigation other than the county authorities, the observation is interesting and it gives an overview and additional information on the geographical focus of institutions performing such investigations. For instance is the NTNU University museum based in Sør-Trøndelag, but has collaborated with Nord-Trøndelag on the Herlaugshaugen survey as well as the Frosta Thing project (Nord-Trøndelag county authority 2012; Stamnes 2015b, 2015c), while NIKU and the LBI ArchPro has performed a range of surveys in Vestfold (NIKU 2011b; Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology 2013a). The observation on this lack of correlation between counties performing many archaeological registrations following the NCHA §9 c.f. 10 and the number of geophysical surveys performed in their respectable area was in article one interpreted as a lack of acceptance of the geophysical methods. The fact that the total number of counties commissioning geophysical surveys each year has been relatively low supports this (figure 33). At the same time, there is a trend of more management than research initiated surveys within the last three years. This might indicate an increased acceptance of the use of geophysical methods within parts of the archaeological community (see figure 30 above). However, the low number of counties representing most of this activity reveals additional information on this (figure 32 and figure 33), indicating that the increased application of geophysical methods in relation to §9 c.f. §10 cases are only restricted to a few county authorities.

These statistics can be broken down even further to get a more detailed insight by looking at which actors that actually commission geophysical surveys (figure 32). By comparing these numbers with the statements made by the same actors, it is possible to investigate their legitimacy of making the statements that the actors present based on the relationship of their experience of the geophysical method as seen in the statistics. The spokespersons, and the legitimacy and strength of their inscriptions, become related to the support the spokespersons can establish. By unravelling the quantitative experience of various spokespersons, it is possible to evaluate and understand the expressive force of their statements, or inscriptions. If an actor makes a strong claim on the statement modality ladder, but lacks the empirical experience to support their statements, the strength and position of their inscriptions can be reevaluated. This refers directly to the fulfillment of objective four in particular, as well as contributes to the fulfillment of objective two and three (see 1.1. – "Aim and Objectives").



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Vestfold				2			2	7	1			2	7	4	12	15
Oslo kommune										2	1				1	4
Hedmark													1	3		
Nord-Trøndelag											1	2	1			
Vest-Agder										3		1	1			
Buskerud																1
Akershus													1		1	
Hordaland												1	1			
Oppland														1		
Sør-Trøndelag												1				
Troms												1				
Sogn- og Fjordane											1					
Norwegian Maritime Museum			1													
The Sámi parliament										1						

Figure 32: Geophysical surveys commissioned by the various county authorities. This includes both research and management-surveys.

The county authorities of Østfold, Møre- og Romsdal, Nordland, Telemark, Aust-Agder, Finnmark and Rogaland has not commissioned geophysical surveys at all between 2000 and the end of 2015 according to the entries in the AGIN-database. Rogaland is the county that, according to the KOSTRA-database, performs the highest number of archaeological registrations related to planning permissions (see figure 31). Nord-Trøndelag has, together with Frosta municipality, supported financially geophysical surveys as part of the Frosta Thing Research project in the years 2012-2014. These are included in the figures for the NTNU University Museum in figure 35 (Nord-Trøndelag county authority 2012). It is interesting to note the high increase in commissioned surveys in Vestfold for 2014 and 2015, following their participation in the LBI project (see figure 35 for additional statistics). Vestfold is the only county that regularly commissions geophysical surveys throughout this time period from 2011-2015.

Of the counties that have commissioned one or more geophysical surveys, only Sør-Trøndelag and Vestfold mentioned geophysical methods in their response to the §9 circular. Sør-Trøndelag emphasized that archaeological registrations performed as part of planning development according to the Cultural Heritage Act §9 should not be an arena for method development, but that in there in *specific instances* could be ideal to include for instance geophysical methods in archaeological registrations (Sør-Trøndelag county authority 2012). Sør-Trøndelag also mentioned geophysical methods in their regional plan for cultural heritage sites and monuments (Sør-Trøndelag county authority 2013b) and the annual letter of prioritization from the DCH. For this letter Sør-Trøndelag county authority had reported *research on and testing of* geophysical methods in Norwegian conditions as one of their main priority areas (Directorate for Cultural Heritage 2015a). Sør-Trøndelag county authorities' focus has been on improved efficiency of the cultural heritage management, by performing obligations appointed to the county authority by law in the most possible cost effective way (Sør-Trøndelag county authority 2013b). I interpret this as an awareness of the possibilities and potential of geophysical methods, but at the same time a hesitation by Sør-Trøndelag county authority in integrating such methods into the daily management unless the geophysical methods can prove themselves cost efficient. The emphasis on *"specific instances"* indicate that this was the case in 2012, and could also be interpreted as an impression by Sør-Trøndelag county authority of the methods as not really proven themselves to be properly applicable in all situations, but only under certain conditions. The only geophysical survey registered in our database commissioned by the Sør-Trøndelag county authority was the geophysical investigation of a mound-structure which was performed by the NTNU University Museum, that indicated that the feature was most probably a natural feature and not man-made (Stamnes 2011a). Therefore, while the interest in geophysical methods have been expressed, and a potential is seen, the methods have yet to become accepted as a part of the daily cultural heritage management in Sør-Trøndelag county. At the same time, Sør-Trøndelag county authority point out the potential for academic collaboration in the region (Sør-Trøndelag county authority 2013b), which can be seen as a positive interest in enrolement and interessement of other actors to participate in some form of collaboration. In this way, actors such as the NTNU University Museum or others can reach out and be included and position themselves, and be mobilized and recruited as participants in the network of heritage management in Sør-Trøndelag (see table 2).The example of the Budalen-survey of the iron age production site Storbekken 1 (figure 9 in this thesis, taken from article four) is situated in Sør-Trøndelag, and the new information from the site will be a beneficial contribution to the county authority's management of this site.

The municipality of Oslo have not mentioned geophysical surveys in their strategy documents, but have commissioned several geophysical surveys. In 2015 the Agency of Planning and Building services (NO: Plan og bygningsetaten) initiated a pilot study on the use of geophysical methods for archaeological registrations in densely built-up areas in collaboration with the DCH and the Ministry of Local Government and Modernisation (MoLGM). In this way the interests and agencies of the actors (Oslo, DCH and MoLGM) were aligned and provided financial support. Interestingly, the MoLGM is not an actor often directly associated with CHM directly, possibly signaling another intention than the other actors in participating in such a research project. The intention was to investigate to what degree geophysical methods could supplement or replace traditional archaeological methods in densely build-up areas. Another aspect was to limit the physical intervention (Oslo Municipality 2015; Ministry of Local Government and Modernisation 2016; Oslo Municipality 2016). This pilot study in Oslo was performed by NIKU. Although I would consider this a difficult endeavor, facing challenging survey conditions and complications of archaeological interpretation related to modern day installations and the influence thereof in the geophysical data, their intention and interest is an interesting development. The results from central parts of Avaldsnes (section 7.6, figure 13, figure 14 and figure 19 and associated discussion) demonstrates the potential difficulties of GPR surveys in an urban and disturbed setting.

This situation is very different with Vestfold county authority, which have been collaborating with NIKU and the LBI ArchPro with several sites in Vestfold acting as their case study. Vestfold was also a collaborator for the Geophysics-project in 2007 together with the DCH and UV-Teknik (Fossum 2010; Gustavsen et al. 2013b; Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology 2013a). When it comes to statements versus actually utilizing geophysical surveys, it becomes very clear that Vestfold's collaboration with NIKU and the LBI has influenced Vestfold's views and opinions on the use of geophysical methods, as Vestfold is to this date the only county that has clearly stated that they see geophysical methods as equal to any other archaeological field methods. Vestfold is also the only county that utilized geophysical methods in a regular manner. Vestfold county council have also passed a policy defining specific areas of archaeological interests where if there should be proposed any development plans, high-technological methods are to be utilized if possible (Vestfold county authority 2012, 2014; Directorate for Cultural Heritage 2015b, dialogue letter of prioritization between the DCH and Vestfold county authority).

While several county authorities have commissioned one or more geophysical surveys within the last few years, it is also interesting to note that these have been commissioned by relatively few counties seen on a year to year basis (see figure 33).

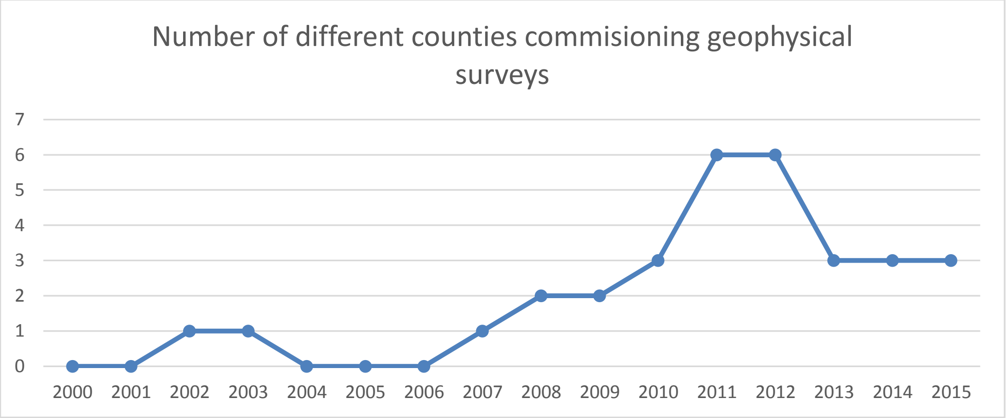
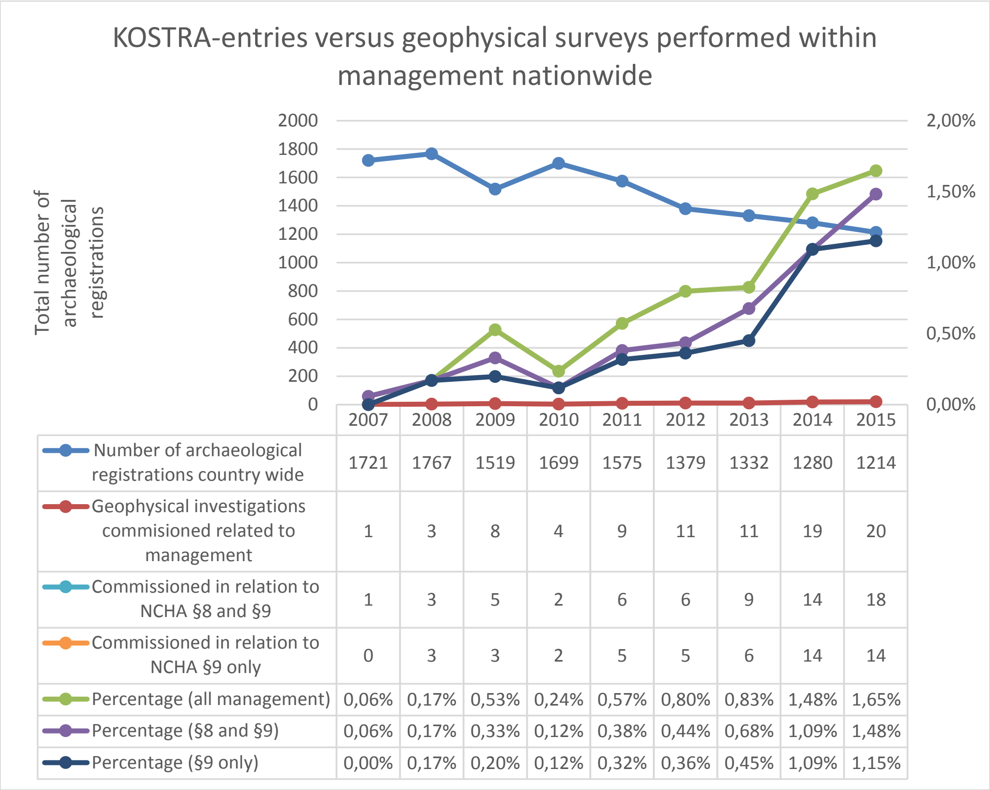


Figure 33: The total number of different counties commissioning geophysical surveys each year between 2000-2015

The following statistics are also highly interesting, and show the total number of reported archaeological registrations nationwide related to planning permissions following the NCHA §9 compared to the total amount of management-initiated geophysical surveys commissioned by the various county authorities:



	2007	2008	2009	2010	2011	2012	2013	2014	2015
Number of archaeological registrations country wide	1721	1767	1519	1699	1575	1379	1332	1280	1214
Geophysical investigations commisioned related to management	1	3	8	4	9	11	11	19	20
Commissioned in relation to NCHA §8 and §9	1	3	5	2	6	6	9	14	18
Commissioned in relation to NCHA §9 only	0	3	3	2	5	5	6	14	14
Percentage (all management)	0,06%	0,17%	0,53%	0,24%	0,57%	0,80%	0,83%	1,48%	1,65%
Percentage (§8 and §9)	0,06%	0,17%	0,33%	0,12%	0,38%	0,44%	0,68%	1,09%	1,48%
Percentage (§9 only)	0,00%	0,17%	0,20%	0,12%	0,32%	0,36%	0,45%	1,09%	1,15%

Figure 34: The total number of entries in the KOSTRA-database versus geophysical surveys commissioned for management purposes by the various county authorities nationwide between 2007-2015.

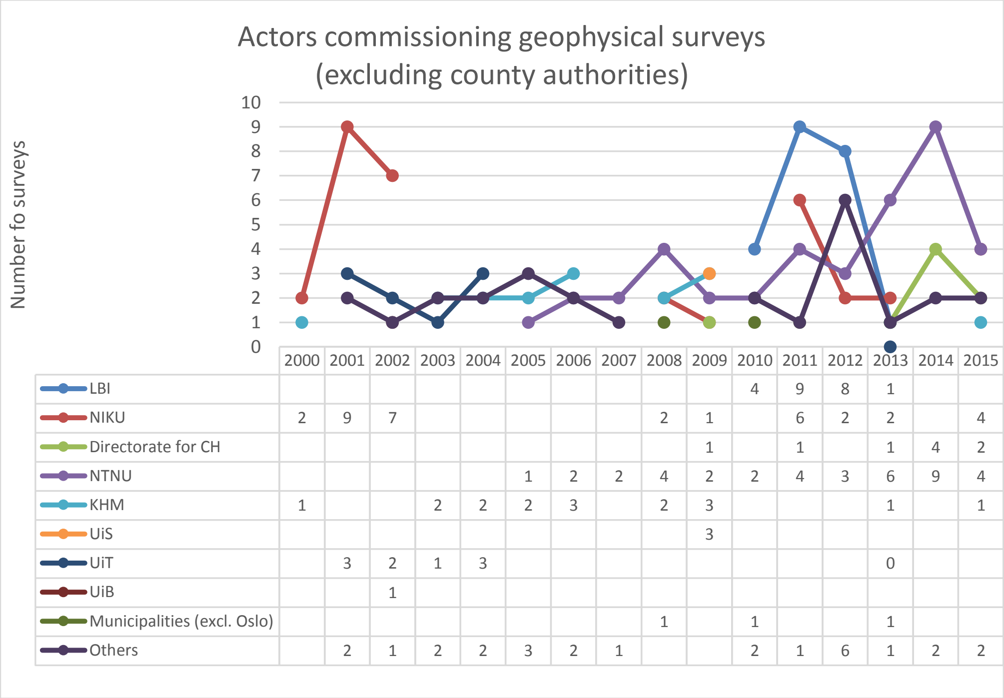
The graph on figure 34 shows that the total percentage of geophysical surveys is very low compared to the reported entries in the KOSTRA-database, although increasing from 0.06% in 2007 to 1.65% in 2015. The total percentage of NCHA §9 cases involving archaeological registrations countrywide rose from 0% in 2007 to 1.15% in 2015. It must be pointed out that it is difficult to investigate how uniform the data entries into the KOSTRA-database are, and that each county authority might collect and enter data differently into this database. While I assume the general trends more or less reflect the real situation, the exact number might be not be completely accurate. The statistics in figure 34 are therefore highly interesting, as they indicate how much the impact geophysical methods have had on archaeological registrations following §9 cases. Nationnwide, the average is 1.15%, while Vestfold had 28% (14 out of 50 reported §9 cases) in 2015. Most of the management cases from Vestfold were defined as less extensive private initiatives for drainage of fields, where the expenses are to be covered by the state. Additional funds to cover any expenses related to drainage were provided by the Ministry of Agriculture and Food (Ministry of Climate and Environment 2007; Ministry of Agriculture and Food 2013; Norwegian Agricultural Authority 2013).

On a county level, it is therefore possible to conclude that while the interests and the mentioning of geophysical surveys have increased, for instance in cultural strategic plans, annual letters of prioritizations and in circulars, geophysical methods have yet to be accepted as a natural part of archaeological registrations, except in Vestfold. Also, the total amount of geophysical surveys commissioned by county authorities is increasing, but it is only Vestfold county authority that has expressed the opinion of geophysical surveys as equal to traditional archaeological registration methods. The various statements by county authorities in various hearings, strategic plans and annual communications in the letters of prioritization with the DCH indicate an interest and curiosity for geophysical methods, and a wish for more integration of such methods in their daily practice. This can be seen as a way of defining aims, and fit their interests to other actors, and build networks and collaborations with other actors and gaining experience with the methods. The statistics, on the other hand, reveal that this has only to a smaller degree actually happened. A few of county councils (Vest-Agder, Nord-Trøndelag and Oslo) have performed research investigations in collaborators with actors providing geophysical surveys, but a systematic and integrated use of geophysical methods is not seen, with one exception.

Vestfold's participation in a larger research project has given the archaeologists in Vestfold an additional advantage when it comes to experience and knowledge, but also regional acceptance and accessibility to a professional network, which can be included in the daily cultural heritage management practice. Seen from an ANT point of view, this situation can also be expressed in another way: Through the LBI ArchPro project, Vestfold has entered, and participated to build up, a separate network of actors where geophysical methods become an integrated part. Their involvement in practical, archaeological research has led to a change in practice also in Vestfold's daily cultural heritage management practice. Also, actors within politics and developers support contribute to the total narrative of this networks practice.

7.8.2.2 University museums, Directorate for Cultural Heritage, NIKU and other initiatives

Figure 35 presents statistics on other actors than the county authorities commissioning geophysical surveys:



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
LBI											4	9	8	1		
NIKU	2	9	7						2	1		6	2	2		4
Directorate for CH										1		1		1	4	2
NTNU						1	2	2	4	2	2	4	3	6	9	4
KHM	1			2	2	2	3		2	3				1		1
UiS										3						
UiT		3	2	1	3									0		
UiB			1													
Municipalities (excl. Oslo)									1		1			1		
Others		2	1	2	2	3	2	1			2	1	6	1	2	2

Figure 35: Statistics over all geophysical surveys commissioned by actors within the Norwegian Cultural Heritage Management (excluding the county authorities). This involves both research and management-surveys.

Looking at the statistics in figure 32 and figure 35, there appears several interesting observations:

1. The LBI-project performed a wide range of surveys in the years 2010-2013. Associated partners at NIKU and Vestfold continued gathering data in 2014 and 2015 (for Vestfold-figures, see figure 32), and in total in the 2010-2014-campaigns an area of 327 hectares of GPR and 460 hectares of magnetometer data was collected (see the section 2.2 on "Geophysical surveys in Norwegian archaeology"). This has led to several publications involving the Norwegian case studies (Bill et al. 2013; Bill and Rødsrud 2013; Gustavsen et al. 2013b; Draganits et al. 2015; Schneidhofer et al. 2016)
2. NIKU commissioned and performed a series of surveys over a wide time span. The numbers in figure 35 represents surveys commissioned by NIKU. The 2000-2002 surveys are related to the Gråfjell project, where NIKU commissioned surveys from external collaborators, while they from 2011 started to perform surveys on their own. At this time NIKU were partners with the LBI ArchPro, and performed several surveys for various institutions including the DCH. The numbers presented in figure 35 are the surveys they performed on their own initiative, while they also were involved with 11 surveys for between 2013 and 2015 for VFK – either performed in collaboration with ZAMG or by NIKU themselves. NIKU also were involved with eight projects for the DCH, where one were in collaboration with NTNU, two projects for Hedmark, and five projects for Oslo. Four projects in Oslo were for research purposes.
3. The DCH has commissioned several surveys geophysical surveys, where all except one were led by NIKU. This is the survey at Peter Egges Plass in Trondheim led by the NTNU University Museum, but where NIKU collaborated (Stamnes and Kristiansen 2014). It is especially the Ruin Conservation project that accounts for most of the DCHs initiated surveys, with five surveys in all until the end of 2015 (Directorate for Cultural Heritage 2015d). They have also provided financial support for research initiatives and method development.
4. The NTNU University Museum have commissioned a wide range of geophysical surveys. The museum started commissioning geophysical surveys in 2005, collaborated with the Irish company Earthsound Asssociates between 2007 and 2009, and from 2010 the museum were able to perform surveys on their own initiative. From 2010 and onwards most of the commissioned surveys have been research initiatives taken by themselves.
5. The Museum of cultural History in Oslo (KHM) have commissioned multiple geophysical surveys over several years. 1/3rd of these are related to the investigation of iron production sites.

6. The other archaeological museums have commissioned a small number of geophysical surveys. The museum in Tromsø in the years 2001-2004, Stavanger with three surveys in 2009, while the museum in Bergen have one survey in 2002.

The previous discussion, as well as the numbers in figure 33 and figure 35, indicate that the experience the various regional archaeological museums have with geophysical surveys varies. This influences how familiar the institutions are with using geophysical data to adjust or regulate their excavation budgets and site investigation strategies relating to the museums' legal obligation to perform archaeological excavations. I believe this can have an influence on whether or not the regional archaeological museums encourage the various county authorities to supply them with additional information from geophysical sources. The experience the University museums have in including geophysical data in the evaluation and presentations of statements and recommendations to the decision made by county authorities in relation to §8 c.f. §10 cases (archaeological excavation after an exemption to the NCHA has been granted) is therefore limited. At Avaldsnes, the excavators from KHM quickly realized a correlation between GPR anomalies and cooking pits excavated there (figure 16 in this thesis, taken from article three). This information helped them prioritize which areas to excavate, and helped with the process of prioritization as the excavation progressed. Section 7.9.1 presents a case study of the impact of additional geophysical information on budgeting excavations.

In the circular responses from the regional archaeological museums concerning the DCH's strategic plan (Directorate for Cultural Heritage 2011), the museums in Stavanger, Bergen and Tromsø all emphasized that the high-technological methods should not be a replacement for traditional registration methods. Such high-technological method should be considered as supplements to other and more traditional methods. At the same times, the archaeological museums in Oslo, Bergen and Trondheim all warn against a strong regulation of practice, as a limitation of the available methods for registration, excavation and documentation could lead to the loss of information and knowledge. An interesting observation is that there are sometimes different opinions within various departments at the same university museum. In Bergen, for instance, the Section for Cultural Heritage Management stated that non-intrusive high-technological methods are an important supplement for knowledge basis for decision making processes and improving efficiency for documentation by registration and excavations – i.e. a positive response in relation to the inclusion of geophysical methods. The Section for Cultural Heritage Management, on the other hand, stated that such methods *never* would replace traditional registration- and excavation methods (University Museum of Bergen 2010a), which represents a more negative attitude. When comparing this statement with the statistics on figure 35, it is clear that the museum themselves had only commissioned one geophysical survey on their own initiative and no geophysical surveys was commissioned by the counties falling under their management district, Hordaland, Sogn- og Fjordane and Møre-og Romsdal, at the time this response was authored in 2010. Seen from an ANT perspective, the strength and impact and influence of a statement is related to the actors that can be mobilized to support it. Examined more in detail, then the legitimacy and strength of an inscription made by a spokesperson speaking on behalf of an actor, is related to the viewpoints, influences, experiences, knowledge and insight the spokesperson can mobilize to gain support for an observation within the network. When the University Museum in Bergen make definite claims that that such methods *never* would replace traditional registration- and excavation methods (University Museum of Bergen 2010a), without empirical experience in integrating the results of geophysical methods into their daily management practice (i.e. no geophysical surveys performed within their district before this statement was inscribed), this creates a situation where the strength of this statement can be reevaluated.

The Museum of Cultural History in Oslo have performed a range of surveys over a rather long stretch of time – where about 1/3 (6 out of 18) focused on iron production sites. Five of these were undertaken in the years 2004-2006, and one was undertaken in 2015. Experiences from the five first projects led to a very positive experience in how magnetic survey methods could help in locating and characterizing iron production sites, as well as associated high-temperature activity in outfield areas (Rundberget 2007; Larsen 2009), and these experiences led to a formulation in the scientific evaluation programme for the investigation of iron production sites saying that using metal detectors or magnetometers should be mandatory when doing field campaigns to locate slag pits or slag tips (Larsen 2009:206). Although very clearly stated here, this comment does not seem to have had much impact on the use of magnetometers in outfield field campaigns since this scientific evaluation programme was released. The only other iron production site surveyed since then, apart from the 2015 survey in Løten searching for traces of iron production in agricultural land (Stamnes 2015a), was the 2010 survey at Mokk in Nord-Trøndelag municipality, commissioned by Nord-Trøndelag municipality (Stamnes 2010b) and the sites first published in article four in this thesis (including examples from the Mokk-site). The fact that the impact this scientific evaluation programme has been small on the choices of archaeological registration and documentation methods chosen is interesting. The scientific evaluation programme concerning iron production sites is one of the most referenced academic sources in the three major Norwegian archaeological journals (Gundersen 2015). The results from article four (see section 7.6.1 and 7.6.3 as well as figure 9) supports the statement regarding the applicability of magnetic geophysical methods to locate, delimit and characterize iron production sites. Meanwhile, the amount of surveys involving such methods within cultural heritage management and archaeological research did not increase (with the exception of the Mokk-site and the Løten-survey mentioned above). The impact of this statement have been minor on the actual practice within the network of cultural heritage management. At the same time, the experiences and publications following the earlier surveys leading up to the statements made in this strategic evaluation programme (Risbøl and Smekalova 2001; Smekalova and Voss 2001; Smekalova and Voss 2002; Abrahamsen et al. 2003; Rundberget 2007; Larsen 2009), inspired the study design, survey design and analytical approach in article four, and in this way acted as a contributor to the network of archaeological research. The results of article four were, as stated earlier, very positive and conclusive, and it remains to see how the results presented in this article might influence the cultural heritage management practices in the future. Examples of the possibilities and potential to do so will was discussed in section 7.6: Locating archaeological sites, monuments and features with geophysical methods.

The development at NTNU, with an early start of commissioned surveys from 2005 and onwards, correspond well with their increased attention and focus on geophysical methods in strategic plans, action plans and research strategies. Being the only regional archaeological museum having access to equipment and personnel, this puts the NTNU University museum in a special position in relation to the other archaeological museums. Oslo, Bergen, Stavanger and Oslo Tromsø have all expressed an interest in increased collaboration with other institutions in relation to research and development related to method development or access to expertise and equipment, but NTNU University museum has to this date only collaborated with the Museum of Cultural History in Oslo on five projects, including the Veøy-site in Møre- og Romsdal county (article two).

7.8.2.3 Statements versus practice for the Directorate for Cultural Heritage

By observing various statements and observed practice from the DCH, it is obvious that the DCH are placed in a situation with different roles, responsibilities, and expectations. These different roles, responsibilities and expectations lead to different, and sometimes conflicting, attitudes towards geophysical methods released in communications and statements from the same actor in the cultural heritage management network. The DCH have several roles: administering and executing the current politics of the government and advice other actors on issues relating to cultural heritage management practice (see table 3). In addition, the DCH has supported research initiatives focusing on geophysical and other technical methods of archaeological documentation and registration. The DCH should also ensure a professional, predictable and fair treatment of developers following the NCHA while at the same time have the responsibility of safeguarding cultural-historical sites, monuments and features and enable the protection of a representative selection of sites and monuments (also following legislations such as the NCHA and The Planning and Building Act (2008) as well as ratified conventions and other judicial sources – see section 4.2). In this lies equal and fair treatment, as well as limitations to expenses that the developer can be charged. The fact that the costs for archaeological registrations following §9 and §10 in the NCHA is not voluntary service which can be appealed, but have to be paid by the developers if they choose to continue with the development makes the obligation of equal, fair treatment and limitations of expenses even more important. This is stated in the preparatory act "Om lov om kulturminner" released by the Ministry of Climate and Environment (1977-1978).

In the statements stated by the DCH in section 7.4, the use of geophysical methods have been attributed different levels of usability by the DCH. Geophysical methods have been included in standard documentation practice initiated by the DCH for investigating and documenting the preservation status of medieval ruins (Directorate for Cultural Heritage 2015d). This is not related to any developers, but is a documentation initiative for the safeguarding of these monuments. The use and applicability of GPR in the ruin project have not been questioned by the DCH, but rather described as an accepted documentation method. The practice is very much in line with the DCHs' own strategic plan (Directorate for Cultural Heritage 2011) – so is economic support to research initiatives involving geophysical methods such as the LBI ArchPro project (NIKU 2011b) and the geophysical research project initiated by Vestfold in 2007 (Fossum 2010) (see section 5.2 and especially 5.2.2). The DCH has signaled that they are positive to the use of non-intrusive methods and wants to stimulate to further development and use of non-intrusive methods in relation to registrations and excavation (Directorate for Cultural Heritage 2011, delmål 1). The DCH has supported several initiatives financially, including commissioning their own surveys and supporting budgets including geophysical documentation methods for emergency excavations of sites and monuments under threat (so called "Post 70" funds for rescue excavations) (NIKU 2011b; Directorate for Cultural Heritage 2012d, 2015d; Stamnes 2015b). This lines up well with intentions of preserving cultural heritage, decreased decimation of cultural heritage sites, in-situ conservation and similar thoughts as outlined in various guidance documents and official documents (Directorate for Cultural Heritage 2010d, 2011; Proposition to the Storting 2012-2013a). At the same time, the MoCE and DCH chose not to include geophysical methods in their suggestions of primary methods for archaeological registrations (Ministry of Climate and Environment 2015). Reading previous communications between the MoCE and DCH indicate that they argue against an increased usage of geophysical methods in archaeological registrations due to concerns related to applicability and certainty in the results provided from such surveys, and economic concerns (Directorate for Cultural Heritage 2014f). The DCH open up for use of geophysical methods in the guidelines for the budgeting directives, but only any increased costs are approved by the developer and the inclusion of such methods are justified based on a professional judgement (Directorate for Cultural Heritage 2015e). Several actors, including Østfold, Vestfold, Hordaland and Norsk Maritimt Museum commented in their circular response that it is the professional judgement in the county authorities which should define which methods is to be considered the most appropriate on a case- by case basis (Hordaland county authority 2012; Vestfold county authority 2012; Østfold county authority 2012; Hordaland county authority 2014; Norsk Maritimt Museum 2014). Also, in the circular response to the DCH's strategic plan (Directorate for Cultural Heritage 2011), the Cultural Historic Museum in Oslo, the NTNU University museum and Bergen museum all warn against a strong regulation of field practices which might be negative for the professional choices made in the institutions, and state that choice of method should always be dependent on the aims and objectives, an assessment of how worthy a site or monument is of protection and its potential for increased knowledge. All of these are points which will be different from case to case.

The geophysical methods are also not given much attention in the scientific evaluation programme for the medieval archaeology of cities, towns, sacral places and fortifications in 2015 (Riksantikvaren 2015). Given that NIKU contributed to this publication, and that the directorate themselves clearly has stated that the DCH wish to stimulate further development and use of non-intrusive methods in relation to registration and excavation (Directorate for Cultural Heritage 2011, delmål 1). Although urban areas can be challenging to survey, depending on degree of modern disturbance and complexity as discussed in article three, the lack of attention of geophysical (and other) documentation methods in the DCH's own scientific evaluation programme released so recently as 2015 is worthy of particular note. Also, several articles had been published with results from geophysical surveys on medieval sites and monuments Norway prior to the publishing of this scientific evaluation programme based on results from geophysical surveys on medieval sites (Foosnæs 2009; Solli and Stamnes 2013, article 2 in this thesis; Gustavsen 2014; Meyer et al. 2014). These academic sources were not mobilized and enrolled in this programme – a programme initially intended to be an overview of knowledge status and identify gaps in the present knowledge.

The DCH can be seen as an important actor that have the power to influence, and impose guidelines, directives and CHM policies on other actors within the Norwegian CHM-network to ensure an equal management and practice. Seen in this way, the DCH becomes an *obligatory passing point* for the acceptance of any tools and technologies (as actors) as part of the daily cultural heritage management practice. Their role is, among other things, to keep themselves updated on the possibilities and limitations any archaeological field methodology (as actors) might represent for the cultural heritage management, and weigh the possibilities against any drawbacks that this might represent. This also makes the DCH important *spokesperson* on behalf of the tools and technologies, as they have the power to enroll and building institutions and practices in which these tools and technologies can be a part of. Any advice and statements given by the DCH becomes *inscriptions*, that carry meaning and intentions and can hide controversies that lie within such statements. At the same time, "*the cultural resource"* that the DCH is set to manage can be seen as several things: object of knowledge and experience, research material, a limited or non-renewable resource, and means of value creation (Brattli 2006, 2013:28; Tuddenham 2015:52). DCH as an actor is therefore set within, and between, different discourses of heritage management. One of these discourses is making sure to follow the legislation and manage the cultural resource accordingly.

At the same time, *the cultural resource* becomes a value for knowledge and experience, which is much defined by politics and opinions, and the national goals for annual loss of cultural heritage set by the government (Proposition to the Storting 2012-2013b). This becomes a different discourse than the legislative and management discourse mentioned above. The operation within different discourses, or networks of interests and practices, creates a situation where the DCH becomes placed in a position with different roles and expectations. By observing different practices within the same actor (the DCH), it becomes clear that the DCH is composed of several actors and interests, and several roles and responsibilities. As the various actors within the DCH have several understanding and practices of their own role as seen through an ANT perspective. The inherent understanding of the DCH's role is experienced differently from other actors that see everything released and stated by the DCH as coming from one and the same actor. The practices performed by the DCH are maybe better viewed as a conglomerate of various networks of practice, which in turn is defined by the goal and role for the various departments, understandings and intentions that exist within the DCH. This, in turn, leads to a situation where the DCH practice not always choose to implement action following their own strategies, as with the wish for an increased use of non-intrusive methods (Directorate for Cultural Heritage 2011). This is often due to other concerns that is considered important. Such an encouragement of increase use of non-intrusive would be in line with the national goal of a decrease in the loss of cultural heritage sites and monuments (Proposition to the Storting 2012-2013b) and recommendations from the ICOMOS and Valletta-convention (ICOMOS 1990; Council of Europe 1992b, 1992a). Similar critique has been raised to the DCH by Vestfold County Authority (Directorate for Cultural Heritage 2015b). The DCH see geophysical methods as not applicable in archaeological registrations due to cost reasons and their understanding of the geophysical methods as not being able to provide enough archaeological information to fulfill any legal requirements. The possibilities of gaining additional knowledge, spatial information and being able to characterize archaeological sites, monuments and features in a non-destructive manner at an early stage of the planning process has not led to the DCH proposing a better implementation and encouragement of an increased use of geophysical methods in this stage of the planning process (Directorate for Cultural Heritage 2015e; Ministry of Climate and Environment 2015). In section 7.5 and 7.6 was this opinion discussed and exemplified by empirical examples from geophysical surveys from article two, three and four in this thesis.

7.8.3 Replace versus supplement

This section refers to objectives on to four and eight (see section 1.1. – "Aim and Objectives").

Akershus (Akershus county authority 2014), Oslo Municipality (Oslo Municipality 2015), The DCH (Directorate for Cultural Heritage 2010d, 2014f) and Bergen Museum (University Museum of Bergen 2010a) have mentioned if or how geophysical methods can replace traditional archaeological registration methods. In addition, the regional archaeological museum in Stavanger (Museum of Archaeology 2010), Tromsø (Tromsø University Museum 2010), Bergen (University Museum of Bergen 2010a) and Oslo (Museum of Cultural History 2010) all responded similarly to the hearing to the DCH's Strategic plan for 2011-2020 (Directorate for Cultural Heritage 2011)- emphasizing that tools for prognosis and non-intrusive prospection methods should be seen as a supplement, and not a replacement for, traditional registration methods. It is interesting to note how the these regional archaeological museums raised this issue, without the document initially stating that such methods were intended, or understood, as a replacement for traditional methods. NIKU has, as an important actor and initiator of geophysical surveys and research work, on several occasions stated that they see geophysical methods as a supplement to other information sources that can be used as a tool for prioritization and effective planning, in a fast and non-intrusive manner (NIKU 2011b; Gustavsen et al. 2013a; NIKU 2015b).

Article one indicated that high and over-optimistic expectations of the potential of the applicability of geophysical methods was one out of several reasons for there is an observed delay in the acceptance and utilization of geophysical methods in Norway compared to other countries in Europe. I interpret the emphasis on geophysical methods as a replacement to other methods as an expression of a similar notion. Such a notion can be viewed upon as an *interessement*, where an actor tries to fit the potential usage of non-intrusive methods into their interest – i.e. a tool that can replace intrusive methods. The presentations and examples of possibilities and limitations observed in the surveys performed as part of article two, three and four (see section 7.6), contribute to a more adjusted expectation and knowledge of which methods that might be beneficial, and when (or in what circumstances) the geophysical methods might be so. As every geophysical methods has their possibilities and limitations, it is important to be aware of how these limitations might be limiting to the possibilities for initiating and paying for surveys if the methods cannot not contribute to the objectives for the investigation in the first place.

The application of geophysical methods, and its following applicability, is dependent on the reasons for choosing them as a supplementary information source. For instance: the question "is there any archaeology here" is different than "can we find the outline of the former burial ground we know have been somewhere in this area" or "can we delimit the settlement area we believe should extend into the next field". The preface to the newly released European Archaeological Councils' (EAC) guidelines for the use of geophysics in archaeology state that it is important to be aware that each project differs in their requirements and there is no "single" best survey technique or methodology. The EAC guidelines follow this by stating that *"using methods and techniques inappropriately will lead to disappointment and may, ultimately, result in archaeologists not using them at all"* (Schmidt et al. 2016; preface). The guidelines also differentiate between different levels of survey purposes, where a level one survey is conducted for prospection, with intentions of identifying areas of archaeological potential and individual strong anomalies. Level two surveys are conducted for delineation, i.e. to delimit and map archaeological sites and features, and level three surveys are conducted for characterization for analyzing in detail the shape and geophysical characteristics of individual anomalies (Schmidt et al. 2016:10-11). It is therefore important to consider why and how geophysical surveys can contribute to the case at hand and the questions that need answers. In this light, the question "can geophysical methods replace traditional registration methods" is very dependent on the circumstances. Depending on the justification and purpose of the survey, and the quality of the survey outcomes, it might not be that a survey need to identify all archaeological features to provide a useful contribution to the management issue at hand. Choosing survey method and methodology should therefore be tailored to the questions asked. The fact that article two and three presented some new archaeological information from each and every method, adds support to this argument. Stating that the increased use of geophysical methods as part of a §9 c.f. §10 archaeological registration scheme is not recommended, as the DCH did in their letter to the MoCE (Directorate for Cultural Heritage 2014f), is therefore a very general statement that does not take such matters into proper consideration. An evaluation of the potential, possibilities and drawbacks of each possible archaeological method, should be weighted against other management concern such as prognosis for finds (i.e. high-potential for finds), previously known archaeology, cultural historical value, the possibilities of damaging important archaeology, costs etc. is important (see section 4.2.3 on professional judgement). The DCH focus on replacement rather than supplementing more traditional registration methods, costs for additional use, and an attitude that do not reflect on the potential and applicability of geophysical methods as part archaeological registrations following the NCHA §9. When the DCH state that it will always be necessary to perform control registrations, or that only certain features can be mapped (Directorate for Cultural Heritage 2014f), then such statements does not take any consideration to the specific aim or focus for a particular investigation, or open up for any tailored application of non-intrusive methods to answer specific research or heritage focused questions. This is relevant even though the question asked might often generic: are there any conflicts with automatically protected sites, monuments and features within the proposed development area.

7.8.4 Archaeological registrations versus archaeological heritage management

This section refers to objectives one to four and eight (see section 1.1. – "Aim and Objectives").

Another important aspect, which is related to the purpose of performing geophysical surveys, is how the use of geophysical results can seen in a broader relationship with the cultural heritage management. The methods need to "prove their worth" in being used to identify archaeological features to properly be integrated within archaeological heritage management. At the same time, it is important to be aware that geophysical methods cannot guarantee a complete overview, with total identification of all types of monuments in all types of survey conditions. This is a tall order. Therefore, it is important to tailor each investigation towards specific aims and objectives, and provide a justification for the choices made concerning which methods to use, at what resolution, and how various geophysical methods can be combined in the best manner to create the most appropriate outcome suited to the need at hand. The presentation of possibilities and limitation in section 7.6 function as reference material for choosing the most appropriate combination of methods on a case to case basis.

Of course, by including more methods, you will also increase the time necessary to spend in the field and the amount of data which needs time to be properly processed, analyzed and presented, which in turn increases the costs. The total costs of a project needs to be balanced against the extent of the planned activity, but an archaeological registration should also be thorough enough so that the regional archaeological museums can plan an excavation based on the initial registration. The initial registration must be thorough enough for it to be possible to assess the cultural historical extent and importance of any activity on site. The Norwegian Public Administration Act also state that any case must be clarified as thoroughly as possible before any administrative decision is made (Ministry of Justice and Public Security 1967, §17). The DCH has indicated that the average costs for an archaeological registration performed by the counties is about 50-60 000 NOK (this probably refer to 2013 figures) (Directorate for Cultural Heritage 2014f), which is taken as an indication of a relatively small average size in terms of size and costs of each archaeological registration. These figures does not distinguish from larger and expensive test-trenching schemes and shorter visual inspections of a site that is to be developed. The argument that follows is that an additional expense for non-intrusive methods will be a costly addition as long as most cases are relatively small and the methods cannot replace traditional methods. The letter from the DCH to the MoCE indicate that it is only in very large cases from either private or public initiatives, or coming from the Cultural Heritage Management's own initiative, that the DCH consider it feasible to include geophysical methods (Directorate for Cultural Heritage 2014f). It can be argued that positive effects of including geophysical, or any other non-intrusive method, might first be beneficial if the size of the investigation area is large enough, and it is then the possibilities for an overall gain becomes present by having an additional knowledge source for prioritization and efficiency on a larger scale and for a larger area.

The argument presented by the DCH is that the average size and cost for each registration project is so small that it is considered neither cost effective nor time saving to include additional registration methods, unless the projects are of a sufficient size to justify these expenses (Directorate for Cultural Heritage 2014f). While this can be correct when referring to costs of a project seen in relation to the archaeological registration stage, it might tentatively be another issue when the whole planning process is seen in a more holistic way – from planning, to archaeological registration all the way to budgeting for and the performance of archaeological excavation. I still miss a discussion focusing more on the overall quality of the management of archaeological sites and monuments. A discussion of the overall gain of introducing and using geophysical information in the handling of archaeological sites and monuments as treated throughout the whole planning process- from planning a development, performing archaeological registrations and throughout the whole bureaucratic process of planning, budgeting and performing archaeological excavations, has not been commented in any of the documents released by the DCH. Any archaeological registrations observed early in the planning process influence the future planning and management process, which adjoins well with an understanding of geophysical methods as a method for planning, prognosis, gaining increased knowledge and overview, and sustainable management of cultural heritage resources (see table 6, table 7 and table 8). Seen in this way, I suggest that geophysical methods can fill a function, even though the methods might not be able indicate each and every archaeological feature on a site and in a field and that a geophysical survey might add costs at the earlier stages of a development project. The possibilities for gaining geophysical data sets covering the whole area subjected for planning permissions, instead of up to 10% - which is recommended for archaeological registrations involving test trenching for sites with low feature density (Hey and Lacey 2001; Verhagen and Borsboom 2009:1814), is one of the main arguments for increased usage of geophysical methods. For this to be feasible, it is important that there is an understanding of limitations, possibilities and geophysical principles among the government officials who are to use such methods in their daily management practice. When, for instance, the University Museums are to budget for an excavation, they are not faced with a complete overview of a site and its monuments, but have to estimate the amount of archaeological features, size and extent based on the information received from the county archaeologists. It takes time to write a statement, project plan and set up budgets. In addition, the consensus of a budget is often reached after discussions with the DCH, which have to approve of any budgets relating to exemptions of the Norwegian Cultural Heritage Act §8 c.f. §10, leading to an archaeological excavation. If there are uncertainties or disagreements in this phase of the development, this leads to an increased time use and additional delay on a bureaucratic level. One of the main benefits of geophysical methods are their potential of gaining an overview and give a prognosis of larger areas (see article one and section 7.3), and is one of the ways where geophysical information can be beneficial at several stages throughout the management process. Precision and accuracy of budgets and excavations, as well reduced time spending throughout the bureaucratic process are therefore benefits that should be considered. See section 7.9.1 for a case study of including geophysical survey results in the budgeting of excavations.

The earlier a change in the project is introduced, the cheaper it will be to implement. Any interests and heritage management concerns should ideally be identified within the feasibility-study phase, as any development project become more expensive to change in the design phase, and especially if any changes are introduced during construction (see figure 36) (Institution of Civil Engineers 2009:19-25; Karlberg and Jerkø 2009:74,89 and 126). In relation to such an approach it becomes interesting to note how the collaborative report on development planning for archaeologists and archaeology for planning developers, mention geophysical methods for developers and geophysical methods used for archaeology separately (Karlberg and Jerkø 2009). The report, however, does not merge and connect the possibilities and interests of both actors (developers and archaeologists respectively) of the collaborative benefits of geophysical methods. Geophysical methods can provide a prognosis and an overview over a larger part of the area subjected to archaeological registrations than ordinary registration methods, but also geological information and data on infrastructure and modern constructions. Thereby, geophysical methods as a supplement to other registration method, contribute to a better management of the area, decreasing any delays for developers and discussions administering exemptions to the NCHA and budgeting details following the NCHA §8 c.f. §10. In this way, introducing geophysical methods also has a potential to decreased the chance of any unexpected hindrances during the construction phase of the project (see figure 36).

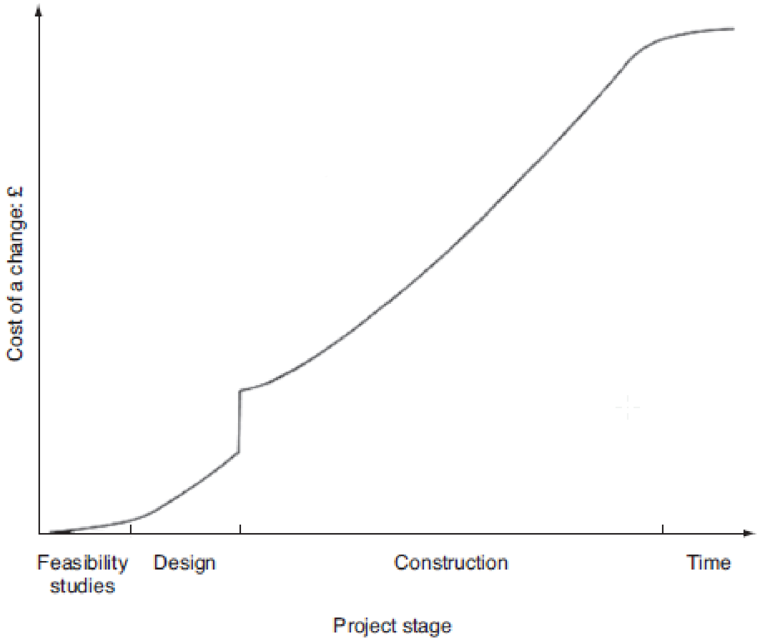


Figure 36: The costs of change against project stage. From (Institution of Civil Engineers 2009:22). Used with permission.

Ringstad (2013) presented statistics from the county Møre og Romsdal on the amount of archaeological registrations, noting that from typically receiving 1200 number of development plans Møre og Romsdal county authority typically demands registrations of 150 of these cases. In 110 out of these 150 cases, the county actually perform archaeological registrations, finding new and unknown archaeological sites and features at 70 of these again. In the end only eight ends up being excavated following the NCHA §8 c.f. §10. This also indicates that there, from a management point of view, is a wide range of development plans where the management decides that they will not do any additional archaeological field investigation. The overall amount of sites that end up being excavated is relatively small. In each step follows new decisions depending on the available information. My point is that the archaeological desk based evaluation, followed by archaeological field investigations is only the first early phases in which the information gained from geophysical investigations might be beneficial. In this lies the potential of an increased knowledge gain from the sites if the initial archaeological registration involved information from a larger area covered with geophysical methods.

Another aspect is the protection of monuments, and balancing heritage protection against costs. The question is rather: would the management consider accepting additional costs at an early stage, and by accepting this have the opportunity to gain additional knowledge and in certain cases be able to identify archaeological sites, monuments and features in a non-intrusive manner? As I've discussed early, much of the focus has been on the NCHA §9 c.f. §10 phase, i.e. the archaeological registrations, and focusing solely on this phase, it would seem that the DCH does not accept applying geophysical methods if they represent additional costs (Directorate for Cultural Heritage 2014f, 2015e). A point of view which seemed to, in a lesser degree, take into consideration how the geophysical methods influence management processes and assessment in all phases of a development management plan.

If loss of control, the involvement of external actors, and the potential improved efficiency also represents a change in the organization and work-load, which in turn alters how the county archaeologists can organize their daily duties. This could represent an additional reason why counties might choose not to involve external actors but rather handle all archaeological fieldwork themselves. The lack of knowledge of geophysical methods and the results they generate should also be considered, as they could lead to a situation where the official in charge might feel a loss of control if he or she is not able to properly understand and integrate the results into a further management process. As stated in section 4.2 it is this official who has to decide if the geophysical anomaly identified is to be considered as an archaeological heritage object of cultural historical value. The geophysical anomalies is on their way to becoming new actors, new phenomena that need to be taken into account and be understood. Also, the idea of turning parts of the archaeological fieldwork to an external actor, either a private company, museum or research institution, could also, indicatively, feel daunting for someone who is used to manage everything themselves. The discussion of protection of monuments, and balancing heritage protection against costs were the focus in section 4.2.3.

Seen from an ANT perspective, there are multiple discourses and networks, also within the same actors, where an actor such as the DCH, a county council or an archaeological museum have several roles, interests and responsibilities. The question is how these roles and responsibilities influence the end result of the overall cultural heritage management narrative. In the controversy of archaeological registrations versus archaeological heritage management, this issue revolves on the various actors understanding of their role and responsibility – both within their own institution but also the roles within a larger network. An actor within the cultural heritage network becomes network by itself, which is viewed as one entity from the outside of the network, but in practice constitutes of a range of actors, roles and responsibilities. Their inner workings are hidden, and becomes a black box for actors looking upon them from the outside of the network. In addition to this is the actors understanding of how their actions influence the possibilities and practices of other actors involved within the same cultural heritage network. The actors' understanding of the influences of their actions also influence the professional choices made, for instance which investigation methods that they consider appropriate. Sometimes the focus is merely on the challenge at hand, but it is forgotten that the information gained at an early stage also might be beneficial for other processes and actors later. In this case, the MoCE and the DCH could have, for instance, included geophysical method in the list of typical registration methods in their budgeting directives for §9 c.f. §10, and used this as an way of enrolling and interessment to make other actors more aware of the geophysical methods. The methods were indeed mentioned in the earlier drafts of the directives (Directorate for Cultural Heritage 2012c, 2014e), but this part was removed in the final version of the budgeting directives (Ministry of Climate and Environment 2015). Being a directorate that have a role as being professional advisors to the other actors, providing and conveying updated knowledge, this action if worthy of notice. With this action, the potential interessment and enrolement and the possibility of aligning an interest of increased usage of non-intrusive methods upon other actors were intentionally omitted- , although most of the section removed was later included in the budgeting guidelines released to accompany the directives (Directorate for Cultural Heritage 2015e), but not in the directives themselves.

7.9 GEOPHYSICAL METHODS AS MANAGEMENT AID

In the previous chapter (section 7.8), I discussed the controversy of viewing archaeological registrations as a separate phase of heritage management, versus viewing the use of geophysical, non-intrusive methods as a management aid throughout the planning process in an integrated manner. It is important that the geophysical methods can provide usable results, and be able to provide information that can be helpful in limiting conflicts, formulating improved and accurate budgets, reduce bureaucracy, as well as and aid to prioritization and formulating project plans when planning excavations. The following section should be seen in direct relation to objective seven (see section 1.1).

The potential in which geophysical methods can provide such information, is directly linked to the methods' possibilities and limitations for locating archaeological sites, monuments and features. This is closely related to the aims and objectives for choosing to carry out a geophysical survey, and the following choices concerning type of geophysical method to use, at what resolution and other site specific conditions.

I will in the following section present examples where geophysical results have contributed to the cultural heritage management of archaeological sites, monuments and features. On the most basic level is the location and delimitation of such sites, monuments and features. The examples in section 7.6 demonstrate possibilities and limitations of the geophysical methods as observed in articles two, three and four. These results have also provided additional knowledge and input to the cultural heritage management. Although several of the investigations in the articles were collected in a research setting, I will still use the collected information to demonstrate how the information gained contribute within a cultural heritage network.

At Veøy, the knowledge of the size and layout is important for the regional understanding of the archaeological settlements and activities (see figure 4, 8, 17-18 and article two). The presence of very early clerical buildings and a larger metal working area within the marketplace is important to understand the spatial organization of the landscape as a whole, and the management of Veøy in particular. It will be beneficial for the management of the landscape, and the archaeological prognosis and importance given for other areas and archaeological sites and monuments nearby.

At Frosta it also became evident that the area of settlements in the national monument registry did not cover the whole zone of topsoil magnetic susceptibility enhancement (see figure 5). The size and layout of the settlement zones south of the farm Logtun and just north of Logstein are larger than the registered site, and this is a cause for reevaluating the monument registry information. At this case, the sites are not part of a current archaeological development plan.

At Avaldsnes, the excavation team soon realized the correlation between visible anomalies and cooking pits observed in Area 2 (see figure 16 and article three). The excavators found the GPR data more understandable, as they experienced a systematic connection between the features they excavated and anomalies observed in the GPR data. The general experience for Area 2 at Avaldsnes in particular, is that the excavators could save time and workload by being able to predict the location and depth of archaeological features with good accuracy. In other areas certain features, such as the subterranean passageway, stones relating to buildings and several cable ditches, showed up clearly in the GPR-data, but it was difficult to clearly interpret them as prehistoric or modern without additional information. Such information could be maps of known infrastructure, earlier excavation results or known geophysical examples from other sites. Other methods gave more complicated plots of geophysical data, which often were difficult to understand and use for an operator untrained in geophysical prospection. Two clear obstructions to this is obvious: first of all, as pointed out above, is the lack of understanding of what the geophysical information is actually indicating, often caused by unfamiliarity with the potential and limitation of the geophysical methods which in turn restricts the usability of the data. The second point is that the geophysical service provider should be able to provide the commissioner with indicative archaeological interpretations of the geophysical data sets. A data plot on its own is less valuable without the additional support of geophysical and archaeological interpretations done by an expert with understanding of both the potential and limitations of the geophysical methods, background knowledge of geological conditions, as well as an understanding and knowledge of the physical nature of potential archaeological features.

Based on the experiences from Avaldsnes as shown in article three, I therefore advocate and suggest keeping a continuous communication between the geophysical service provider and heritage management officials involved during planning, excavations and post-excavation work, as support and advice for best possible use and understanding of the geophysical datasets. If additional information, such as archaeological registrations or archive sources, can help in providing better archaeological interpretations of the geophysical datasets, I encourage sharing this information with the geophysical service provider so that the geophysical data can be reexamined and potentially provide additional information and increase the quality and usability of the geophysical data sets. This also facilitates increased knowledge transfer and experience for the geophysical contractor as well. Unless the receiver of the geophysical reports are able to understand and apply the geophysical information provided in a good manner, a geophysical survey might prove less valuable. At Avaldsnes there were some issues with georeferencing of data sets. Making depth slices and data plots available as digital files with high resolution is vital for the best possible transition of knowledge, and the receiver should also include this information in future planning.

Earlier geophysical investigations of iron production sites have shown how the methods contribute to location and delineation, and characterization of iron production sites (Risbøl and Smekalova 2001; Smekalova and Voss 2002; Rundberget 2007; Larsen 2009). The results from article four demonstrate how easily magnetic geophysical prospection methods can be integrated to locate and delineate sites, as well as provide a better understanding of the location and nature of archaeological features associated with the iron production activity. At all the four sites presented article four, new and valuable information on site layout, size, number of slag pits and the possible location of furnaces, roasting sites for iron ore and storage areas for roasted iron ore was gained. In all these cases, the data is ideal to estimate the size of the activity area, as well as pinpointing particular archaeological features. The site of Tromsdalen can serve as a good example. At this site, the county archaeologists delineated the site based on test pits and ground observations, and the outer edges of the site as defined by them is visible as a grey line marked as "Askeladden id# 147029" (figure 37). The site and monuments registry information (called Askeladden) reports a singular slag mounds with indications of the furnace nearby (Arnkværn 2013). I will use the Tromsdalen as an example of the additional gain of having access to geophysical information for locating, delimiting and characterizing iron production sites, and how this information contribute to a better knowledge basis for proper cultural heritage management, more accurate budgeting of excavations and the potential for saving time and money within bureaucratic processes in communications between the county, the museum and the DCH.

7.9.1 Case-study: managing and budgeting the archaeological registration and future excavation of the iron production site at Tromsdalen.

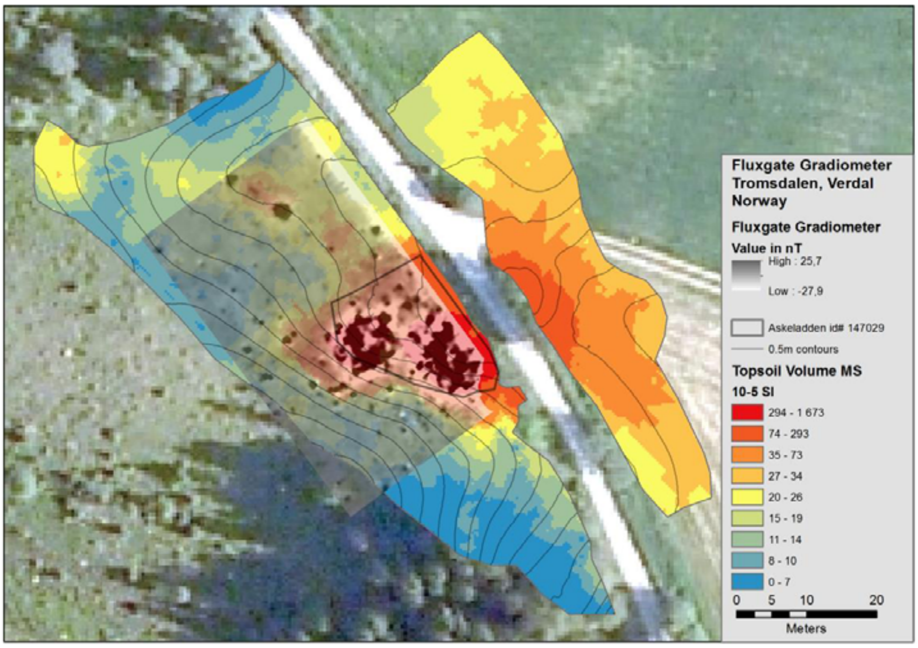


Figure 37: Geophysical data plot from the iron production site at Tromsdalen.

The NTNU University Museum drafted a project plan and a budget for excavating the Tromsdalen iron production site prior to the geophysical survey, based on a visit to the site and the county authorities' registration. The museum estimated that the size of the site was much bigger than estimated by the county authority, and their proposal for an excavation represents a larger area than what was registered by the county in order to gain knowledge of the whole complex – not only the furnaces and the slag pit (see figure 37). However, the museum did not question if the county had fulfilled the requirements for the archaeological registrations. The DCH did not commented on this either. The NTNU University Museum estimated that the site could contain as many as four furnaces with related slag heaps, and suggested to soil strip a larger area around the site, which the museum estimated to be 2-3000 m². The site extent in the national database for cultural heritage (Askeladden) is only approximately 280 m², and focuses on the slag mound only and does not take into account the assumed additional activity expected to be in the vicinity. In addition to this, the NTNU University Museum notes in their project plan that they consider the site much larger than what is registered, but the entry in the national database has not been changed by the county archaeologists. The NTNU University Museum therefore budgeted for four furnaces and four slag heaps, in addition to soil stripping 2000 m², and calculated 150 working hours per furnace, 75 working hours for pits surrounding each furnace, 150 working hours per slag heap and 4.4 working hours per square meter of soil stripping excavation. The total estimated costs (in 2013 budgeting rates) were 4 177 279 NOK, including 300 hours of geophysical surveys and 30 000 in expenses for hire of equipment (NTNU University Museum 2013).

The geophysical surveys indicated the presence of two slag mounds, and a main industrial activity area of approximately 1150 m², although settlement areas without much traces of industrial activity might be present in the vicinity, but overshadowed and consequently masked by the high magnetic susceptibility from the industrial activity (article four and figure 37). At the site of Storbekken 1 in Budalen, the area of possible house foundation had a detectable topsoil MS contrast to natural background (article four and figure 9). The results from Tromsdalen are very informative and useful. The geophysical investigations took two working days, and a usual post-survey report would equal maybe eight working days, which I estimate as representing a total of 75 working hours for the magnetic survey alone. The proposed project plan also suggested including Earth Resistivity Survey and GPR (NTNU University Museum 2013). The magnetic survey indicated the presence of three potential furnaces and two definitive slag mounds, the presence of several possible iron ore roasting sites and an activity area of at least 1150 m². By reevaluating the budget proposed by the NTNU University museum it becomes clear that the budget can be reduced with one furnace and two slag heaps including pits surrounding one furnace. This includes still including soil stripping up to 2000 m² and do not take into account some leeway for additional unexpected features. According to the figures above, this reduction equals to a total of 525 working hours. This, in turn, reduces the costs for post-excavation work, the amount of per diem allowance and expenses related to travel, the total number of natural scientific samples and similar aspects in the budget. A reevaluation of this budget for an excavation with one less furnace including surrounding pits and two less slag heaps would end up in the vicinity of 3 400 000 NOK, if reduced with 175 working hours for a site director and 350 hours for site assistants. This equals a grand approximately 770 000 NOK less than the original excavation budget. Retracting the expenses of a geophysical survey of 75 hours, which including all expenses would equal to around 50 000 NOK in 2013 budget figures, the total reduction of such a budget could be as much as 720 000 NOK. It becomes evident that the inclusion of magnetic geophysical surveys alone represent a beneficial addition for proper budgeting of the archaeological excavations alone. It is also evident that the collected geophysical information is beneficial for locating, delineating and characterizing the site in a non-intrusive manner. Time saving a range of aspects such as discussing budgets and project plans for excavations, the inclusion of magnetic methods in the archaeological registration work, and the positive influence on the cultural heritage management process of handling the initial planning permission, comes in addition to this. It is unsure if it would be possible to provide the same information by test pitting or other archaeological registration methods on an iron production site in outfield areas. Results from article four indicate that the sites extends as far back as 30 meter behind the furnaces, and there are buildings, pits and other features known to be in this vicinity at several sites (article four). Test pitting would potentially help to locate distribution of slags, and maybe any construction elements or pits with some luck. Test-trenching in outfield areas is difficult due to trees and obstructions. The fact that the activity areas are known to be in the vicinity, the knowledge based reasoning that building remains should be expected, and the geophysical methods do indicate both features and extent of the site, is a good reason for including magnetic geophysical methods rather than testpitting and test-trenching in the archaeological registration process of locating, delimiting and protecting iron production sites.

The fact that this survey was performed in relation to a research project, and not as part of the archaeological registrations following the NCHA §9, creates some legal subtlety. Currently the §10 concerns, relating to approval of the project plan and expenses the developer will be charged for, has not been handled yet. Legally, the NTNU University Museum has to respect the limits of the registered monuments as presented in the national monuments registry by the county authorities, which is only 280 m². The limits set by the county archaeologist did not factor in any expected activity area in the vicinity of the slag tips, but only focused on the existence of slags. A budget for only this area was not made. The developers can therefore only be charged for excavation costs related to the area entered in the national monuments registry. The topsoil magnetic susceptibility and gradiometer results presented in indicate both additional archaeological features, an extension of the main activity into the field to the north-east, as well as towards North-Northwest. The question is whether or not the county archaeologists can alter the limits of this area. The answer to this is that the limits can be altered when new information has been made available, but there should be predictability for the developer in the way the case has been treated. The legal protection of a site is granted through the NCHA, i.e. the legal protection is the site and the monuments and features therein, and not the regulation plan and the indicated areas of known layout therein. The initial archaeological registrations should be thorough enough for indicating the correct layout of a site in the regulation plan. If the regulation plan is already accepted and an exemption to §8 subsection 4 is granted, then a new regulation plan has to be proposed if any enlargement of the known outline of the archaeological sites is indicated. The university museum and the DCH then have to agree on a budget following the NCHA §10. This in turn controls the possible costs that it is possible to charge the developer for. This is unlikely to happen due to the size and extent of the whole development plan. Ideally, either the county archaeologists, the regional archaeological museum or the DCH should have pointed out early in the planning and bureaucratic process that the site limits in the national monuments registry were too small compared to the DCH's or the university museum's professional judgement and knowledge of spatial activity of similar sites. Although the museum pointed out that the type of iron production site was different than registered, they did not ask for additional registrations or the enlargement of the protected area in their letter to the DCH (NTNU University Museum 2013). Although new and updated information is available through the research presented in article four (see figure 9 and figure 37), this information cannot at this stage be used in this case without starting a new regulation process. It would have been better for the management of the cultural heritage and the following bureaucratic process if this survey had been performed in advance of the §8 section four treatment, potentially directly followed by the §9 registrations, or by including the potential of large scale magnetic susceptibility sampling as part of the §9 registrations.

7.10 TOWARDS AN IMPROVED INTEGRATION OF GEOPHYSICAL METHODS IN THE CULTURAL HERITAGE MANAGEMENT?

The cultural heritage management advocates predictability for the society, with ordered and structured management. This involves ensuring a clear, uniform and transparent practice concerning budgeting in relation to all aspects of archaeological fieldwork. The former presentation of examples of possibilities and limitations associated with the various geophysical methods used in article two, three and four indicates that geophysical methods can provide additional information and archaeological knowledge. Geophysical methods can also contribute to a more structured and effective management by localizing archaeological features, gaining new experiences in characterizing the geophysical responses, and providing archaeological interpretations, and delineating sites and monuments in the landscape in a non-intrusive manner. It is not necessarily possible to guarantee positive and easily interpretable data on all occasions, which is why I argue for a more tailored application of geophysical methods on a site-by-site basis. The experiences presented in section 7.6 can function as a reference for future priorities and decisions. The provided geophysical results presented in article two, three and four, as well as in section 7.6, provide empirical experience which act to improve the understanding and knowledge of the geophysical responses of archaeological features under varying conditions, as well as the potential effects of geology and modern influences. This improved understanding and knowledge provide answers to objective eight (see section 1.1). At several occasions, there is no doubt of the presence of significant archaeological features. On other sites, the quality and trustworthiness of the interpretations of the geophysical data helped provide additional support for an archaeological interpretation of the feature, monuments and sites. At every site presented in the articles additional and important information was gained from the geophysical methods applied. The presented results act as a mean for knowledge transfer from archaeological research to management, and function as inscriptions that can be used in future archaeological research and management practices. Appropriate methodological choices in relation to survey conditions and the expected archaeology is vital. The key here is a clear and well-considered justification and survey purpose for choosing geophysical methods as a tool for solving the archaeological question at hand.

The difficulty is in deciding when geophysical methods can be justified based on potential of providing or contributing with the necessary archaeological results. Such a decision should balanced against the size and nature of each case, the costs applying such methods represent for the developer and the potential of geophysical methods to answer the relevant questions at hand in relation to survey, archaeological- and geological conditions. Sometimes it can be recommendable to omit geophysical surveys depending on the circumstances as mentioned above. Examples of the application of geophysical methods in a manner that contributed to additional archaeological knowledge is therefore important. I have discussed several such examples in the former section of this chapter, showing how geophysical methods can contribute to additional archaeological knowledge. All such results from published reports, articles and presentations function as a reference base, which can be used to gain additional justification for any choices made.

At the same time, the main challenges in an improved integration of geophysical methods as a tool to the archaeological toolbox for both archaeological research and in relation to cultural heritage management discussed earlier, are as follows:

- Costs vs knowledge gain
- Knowledge of the potential and limitation of geophysical methods
- Defining proper aims and objectives for geophysical surveys
- Survey purpose and justification
- Methodological choices (choice of method(s), resolution, traverse direction etc.)

The possibilities to integrate geophysical surveys properly within cultural heritage management lies in good advice and knowledge of the potential and limitations of each survey method by the official who has to reach decision relating to the daily cultural heritage management and planning applications following legal regulations and advices of proper practice. This can happen at a county level, in the response from the regional archaeological museums or by the DCH, where officials at various levels have the opportunity to suggest inclusions of geophysical methods when the officials see it can serve a purpose within the limits of the challenge at hand. I have advocated that this is not an either-or question if the methods “work” or not. It is not that black or white. It is also not a question of necessarily replacing traditional methods (unless the challenge at hand can be answered in this way – for instance; is there any preserved ring ditches indicating the presence of earlier burial mounds in this field?), but rather as a supplement and management aid in all phases of the cultural heritage management process. It is more a matter of asking what an archaeological registration should represent and provide of information, why, who for, and what the best manner of choice of archaeological method might be. As discussed earlier, the archaeological registration should locate and delineate the cultural heritage site and monument for entry in the national monument registry and area regulations and provide information sufficient for proper budgeting and planning of potential excavations. The archaeological registration should also provide information on the importance of an archaeological site, monument or feature and its cultural historical, scientific and social value, its connection to the cultural landscape, and its knowledge potential and preservation conditions. All of these elements will have relevance for actors within the cultural heritage management network, and their actions at a later stage in their handling of planning applications and other decisions relating to cultural heritage management.

One of the main challenges, as presented earlier, is cost. Compared with traditional archaeological methods, the inclusion of additional survey methods as part of archaeological registrations represents an additional cost. The DCH has clearly stated that they, at this time, do not accept additional costs for archaeological registrations than what traditional registration methods represents (Directorate for Cultural Heritage 2014f, 2015e). By stating this, the DCH creates an obligatory passing point which the actors have to have as an aim – i.e. costs should not be higher than traditional methods. This question does not take into consideration the cultural historical value of the monument, the site, landscape or any other questions relating to the network of cultural heritage management other than expenses. Such a focus does, to a large degree, create a situation where "costs" – either real or intended- becomes a point in the network that hinder the inclusion of geophysical methods in the network of cultural heritage management. The developer *can* agree to cover any additional expenses associated with adding another field method, but first of all: this to be proposed by the government official as a potential way of providing useful archaeological information and be beneficial for the developer in the long run. Secondly: the developer has to agree to cover the additional costs. I have advocated that the information derived from geophysical methods have the potential to improve the management process throughout several of the bureaucratic stages. In addition to this are considerations related to the value of a non-destructive protection of sites and monuments – compared to costs of a destructive manner of archaeological detection and registration. The most costly part of a geophysical survey is not the expenses of the archaeological field work or rental of the geophysical equipment. As the data gathering speed, area coverage and resolution is increasing following constant innovation and improvement of the available equipment and field practices, it follows that the increasing amount of data gathered creates archaeological possibilities, additional challenges concerning proper data processing, interpretation and presentation. The main expense is therefore at the post-survey level, related to the time for necessary data processing, interpretation and presentation. I consider that one of the main challenges for the reduction of costs of a geophysical survey, is finding ways to improve the efficiency of the post-survey work, as well as finding an ideal balance between detail level of the survey purpose, report and time use. As mentioned earlier, there have been several publications on automatic and semi-automatic feature extraction and interpretation of geophysical data in the later years (Leckebusch et al. 2008; Conyers and Leckebusch 2010; Pregesbauer et al. 2013; Schmidt and Tsetskhladze 2013; Pregesbauer et al. 2014; Hinterleitner et al. 2015; Johnson et al. 2015). While it is possible to improve the efficiency by reducing the time required for the stages of processing, analysis and interpretation of the geophysical data, there are certain elements that should be included in the geophysical reports. Time must be allocated for providing a geophysical survey report with the necessary archaeological interpretations, metadata descriptions and processing details- all vital for a better understanding of the collected data and its treatment. It should also be stressed that there are certain information that has to be included in a report, and the English Heritage Guidelines (David et al. 2008:4-5) and the EAC Guidelines (Schmidt et al. 2016:17-18) have very good and clear advice on what this should be. I suggest using the EAC Guidelines as a template for report content also in Norway. At Avaldsnes the experience was that decent georeferenced data plots were not always provided by the geophysical survey providers. This created additional problems for proper use of this information at later stages. One of the advices presented in article three is that digital version of data plots and interpretation should be made readily available as part of the information provided to the commissioner. This information should be used actively in later stages, and the communication between the field staff and geophysical provider should be maintained throughout all later stages (article three).

All issues relating to survey purpose and justification, aims and objectives as well as survey purpose and justification is related to an increased knowledge of the potential and limitations of geophysical methods. Section 7.6 in this thesis on “Locating archaeological sites, monuments and features with geophysical methods”, The EAC “*Guidelines for the use of geophysics in archaeology”* (Schmidt et al. 2016), as well as Bonsall et al. (2014)s *“Preparing for the Future: A reappraisal of archaeo-geophysical surveying on Irish National Road Schemes 2001-2010”,* all provide good advice on potential, limitation and field methodologies that is easily transferrable to a Scandinavian situation, as long as choices made take into consideration the properties of typical Scandinavian archaeology. Survey resolution and field methodology should be tailored to the aims and objectives of the survey. The empirical results presented in articles two, three and four function as examples of various possibilities and limitations of a series of methods in various geological and archaeological conditions in Norway.

The previous discussions in section 7.8.2 (“Statements versus practice”) has shown that the level of experience with commissioning and utilizing geophysical methods within Norwegian heritage management and the Norwegian archaeological community varies. Several county authorities have never commissioned geophysical methods, and it is only since 2007 that the various county authorities really start to commission geophysical surveys. In addition, experience of including geophysical survey results in daily management issues and budgeting varies between the various regional archaeological museums. This is presented in figure 32 and figure 35. While several county authorities have commissioned several surveys the last few years, it is only Vestfold that consistently applies geophysical surveys as part of their heritage management strategies. Vestfold has also defined a series of 37 high-potential areas where they have stated that high-technological methods should always be used for archaeological registrations, which is acknowledged politically by the County Authority. By defining areas, or cultural environments, with high archaeological potential based on a professional judgement and available cultural historical sources, and setting a clear agenda for how any development in such areas should be approached, this also represents one way of presenting a clear and predictable management (Vestfold county authority 2014). It can also be seen as a mechanism of acceptance, as it has been proposed by the county authorities and approved by the county council, and is one way in which geophysical methods can be included as a management aid. If given proper consideration, defining typical conditions and circumstances in which geophysical methods can or should be included, this approach can serve as an example for other municipalities and counties where the potential knowledge gain from geophysical or other registration methods can be maximized. Again, the issue here is cost. Studies on the overall gain from collaborating with developers in early phases should be encouraged. This involved the mutual gain from having access to geophysical information, both in terms of developer specific use (ground conditions, soil information etc.) and archaeology. Cost-efficiency studies and studies the long term gain of having access to geophysical data for increased archaeological knowledge, better planning and management, and as mechanisms of archaeological prognosis should be supported.

To undertake such an approach, requires mechanisms of support and the mobilization of allies in the network, including political, professional and sometimes also financial support. In Vestfold, the county utilize the political support in the county council for the inclusion of non-intrusive method (Vestfold county authority 2014). A similar approach can be promoted elsewhere. The main issue is gaining the acceptance for the costs associated with performing geophysical surveys. The guidance documents for budgeting for archaeological registrations (Directorate for Cultural Heritage 2015e), does not consider geophysical methods as equal to more traditional methods. Other opportunities includes for instance collaboration with local municipalities, larger developers such as the Norwegian Public Roads Administration, or research- and development collaborations between geophysical service providers and the actors involved in archaeological research and cultural heritage management. Sadly, no specific fund or financial source, governmental or otherwise, is set up where actors involved can apply to get potential additional expenses covered related to including non-intrusive method, based on a sound project plan, and a well thought out justification and survey purpose. Such a proposal for funding might be more relevant in archaeological registrations or investigations where there is a good prognosis for the potential of important archaeology value, but the size or budget is too small for such a registration or investigation scheme to be professionally justifiable. Such a project could for instance be where the management is faced with a development proposal on an area of land with known existence of now removed burial mounds with a high potential of important archaeology, or where the management is faced with an increasing occurrence of object from metal detecting schemes, but where the archaeological context and the potential delineation of a site or monument is unknown.

8 CONCLUSIONS

The aim of this thesis was to examine the role, function and status that geophysical methods have within Norwegian archaeological research and cultural heritage management, and evaluate the impact the introduction of geophysical methods have had on archaeological practice in Norway. This would identify important research areas for a more integrated use of geophysical methods within Norwegian archaeological research and cultural heritage management, and perform methodical and empirical research on the identified research areas. In this way, a new view on the potential of geophysical methods within Norwegian archaeological research and cultural heritage management could emerge. A series of objectives was set up to accomplish this (see section 1.1 on "Aim and Objectives").

The first objective in this thesis was to review the ways geophysical methods have been used within Norwegian archaeological research and cultural heritage management. A review was performed and published in article one. In chapter 7 the statistics presented in article one was updated with figures until the end of 2015, and resulted in the following results. The idea of geophysical surveys as something new in Norwegian archaeology is not correct, although an increased use of geophysical methods is present. What is new, is the establishment of domestic competence, easier access to geophysical equipment and providers of geophysical surveys. In addition to this are the improvements in relation to software and hardware capabilities- making it possible to gather more data, with a higher resolution from larger areas. The earliest geophysical survey was as far back as 1968, with a small increase of the amount of surveys in the late 1980s and more surveys performed into the 1990s. The amount of surveys performed increased from approximately 2000, with a notable rise from approximately 2007 – and especially within the last five years (see figure 1 and figure 30). 163 of a total of 293 surveys performed until the end of 2015 were performed within the last six years (i.e. 2010-2015)- approximately 56% of all surveys. GPR has to a large degree become the preferred geophysical method in Norway (see figure 25 and figure 26), and even though multi-method surveys are recommended, as many as 75% of all geophysical surveys performed involved just one geophysical method (figure 27). Settlement sites and graves are the types of archaeological targets most often surveyed, and the amount of management-related geophysical surveys has increased in the later years compared with research-initiated surveys. Still, the overall amount of surveys performed for research purposes count for 57% and management-initiated surveys count for 43% (table 12). There is no correlation between counties performing large amounts of archaeological registrations and the counties where a large amount of geophysical surveys is being performed (figure 34), and it is not really until 2007 that any real interest in commissioning geophysical surveys began for the various county authorities (figure 32). In the year 2015 the relationship between surveys commissioned was 39% for research purposes and 61% for management purposes, where 41% were for NCHA §9 cases only (Figure 30).

The results of the review in article one, as summarized above, was combined with a presentation and analysis of the contents and statements in strategic documents, communications and other initiatives from the various actors involved in archaeological research and cultural heritage management. This was done in a perspective inspired by actor-network theory, which I consider a methodical framework well suited to study the role, intended function and status of geophysical methods within the networks of archaeological research and cultural heritage management. By investigating the entitlements and descriptions the actors use when describing geophysical methods, and analyzing in detail the statement modalities in the various statements, this creates a good insight in the actors' acceptance of geophysical methods under varying circumstances. The various actors' main focus is different, and to a large degree reflect the actors main interest and their understanding of their role and function.

For instance, the main focus for the DCH on the *entitlement* of geophysical methods is on non-intrusive or non-destructive management of cultural heritage, the registration and identification of archaeology and an interest in non-destructive techniques by the counties and documentation by the museums. For the perceived role and function, most statements focus on issues on how the geophysical methods can contribute to management, as well as geophysical methods as a way of doing of field investigations (see table 6, table 7 and table 8). The focus on the *roles and functions* of geophysical methods is different for the various institutions, with a main focus on integration in cultural heritage management for the counties, the archaeological museums and NIKU, and methods for archaeological registration for the DCH (see table 8). There is to a certain degree overlap in the intended roles and functions. These results fulfill objective two and contribute to objective three of this thesis (see section 1.1). In article one, the non-intrusive nature of the methods and the potential for acquiring more information without destroying them was highlighted. Although the entitlement of geophysical methods include non-intrusiveness/non-destructiveness of the methods, this is something that receives less attention by the various actors within their description of the geophysical methods' role, function and purpose. From an Actor-Network Theory -perspective, the entitlements, roles, functions and purposes in the statements made by the various actors define how the various actors view geophysical methods. The actors' presentation of entitlements, roles, functions and purposes can also be understood as obligatory passing points- as interests within the networks of which the methods need to prove their worth, and becomes a way to enroll and coordinate allies within the network towards a mutual goal.

Another perspective gained by the Actor-Network Theory inspired analysis, was to both examine how the various actors have been influenced by the introduction of geophysical methods and compare the statements and intentions of the actors to their actual application of geophysical methods. The analysis undertaken fulfills objective four (see section 1.1). One observation is an increased attention given to geophysical methods by various actors in different documents and communications such as the Propositions to the Storting, various reports, cultural strategic plans, scientific evaluation programmes, guidelines, directives, annual letters of prioritizations and in circulars. At the same time does the analysis of statement modalities in the statements reveal that geophysical methods are not accepted as a natural part of archaeological registrations and other investigations, where the geophysical methods are often described with words such as "in certain cases", "can be used", "can show" or "may map features" (see section 7.4). Of the county authorities, it is only Vestfold county authority that clearly state that they view geophysical methods as equal to other archaeological registration methods. Nord-Trøndelag and Hedmark county authority, as well as Oslo and Frosta municipality, have been involved in research projects involving geophysical methods by the end of 2015, either in collaboration with the NTNU University Museum or NIKU. The NTNU University museum have research on the use of geophysical methods in archaeology as one of their research interests, and is the only university museum with access to their own geophysical equipment and competence. The analysis of the statements from the DCH and the MoCE show several stages of acceptance, as well as doubts towards the applicability of geophysical methods for archaeological registrations following the NCHA §9 c.f. §10. The DCH want to encourage the development and use of non-intrusive methods in connection with registration and excavation, but at the same time chooses to omit geophysical methods as one of the main registration methods for archaeological registrations. The DCH's statements on the function and status of geophysical methods are perceived as different and conflicting, depending on the intended use and setting for commissioning geophysical methods. In addition, the focus is more often on avoiding additional cost rather than the cultural historical and the overall management gain of a non-intrusive and non-destructive management (see section 7.8.2.3). Generally, for actors within cultural heritage management and archaeological research, the acceptance is higher for the use of geophysical methods within research projects than for the integration of geophysical methods for a non-destructive cultural heritage management. This can be exemplified by the small impact a positive statement on the use of geophysical methods from the scientific evaluation programme on iron production sites had on the actual field practice relating to management projects in the various counties and archaeological museums. At the same time, this statement functioned as an influence to the methodical research undertaken in article four (see section 7.8.2.2).

Objective five (see section 1.1) was to identify important research and perform methodical and empirical results to gain a deeper understanding of the potential, possibilities and limitations of geophysical methods in investigating archaeological sites, monuments and features in Norway. Article one presented several suggestions for further work (see section 7.5), where article two, three and four focused on assessing the geophysical techniques under varying archaeological and natural conditions. The focus was on comparing the geophysical information with excavation results, compare the geophysical data to other archaeological information, investigate reasons for geophysical detectability or the lack thereof, as well as discussing the potential impact these geophysical examples can have on archaeological research (objective six) and on decision making processes within cultural heritage management (objective seven).

Geophysical surveys undertaken in Norway have provided new and highly interesting results viewed from both a knowledge and research perspective, as well as for management purposes (see section 2.2 for an overview and section 7.6 for the particular contributions from article two, three and four). The main contribution to archaeological knowledge from article two, three and four was as following: At Veøy (article two) the geophysical results revealed very early clerical buildings, helped to delineate a Viking-age and early medieval Christian burial ground, and gave new and valuable information on the spatial organization of the early medieval market place. This includes the information on the metalworking area of the site, which covered approximately 10% of the whole market place. The use of GPR at Avaldsnes accurately indicated the presence of cooking pits, as well as their exact placement and approximate depth, makes it possible to estimate the amount of cooking pits not yet excavated on site (article three). Article four demonstrates how magnetic geophysical methods contribute to the location, delineation, and characterization of iron production sites and inherent archaeological features such as slag heaps, iron production furnaces and ore-roasting sites. Additional examples from elsewhere also demonstrate how topsoil magnetic susceptibility can be used to delineate settlement- and activity sites, and how the combination of magnetometer and GPR-surveys can be used to characterize buried archaeological features. These results fulfil objective six.

Objective seven was to examine and analyze how the results from the methodical and empirical investigations can alter or influence decision makers, decision-making processes and the actors practice within cultural heritage management in Norway. The geophysical results from the presented articles contributed to planning excavation, understanding of size and layout of sites and monuments in the landscape, and for the first time to be able to estimate the size of typical older iron-age iron production sites in mid-Norway. The lessons learned will contribute to the understanding and management of each site in particular, and have value that is transferable to other cases and other similar monuments elsewhere. In addition to this, is the practical geophysical experiences, and the additional knowledge of the possibilities and limitation of the various geophysical methods that were gained as a result of the work presented in articles two, three and four (see section 7.6). These are issues relating to magnetic contrast, varying geophysical response on different types of soil and geological conditions, the attainable resolution, and how the various geophysical methods complement each other and contribute to the process of feature characterization.

From the methodical and empirical examples presented in article two, three, four and in section 7.6, it is clear that there is not necessarily one particular method that is more appropriate than others. The geophysical method chosen has to be applicable to the specific aims and objectives of that particular investigation, and the initial justification of commissioning a geophysical survey. Site conditions such as expected type and size of archaeological features, ground conditions, geology, modern influence etc. all have to be considered before choosing a field strategy for the investigation at hand. A development towards more effective data gathering and resolution open up for new possibilities, including understanding archaeological landscapes, early prognosis over larger areas, and more accurate characterization of archaeological sites, monuments and features within those landscapes. The results from articles two, three and four also revealed a series of limitations that it is important to be aware of. Some are specific to certain geophysical methods, while other limitations related to survey strategies and survey conditions. Generally, the influence of modern disturbance and choices relating to survey resolution, as well as the access to georeferenced data plots and raw data decreased the usability of the results. If the survey resolution is low, then certain archaeological features would not be possible to detect. Also, the geophysical contrast of archaeological features may vary dependent on size, volume, backfill and content and their inherent geophysical contrast to the subsoil. The archaeological features might be possible to detect with one method, and do not have a geophysical response in another. Sometimes the archaeological features do not have a detectable geophysical contrast at all. Other times a geophysical contrast is detected, but any archaeological observation is not possible for the naked eye. This does not mean that there have not been any activity there – the geophysical contrast is real and examinable. Modern activity often lead to an increased magnetic disturbance in gradiometer data due to magnetic debris accumulating in the ground. Similarly, magnetic bedrock and changes in the presence of magnetic minerals in the subsoil can create conditions that are suboptimal for surveys based on magnetic principles. For GPR the presence of marine clay, waterlogged soils as well as complicated stratigraphical conditions with intercutting features can influence the geophysical response and the possibilities for easy archaeological interpretations. Electromagnetic induction can be used to overcome some difficulties with magnetic bedrock and clayey subsoil, but this method have not been used much in Norway.

Statements by certain actors that geophysical methods only work in “specific instances”, that it “always will be necessary to do control registrations”, and that geophysical methods “never can replace” traditional methods of registrations” (see section 7.4) are statements that do not take into consideration a tailored application of geophysical methods towards specific aims and objectives, and the potential and limitation of each method. Depending on the question, one method can be able to provide useful information, while another might fail due to magnetic bedrock or wrong choice of survey resolution depending on the archaeology present. Sometimes it could be advisable to leave the option of performing a geophysical survey all together. There is also a lack of attention to the whole process of cultural heritage management, from early assessment, to planning archaeological registrations, performing the archaeological registrations, and the following implications the quality and usefulness of these registrations for the other stages of cultural heritage management. While keeping the issues mentioned above in mind, it is still clear that there is a legal framework that needs to be followed, and that the size and extent (and in turn- the costs) of the archaeological assessment work should not be unreasonable for the developer. While a professional judgement is necessary, it is also clear that for geophysical methods to be properly integrated in the daily archaeological cultural heritage management, then actors within the cultural heritage management network need to assess the geophysical methods as one of the possibilities present in their strategy. The option of being able to perform a geophysical survey must be present, and the knowledge of the possibilities, limitations and potential of geophysical methods have to be disseminated to the users.

As a result of the analyses and examinations made, it is possible to conclude that geophysical methods are used increasingly in Norway. The introduction of geophysical methods have had some impact on the Norwegian archaeological community, but the geophysical methods are not a part of the everyday considerations and archaeological field practice in the country. The use of geophysical methods need to gain additional acceptance, and knowledge on the possibilities and limitations of geophysical methods needs to reach the actors involved in archaeological research and cultural heritage management. The amount of geophysical survey reports, articles and knowledge from the utilization of geophysical methods on Norwegian case studies is growing, and is helping to build a set of reference points and experiences that previously have been unattainable. Currently, geophysical instrumentation and trained staff are only in place at a few institutions in Norway, and there are limited options for professional training involving the application of geophysical methods. Mechanisms of support for training, knowledge dissemination, experience and knowledge on the possibilities and limitation of geophysical methods and the potential gain for including them in the daily practice of cultural heritage management should be encouraged.

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10APPENDIX

10.1ANT GLOSSARY

Actant/Actor: Someone or something that is the source of an action. The actant is constructed by a network of associations – the actant becomes what is being said about it, and what it is associated with in connection with other actants

Associations: How actors relate to each other, and how they are aligned, transformed or mobilized.

Controversies: The creation of boundaries in different system of narrative construction. Mapped differences can be controversies. A controversy can be everything not yet stabilized.

Enrolement: How to define and coordinate the roles – building institutions, stabilization, eliminate opposite claims, and getting acceptance and increased legitimacy, strategy

Inscription: Maps and illustrations over new objects that previously have been inaccessible or unattainable. Inscription leads to the validity being segregated and moved away from anyone which wants to contest the inscriptions.

Instruments: Means of detection and inscription

Interessement: How allies are fit into place – fitting obligatory passing points with the networks interests. Positioning, increasing influence, getting acceptance for claims/legitimacy, inclusion of actors in management.

Mediator: An actant who creates a change.

Mobilization of allies: Mobilization of resources and recruiting new participants to the network

Modalities: Sentences that modify or qualify another sentence. **Positive modalities** as sentences that lead a statement away from its conditions of production, making it solid enough to render some other consequence necessary" and **negative modalities** as "those sentences that lead a statement in the other direction towards its conditions of production and that explain in detail why it is solid or weak instead of using it to render some other consequences more necessary.

Problematisation: how to become indispensable – define aims and objectives, positioning in the network, establishing obligatory passing points.

Spokesperson: Someone who speaks on behalf of the geophysical data (or the actor in a more general sense). This can be used in a way to position one self within the existing networks, and try to find the interests of other actors towards mutual goals or interests of the inherent research project or the importance of the results derived from the investigation in question.

Statement modalities: A set of steps of claims, moving from speculation and guesswork, uncertain claims, assumptions, facts, and un-themed assumptions. Something is ascribed properties, competence, vigor and position in this process.

Translation: Moving claims from type 1 to type 4 or 5 by getting them accepted in an uncontested manner. This could be for instance the acceptance of using geophysical data to sources of cultural historical information.

References used for the abovementioned glossary: (Latour 1987, 1996; Schaanning 1996; Myklebust 1997; Latour 2005; Brattli 2006; Venturini 2010; Nielsen 2011; Brattli 2013; Khazraee 2013; Nielsen 2013; Tuddenham 2015; Brattli and Brendalsmo 2016)

11ARTICLES

Article I

Culture

UISPP

EAA
European Association
of Archaeologists

A Sense of the Past

Studies in current archaeological applications of remote sensing and non-invasive prospection methods

Edited by

Hans Kamermans
Martin Gojda
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Front cover illustration: DTM of a set of artillery forts (a later addition to the great fortified town of Terezín (north-west Bohemia, Czech Republic) which was constructed across the Labe river in the mid 19th century), a result of ALS (March 2011). The current state of the monument which has been partly levelled (forts 1 and 4) is well illustrated by this way. Also, a dense network of former trackways and linear earthworks of which some may have been connected with the fort system is apparent.

Back cover illustration: Vladař (western Bohemia, Czech Republic) DTM of extensively fortified Iron Age hillfort produced from airborne laser scanned data acquired in March 2010. The image displays perfectly the current state of the site and its individual components, such as the so-called acropolis situated in the highest part of the hillfort (coloured blue) and the fortification system of ramparts and ditches in the western and northern parts of the flat table hill.

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ARCHAEOLOGICAL USE OF GEOPHYSICAL METHODS IN NORWEGIAN CULTURAL HERITAGE MANAGEMENT – A REVIEW

Arne Anderson Stamnes and Lars Gustavsen

Abstract*: The aim of this paper is to review the way geophysical prospection methods have been used in Norway, and gain a better understanding of the role and status of geophysical methods within Norwegian cultural heritage management. This is done by reviewing and analysing the content of a database on all known geophysical surveys conducted in Norway over the last 40 year - 197 surveys in all. The results show that the number of surveys in Norway has increased since the beginning of this millennium, but geophysical surveys are nothing new. 64 % of all surveys were initiated for research purposes and 36 % for management purposes - a number much lower than in England and Ireland. Only 29 % of all surveys involved more than one geophysical method. While strategic documents and signed treaties justify the use of geophysical methods, the analysis shows that the application of such methods has yet to be generally accepted within the existing cultural heritage management in Norway. The reasons for this is a combination of lack of resolution and technical limitations of earlier surveys, challenging natural conditions and ephemeral archaeology, combined with a lack of trained personnel and competence. Recent research initiative by domestic institutions related to the application of and research on geophysical methods is considered to be a step toward building up domestic experience and knowledge.*

Keywords*: Archaeology – Cultural Heritage management – Geophysical Survey Methods – Norway*

Introduction

Geophysical methods of prospection, defined as "*The examination of the Earth's physical properties using non-intrusive ground surveys techniques to reveal buried archaeological features, sites and landscapes"* (*Gaffney - Gater 2003*, 12), have been used with success for some time in countries such as Great Britain, Italy, Austria, Germany and elsewhere *(Doneus et al. 2001; Gaffney - Gater 2003; David 2008; Piro 2009*).

This is often done by applying a range of geophysical methods based on different physical principles. The most widely used methods are electric, magnetic or electromagnetic methods, employing a variety of instrumentation and field procedures. There are also instances in which seismic or microgravity methods have been applied (*Clark 1996; Gaffney - Gater 2003)*. The following benefits of geophysical surveys have been highlighted: the non-intrusive nature of the methods and the potential for acquiring more information about archaeological sites without destroying them, the fast speed at which surveys can be conducted, yielding a large amount of information in a short amount of time, and a level of accuracy and detail providing a useful means for pinpointing the location of interesting anomalies and activity zones (*Clark 1996; Gaffney - Gater 2003; Lockhart - Green 2006; Gaffney 2008; Ernenwein - Hargrave 2009,* 9-13*; Viberg et al. 2011*).

While all of these aspects appear beneficial to a proper management of archaeological heritage, widespread use and acceptance of remote sensing methods has not been forthcoming in Norway, and the impact of geophysical prospection methods on the archaeological community might be claimed to be less than elsewhere in Europe. It is therefore interesting to note a change in the application of these methods within the last decade, when several well-performed surveys have produced interesting results *(Gustavsen - Stamnes 2012*).

The aim of this paper is therefore to review the way in which geophysical prospection methods have been used in Norway, in order to gain a better understanding of the reasons behind the delay in their use. This will increase our understanding of the role and status of geophysical methods within Norwegian cultural heritage management. It involves analysing who commissioned such surveys, why they were undertaken, where and when, as well as how – i.e. the choice of methods applied. This will be combined with an analysis of the content of official documents from central government agencies concerning the application of or research on geophysical methods within the Norwegian heritage management system. Such an investigation will give some clues to important topics and objectives that should be addressed for further research in the future.

Method

A database containing information on geophysical surveys undertaken for archaeological purposes has been compiled by the authors of this article. This is a joint project of The Norwegian Institute for Cultural Heritage Research and The NTNU Museum of Natural History – Section for

Archaeology and Cultural History. The database covers all known geophysical surveys which have been identified in published literature, technical survey reports, media coverage, archival sources and other grey literature. The following information has been included in the database:

- Location (county, municipality, farm name and number)
- Time and date
- Survey type
- Archaeological site type
- Commissioning authority
- Survey company and personnel (representing either public archaeological institutions or private companies)
- Methods used (including instrument manufacturer and model details if known)
- Geological information and soil conditions (if known)
- The total number of survey schemes, and the number of projects they can be related to (sometimes several surveys were undertaken at different times within the same project)
- References

This database is a good source for investigating the aims of this paper. It provides an overview of the development over time, the geographical distribution of surveys, methodological choices and combination of methods. It is also a good source of information for further analysis of the reasons for performing geophysical surveys – be it for archaeological research purposes or heritage management. As the main aim of this article is to review how the methods have been used, a short historical overview will be presented, in which the main focus will be on general trends rather than on separate survey details. A general discussion on the results obtained and the identification of important challenges and experiences extracted from this overview will also be raised.

The second aim is to evaluate the current status of geophysical methods within Norwegian cultural heritage management. By investigating strategic documents and other documents from participants within cultural heritage management, their impressions of the applicability of geophysical methods and intentions for future use of such methods can be indicated. The combined results of such an analysis with information from the geophysical survey database will reveal important information on topics and objectives that can be addressed in the future. To make it easier for the reader to relate to this information, a short general description of the Norwegian heritage management system will also be provided.

A Short History of Archaeological Geophysics in Norway

The first documented use of geophysical prospection methods in Norway is a magnetometer survey at Stødleterrassen in the municipality of Etne in the county of Hordaland in 1968. This experimental work was directed by Norwegian archaeologist Bjørn Myhre, and led to the successful discovery of two Iron Age cooking pits (*Myhre 1968*). Another early survey was carried out for the "Hoset Project" in the municipality of Stjørdal in the county of Nord-Trøndelag, where an iron production site from the early Iron Age was mapped with a proton magnetometer. The results successfully delimited a slag heap and indicated the location of the furnace associated with the site (*Farbregd 1973; 1977*). The methods and technologies, however, were not generally accessible and not much further work was undertaken until the mid-1980s.

From these initial surveys and until the end of the 1990s, an increase in the number of surveys undertaken on a range of different archaeological sites can be observed (Fig. 1). This includes several georadar and magnetometer surveys at the mound cemetery at Borre in Vestfold county (*Myhre 2004*), as well as various magnetometer investigations carried out by the geologist Richard Binns. Binns' work includes an Iron Age courtyard site and activity areas associated with the Frosta *thing* site in Nord-Trøndelag county, where an early medieval farmstead and a ploughed-out burial mound were detected *(Binns 1994; 1996; 1997*). From the late 1980s software and hardware became more accessible, and it was increasingly possible for private companies and consultants to offer their services. The survey procedures chosen could be seen as normal for their time, but some of the results would today be deemed of limited value due to the lack of resolution and underdeveloped processing- and visualisation-techniques. Matrix plots of magnetometer data and the presentation of single georadar profiles printed on paper made it hard to relate the data to their physical position and therefore clearly limited good archaeological interpretations. This also gave the general impression of geophysical methods to be of limited value, either due to a lack of correlation between the geophysical results and the excavated archaeological features, poor quality of the archaeological interpretation of the geophysical data, or a limited understanding of the methods and their underlying geophysical principles – including the potentials and limitations associated with each method (*Gustavsen - Stamnes 2012,* 85-86).

With the introduction of more powerful computers, as well as the increased application of GIS-systems and accurate GPS-systems within the archaeological community, came new possibilities for accurately plotting the geophysical data geographically. It became easier to associate different data sources with archaeological findings (*Chapman 2006*). Increased amounts of data covering larger areas could be gathered and processed, and the quality of the known surveys increased from the turn of the millennium onwards *(Gustavsen - Stamnes 2012*). In this period we find several successful magnetometer investigations of iron production sites with associated activity, especially related to the "Gråfjell Project" in Hedmark county *(Risbøl - Smekalova 2001; Risbøl et al. 2002*), as well various surveys undertaken over ploughed-out burial mounds in cultivated fields throughout the country *(Lorra 2003; Binns 2004; Gjerpe 2005*). Generally, it could be argued

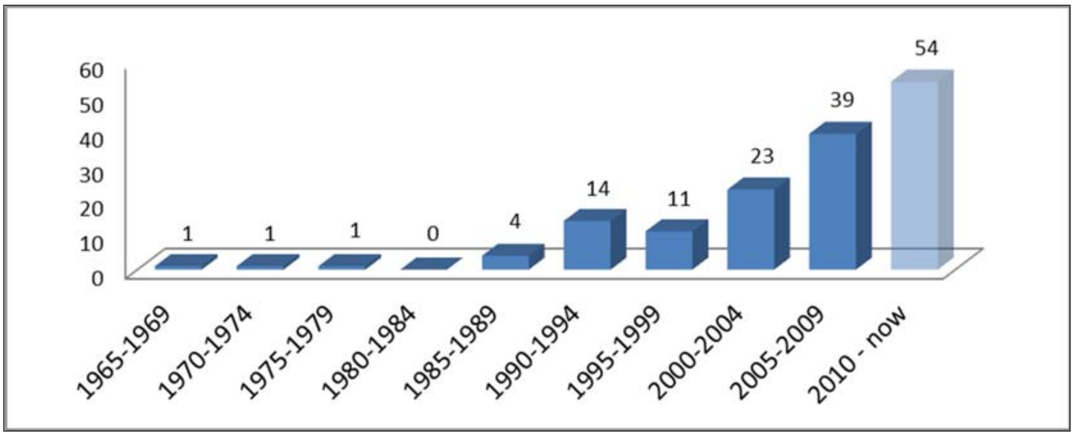


Fig. 1. Graph showing the incremental use of archaeological geophysics in Norway from 1968 until February 2013. The light blue bar indicates the current non-complete five-year period.

that surveys were often undertaken by professionals or companies not based in Norway. These were of a high technical quality, although a lack of focus on the reasons for undertaking such surveys as well as on the survey methodologies in general can sometimes be noticed. If the results were disappointing from an archaeological point of view, i.e. where archaeological features were not positively identified by geophysical methods, but were later found when excavating the site, there was often not an opportunity to investigate this further as part of the project. This limited the value of some of the surveys undertaken from a geophysical point of view. A lack of nationally based professionals and methodological research projects also led to a limited long-term gain and availability of skilled personnel and experience (*Gustavsen - Stamnes 2012*).

This changed in 2006 when the *Directorate for Cultural Heritage* chose the *Vestfold County Council* as collaborators in a national project concerning the use of geophysical methods. The goal of this methodological project was to investigate the potential and possibilities of geophysical methods on a range of sites, and the project was carried out in collaboration between the *Directorate*, the county archaeologists in Vestfold, as well as professionals and geophysicists from the *Swedish National Heritage Board*. From 2010 this county council proceeded with a collaboration with the *Norwegian Institute of Cultural Heritage Research* (NIKU) as partners in a multinational research led by the *Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology* (LBI ArchPro) in Vienna, which is an on-going project for developing new technological and non-destructive methods for documenting and identifying archaeological sites, monuments and landscapes. This involves geophysical prospection methods as well as other remote sensing techniques such as aerial LiDAR scanning, hyper spectral scanning and satellite imagery. NIKU later invested in their own geophysical equipment. NIKU, in collaboration with the LBI-project, has investigated substantial areas using several methods, and can demonstrate a range of positively identified archaeological features, and considerable experience in the applicability of such methods to a variety of natural conditions and archaeological monuments. Another archaeological institution that carried out methodological research is the *NTNU Museum of Natural History and Archaeology* in Trondheim, which have had a research interest in the application of geophysical methods since the beginning of the millennium. In 2007 the NTNU initiated a collaboration with the Irish company *Earthsound Associates*, and undertook several geophysical investigations in central Norway, as well as at the Iron Age centre of power and wealth at Avaldsnes in Hordaland county (*Barton et al. 2009*). NTNU was the first (and to this day – only) regional museum in Norway to invest in their own geophysical survey equipment and personnel, and was the first university body to engage a PhD-candidate on the subject of archaeological geophysics as from the autumn of 2011. The county of Vest-Agder has also commissioned several surveys on their own initiative, in collaboration with the *Moesgaard museum* in Denmark and geophysicist Tatjana Smekalova. These three initiatives in particular have led to the increase in the number of geophysical surveys from 2007 onwards, as noticed in (Figs. 1 and 2).

The Norwegian Cultural Heritage Management System

The cultural heritage management system in Norway is designed to preserve a representative selection of monuments and sites from all periods, and its aim is to provide an overview of the arts and crafts and the general way of life throughout Norwegian history. Through the Cultural Heritage Act of 1978, all monuments predating 1537 AD and standing buildings predating 1650 AD are automatically protected by law, while monuments more recent than 1537 or standing buildings built after 1650

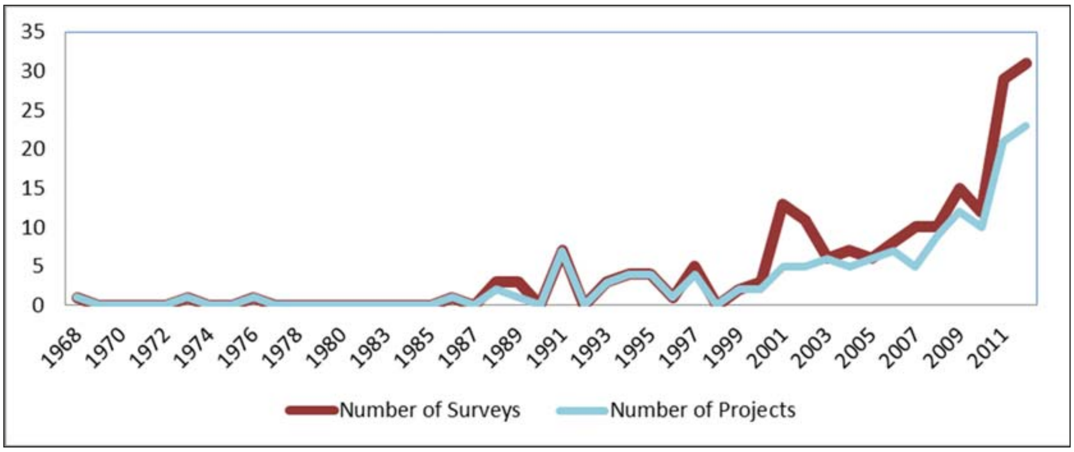


Fig. 2. Graph showing the development in the number of archaeological projects involving individual geophysical surveys (red) and the number of projects involving geophysical surveys (blue).

can be protected through a protection order granted on a case-by-case basis. All archaeological monuments predating 1537 are protected automatically whether or not they have been positively identified (*Kulturminneloven 1978*). A range of new monuments are being rediscovered or identified every year, either through archaeological excavations, by outfield visual surveys, through LiDAR image analyses or other mapping schemes. The Cultural Heritage Act can also justify the protection of cultural landscapes and environments.

As for managing, preserving, locating and documenting the archaeological heritage older than 1537, the responsibility is shared by a range of governmental or public institutions. Rescue archaeology is not privatised. The main bodies within the Norwegian Cultural Heritage Act are as follows:

The Ministry of Environment (MOE) (Miljøverndepartementet) – The MOE has the overall responsibility for ensuring that the policies of the government are being followed, and shapes the aims, objectives and management instruments according to the relevant political guidelines.

The Directorate for Cultural Heritage (Riksantikvaren) – The Directorate is responsible for the practical implementation of the Norwegian Cultural Heritage Act and the aims and objectives instituted by the MOE. It serves as counselling body to the MOE, and provides and disseminates relevant knowledge pertaining to cultural landscapes, monuments and buildings.

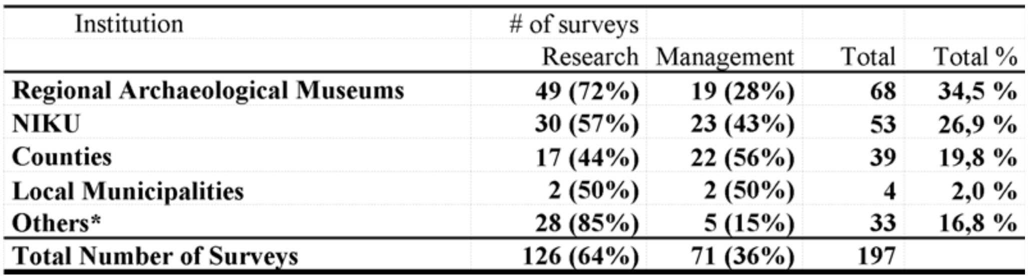
The County Administrations – Norway is divided into 19 counties, where each county has a duty to employ officers responsible for cultural heritage conservation, including planning permissions, and to advise the county administration and the public on questions regarding cultural conservation and dissemination. Archaeologists employed by the county conduct initial archaeological investigations to decide whether or not a planned development might impose a threat to any archaeological monuments or remains.

The Regional Archaeological Museums – Norway is divided into five museum districts, where each regional archaeological museum is responsible for undertaking archaeological excavations needed when an exemption to the Cultural Heritage Act has been granted on the condition that the archaeology will be documented by record. They manage the archaeological collections, and are responsible for the preservation of cultural historical objects, as well as research and dissemination. The Regional Archaeological Museums are defined as university museums in their region. This means that they are often involved in higher education and the training of archaeologists, and that there is a close link between the relevant university in the region and the archaeological museum, which again leads to some opportunities for academic collaboration.

The Sámi Parliament – The Sámi parliament has the same responsibility as the county administrations for cultural heritage monuments, sites and landscapes defined as Sámi and older than 100 years. The Sámi, as an indigenous people of Norway, employ their own cultural heritage officers, based in four regional offices.

The Norwegian Institute for Cultural Heritage Research (NIKU) – This is an independent institute for research and development, and has a status as a national centre of competence in issues regarding cultural heritage management, including conservation, technology and methodology. It acts as a consultancy to any cultural heritage management body. It is by definition not a public institution but has, through licence, a responsibility for managing medieval monuments in the major medieval

Table 1. Summarising statistics on who commissioned surveys, as well as the number of surveys categorised as either "research" or "management". "Others" can involve local museums, local historical groups, private companies or other institutions.



Institution	# of surveys			
	Research	Management	Total	Total %
Regional Archaeological Museums	**49 (72%)**	**19 (28%)**	**68**	**34,5 %**
NIKU	**30 (57%)**	**23 (43%)**	**53**	**26,9 %**
Counties	**17 (44%)**	**22 (56%)**	**39**	**19,8 %**
Local Municipalities	**2 (50%)**	**2 (50%)**	**4**	**2,0 %**
Others*	**28 (85%)**	**5 (15%)**	**33**	**16,8 %**
Total Number of Surveys	**126 (64%)**	**71 (36%)**	**197**	

towns, as well as clerical buildings and monuments from this period.

(Sources for the list above: *Gaukstad - Holme 2000; Riksantikvaren 2012*).

Results

Statistics

As of February 2013, the geophysical database consists of 197 separate surveys conducted as part of 148 different projects. The reason for the separation between survey and project is that sometimes an area might be revisited, for instance in order to supplement an earlier survey or archaeological investigation with greater area coverage or by using an alternative geophysical method. (Figs. 1 and 2) show the development in the use of geophysical methods since the first known survey from Stødleterassen in 1968.

As our main aim is to review how the methods have been used, it is possible to shed further light on this by summarising some statistics from the compiled database by investigating who commissioned surveys, why they were undertaken, as well as where and how.

Who and why

It is of interest to investigate who commissioned geophysical surveys and why. The question of why can be multifaceted, and we have therefore chosen to separate the surveys into two categories: "research" and "management". While a survey initially conducted for research purposes might yield results that are interesting from a cultural heritage management point of view, it might not be why the survey initially was conducted. Surveys labelled "management" are either surveys conducted as part of a developer-led planning application and excavation, or they were conducted for specific dissemination purposes or to answer specific questions relating to the proper management of an archaeological site. The latter could for instance be the delineation of sites or providing further information on preservation conditions or additional archaeological features. While it is possible that some surveys have been conducted for several purposes, as well as being a collaboration between different institutions, we have to the best of our ability separated them based on main purpose or contributor.

By separating surveys conducted for research purposes from surveys conducted in management contexts (dissemination and development), these results can shed light on how geophysical methods are being utilised by the different institutions. The following summarisation can be presented (Table 1):

While these results will be discussed more in-depth later, it is interesting to note the percentage of the total number of surveys, where 64 % were initiated for research purposes, whereas 36 % were for management purposes.

Where

The following map shows the distribution of known geophysical surveys in Norway at county level (Fig. 3):

Vestfold clearly stands out with 56 surveys, and is within the highest quantile together with Nord-Trøndelag (27 surveys) and Hedmark (25 surveys). Sometimes a large variance can be noticed between neighbouring counties. There does not seem to be a direct link between county size and the number of surveys. As the number of archaeological site evaluations performed by the county archaeologists in relation to planning permissions is a reasonable indicator of the rate of development in each county, it is interesting to compare this with the number of geophysical surveys undertaken within that county. This might indicate if this uneven geographical distribution is related to the rate of regional development in the various counties. The data for the number of archaeological investigations related to planning applications is gathered from the *Statistics Norway*'s KOSTRA database for municipal and county municipal activities[1]. As only statistics for the years 2007-2011 are available, the geophysical investigations in the same period was separated, and the following graph could be made (Fig. 4):

As can be seen, there is a wide variation of archaeological activity in relation to planning applications between

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[1] http://www.ssb.no/english/subjects/00/00/20/kostra_en/ (last accessed 25.01.2013)

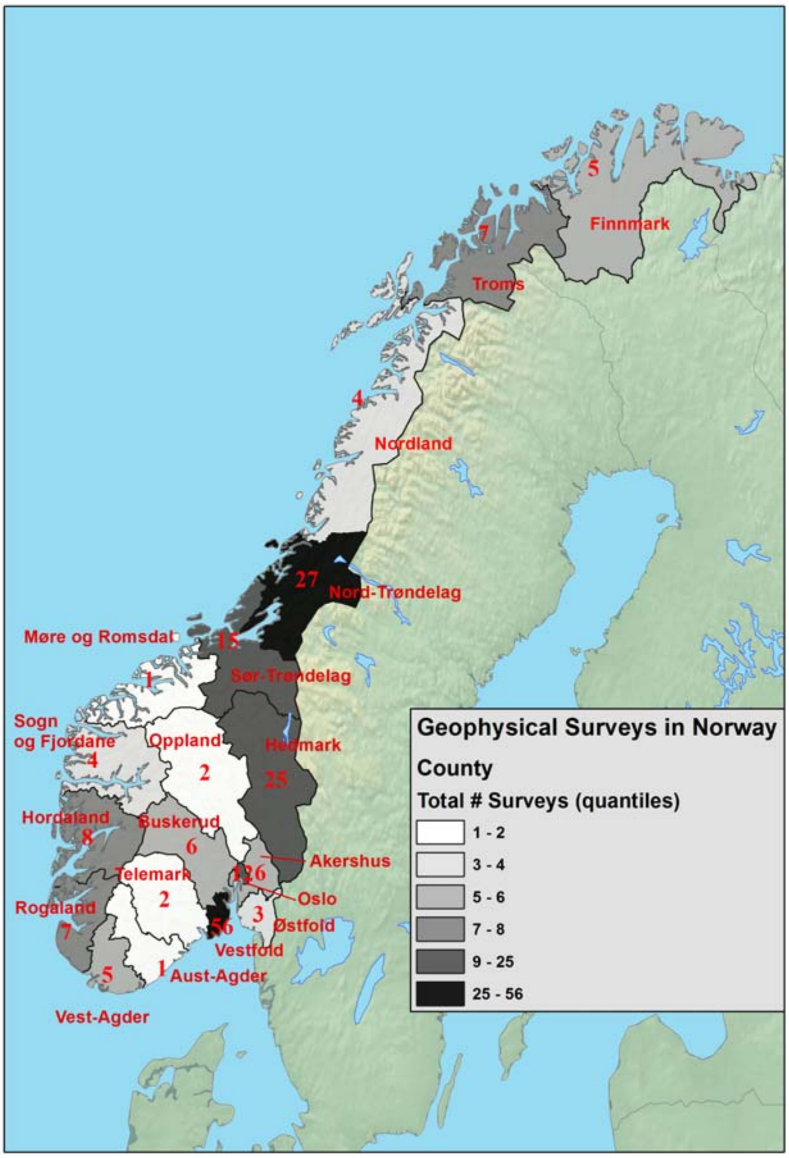

Fig. 3. Map of Norway showing the number of geophysical surveys undertaken for each county. Made with digital map data from Natural Earth and the Norwegian Mapping Authority.

the different county municipalities, and the number of geophysical surveys performed do not seem to be directly related to these. The Pearson r correlation coefficient for the correlation between these two variables was calculated to -0.19, where a number closer to ±1 is a perfect correlation (*Madsen 2011*, 114). This therefore means that there is no statistical linear relationship between the archaeological activity within each county and the use of geophysical methods at a national level.

How

Another way of evaluating the use of geophysical prospection methods to date is to evaluate how the geophysical methods have been utilised. This involves both choices of methods, site selection and issues relating to resolution.

The choices of archaeological targets and geophysical methods, as well as the combination of several geophysical methods can be important in the success of a survey to positively identify archaeological remains. First of all the following figure can be presented (Figs. 5 and 6):

While (Fig. 7) also reflects the trend of the number of surveys performed (see Figs. 1 and 2), it is most relevant for noticing how the preferred method of choice has changed from magnetometers to ground penetrating radar.

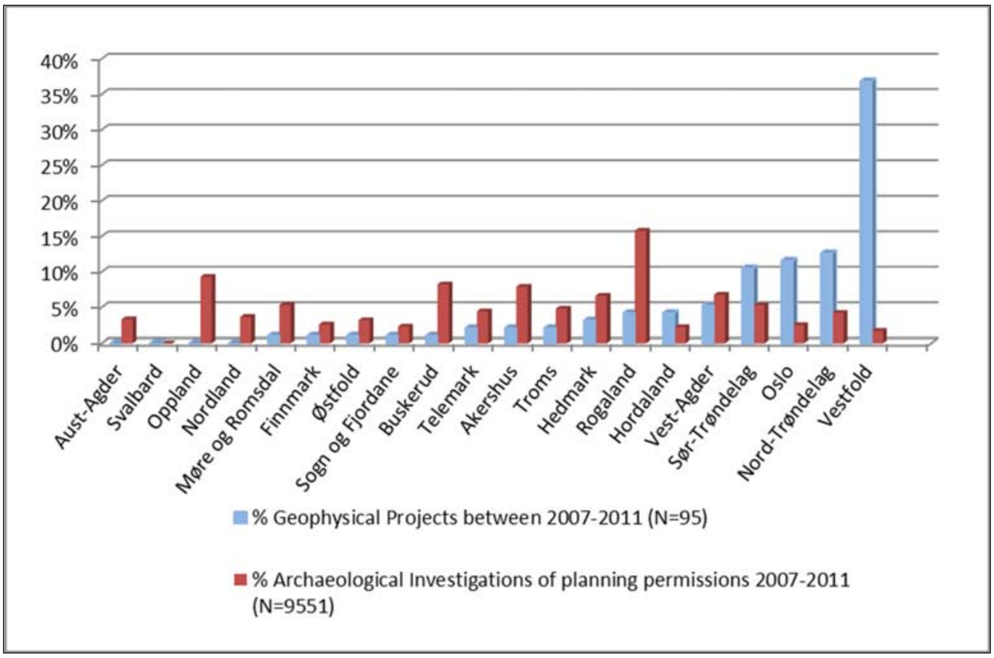

Fig. 4. The relationship between the number of geophysical surveys compared with archaeological investigations of planning permissions between 2007-2011. There is no data available on archaeological investigations for Svalbard in the KOSTRA database.

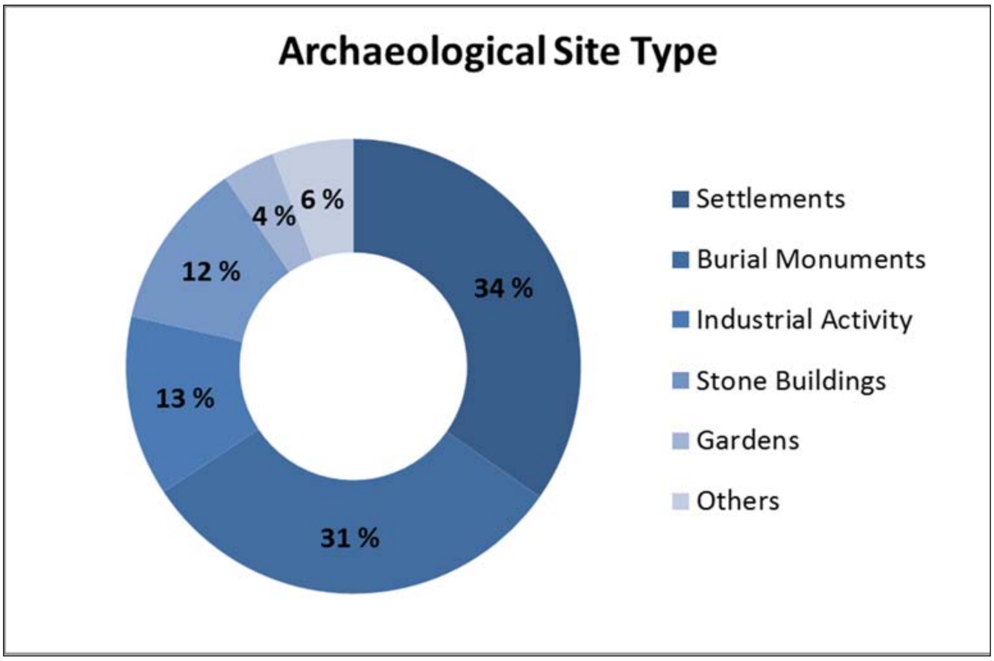

Fig. 5. The percentage distribution of different site types targeted by geophysical surveys in Norway as of 31.01.2013. Please note that separate surveys may have several objectives or cover different site types, and have therefore been classified as for instance both settlements and burial monuments. While the total number of surveys is 197, the total number of classified survey site types is 242.

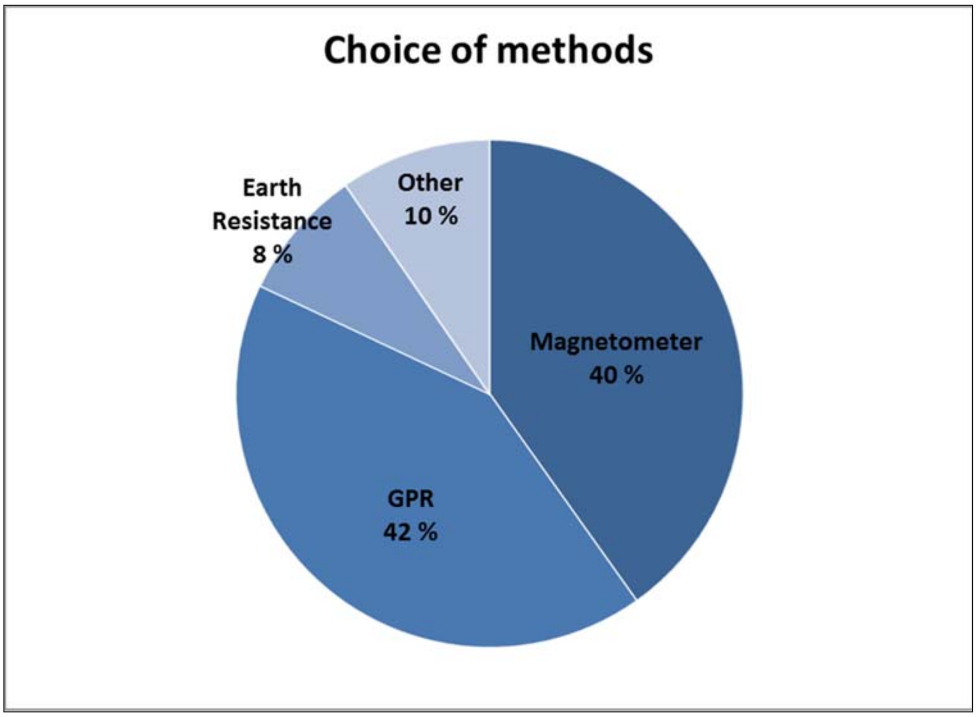

Fig. 6. Graph showing the degree of use of each main geophysical technique. This is based on 239 data inputs, where several methods may have been applied at one survey. This percentage is related to the number of surveys involving a technique, and not the size of the surveys.

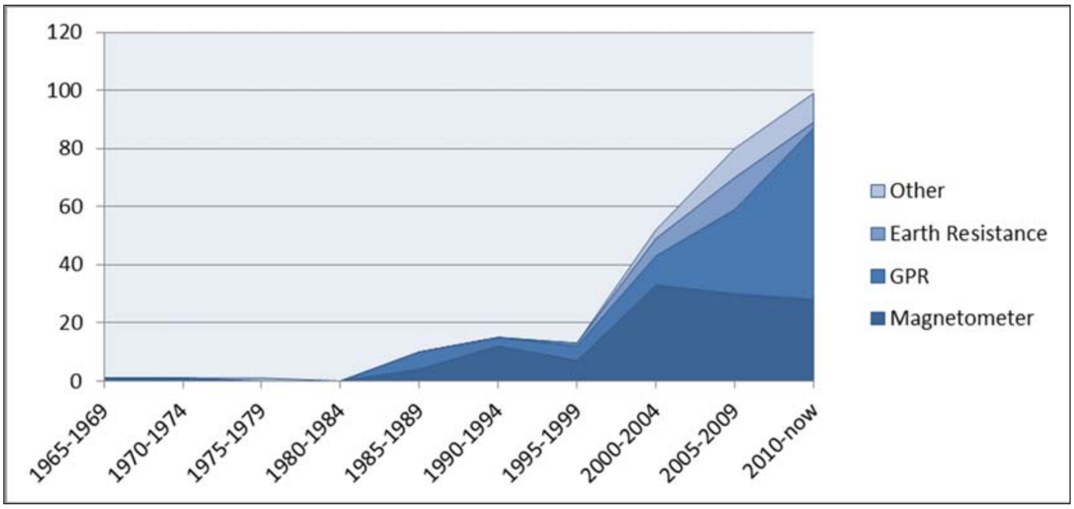

Fig. 7. This graph shows how the utilisation of different geophysical methods has developed over time. The category "Others" involve magnetic susceptibility mapping and different electromagnetic imaging techniques.

As a comparison, magnetometer surveys have long been considered as the main choice of methods in the UK (*Gaffney - Gater 2003; David 2008; Jordan 2009*), while in Norway it is one of the main methods together with georadar. Earth resistance surveys have never been used much in Norway, although good examples of successful application do exist (e.g. *Horsley 2003; Stamnes 2011*). Examples of electromagnetic imaging are known, as well as the use of topsoil magnetic susceptibility for delineating sites and activity areas (e.g. *Stamnes 2011*). Another way of investigating the application of geophysical methods is to look at the number of different techniques applied at each survey. This is relevant to understand the rate of success or scepticism related to the applicability of geophysical methods. An increase in the number of geophysical methods applied increases our understanding of the archaeological site, as each method can be used to characterise different physical properties of the subsoil. An archaeological feature can be seen in data from one technique, while being absent in data from another (*David 2008; Ernenwein - Hargrave 2009; Stamnes 2011; Gaffney - Gaffney 2011*).

Official documents

In the introduction, the following positive benefits of geophysical methods were highlighted:

- The non-intrusive and non-destructive nature of the methods
- The possibilities of acquiring more information about an archaeological site or cultural landscape without destructive interference
- The high speed of data gathering
- The high spatial precision, making it possible to pinpoint the location of interesting anomalies and zones of activity

(*Clark 1996; Gaffney - Gater 2003; Lockhart - Green 2006; Gaffney 2008; Ernenwein - Hargrave 2009,* 9-13*; Viberg et al. 2011*).

All of these points should be in the best interest of the cultural heritage management in Norway, as Norway has ratified several treaties and conventions such as the Valetta-convention and the ICOMOS-charter that both encourage the use of non-intrusive methods and the conservation of cultural heritage *in-situ* (*Valetta 1992; Icomos 1990; Gustavsen - Stamnes 2012,* 87).

A report commissioned by the *Research Council of Norway* on future research focus within cultural heritage management for the years 2004-2014 explicitly pointed out the need for development of and research on methods for locating and mapping sites, as well as tools to analyse and create prognoses for the potential for cultural heritage sites (*Norges Forskningsråd 2003*). The *Directorate for Cultural Heritage* have later indicated in a strategy plan for cultural heritage management valid for the years 2010-2020 that they wish to encourage the development of technological aids as a valuable supplement to the methods generally used for identification and excavation of archaeology, with particular emphasis on non-intrusive methods (*Riksantikvaren 2010,* 11). The Cultural Heritage Act of 1978 does not specify how any archaeological investigation should be conducted in the different stages, but leaves it up to the county archaeologists or regional archaeological museum to decide how they choose to evaluate, investigate or excavate any area influenced by development (*Kulturminneloven 1978*). They need to get acceptance and support from the *Directorate for Cultural Heritage* for any decisions made, be it through acceptance of budgets or suggestions for field strategies and the inclusion of scientific methods in their budgets. As the Directorate is not directly involved in the actual field work, this is one way they might influence the strategic choices made for any field archaeological investigation. They have also released an advisory document for budgeting for excavations performed by the regional archaeological museums in instances where an exemption to the Cultural Heritage Act has been granted. Geophysical methods are not mentioned explicitly in this document, but it is possible to budget for scientific analyses. The use of scientific analyses should then be limited to the extent that is deemed necessary to "*decide, identify, date and interpret the site, cultural layers and finds*" (*Riksantivaren 2011*, authors' translation). This document is not valid for budgeting for the surveys performed by the county archaeologists in relation to the initial planning permission. It is then up to the county archaeologists to decide which method they find suitable. Another relevant document is an advisory document released by the Directorate in collaboration with the research institution *Sintef Byggforsk*, concerning archaeology and their collaboration with the construction engineering industry, where archaeology is explained to construction engineers and vice versa. This document explains the different methods, both intrusive and non-intrusive, that archaeologists use. The authors of this report note that the geophysical methods "*are still more at an experimental stage"* in Norway (*Karlberg - Jerkø 2009,* 121, authors' translation).

This short presentation of the main official documents regarding the use of geophysical methods in relation to practical cultural heritage management shows that an awareness of the methods does indeed exist, but that they have not necessarily been given much focus. While treaties and charters justifying the use of non-intrusive methods have been ratified, it is still left up to the responsible governmental institution or official to decide which methods to utilise. This will be discussed further in the next section.

Discussion

As seen in (Figs. 1 and 2), the use of geophysical techniques in archaeology in Norway has increased significantly within the last decade. It is also apparent that the application of such methods is not connected to the level of archaeological activity related to planning permissions in the different counties (Fig. 4). In total 36 % of all geophysical surveys have been conducted within a management context. This number becomes more informative when you compare it with data from Ireland and England.

In Ireland about 80.4 % out of 514 licensed geophysical surveys between 1999 and 2007 were conducted within a commercial management context, while the remaining 19.6 % were research surveys (*Bonsall et al. 2013*). Bournemouth University in England has made a database of so-called "grey" literature from different regional archives, registries and different contractors in England covering the years 1990-2010, as part of their "Archaeological Investigations Project"[2]. This "grey" literature consists typically of unpublished survey and excavation reports, as well as work related to research projects. The database is searchable online, and its content can be exported and analysed. By looking at the geophysical surveys only, it was possible to separate them into "planning" and "non-planning" surveys. Out of 3656 entries, 64 % was planning-related, 30 % was non-planning and 6 % was "other". The separation between these categories is somewhat ambiguous, and it is unclear which type of surveys the 6 % in the "other" group represent. It is possible that these involve mostly research or rescue surveys. While it is difficult to test the accuracy and quality of this information, the number of surveys categorised is generally quite high, improving the possible statistical significance. At the same time *Bonsall et al.* 2013 (this volume) has questioned the accuracy of the AIP Database due to the large number of duplicate records. The important aspect is that while 36 % of all surveys in Norway were within a management context, it was 80.4% in Ireland and 64 % in England. Some error may be introduced due to the timescale these compilations of surveys represent as well as possible duplicate records, but most importantly, the comparison demonstrates that geophysical methods do not seem to be an integrated part of Norwegian everyday archaeological practice to the same extent as in England and Ireland. (Table 1 and Fig. 4) support this conclusion.

The important question that arises from this result is why such methods are not applied to the same extent. This is probably related to two aspects: 1. How the methods have been used, and 2. The lack of domestic competence. These will be discussed in turn.

The interplay between expected archaeological site type, methodological choices and combination of geophysical methods is important. If archaeological features of a certain type are to be identified by a geophysical method, they need to have a sufficient geophysical contrast and a shape, form or pattern that can be recognised as archaeological by the interpreter. It is therefore important that the end user and field technician is able to properly understand the effect of different methodological choices, such as resolution, possibilities and limitations of each method. If the expected targets are small postholes and pits with a diameter of 50 cm or less, which is typical of Norwegian Iron Age settlement sites (*Løken 1999*, *Myhre 2002*), the choice of resolution and method that can potentially identify such small features will be important. We see in (Fig. 5) that 34 % of all surveys performed in Norway targeted settlement sites. Unless these consisted of larger ditches, stone buildings or highly contrasting material from burnt material or stone-lined post holes, then surveying such a site with can be difficult. It is likely that several of the surveys were taken with an expectation of a better performance rate, due to a lack of understanding of the limitations present. Even so, we still have examples where buildings of postholes and pits have been located (*Trinks et al. 2007*). When the surveys targeted ploughed-out burial mounds, there are examples in which the ring-ditch was not visible in magnetic datasets, while they could be seen clearly in the GPR or electric resistivity data (*Stamnes 2011*). There is also an example from Gulli in Vestfold, in which ploughed-out burial mounds were not visible at all. The reasons for this last example were not investigated further from a geophysical point of view (*Gjerpe 2005*). We also notice in (Fig. 8) that a majority of all surveys, 71 %, involved just one method. The general consensus is that the more methods are applied, the better is the information gain concerning a site or feature and the higher are the chances of positively identifying a feature (*Clark 1996; Gaffney - Gater 2003; David 2008; Ernenwein - Hargrave 2009; Gaffney - Gaffney 2011*). Several case studies from Norway demonstrate this (i.e. *Trinks et al. 2007; 2010; Stamnes 2011*). Magnetometers had been the preferred method of choice until around the turn of the millennium, when the number of GPR surveys appears to increase. Magnetometers were involved in 40 % of all surveys, and we know that the earlier surveys were often conducted with a relatively low spatial resolution using limited software options for data processing and presentation. We consider it likely that earlier surveys sometimes created an impression of archaeological geophysics as being unreliable and inefficient, since the surveys failed to positively identify archaeological features which were found during subsequent excavations, or that over-interpretation or high expectations led to a false impression of the applicability of the methods. This does not necessarily imply that the actual geophysical mapping was poorly performed, but rather that technical restrictions reduced the actual applicability under the conditions present. An understanding of the geophysical principles, possibilities and limitations is therefore necessary to provide a proper archaeological interpretation of the geophysical data as well. The quality of such interpretations will increase with experience.

Today there are two domestic institutions that execute geophysical surveys for archaeological purposes: The *NTNU Museum of Natural History and Archaeology*, which is connected to the *Norwegian University of Science and Technology*, and the *Norwegian Institute for Cultural Heritage Research* (NIKU). Their venture into archaeological geophysics is something relatively new within Norwegian archaeology, starting in the second half of the last decade. Other practitioners are rare, and are often

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[2] http://csweb.bournemouth.ac.uk/aip/aipintro.htm (last accessed 24.05.2013)

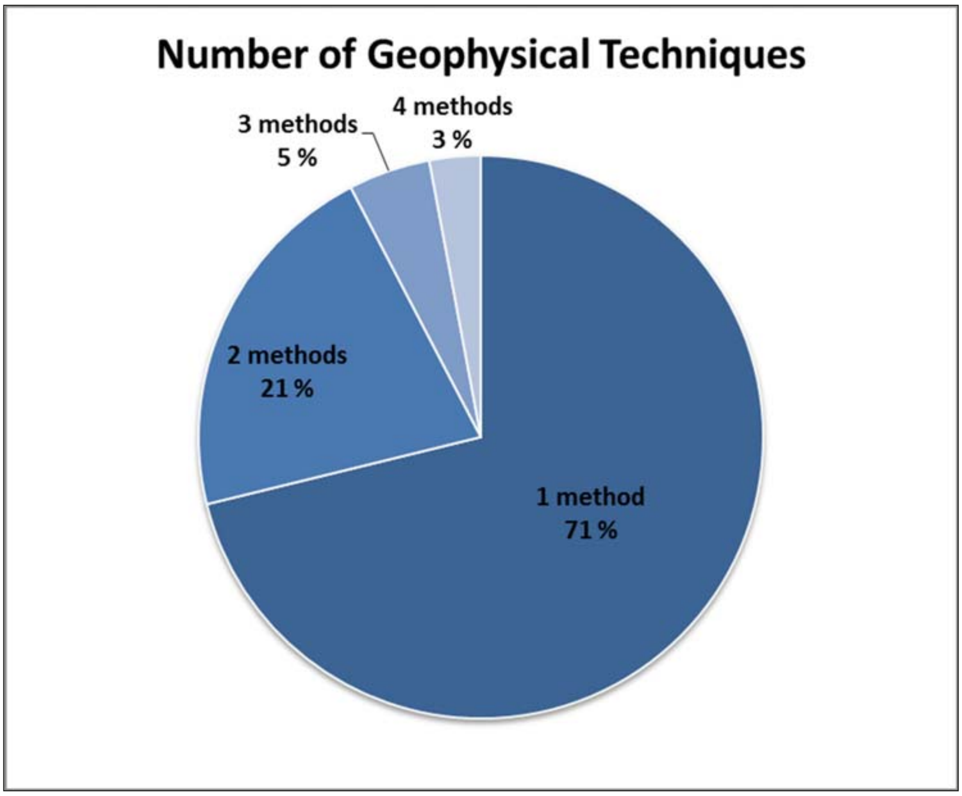

Fig. 8. Graph showing the number of different geophysical methods utilised at each survey.

either smaller private companies or professional competence from abroad, often delivering work of high technical quality. This might create a problem, as competence is not being embedded into institutions involved with archaeological geophysics on a regular basis, and thus specialist knowledge is lacking. The possibilities of acquiring domestic experience-based knowledge have therefore not been ideal. The fact that NTNU and NIKU have started building competence and gaining experience in the field is therefore a positive development of archaeological geophysics in Norway. This creates new possibilities in identifying relevant research questions and developing geophysical field methodologies to tackle the prevailing natural conditions and to better investigate cultural historical sites and features. Archaeological geophysics has not been part of archaeological academic education in Norway, which might have restricted the knowledge about the possibilities and limitations of such methods within the different decision-making bodies responsible for various stages within the Norwegian cultural heritage management. While there is a large expertise in geophysics for marine oil exploration and geological application in Norway both professionally and academically, the possibilities of collaboration and cross-disciplinary knowledge exchange have yet to be exploited.

It is the county archaeologists who are given the main responsibility for the daily management and initial responses to various planning applications. It is here that sites and monuments are being discovered, in addition to some responsibility regarding dissemination and questions from the public. It is therefore interesting to note that only 20 % of the total number of surveys undertaken were commissioned by various county units. Of these, only 22 out of 39 surveys initiated by the counties (out of a total of 197) were for management purposes. This leaves only a total of 11 % of all surveys that were performed in relation to archaeological field evaluation prior to all other archaeological stages. It is also clear that the use does not correlate with the amount of archaeological fieldwork they undertake (Fig. 4). Presently, the Cultural Heritage Act leaves it up to the county archaeologists to choose which method they find suitable to investigate whether or not an area may contain any archaeology protected by law. The uneven distribution of surveys, both geographically (Fig. 3) and compared to the number of archaeological investigations initiated by the county officials due to planning applications (Fig. 4), indicates that there is something else that governs this distribution. The geographic location of available technical personnel, or institutions able to perform a geophysical survey probably influence this distribution. Another factor is the personal interest and knowledge of the official responsible for archaeological field projects related to planning applications or excavations. A notion that the methods are not properly developed, or that their applicability has not been proven, makes it difficult to argue for the additional costs.

The Directorate is currently working on guidelines for counties budgeting for archaeological investigations, i.e. what the developer will have to pay for, but these guidelines were not yet implemented as of March 2013. At present, it is up to the Directorate to approve the budgets, including field methodologies and strategies concerning final excavations performed by the regional archaeological museums, ensuring a fair management practice nationwide. It is likely that the new budget guidelines for the county officials may have implications for or impose restrictions on the approval of choices made by the county archaeologists. Even today the use of geophysical methods is limited, so it will be more important than ever that the personnel involved at county level and in the Directorate have a reasonable knowledge of geophysical methods, if they are to be generally accepted and integrated further so that an optimal gain can be made. It is still difficult to guarantee that any archaeological features will be safely identified by applying geophysical methods, and this creates problems for justifying the application of such methods within a heritage management framework. While the Directorate is positive about the use of non-intrusive methods, they cannot impose costs for research or methodological development on the developer. From a developer's perspective, experience has shown that a good investigation of a planned area early in the planning process could save time and money later in the development process by revealing hindrances, complications and problems early. If alterations are required to the initial planning permission, such costs will be increasingly higher the later on in the process they appear. An inadequate initial archaeological evaluation may lead to additional costs for the developer in later stages (*Karlberg - Jerkø 2009,* 79, 84 and 126). While investigations for the effectiveness of geophysical methods exist elsewhere (for instance *Horsley - Dockrill 2002; Lockhart - Green 2006; Jordan 2009; Viberg 2012; Bonsall et al. 2013*), a detailed study is not yet available in Norway. Studies of cost-benefit aspects of integrating geophysical methods within a cultural heritage management point of view are even scarcer, although a couple of examples from the United States do exist (i.e. *Johnson - Haley 2006; Monaghan et al. 2006*). It is therefore clear that more research on topics such as effectiveness, cost-benefit analysis, and general assessment of different geophysical techniques under varying natural and archaeological conditions is needed. It would also be very interesting to investigate the potential effect of performing geophysics as early in the planning stage as possible, and how the results might alter or impact on the decision-making process throughout the whole project. One potential situation may be that overall costs increase, but that the quality of the management and the degree of protection without the destruction of monuments or features may improve as a result of such integration.

To achieve a general increase in knowledge of the applicability, possibilities and restrictions that exist for the use of geophysical methods, it is important to strengthen the domestic research on the application of such methods. Within Norway there is a vast range of natural conditions and archaeological site types, which can make it problematic to automatically transfer field methodological routines for geophysical surveys from elsewhere. That said, it is not unlikely that several applications could be more or less directly integrated into research and excavation projects, as good parallel examples exist elsewhere. Sometimes scepticism may exist to a proposed application because of a lack of domestic examples, or because the officials are not aware of either domestic or international examples. In such instances it is up to the practitioner and institutions performing geophysical surveys to provide information on the existence and applicability of such examples. An impression we gained when reviewing past geophysical work is that the geophysical reason for a site or feature not being seen in the geophysical data was not revisited and investigated. The archaeological result was in focus, and not the methodological development. This is quite surprising considering that 64 % of all geophysical surveys were performed within a research context. This does not necessarily mean within an archaeological-*geophysical* research context. If the initial integration of such methods in the research project had also included an element of research on the actual geophysical data, and not only expecting archaeologically important information, new lessons could have been learned. Comparisons of the geophysical data with archaeological excavation results is important, and ground-truthing and additional analysis of the geophysical data might provide information that improves our ability to process, analyse and interpret such data (i.e. as described by *Hargrave 2006*), which will in turn influence the way in which the geophysical methods are applied or integrated in future cultural heritage management. This new knowledge needs to be disseminated through published research, at conferences and seminars, as well as at the academic institutions teaching archaeology. It is also important to have targeted research questions to the use of geophysical methods that are connected to issues relevant for current archaeological research and heritage management.

Conclusion

The aim of this paper was to review the archaeological use of geophysical methods in Norwegian cultural heritage management. A database has been compiled with all identified geophysical surveys conducted for archaeological purposes in Norway, which has been used for further analysis. By investigating factors such as who commissioned geophysical surveys, why they were undertaken as well as where, when and how, a deeper understanding of the application of geophysical methods on archaeological sites in Norway could be presented. By combining this with an analysis of the content of official documents from central government agencies, the current status of geophysical methods within the Norwegian cultural heritage management system could be evaluated.

Analysis of the database showed that the use of geophysical has increased within the last decade, with several institutions being involved in the application of geophysical methods. A range of site types had been targeted, with settlement sites and burial monuments dominating. Of all surveys, GPR application has taken over as the most used method, while magnetometers used to dominate – though is still often applied. 71 % of all surveys utilised only one method. Several examples show us that a combination of methods measuring different geophysical properties increases the detectability and available knowledge of an archaeological site (i.e. (*David 2008; Ernenwein - Hargrave 2009; Stamnes 2011; Gaffney - Gaffney 2011*), so this may have restricted the level of success of the surveys. The geographical spread of surveys conducted was large, and there was no correlation between the archaeological activity frequency at county level and the application of geophysical methods within each county. 36 % of all surveys conducted were undertaken for management reasons, while the remaining 64 % were for research purposes. The resulting conclusion of this is that geophysical methods are not an integrated part of everyday cultural heritage management in Norway. While official documents encourage the use of geophysical methods, their application has yet to be generally accepted within the existing cultural heritage management Scheme.

The reason for this is multifaceted. Earlier examples were sometimes of limited value compared with the standards of today, due to poor resolution or technical limitations concerning speed of survey, processing options or visualisation, or methodological choices made. This may have created an impression that such methods “do not work”. However, there are several good examples of interesting survey results in the prevailing natural and archaeological context. We believe that there is large unexplored potential for the successful use and integration of such methods within Norwegian cultural heritage management. Targeted research on field-methodological use of geophysical methods under various natural and archaeological conditions is vital to properly understand how these methods can be beneficial within Norwegian cultural heritage management. This should also involve ground truthing, as well as cost-benefit analysis of the added knowledge gain for proper management and legal protection of sites. Financial aspects of introducing geophysical methods should also be evaluated. The increased focus of such methods within the last decade is seen as positive, and the relatively recent initiative taken by institutions such as the Norwegian Institute of Cultural Heritage Research and the NTNU Museum of Cultural History and Archaeology related to geophysical methods is a step in the right direction for building up domestic experience and knowledge.

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Article II

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Redaksjon:

TIDSFRIST FOR INNSENDELSE AV MANUSKRIPT
TIL VIKING 2014 ER **1. MARS 2014**.

På forsiden:
Spinnehjul med spinnende solmotiv. Holmen, Bjerkreim (S8607).
Foto: © Ragne Johnsrud, Arkeologisk museum, Universitetet i Stavanger

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Geofysiske undersøkelser av kirkegårder, kirketufter og svartjord på Veøya i Romsdal

Veøya ligger midt i det gamle Raumsdalafylket (figur 1). Øyas nordre del betegnes som Nordøya, og her er terrenget lett kupert og preget av grønne enger og løvskog. Den søndre, mer brattlendte delen av øya kalles Sørøya; den er bevokst av furuskog og sitkagran (figur 2).

Over 12 måneder i årene 1989–1992 foretok Brit Solli registreringer og utgravninger i forbindelse med sitt doktorgradsprosjekt (for utfyllende informasjon og referanser, se Solli 1996, 1999). I juni 2011 ble det et nytt gjensyn med Veøya, denne gang i samarbeid med Vitenskapsmuseet (NTNU), som stilte med kompetanse og utstyr til å utføre geofysiske undersøkelser på et nøye utvalgt område (Stamnes 2012).

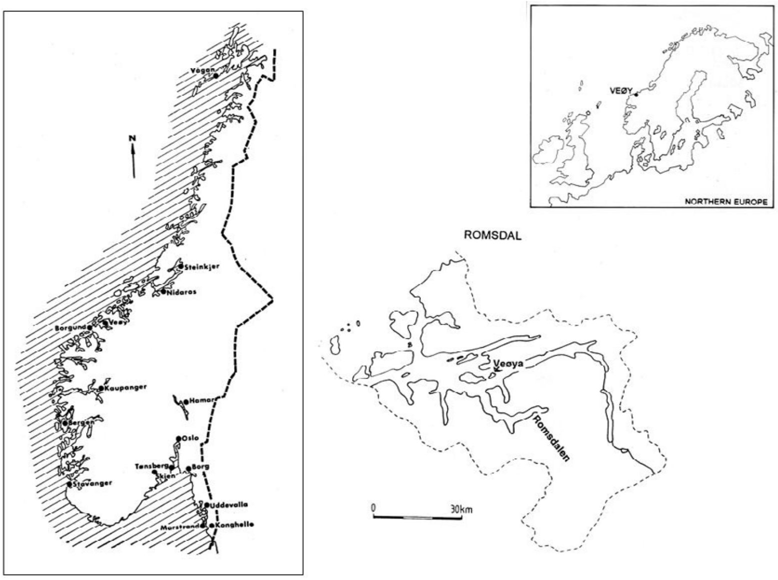
Hovedproblemstillingene med de geofysiske undersøkelsene var å avgrense utstrekningen av og størrelsen på kirketuftene som tidligere har vært påvist midt på to kirkegårder datert til 900-tallet på Veøya. Videre ønsket vi å lokalisere og estimere antall graver, samt å påvise eventuelle andre arkeologiske strukturer og spor etter aktiviteter. Vi hadde også som mål å reflektere over de ulike geofysiske metodenes anvendelse under de gjeldende geologiske forholdene.

I utgangspunktet antok vi at bruken av geofysiske metoder på denne lokaliteten kunne bidra til å øke kunnskapen om grensesnittet mellom svartjorda og de to tidlige kirkegårdene. Vi hadde også et håp om at geofysiske undersøkelser skulle kunne avtegne de to kirketuftene og et visst antall graver. Siden utgravningene tidlig på 1990-tallet hadde avdekket både graver og tufter, ville det være interessant å se om eksempelvis bruk av georadar ville identifisere strukturer som Sollis utgravninger hadde påvist, altså en sjekk mot kjent fasit.

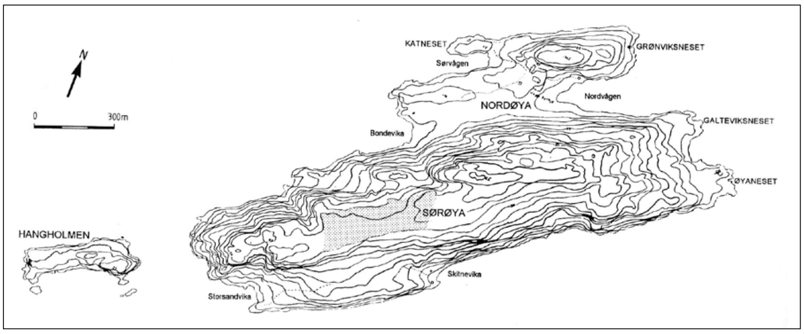
I første del av artikkelen fremlegges resultater fra Sollis undersøkelser i 1990–1992. Disse funnene, som ble avdekket med tradisjonelle arkeologiske utgravningsmetoder, sammenlignes så med resultater fra de geofysiske undersøkelsene.

Kort om Veøyas historie

Første gang Veøya nevnes i en skriftlig kilde, er i Magnus Erlingssons saga (kap. 5–7). I 1161 var Håkon Herdebrei blitt tatt til konge, og sagaen forteller at våren 1162 hadde kong Håkon Herdebrei og hans menn oppholdt seg noen netter i kjøpstedet (*kaupboenum*) på Veøya (Nilsen 1976). Håkon skulle samle folk og skip. Etter noen dager seilte kong Håkon og hans flokk mot sørvest. Da kongen og hans menn drev med våpenlek i en ikke navngitt uthavn ved munningen av Romsdalsfjorden, kom to karer roende med et illevarslende bud: Erling Skakke seilte nordover med 20 skip og var så nær at «nå vil dere snart få se seilene deres». Alle sprang i skipene og satte kursen mot Veøya. Snorre forteller at Håkon ventet seg



Figur 1. Veøya ligger sentralt plassert i det romsdalske fjordsystemet. Tegning: Brit Solli.



Figur 2. Veøya har en utstrekning på 1,1. km^2 og er delt i en nordre og søndre del. Tegning: Brit Solli.

mye hjelp av bymennene (*býjar-monnum*). Det kom til kamp «rett ut for øya Sekken». Den unge kongen fikk banesår i dette slaget.

Midt under borgerkrigstiden ble det reist en steinkirke på Veøya viet til St. Peter. Denne Peterskirken ble bygget i løpet av to faser i perioden 1140–1200 (Stige 2008:79).

Oppkomsten av et kjøpsted på Veøya har hovedsakelig vært forklart med følgende faktorer: sentral beliggenhet i fjordsystemet, gode naturhavner og førkristen kult, jf. øyas navn «ve», som betyr hellig (Bendixen 1878:134; Bergsvik 2003; Fylling 1875:20; Herteig 1954:74; Kraft 1832:187; Olafsen 1926:336; Olsen 1982; Schnitler 1974 [1768]:44; Schøning 1979 [1778]:133; Vik 1959). Solli har argumentert for at Veøyas rolle som en tidlig kristen sentralplass kan ha hatt stor betydning for oppkomsten av et kjøpsted på øya (Solli 1996:183–207).

Det finnes imidlertid også spor etter menneskelig aktivitet på Veøya som går flere tusen år tilbake i tid. De tidligste kjente kulturspor er lokalisert på Sørøya og C14-datert til perioden 1900–1500 f.Kr. Det dreier seg om tykke trekullag, sannsynligvis rester av svirydding, i bunnen av åkerreiner fra overgangsfasen yngre steinalder/eldre bronsealder.

På Sørøya-platået er det også registrert 69 røyser, hvorav 15 antas å være gravrøyser fra jernalderen (Solli 1996:99, figur 34). En gravrøys og en oval steinkrets er sikkert datert til eldre jernalder. I Storsandvika på sørvestsiden av Sørøya er det også påvist gravrøyser. Den største røysa ligger kun 3,1 m over dagens flomål, og antas derfor ikke å kunne være eldre enn fra 900-tallet på grunn av endringene i havnivå (Solli 1996:51; Svendsen og Mangerud 1987).

Om svartjord og oppdagelsen av to kirkegårder

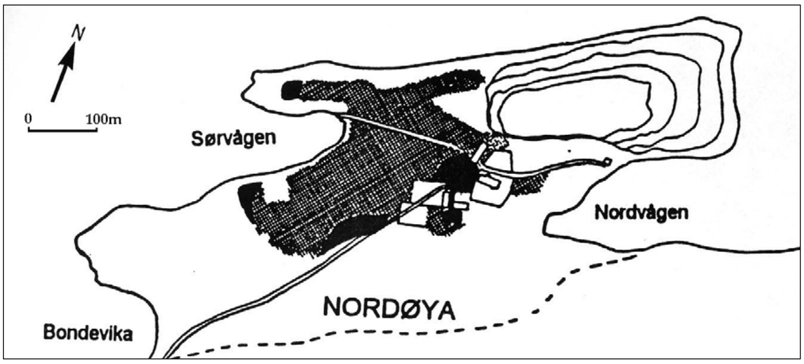
Hans Peter Schnitler nedtegner i 1768 noen meget interessante iakttagelser. På Veøya er den «sorte muldjord» meget dyp, fin og løs. Schnitler tenker seg at jorden er dannet av blant annet råtnende trestubber:

> «Foruden de forraadnede vegetabilia, hvortil kan legges raadent Tømmer og ditto Spone af Brende-Veed, som levninger fra den gamle Kjøbstad Wedøe, have maaske ogsaa af Dyre-Riget de mange begravne Menniskers Kroppe og excrementa fra samme Kjøbstad-Tiid af gjort meget dertil, at denne lille Øes Jord-Art haver i Fedme saa meget forud fremfor alle andre Jordmone i heele Romsdalen» (Schnitler 1974 [1768]:53).

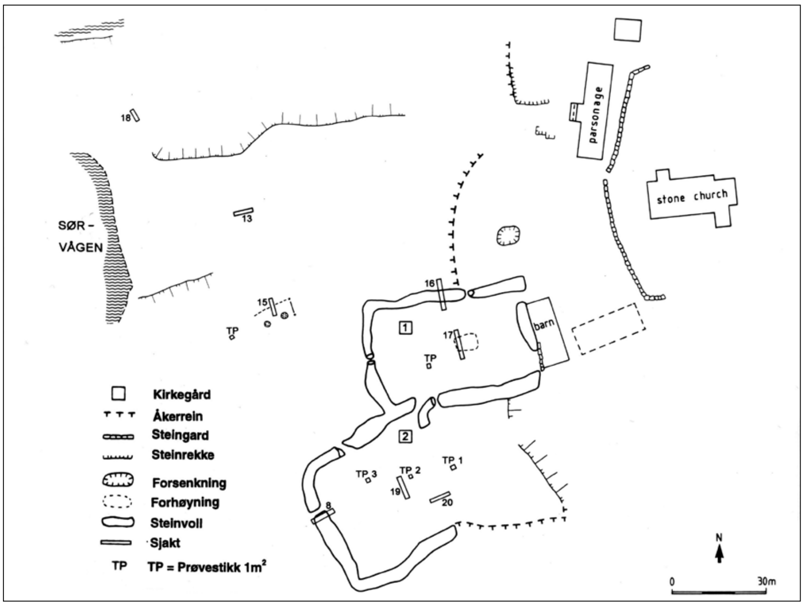
Det Schnitler her beskriver, er forekomsten av arkeologiske kulturlag. De andre topografer, antikvarer og lokalhistorikere kan ikke ha festet særlig lit til Schnitlers tolkning av Veøyas «sorte muld», fordi ingen av dem nevner hans tolkning i sine egne beskrivelser (Bendixen 1878:134; Fylling 1875:20; Kraft 1832:187; Olafsen 1926:336; Schøning 1979 [1778]:133).

Ikke før arkeologen Asbjørn Herteigs utgravninger i 1953 skulle jordsmonnet bli fortolket som rester etter kjøpstedet (Herteig 1954:74). Utbredelsen av svartjorda viser at middelalderkjøpstedet hovedsakelig lå mellom Sørvågen og Nordvågen (figur 3). Svartjorda utgjør et område på om lag 40 mål.

Både Schnitler (1768), Gerhard Schøning (1778) og Bendix E. Bendixen (1877) registrerte på sine befaringer noen lave steinvoller som innhegnet to rektangulære plasser (figur 4–5) vest og sørvest for steinkirken som fremdeles står. Schnitler mente at steinvollene innhegnet to små kirkegårder hvor det hadde stått to kapeller, eller at den ene av innhegningene var restene etter kongsgården på Veøya. Schøning tolket steinvollene til å være rester etter et kloster og et kapell. Christian C.A. Lange (1856) avviser at det noen gang har vært et kloster på Veøya. Han fremholder at den tradisjon rundt 1850 som fortalte om at det hadde vært et kloster på øya, nok var skapt av Schøning selv. I folketradisjonen lever i dag fortsatt fortellinger om at steinvollene er rester etter kongsgården og tingplassen.



Figur 3. Utbredelsen av kulturlag kalt «svartjord», legg merke til to rektangulære områder uten svartjord sørvest for kirken (tegning delvis etter Herteig 1954, de mørkere partiene er Sollis justering av Herteigs kart).

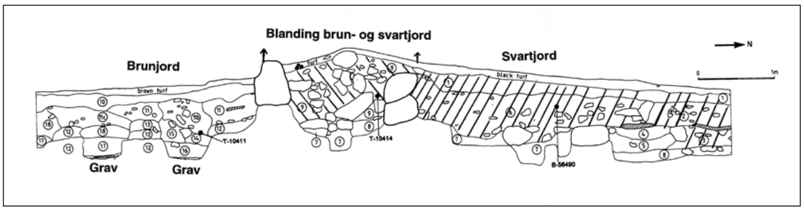


Figur 4. Oversiktskart over sjakter og prøvestikk, samt steinvollene («enclosures») vest og sørvest for steinkirken (jf. Figur 3). Steinvollene omkranser kirkegård nr. 1 og nr. 2. Tegning: Brit Solli.

Figur 5. Undersøkelsesområdet med kirkegård nr. 1 og nr. 2 mot nordøst. Foto: Brit Solli.

I et diplom nedskrevet i Bjarnegården («j Bernargarde j Veæy») på Veøya 19. mai 1343 (Diplomatarium Norvegicum [DN] I:s.226/nr. 285) nevnes et vitne som kalles prest Benedict til Korskirken: «Bendict prestr at Kross kirkiu i Veæy». Den samme Benedict nevnes også i et annet diplom fra 28. januar 1336 (DN I:s.125/nr.105), som kjøper av 2 øresbol i gården Haukås, Vågøy sogn. I dette brevet, som ble skrevet på Vågøya, omtales han som «Benedict prester», oversetterne har tilføyd «i Veö». Utforskere av Veøya har derfor helt siden slutten av 1700-tallet antatt at det fantes flere kirker enn den ovennevnte Peterskirken, som fremdeles står på øya (Schøning 1979 [1778]).

Herteig fikk i 1953 opplyst fra daværende grunneier, Wilhelm Coucheron-Aamot, at det på innsiden av steinvollene ikke er svartjord (jf. figur 3–4). Solli gikk ut fra at hvis dette var korrekt, kunne steinvollene *ikke* være spor etter et kloster eller en kongsgård fordi der hvor folk bodde i middelalderen, vil det være avsatt kulturlag. Det var derfor viktig å sjekke konkret om det fantes svartjord innenfor steinvollene. En sikrere tolkning av hvilken funksjon disse steinvollene hadde hatt, ville dessuten kunne antyde en løsning på problemstillingen omkring *hvorfor* det kom opp et kjøpsted på Veøya. Dette fordi dateringer andre steder i svartjorda viser at kulturlagene begynte å hope seg opp allerede på tidlig 900-tall. Avstengningen og innhegningen av disse plassene kunne derfor vise til en viktig og *primær aktivitet* i kjøpstedets historie.



Figur 6. Profiltegning av sjakt 16 med svartjord på utsiden og brunjord og to graver på innsiden av steinmuren. Tegning: Brit Solli.

Utgravningene på 1990-tallet

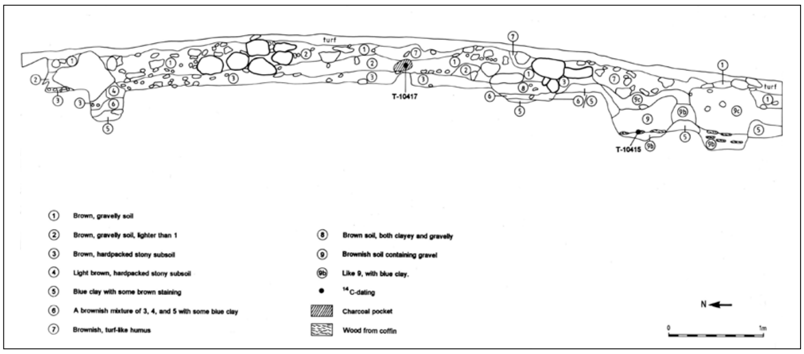
En viktig målsetning med de geofysiske undersøkelsene var å sammenholde geofysikkresultatene med resultatene fra de arkeologiske undersøkelsene på 1990–tallet.

Solli gravde den gang flere sjakter gjennom steinvollene (jf. figur 4). I alle sjaktene var det et markant skille med brun jord innenfor steinvollene og kullsvart jord utenfor (Solli 1996:111).

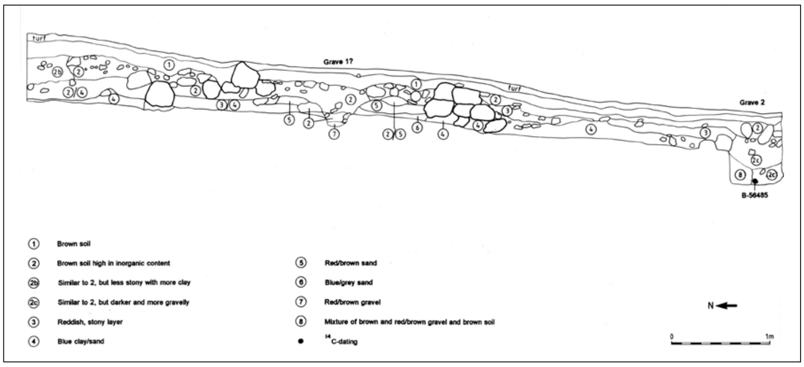
Sjakt nr. 16, som ble lagt tvers gjennom den nordre steinvollen i innhegning nr. 1, skulle gi svaret på det flere hundre år gamle mysteriet om innhegningenes funksjon (figur 6). Muren er bygget opp slik at kraftige steinblokker er lagt ytterst, og slik danner et skall. Hulrommet mellom de ytre veggene er fylt opp av mindre stein, jord og avfallsprodukter av ymse slag. Fyllmassene inne i veggen var en blanding av brun og svart jord. Inne i muren fantes fragmenter av keramikk fra Øst-England (datert til årene 1250–1350) inntil 0,4 m under markoverflaten. Det var færre funn inne i muren enn fra utsiden av muren. Utsiden av muren var dominert av kullsvarte, feite kulturlag. Innenfor muren var det ikke spor av svartjord. Jorda var her sandig og ganske lys brun. Innenfor muren, omlag 0,7 m under markoverflaten, kom det frem to flekker av mørkere brun karakter. De var spor etter to nedgravninger. Like ved steinmuren hadde det dukket opp knokler, bl.a. et helt ribbein og en del av lårbeinet og bekkenet til et menneske. Forsiktig utgravning av de to flekkene som antydet nedgravninger, avdekket en treplanke (grav 1) og et tykt lag av bark (grav 2). Det var ikke lenger noen tvil om hva dette kunne være; det måtte være rester etter to kristne graver! Noen fragmenter av tysk keramikk, såkalt *paffrath* svartgods datert til 1100-tallet, ble funnet innenfor muren, men ikke i direkte tilknytning til de to begravelsene. Steinvollene må ha vært bygget som kirkegårdsmurer, og de innhegnet to kristne kirkegårder.

Siden Solli hadde påvist dateringer fra tidlig 900-tall andre steder i svartjorda, måtte disse to kirkegårdene være anlagt meget tidlig: De innhegnede plassene må ha blitt avstengt fra «dagligdagse» aktiviteter allerede på 900-tallet. Midt inne i muren (sjakt 16), helt i bunnen av kulturlagene, var det en forsenkning som Solli tolket som et stolpehull. Den første innhegningen var derfor trolig en lettere trekonstruksjon. Byggingen av steinmurene hadde skjedd seinere. Disse to rektangulære plassene ble «utparsellert» i den aller tidligste fase av kjøpstedets historie, og plassene var ment å være gravsted for kristne.

I sjakt 17, lagt tvers over en liten forhøyning bestående av stein midt ute på kirkegården, ble det avdekket flere graver, samt klare indikasjoner på at det hadde stått en bygning midt ute på kirkegård nr. 1 (figur 7). Rester etter skjeletter fremkom i form av en feit, brun masse



Figur 7. Profiltegning av sjakt 17 med en plattform med to graver på sørsiden og en på nordsiden, antatt spor etter kirketuft på kirkegård nr. 1. Tegning: Brit Solli.

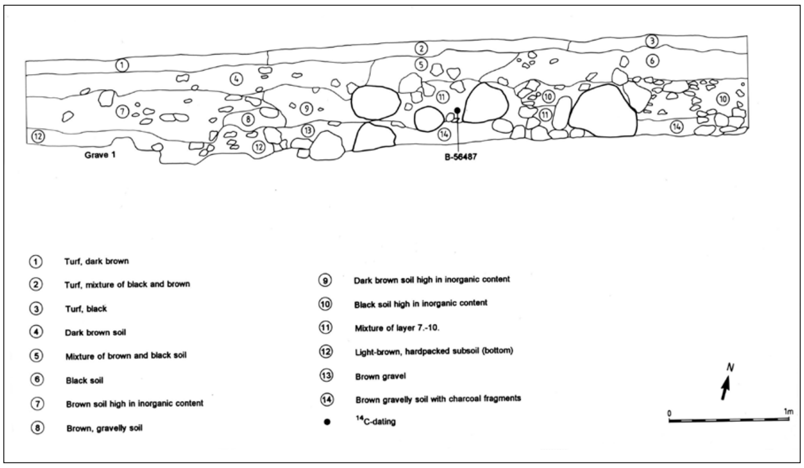


Figur 8. Profiltegning av sjakt 19 midt på kirkegård nr. 2. Tegning: Brit Solli.

på treplankene. Treplankene var bevart fordi de lå nede i blåleira, som hadde virket konserverende på treverket. I de øvre jordlagene hadde det porøse jordsmonnet ført til at det hadde kommet luft ned i jordlagene, og gjort at alt organisk materiale, både treverk og skjeletter, hadde råtnet bort.

Gravene var lagt helt inntil en plattform av hardpakket jord som ikke hadde spor etter graver. Oppe på denne plattformen lå et lag av stein. I både nord og sør var steinene av en slik størrelse at de trolig har fungert som fundamenter for den bygningen som har stått der. Denne bygningen kan ikke ha vært noe annet enn en kirke. Kirken har vært 6,2 m bred, og må ha vært en trebygning. Bredden antyder at dette har vært en relativt stor kirkebygning.

Midt ute på kirkegård nr. 2 (jf. figur 4) ble det funnet spor etter en bygning (sjakt 19) i form av kraftige murrester (figur 8). Også her ble det påvist graver. I den ene var det nagler med fastrustede trerester.



Figur 9. Profiltegning av sjakt 20, der avgrensningen mot øst av kirkegård nr. 2 ble avdekket i form av rester etter en steinmur under markoverflaten. Tegning: Brit Solli.

Inne i fundamentene til den bygningen, som må ha stått midt på kirkegård nr. 2, lå et keramikkfragment som stammer fra Beverly i Øst-England. Dette er en type keramikk som ble produsert på 1000- og 1100-tallet. Keramikkskåret viser at denne bygningen ble reist i løpet av 1000- eller 1100-tallet. Også bygningen på kirkegård nr. 2 kan ha vært en kirke eller et kapell. Hvis det er kirkens skip sjakten løper gjennom, tyder det på at denne kirken har vært en mindre bygning enn kirken på kirkegård nr. 1. Avstanden mellom fundamentene i nord og sør er bare litt over 2 m. Til sammenligning kan nevnes at stavkirken på Høre i Valdres har et «skip» som ikke er større enn 3,6 x 3,6 m. Det er også mulig at sjakt 19 løper gjennom kirkens kor og ikke dens skip.

Inne på kirkegårdene ble det også gravet tre 1 x 1 m store prøveruter. Det var kun i den ene på kirkegård nr. 1 at Solli fant nok en grav. De to prøverutene på kirkegård nr. 2 viste at jordsmonnet her er grunnere og består av mer hardpakket grusig jord. Det er mulig at mens kirkegård nr. 1 er fullpakket med graver, er det noe mer glissent på kirkegård nr. 2, trolig pga. skrinnere jordsmonn og mer uegnede forhold. En prøverute ble lagt i svartjorda rett øst og altså utenfor den antatte kirkegårdsmuren. Denne prøveruten inneholdt funn av vanlig svartjordskarakter.

I sjakt 20 avdekket Solli den østlige avgrensningen av kirkegård nr. 2 i form av murrester under markoverflaten, på utsiden var det svartjord, på innsiden brunjord. I tilknytning til sjakt 20 ble det funnet en grav orientert øst–vest (figur 9). Alle gravene som ble avdekket, var orientert øst–vest. I noen av dem fant Solli fragmenter av tenner i den vestlige delen av graven. Det mønster dateringene av gravene og jordsmonnet innenfor, i og utenfor steinvollene danner, er oppsiktsvekkende (tabell 1). På Veøya har folk fått en kristen begravelse allerede på 900-tallet, og siden det ikke finnes svartjord innenfor kirkegårdsmurene, må anleggelsen av de to kirkegårdene ha skjedd i den aller tidligste fasen av kjøpstedets historie.

Tabell 1. Nedenfor følger 19 ^{14}C-dateringer som er direkte relatert til kirkegård 1 og 2 (BP = Before Present, kalibrerte kalender dateringer AD = etter Kr.f., for kalibreringskurver se Solli 1996:152–178):

Sjakt 8:			
Utenfor muren, T-9284:	835 ± 70 BP	AD 1065–1265	(bjørk)
Sjakt 16:			
Grav 2, T-10412:	1115 ± 80 BP	AD 820–1000	(furu)
Grav 2, Beta 56480:	1060 ± 60 BP	AD 897–1018	(furu)
Grav 1, Beta 56479:	1180 ± 70 BP	AD 772–953	(bjørk eller ospebark)
Grav 1, T-10411:	1110 ± 150 BP	AD 725–1030	(menneske)
Innenfor muren, T-10413:	885 ± 95 BP	AD 1025–1250	(bjørk)
Inne i muren, T-10414:	870 ± 65 BP	AD 1040–1230	(bjørk)
Inne i muren, Beta-56881:	890 ± 80 BP	AD 1027–1230	(bjørk og furu)
Utenfor muren, Beta-56490:	900 ± 80 BP	AD 1024–1225	(lind, bjørk og furu)
Sjakt 17:			
Grav 1, Beta-56482:	910 ± 50 BP	AD 1030–1183	(furu)
Grav 2, Beta 56483:	1090 ± 60 BP	AD 889–1008	(furu)
Grav 2, T-10415:	1100 ± 40 BP	AD 890–990	(furu)
Grav 3, Beta-56484:	1130 ± 60 BP	AD 828–980	(furu)
Grav 3, T-10416:	1100 ± 40 BP	AD 890–985	(furu)
Trekullansamling i profilen, T-10417:	520 ± 90 BP	AD 1305–1445	(furu og bjørk)
Sjakt 19:			
Grav 1?, T-10418:	985 ± 100 BP	AD 970-1160	(bjørk, furu, hassel)
Grav 2, Beta-56485 (AMS):	1160 ± 50 BP	AD 789–954	(muligens furu)
Under muren, Beta-56486:	950 ± 70 BP	AD 1012–1166	(bjørk og hassel)
Sjakt 20:			
Under muren, Beta-56487:	1080 ± 90 BP	AD 883–1021	(bjørk 29 fragm.,furu 1 fragm.)

Kulturhistorisk tolkning

Harald Hårfagre sendte sin sønn Håkon til England for å vokse opp hos den angelsaksiske kong Athelstan. I England fikk Håkon en kristen oppdragelse. En gang i løpet av 930-årene kom han til Norge. Sagaen forteller at han sendte bud etter prester og en misjonsbiskop som het Sigfried. I Håkon den godes saga (kap. 13) heter det:

> «Da nå kong Håkon trodde han hadde fått støtte nok av noen stormenn til å få fram kristendommen, sendte han bud til England etter en biskop og noen andre prester, og da de kom til Norge, gjorde kong Håkon det kjent at han ville by kristendom over hele landet. Møringene og romsdølene sa de ville gjøre som trønderne. Kong Håkon lot nå vie noen kirker og satte prester til dem.»

Seinere ble det klart at trønderne ikke syntes noe om den nye sed og skikk som Håkon ville innføre i landet, og «uttrønderne seilte med fire skip sør til Møre, og der drepte de tre prester og brente tre kirker, så seilte de hjem» (Håkon den godes saga, kap.18).

Disse tre kirkene på «Møre» kan ha blitt bygget i 950-årene i hvert av de middelalderske fylker, én på Sunnmøre, én i Romsdal på Veøya og én på Nordmøre. Siden en korskirke nevnes så seint som i 1343, er det sannsynlig at minst én av de to trekirkene på kirkegård nr. 1 og nr. 2 fortsatt var i bruk på den tiden. Peder Fylling (1875:12) nevner at en «Sigurd

Johgrimsen» skal ha vært prest i Korskirken så seint som i 1439, men i kilden (diplomet) han bygger på, sies det kun at Sigurd Johgrimsen var «kirkiu prester j Vidhøy j Raumnsdale»/«prest i Veøy kirke i Romsdal» (DN V:s.493/nr.683). Korskirken var trolig forsvunnet i 1439. Etter svartedauden omkring 1350 må begge trekirkene på Veøya ha forfalt raskt, og etter hvert som tiden gikk, ble de offer for historiens glemsel.

Sæbjørg W. Nordeide har ganske nylig rekalibrert Sollis BP-dateringer (jf. tabell 1) ved bruk av et nyere kalibreringsprogram: OxCal (Nordeide 2011:143–144). Med bakgrunn i rekalibreringen argumenterer hun for at noen graver kan dateres til 800-tallet. Nordeide diskuterer imidlertid ikke kildekritiske forhold omkring dateringsmaterialet (hovedsakelig furu, ytre årringer der det var mulig) og dateringsmønsteret innenfor kirkemurene sammenholdt med svartjordsdateringene. Hun postulerer at de tidlige kristne gravplassene på Veøya har sin bakgrunn i at det på 800-tallet var et kloster på øya grunnlagt av utenlandske munker som ledd i en misjonsstrategi (Nordeide 2011:146). Nordeide (2011:301) mener at Veøya har «a remote location» som kunne passe for britiske munkers lokaliseringsstrategi. Veøya har imidlertid *ikke* en «remote» plassering der den ligger sentralt i det romsdalske fjordsystemet, så å si midt i leia. Hun avskriver også betydningen av de hedenske gravfeltene på Sørøya som «not overwhelmingly present» (Nordeide 2011:318). Det er overveiende sannsynlig, på grunn av endring i havnivå (se ovenfor), at gravfeltet i Storsandvika ble anlagt da de angivelige britiske munkene skulle ha hatt et kloster på øya. Nordeides spekulasjoner om britiske munker på Veøya i det niende århundre har verken støtte i skriftlige eller arkeologiske kilder.

Solli (1996) argumenterer for at den eller de som kontrollerte Veøya omkring 950, må ha konvertert til kristendommen, og fremholder derfor at det er sannsynlig at Veøya i løpet av 900-tallet ble kontrollert eller forsøkt kontrollert av en stormannsfamilie med sterke bånd til det ekspanderende rikskongedømmet med misjonskongene Håkon den gode og Olav Tryggvason som frontfigurer. Men bildet er ikke entydig, fordi det på 900-tallet fortsatt gravlegges folk på hedensk vis sørvest på Veøya.

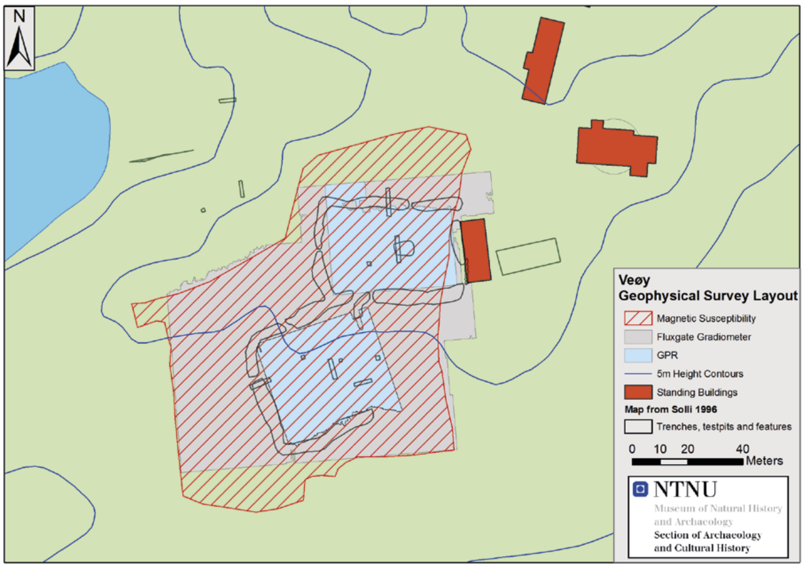
Veøya kan ha vært et regionalt møtested under sesongvise kulthandlinger i førkristen tid, men slike handlinger er det selvfølgelig vanskelig å finne konkrete arkeologiske spor etter (Solli 2005). Hvis Veøya var et førkristent kultsted, ville det vært viktig for kristningskongene, eksempelvis Håkon den gode, å få fotfeste på øya. Veøya var derfor trolig det første kristne stedet i Romsdal. Begrepet *mikrokristenheter* (Schumacher 2005:71) kan være en måte å beskrive slike kristne «lommer» som oppsto under den lange kristningsprosessen av Vest-Norge. En mikrokristenhet kunne oppleve tilbakeslag, forsvinne, for så å oppstå igjen. Rikssamlingsprosessen, misjonskongene og etter hvert kristne gravplasser og kirker gjorde at den sentrale øya midt i fjordsystemet ble enda mer sentral i løpet av den tidlige kristne middelalder.

Undersøkelsesområdet og de geofysiske metodene

Vårt primære mål var å undersøke de to tidlige kirkegårdene. I den forbindelse var det viktig også å få et inntrykk av forholdene i tilknytning til kirkegårdene. Derfor strakte undersøkelsesområdet seg utover steinvollene som omkranser de to kirkegårdene (figur 10).

Vi anvendte tre forskjellige geofysiske metoder:

Målemetode 1: *Magnetisk susceptibilitet* ble målt for å kartlegge variasjoner i jordas magnetiske egenskaper, og er en metode som kan anvendes til å avgrense spor etter menneskelig aktivitet. Aktivitet som brenning, biologisk nedbrytning samt temperatursvingnin-



Figur 10. Utbredelsen av området for de geofysiske undersøkelsene. Kart: Arne A. Stamnes.

ger kan endre de magnetiske egenskapene i de jernmineralene som er til stede i bakken, og gjøre at jorda blir mer mottagelig for påvirkning av et magnetisk felt. Dette kalles også for magnetisk mottagelighet. Tilførsel av menneskeskapt materiale som keramikk eller verkstedsavfall har samme effekt på målingene. Magnetisk susceptibilitet er dermed en måling av hvor mye jorda blir påvirket av nærværet av et eksternt magnetfelt (Clark 2001; Dalan 2008; Dearing 1999; Gaffney og Gater 2003; Linderholm 2003).

Det er kontrasten mellom arkeologiske strukturer og den omliggende massen som er avgjørende for hvorvidt arkeologiske strukturer kan oppdages ved hjelp av et magnetometer (Aspinall mfl. 2009; Clark 2001). Slike arealundersøkelser med magnetisk susceptibilitet har tidligere gitt positive resultater ved avgrensningen av fortidig menneskelig aktivitet i Norge (Gustavsen og Stamnes 2012; Stamnes 2010, 2011). På Veøya ble det utført 318 målinger over et ca. 10 500 m² stort område; det tilsvarer en måling pr. 5,7 x 5,7 m (utført med en Bartington MS2 D sensor).

Målemetode 2: Hvis en struktur har et materiale med høyere eller lavere magnetiske egenskaper enn det omliggende materialet, kan det måles med et magnetometer. Ved å ha to magnetometre montert over hverandre, noe som kalles et *gradiometer*, kan man fjerne effekten av jordas magnetfelt og derved måle variasjoner i styrken til et lokalt magnetfelt forårsaket av strukturer under bakken. Litt enklere forklart får man ved å utføre systematiske målinger et kart over lokale «magneter» i bakken som har en avvikende magnetisk styrke sammenlignet med omgivelsene, gjerne kalt magnetiske *anomalier*, og disse anomaliene kan representere arkeologiske strukturer.

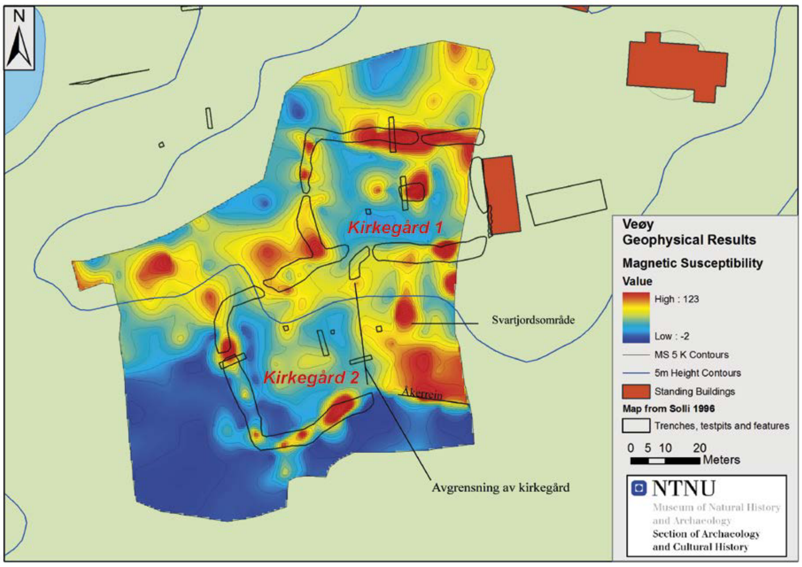
Typiske strukturer som kan gi seg utslag som magnetiske avvik eller anomalier, kan være grøfter, groper eller steinstrukturer. Metoden er regnet som velegnet til å oppdage spor etter brenning eller «industriell» aktivitet, eksempelvis smieområder. Gjennom metoden kan man oppdage strukturer med en diameter ned mot 0,5 m (Aspinall mfl. 2009; Clark 2001; Gaffney og Gater 2003). I alt ble ca. 9300 m² undersøkt med denne metoden (utført med en Bartington Grad 601–2 med to fluxgate gradiometer-sensorer).

Målemetode 3: Ved å sende pulser av elektromagnetiske bølger ned i undergrunnen med en *georadar* og måle tiden det tar for disse bølgene til å bli reflektert tilbake til en mottaker, kan man danne seg et detaljert bilde av undergrunnen. Der signalet møter ulike lag eller forskjeller, vil noe av energien bli reflektert, mens noe av energien vil fortsette dypere ned og bli reflektert av strukturer dypere nede i bakken. Det er i stor grad endringer i materialets elektriske ledeevne som avgjør om et materiale skaper en refleksjon av de elektromagnetiske bølgene. Refleksjoner som avviker, såkalte *anomalier*, bør ha en form og/eller geofysisk signatur som kan tolkes som arkeologisk, eller fremstå i et system eller en kontekst som antyder menneskeskapte strukturer. For eksempel kan enkeltliggende «stolpehull» være vanskelige å tolke som menneskeskapte, mens systematiske rader av stolpehull med en tilstrekkelig geofysisk kontrast er lettere å gjenkjenne. En georadar kan brukes til å oppdage grøfter, groper og murverk, og metoden er den som med høyest sikkerhet kan påvise stolpehull. Ved å foreta målinger i linjer hver 25. cm, bør strukturer på en størrelse på ca. 50 cm i omkrets kunne påvises hvis de består av et materiale med den nødvendige kontrasten sammenlignet med omgivelsene (Conyers 2004; Gaffney og Gater 2003:47–51; Goodman 2009; Stamnes 2010). I alt ble det samlet inn 12 089 lengdemeter georadardata over et område på ca. 3040 m², med respons ned til ca. 1,4 m dybde (med en GSSI Sir-3000 georadar med 400Mhz antenne; for mer informasjon om databehandling, se Stamnes 2012:61).

Kunnskap om undergrunnen er viktig ved anvendelse av geofysiske metoder. På Veøya består berggrunnen hovedsakelig av metamorfe bergarter som diorittisk til granittisk gneis og migmatitt (Norges geologiske undersøkelse 2013). De er dannet under høyt trykk eller høye temperaturer, som kan medføre at de vil ha en viss form for egenmagnetisme. Det *kan* medføre forstyrrelser i eventuelle magnetiske målinger. Løsmassene på Veøya er hav- og fjordavsetninger. Leire, og spesielt homogen saltholdig blåleire, kan vanskeliggjøre bruken av georadar, siden den kan helt eller delvis absorbere energien som sendes ned i bakken (Conyers 2004; Gaffney og Gater 2003).

Resultater av målingene av magnetisk susceptibilitet

Målingene av *magnetisk susceptibilitet* viste tydelige soner med forhøyede verdier (figur 11). I felt ble det også gjort målinger av den magnetiske susceptibiliteten oppe på steinvollene, og det kommer klart frem at mange av de steinene som er brukt i muren, er mer magnetiske enn sine omgivelser. Solli påviste i sine sjakter svartjord på utsiden av kirkegårdene, men ikke på innsiden. Det er også en åkerrein på østsiden av kirkegård nr. 2, på den sørlige siden av et område med registrert svartjord. I den sammenheng er det derfor trolig at de forskjellene som sees tydelig i de magnetiske målingene på østsiden av kirkegård nr. 2, med lave verdier på innsiden og høye verdier på utsiden, reflekterer kirkegårdens utstrekning mot øst. Der er det i dag ikke bevart noen steinmur på markoverflaten, men det ble funnet rester fra en steinmur i Sollis sjakt 20. Som vi vil se senere, reflekteres det også klart i



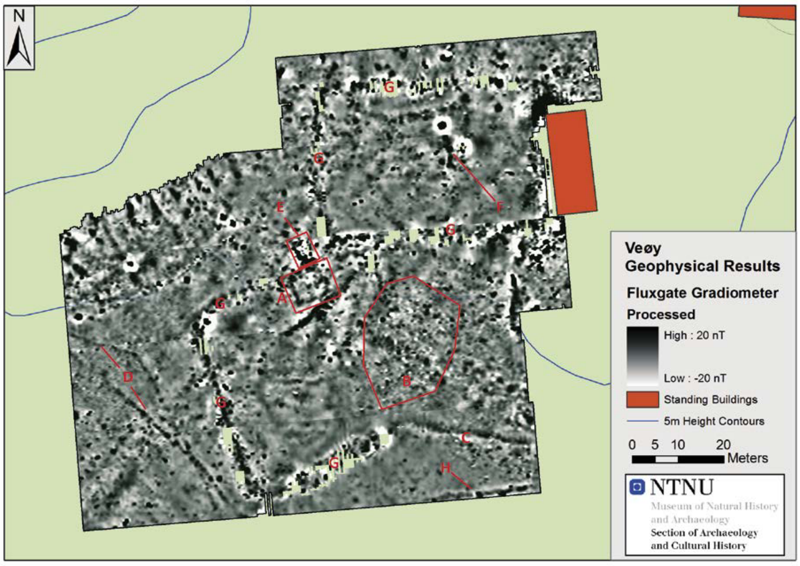
Figur 11. Geofysiske resultater av målingen av magnetisk susceptibiltet. Kart: Arne A. Stamnes.

gradiometer-kartleggingen. I den sørøstlige delen av området øker verdiene mot kanten av åkerreina i sør (jf. figur 4). Det kan ha sammenheng med at mer magnetisk materiale er blitt flyttet nedover mot sør som følge av pløying og avrenning. I den sørvestre del av området er det ganske lave verdier, og det sees et skille i de målte verdiene som går i retning øst–vest omtrent rett vest for den vestlige inngangen til kirkegård nr. 2. Det sammenfaller godt med Herteigs og Sollis kartlegging av utstrekningen av svartjordslaget på Veøya (jf. figur 3). Nord for denne inngangen ble det målt relativt høye verdier, som kan reflektere et fortidig aktivitetsområde. I midten av begge kirkegårdene er det områder med forhøyede verdier. Det kan ha sammenheng med eventuelle bygningsmasser, som påvist av Solli. Områdene mot sør er lavereliggende i terrenget og relativt fuktige. Trolig bidrar fuktigheten i bakken til å vaske ut de magnetiske jernmineralene fra toppen av matjorda og slik bidra til de lave måleverdiene.

Vi kan konkludere med at den kjente distribusjonen av svartjordslag reflekteres godt i målingene av magnetisk susceptibilitet. Målingene bekrefter observasjonene Solli gjorde angående skillet mellom jordlagene innenfor (brun) og utenfor kirkegårdene (svart).

Resultater av målingene med gradiometer

I figur 12 er enkeltstående anomalier eller større områder med avvikende signal merket av med bokstavene A til H. I tillegg til dem er det en rekke enkeltliggende anomalier og soner



Figur 12. Geofysiske resultater av målingen med fluxgate gradiometer, tolking A-H, se teksten. Kart: Arne A. Stamnes.

som kan ha arkeologisk betydning. Blant annet ble det påvist en bygning (A), en sone med avvik som er satt i sammenheng med avgrensningen av svartjordslaget (B), og en åkerrein (C). De blir beskrevet mer i detalj nedenfor:

A: Innenfor det avmerkede rektangelet er det en noenlunde rektangulær anomali som måler ca. 8 x 6,5 m. Den ligger inntil kirkegårdsmuren og tilsier at det ikke er forårsaket av arkeologi eldre enn muren. Denne anomalien kan med stor sannsynlighet tolkes som en bygning.

B: Innenfor og omkring det avmerkede arealet kan det observeres en sone med økt magnetisk aktivitet, hvor det er en rekke små avvik med høye og lave verdier om hverandre. Grunnen til det er trolig masse som inneholder en del mindre magnetiske strukturer som er blandet sammen, trolig et kulturlag som inneholder skjørbrent stein. Vi vet fra Sollis undersøkelser på 1990-tallet at det er et svartjordsområde med skjørbrent stein innenfor dette området, og vi anser derfor denne tolkningen som svært sannsynlig. Dette resultatet er ett av få positive identifikasjoner av et svartjordsområde gjort med gradiometer i Norge, en parallell finnes på Logtun i Frosta kommune (Binns 1997). Ytterkantene av dette området kan sees i sammenheng med de målte verdiene for magnetisk susceptibilitet, og kan bidra til å avgrense kirkegården i øst.

C: Den rettlinjede anomalien som strekker seg fra øst-sørøst mot vest-nordvest, er nedre kant av en åkerrein som også er synlig på markoverflaten (jf. figur 4). Det gir et interessant bilde av hvordan en slik åkerrein kan arte seg i gradiometerdata.

D: Disse to anomaliene har en temmelig rak retning og brå vinkler. De kan være forhistoriske, men veldig rette anomalier er erfaringsvis ofte moderne. Det kan derfor være spor etter drenerende veiter hvor mer magnetisk materiale, for eksempel overliggende kulturlag eller magnetiske steiner, kan ha falt ned i grøftene ved etterfylling. Kunnskapen om plasseringen av disse veitene kan komme godt med hvis man seinere en gang ønsker å foreta målrettede arkeologiske undersøkelser. For eksempel vil det være mulig å fjerne masse fra veitene uten å gjøre inngrep i de omliggende arkeologiske kulturlagene.

E: Denne anomalien sammenfaller med plasseringen av en kjent smie. Det er et etterreformatorisk bygg, og syllsteiner er synlige på overflaten. Det relativt avgrensede området med magnetisk forstyrrelse tyder på at noe smieslagg eller andre avfallsprodukter er spredt rundt selve bygningen, men i et begrenset omfang.

F: Den positive (mørke) linjen ligger litt øst for Sollis sjakt 17 (jf. figur 7). Den kan være et resultat av opplagte masser, som skaper en linje ca. 1 m øst for sjakten. De to runde, kraftige anomaliene omgitt av en negativ glorie er kraftige metallutslag. Hva dette metallet er, vet vi ikke, men plasseringen viser en viss mulighet for at et graveredskap ble gjenglemt da sjakt 17 ble fylt igjen.

G: Dette er kirkegårdsmurene. De er klart synlige i overflaten, men gir også kraftige avvik. Det forteller oss at mye av steinen som er brukt i murene på Veøya, er magnetisk i seg selv. Enkeltliggende avvik viser en sterk egenmagnetisme, og kan være forårsaket av stein, ikke i selve steinvollene, men i undergrunnen. Det er derfor også grunn til å anta at deler av de presenterte dataene bærer preg av forstyrrelser fra magnetisk geologi, som vanskeliggjør identifiseringen av mindre arkeologiske strukturer.

H: Denne rettlinjede anomalien er sannsynligvis forårsaket av moderne drenering av myra. Det ble lagt ned dreneringsrør i 1977 (Eide 1978).

Resultater av georadarmålingene

Vi vet fra tidligere arkeologiske undersøkelser at graver er blitt påvist innenfor begge kirkegårdene. Disse gravene er ca. 0,4–0,7 m brede og orientert noenlunde øst–vest. Undergrunnen innenfor kirkegård nr. 1 er i profiltegningen (jf. figur 7) for sjakt 17 beskrevet som brun, hardpakket og steinete. I den søndre enden av sjakt 17 var det våt blåleire i bunnen. I bunnen av sjakt 16 var det hard blåleire. Nedgravningene med gravene er i sjakt 17 fylt med grusholdig, brunaktig jord. I sjakt 16 (jf. figur 6) er fyllet lett, leiraktig jord eller sandig og feit brun jord. På kirkegård nr. 2 er det i sjakt 19 (jf. figur 8) en undergrunn av blåleire/sand, hvor gravene er fylt med en blanding av brun jord og rød og brun grus. I noen tilfeller var det bevarte rester av bark (i sjakt 16) og treplanker i bunnen av gravene (Solli 1996:141–170).

Siden man er avhengig av en forskjell mellom kutt og fyll for å få en geofysisk kontrast, er informasjonen ovenfor *meget viktig*. Ren, salt leire vil i ekstreme tilfeller kunne sluke all energien og ikke reflektere den tilbake til overflaten (Conyers 2004). Ved analysen av georadardataene fra kirkegårdene lette vi spesielt etter strukturer som kunne være rester av bygninger eller graver som tidligere var identifisert av Solli.

Georadarresultater på kirkegård nr. 1

På kirkegård nr. 1 viste det seg å være vanskelig å etterspore individuelle graver. Responsen over hele kirkegården varierer. Gjentatte oppgravinger og tilføring av masser, som ved gra-

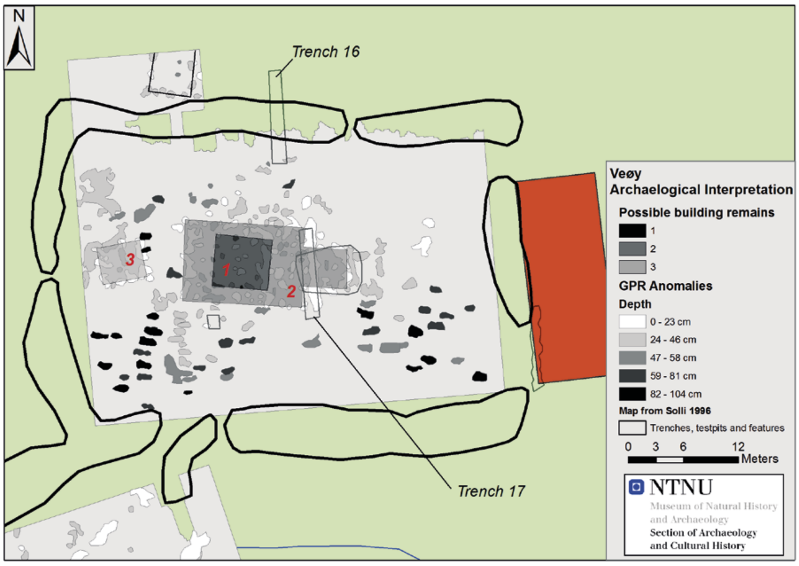
Figur 13. Den arkeologiske tolkningen av georadarmålingen med anomalier. Kart: Arne A. Stamnes.

ving av graver, har sannsynligvis endret den elektriske ledeevnen og derfor ført til en slik variert respons (jf. figurene 38–42 i Stamnes 2012).

En rekke av anomaliene har imidlertid en form og orientering som antyder at de reflekterer graver (figur 13), men det er ikke en sikker tolkning.

Når det kommer til mulige bygningsrester, er det et område i midten av kirkegård nr. 1 som peker seg ut som spesielt interessant. To tufter, hvorav én er mer dyptliggende, tolkes som mulige kirkebygg. Spor etter en tredje bygning, med en litt annen orientering, ligger vest for de to mulige kirketuftene. Det er også en mulig bygning utenfor kirkegårdsmuren mot nordvest. Det passer godt med Sollis utgravningsresultater, i og med at bygningene 1 og 2 ligger ved og rundt den plattformen med hardpakket jord som Solli da tolket som fundamentet til en kirke inne på kirkegård nr. 1 (jf. figur 7). Nedenfor følger en detaljbeskrivelse av disse tre bygningene (se figur 14):

Bygning 1 ser ut til å være kvadratisk, og er ca. 5,6 m x 5,8 m. Bygningen er orientert omtrent øst–vest. Den er mest tydelig fra 45–80 cm dybde, men den nord–sør-gående langsiden på østsiden av bygningene er synlig høyere oppe. Denne geofysiske responsen kan muligens forklares med større hjørnestolper, med en diameter på opp mot 55 cm, forbundet med mulige syllstokker. Det er mulig å spore 6–7 stolper på den sørlige og østlige langveggen. Dybden av dette relativt klare mønsteret kan tilsi at det er en eldre bygning, og da muligens en eldre fase av flere mulige kirkebygg inne på området. Plasseringen er ikke helt



Figur 14. Tolkning av resultater på kirkegård nr. 1 med bygning 1–3. Kart: Arne A. Stamnes.

sentral og har et ørlite avvik i orientering fra det som er tolket som bygning 2, som presenteres nedenfor.

Bygning 2 ser ut til å være en rektangulær bygning, hvor det er mulig å tolke inn et skip på ca. 12–13 m x 8,2 m, orientert noenlunde øst–vest, og et kor på kanskje 4,7 m x 4,5 m øst for skipet. Det gir totalt en bygning på en lengde opp mot 16,5–18 m og en bredde opp mot 8,2 m. Sollis sjakt nr. 17 kan sees tydelig i de geofysiske dataene, og hjelper til med å relatere noen av hennes resultater med den tolkning som er presentert her. Sjakt nr. 17 avdekket en hardpakket plattform (ca. 6,2 m bred), der det ble påvist graver både nord og sør for denne plattformen. Plattformen sammenfaller med det som er tolket som et kor, og som da strekker seg ca. 3–3,5 m øst for sjakt 17. Bygning 2 er muligens yngre enn bygning 1.

Bygning 3 er orientert vest–sørvest og øst–nordøst, og er noenlunde kvadratisk, med målene 4,5 x 4,5 m. Omrisset av bygningen kan også skimtes i magnetometerdataene presentert i figur 12. Orienteringen og plasseringen avviker fra de andre påviste bygningene. Bygning 3 kan være et frittstående klokketårn, en såkalt støpul, som ikke er uvanlig ved stavkirker (Swensen 1981:523).

Georadarresultater fra kirkegård nr. 2

Det generelle inntrykket av den geofysiske responsen er som på kirkegård nr. 1. Enkelte områder fremstår med kraftige refleksjoner, og enkeltliggende anomalier fremstår med en utstrekning som gjør at de kan være av arkeologisk art. Dessverre er det få anomalier nær

Sollis sjakt 19 som kan sees i noen romlig sammenheng, eller ha et system som kan hjelpe oss med å identifisere noen bygningsrester her. Dette er metodologisk påfallende fordi det i sjakt 19 ble avdekket en solid mur av store steiner (jf. figur 8). Enkelte systemer av anomalier bidrar imidlertid til å øke den arkeologiske kunnskapen om området. De viktigste av dem er følgende:

- Det er mulig å se en del av refleksjonene i georadardataene i sammenheng med veien/stien fra åpningen i vest og opp mot den andre åpningen i det nordøstre hjørnet. Det er vanskelig å anslå om vi her snakker om en eldre vei, eller om denne responsen er forårsaket av dagens sti.
- Nord for denne veien er det enkelte anomalier som kan relateres til en mulig bygning som ble identifisert i gradiometerdataene (se bokstav «A» i figur 12).
- Mot øst lar det seg gjøre å identifisere rester av kirkegård nr. 2s østre avgrensning. Disse anomaliene kommer ikke klart frem, men enkelte bruddstykker er synlige, og en helt klar soneforskjell i responsen er tydelig ved et visst dyp (se for eksempel Stamnes 2012:figur 37, ved 58–65 cm dyp). Denne avgrensningen sammenfaller med både dataene fra magnetisk susceptibilitet og gradiometer (Stamnes 2012:figurene 6–13).

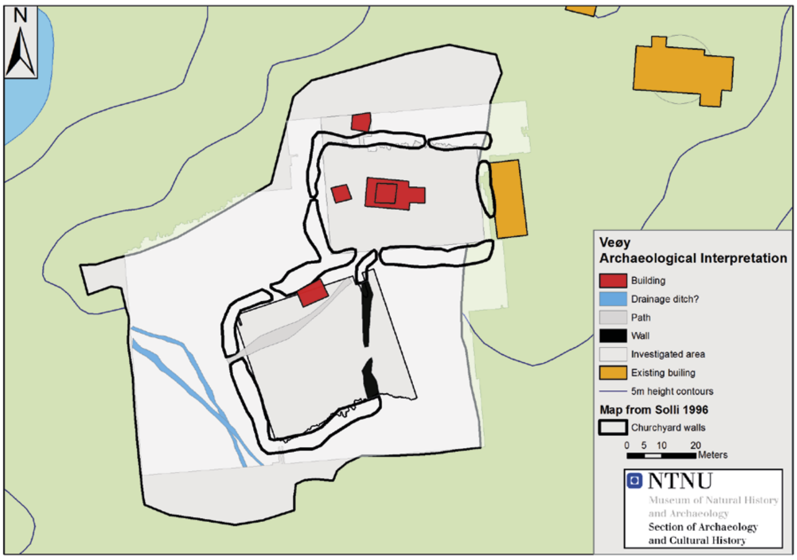
Refleksjoner omkring kombinasjonen av de tre metodene

Kombinasjonen med måling av magnetisk susceptibilitet og måling med fluxgate gradiometer og georadar utfylte hverandre, spesielt når det gjaldt å finne avgrensningen til kirkegård nr. 2 mot øst. Det var ved denne undersøkelsen vanskeligere å påvise enkeltstrukturer med de to magnetiske metodene grunnet enten oppløsning eller magnetisk geologi, men metodene viste fremdeles en mulig bygning (usikker funksjon) i den nordre delen av kirkegård nr. 2 samt en distinkt respons fra svartjordområdet øst for kirkegård nr. 2.

Gradiometerdataene har i liten grad bidratt til å støtte tolkningene fra georadardataene i andre tilfeller. Et unntak er kanskje en svak negativ rand sør for bygning 2 påvist inne på kirkegård nr. 1 med georadar. Gradiometeret kunne i dette tilfellet ikke bidra noe særlig med tolkninger eller lokalisering av gravene.

Selv om det hadde vært optimalt med enda mer presise resultater, er det klart at de tre metodene som ble anvendt, hver for seg og sammen, bidro til økt kunnskap om undersøkelsesområdet og kulturhistorien på Veøya. Både de to magnetiske metodene og georadarmålingene bidro eksempelvis til å avgrense kirkegård nr. 2. En samlet arkeologisk tolkning av de tydeligste påviste anomaliene presenteres i figur 15.

Når det kommer til erfaringer av bruken av de valgte geofysiske metodene under de gjeldende topografiske forholdene, er det tydelig at den metamorfe bergarten i undergrunnen (diorittisk til granittisk gneis og migmatitt) påvirket de magnetiske målingene med gradiometer, og gjorde at det var vanskelig å identifisere enkeltstrukturer. Men vi identifiserte én mulig bygning, to veiter og noen interessante trender og soner med avvikende respons. Den magnetiske geologien ser ikke ut til å påvirke målingene av magnetisk susceptibilitet på samme måte. Også med denne metoden ble det målt høye verdier på steinene i selve muren, mens resten av målingene antas å reflektere den magnetiske aktiviteten i selve undergrunnen. I de mer våtlendte områdene mot sør og sørvest for kirkegård nr. 2 er det målt lave verdier. For bruken av georadar virker det som om penetrasjonen er god, selv om det er kjent at deler av undergrunnen skal være marin leire. Været ga noen utfordringer, og kan til



Figur 15. En samlet tolkning av de tre geofysiske målingsmetodene på kirkegård nr. 1 og nr. 2. Kart: Arne A. Stamnes.

en viss grad ha påvirket resultatene fra georadarundersøkelsen. Det hadde regnet mye i måneden før feltarbeidet, og det var vått i marka og i undergrunnen. Hvis georadarmålingene gjøres på nytt etter et par uker med tørrvær, kan resultatene bli noe annerledes.

Konklusjon

De geofysiske metodene som ble anvendt, bidro alle på sitt vis til et økt kunnskapsgrunnlag om de to kristne gravplassene fra 900-tallet på Veøya.

Magnetisk susceptibilitet fortalte oss noe om utstrekningen og karakteren til svartjorda på denne delen av Veøya. Avgrensningen av kirkegård nr. 2 mot øst antydes også.

*Gradiometer*dataene viste oss hvordan et svartjordslag arter seg visuelt ved bruk av denne metoden. Avgrensningen av kirkegård nr. 2 i øst (jf. Sollis sjakt 20) ble ytterligere bekreftet. Det ble også påvist en mulig hustuft innenfor kirkegård nr. 2. Metoden viste seg å ha visse begrensninger på grunn av magnetisk undergrunn.

*Georadar*målingene bidro også til å bekrefte avgrensningen av kirkegård nr. 2 mot øst. Det var imidlertid merkelig at georadaren ikke fanget opp den kraftige steinkonstruksjonen påvist i sjakt 19. At det var gravet sjakter (17 og 19) om lag midt på kirkegård nr. 1 og nr. 2, ble imidlertid fanget opp ganske klart.

Målingene med georadar ga de mest spennende kulturhistoriske resultatene på kirkegård nr. 1 (jf. figur 14). Her ble tre mulige bygninger påvist, hvorav to klart kan settes i sammenheng med tidligere kirkebygg på stedet. Bygning 1, på ca. 5,6 m x 5,8 m, ble påvist dypere nede enn restene av bygning 2. Bygning 2 ligger sentralt i midten av kirkegård nr. 1, og bygningen er 12–13 m x 8,2 m nord–sør, orientert noenlunde øst–vest, og har et mulig kor på kanskje 4,7 m øst–vest x 4,5 m nord–sør øst for dette.

Bygning 1 kan faktisk være spor etter den *eldste kirken* bygget i Norge, allerede på 900-tallet. Bygning 2 kan være spor etter en større kirke, muligens den korskirken som er nevnt i dokumenter fra seinmiddelalderen. Den vesle bygning 3 kan muligens være spor etter en støpul, altså et frittstående klokketårn.

Det var vanskelig å identifisere sikkert graver i datamaterialet, men det finnes en viss mulighet for at enkelte av de anomaliene som er påvist (jf. figur 13), faktisk kan være graver.

Geofysiske metoder som anvendes på en gjennomtenkt måte, kan, som vi ser, gi interessante resultater. Men det er fortsatt bare en arkeologisk utgravning av den tradisjonelle sorten som med absolutt sikkerhet kan avklare om det på eksempelvis kirkegård nr. 1 har stått en eldre og en yngre kirkebygning og en støpul vest for den.

Takk

Takk til Romsdalsmuseet for praktisk hjelp under feltarbeidet, blant annet med strømaggregater og gratis husrom i Prestegården og Borgstua. Takk også til Kristin Foosnæs og Bjørn Dretvik for formidabel innsats under feltarbeidet og hyggelig *kveldsete* i Borgstua. Lars Stenvik skal også ha takk, fordi han var så positiv og bidro aktivt til å skaffe midler til utprøvingen av geofysiske metoder på de to kirkegårdene på Veøya. Undersøkelsen ble finansiert som et spleiselag mellom Vitenskapsmuseet ved NTNU og Kulturhistorisk museum ved UiO.

Summary

Geophysical investigations of churchyards, church foundations and the black soil on Veøy in Romsdal.

Geophysical investigations were carried out on Veøya in June 2011. The main objective of the investigations was to detect archaeological structures, both known and unknown, at two churchyards dated to the 10th century (Solli 1996). Georadar and methods detecting magnetic susceptibility revealed anomalies pointing to distinct zones of human activities. The distribution of black soil in relation to the stone walls enclosing the churchyard was detected and confirmed observations made during Brit Solli's excavations in the early 1990s. In churchyard/enclosure no. 1 postholes associated with the remains of three buildings (Figure 14) were detected, two of them probably church-buildings; the older was small, and the later, larger church may be associated with the Cross-Church mentioned in documentary sources in the mid-14*th* century. The third and smallest building detected may have been a bell-tower/campanile (Norw. *støpul*).

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Article III

Geophysical Surveys at Avaldsnes

Arne Anderson Stamnes and Egil Lindhart Bauer.

Stamnes, Arne Anderson and Egil Lindhart Bauer (in press): Geophysical Surveys at Avaldsnes. In Skre, Dagfinn (ed.): Avaldsnes: *A Sea-King's Seat at the Island of Kormt*. De Gruyter. Berlin, New York.

Please note that this text sometimes referes to other illustrations and book chapters in the forthcoming book.

Abstract

This chapter presents the geophysical surveys of Avaldsnes carried out by several actors between 2004 and 2013 and discusses the surveys' results. An important part of the discussion is a quantitative and qualitative comparison of the geophysical data compiled and archaeological discoveries made during the field campaign. Such comparisons have seldom been performed on Norwegian material. This work will therefore lead to discussions of the different surveys' usability for planning archaeological excavations, enabling suggestions for improvements in the quality of geophysical data and methods for data processing so that archaeologically relevant anomalies under similar conditions can be more easily distinguished. The GPR surveys, most notably the survey conducted by the Vienna Institute for Archaeological Science (VIAS) in 2009, revealed a high number of clearly defined, archaeologically significant anomalies; the data was easily applied both prior to and during excavation. Several of the other surveys proved difficult to interpret, as the data lacked spatial detail or was muddled by large amounts of stones, waterlogged soil, or the effects of magnetic geology of volcanic origin. However, during reprocessing and reinterpretation of the data with the excavation results at hand, it became clear that the various surveys have provided significantly more information than was appreciated by geophysicists and archaeologists before the excavation commenced. That the excavation results needed to be known in order to recognise relevant archaeological features illustrates the difficulty of interpreting geophysical data. Such data must be tried against a number of hypotheses for the site in question. Otherwise, the sheer amount of data can be overwhelming and impractical to utilise. Furthermore, the data must be used not only prior to, but also during excavation, and the excavation staff and the geophysics technicians must be able to discuss data and excavation results throughout a project's lifespan. By evaluating data and adjusting methods, targeted investigations can be carried out in relevant areas, rendering the field campaign more effective.

Introduction

The large quantity of geophysical surveys carried out at Avaldsnes allows thorough evaluation of the different methods by comparing the collected data with the excavation results from the 7,715 m^2 excavation areas from the investigations from 1992–2012 combined. One of the main aims of the evaluation is to review the various geophysical methods' applicability under the geological and archaeological conditions encountered at Avaldsnes. As the surveys were carried out by different parties and with different goals, methods, and equipment, a thorough evaluation is possible. This chapter presents this evaluation as a reference for further development of geophysical survey strategies for archaeological purposes, including for determining how best to apply geophysical methods under the ruling survey conditions elsewhere. One of the main advantages to geophysical surveys is that they enable the on-site archaeological staff to conduct targeted investigations. Thus, a key point in the evaluation of the geophysical methods is how readily the various geophysical data could be interpreted by the on-site staff, both prior to and during excavation. The following discussion involves features in areas 1, 2, 5, 6, and 8 (see ###[reference to figure showing all excavation areas]) at Avaldsnes – areas with features exemplifying relevant possibilities and limitations related to the geophysical surveys applied at the site. For a discussion of surveyed areas and features not mentioned here, please refer to the geophysical reports (Sandnes and Eide 2004; Persson 2006; Smekalova and Bevan 2009; Barton 2010). For descriptions and interpretations of archaeological features and deposits, please refer to the relevant chapters in this volume (###).

Geophysical surveying at Avaldsnes – a brief history

A complete overview of all the geophysical surveys at Avaldsnes is given in tables 1 and 2, as well as figure 1.

Initiated by Karmøy Municipality, the first geophysical survey at Avaldsnes was conducted in August 2004 by the georadar manufacturing company 3-d Radar AS using a prototype of their Step-Frequency ground-penetrating radar (GPR) system. The data quality was restricted by the equipment's limitations coupled with water-saturated ground and standing surface water. The current, fourth-generation commercially available system features sensitivity, signal quality, and processing software that are significantly enhanced compared with the prototype used in 2004. The report contains selected time-slices and GPR sections (Sandnes and Eide 2004; Eide 2013, personal communication).

Likewise initiated by Karmøy Municipality, a geophysical survey was conducted in April 2006 by GeoFysica, managed by Kjell Persson, using a Malå Geoscience GPR system with a 500-MHz antenna and a Geonics EM38 electromagnetic induction meter. The report contains combined contoured and greyscale plots for the EM data; the GPR data was presented as contoured horizontal depth slices and selected GPR sections (Persson 2006). It is uncertain what methods were used for positioning and mapping the surveyed areas.

Following the Avaldsnes Royal Manor Project's first application to excavate in 2009, the Directorate for Cultural Heritage required that survey methods and the testing and development of geophysical technology be systematically non-destructive (Directorate for Cultural Heritage 2009). The Project arranged with three different parties to carry out new surveys: the Museum of Natural History and Archaeology at the Norwegian University of Science and Technology (NTNU) in collaboration with the Irish company Earthsound Associates performed the most extensive survey, while Moesgård Museum/Geosight and the Vienna Institute for Archaeological Science (VIAS) surveyed limited parts of the planned excavation areas.

In connection with Dr Natascha Mehler's project "HANSA: The Hanseatic Expansion in the North Atlantic", the Vienna Institute for Archaeological Science (VIAS) conducted a GPR survey of the northern part of Area 2 in April 2009. Using a Sensors and Software Noggin system with a 500-MHz GPR antenna, the project collected georeferenced horizontal time-slices and shared the results with the Avaldsnes Royal Manor Project. Analyses of the provided images indicated a traverse interval of 0.25 m; no other technical information is available. The method used for positioning the surveyed area is unknown, but the accurate size and correlation with known archaeological features indicate a high-level GPS or total station.

In June 2009, US-based Geosight, in collaboration with Moesgård Museum in Denmark, performed a total field magnetometer survey, combined with an EM38 and earth resistance survey. The report contained data plots with contours and colour plots, apparent gradiometer plots, depth-, mass-, and shape-modelling, and estimates of selected anomalies (Smekalova and Bevan 2009). The positioning was based on the grid set by VIAS.

Earthsound Associates performed a geophysical survey on behalf of the Museum of Natural History and Archaeology (NTNU) in August 2009. The survey had four phases: 1) a reconnaissance magnetic susceptibility survey performed with a Bartington MS 2 with the MS2D loop probe, 2) a fluxgate gradiometer survey performed with a Geoscan Research FM 256, 3) an earth resistance survey performed with a Geoscan RM 15 and a TRS/CIA twin probe array, and 4) a detailed GPR and Earth Resistivity Tomography survey performed with a GSSI Sir 3000 system with a 400 MHz antenna (Barton 2010). NTNU returned to conduct post-excavation GPR surveys in 2013, intended to map the extent of archaeological features investigated during the 2011 and 2012 excavations in areas 1 and 8. The results from this investigation are presented exclusively in this chapter and are not available in a separate report. Positionings were obtained by total station and a differential GPS.

Table 1: Summary of survey institutions, methods, and areas covered by the various surveys. Only the surveys from 2009 and 2013 were directly related to the Avaldsnes Royal Manor Project.

	MS	**Magnetometer**	**GPR**	**EMI**	**ER**	**Total**
3d-radar AS (2004)	-	-	4410 m²	-	-	4410 m²
GeoFysica (2006)	-	-	1669 m²	1851 m²	-	3520 m²
VIAS (2009)	-	-	4000 m²	-	-	4000 m²
Moesgård/Geosight (2009)	-	4870 m²	-	801 m²	-	5671 m²
Earthsound Associates/NTNU (2009)	26,863 m²	22,000 m²	9745 m²	-	3213 m²	63,641 m²
NTNU (2013)	-	-	2449	-	-	2449 m²

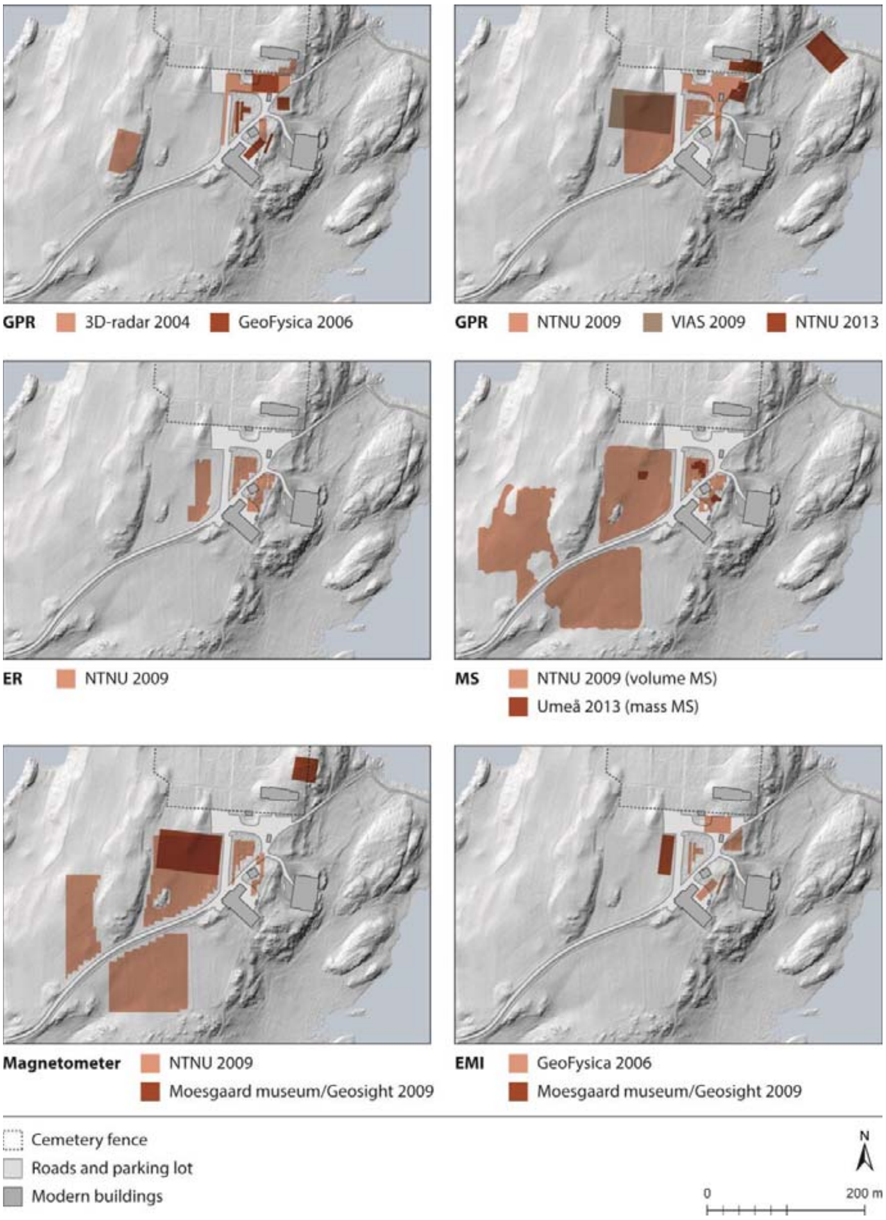

Figure 1: Map of the location of all geophysical surveys carried out at Avaldsnes (see table 1). Illustration by Ingvild Tinglum Bøckman Bøckman and Arne Anderson Stamnes

Table 2: Overview of the various survey setups, GPR frequencies, instruments and manufacturers used at Avaldsnes

Survey setups

GPR	Crossline	Inline	GPR frequencies	Instrument and manufacturer
3d-radar 2004	0.09 m	0.05 m	?	3d-radar Geoscope mark 1 prototype
GeoFysica 2006	0.5 m, 1 m and 5 m	0.03 m	500 Mhz	Malå Ramac
VIAS 2009	0.25 m	?	500 Mhz	Sensors and Software Noggin GPR
NTNU 2009	0.5 m, 1 m and 5 m	0.02 m	400 Mhz	GSSI Sir-3000
NTNU 2013	0.25 m	0.025 m	400 Mhz	
ER	Crossline	Inline	Electrode spacing	
NTNU 2009	0.5 m	0.5 m	0.5 m/1 m	Geoscan Research RM 15 and Tr/CIA Resistivity meter
MS	Crossline	Inline		
NTNU 2009	5 m/2 m	5 m/2 m	Bartington MS2 with the D field probe	Bartington
Umeå 2013	1 m	1 m	Bartington MS3 with the MS2B probe	Bartington
Magnetometer	Crossline	Inline		
NTNU 2009	0.5 m	0.125 m		Geoscan Research FM256
Moesgaard Museum/Geosight 2009	0.5 m	0.2 m in average (reading every 0.2 second)		GEM Overhauser GSM-09WG
EMI	Crossline	Inline		
GeoFysica 2006	0.5 m	0.5 m		EM38
Moesgaard Museum/Geosight 2009	1 m and 0.5 m	1 m and 0.5 m		EM38

Linking geophysical data sets

The geophysical surveys performed at Avaldsnes from 2004 to 2013 provided data sets from different areas, using different methods and equipment. Only the surveys from 2009 onwards were directly related to the Avaldsnes Royal Manor Project, and only the 2009 and 2013 NTNU surveys were part of an overarching geophysical survey strategy. However, all surveys are evaluated here, including those from 2004 and 2006 as they covered areas subsequently excavated in 2011 and 2012.

Accuracy is essential when comparing geophysical data with excavation results. Data of high spatial detail is required for identifying small archaeological features. All reports from the above-mentioned surveys contain maps and data plots, usually with discussions of selected anomalies and observations, their origin, and their potential archaeological significance. However, each field crew documented their survey location using different survey equipment with inherent variations in accuracy. Consequently, georeferencing for an effective comparison of the data sets was a challenge, as most of the geophysical survey reports did not contain georeferenced maps or additional information in GIS or CAD format of either geophysical data or archaeological interpretations of anomalies. The 2009 VIAS GPR survey provided georeferenced depth-slices, which in turn were very helpful in georeferencing the survey data and interpretations from the 2009 Moesgaard/Geosight survey, which was collected on the same grid (Smekalova and Bevan 2009). The GeoFysica data was difficult to georeference due to the low resolution of the maps published in the report (Persson 2006), while we observed some discrepancies in the 2009 NTNU dataset (Barton 2010). For the latter two surveys, grid-plot sizes did not always match those presented in the reports, and for the 2009 NTNU survey anomalies in GPR survey time-slices performed in different directions in the same area did not always correspond. Such discrepancies required data repositioning to ensure accuracy, taking as reference points mainly those anomalies visible in several or all data sets. We have strived to the best of our ability to identify and compensate for any inherent discrepancies that might introduce errors.

Geophysical survey methods, interpretation, and data comparison

Magnetic methods involve measuring various magnetic properties, including the topsoil magnetic susceptibility (volume MS or K) or the mass magnetic susceptibility (mass MS or χ) of soil samples, as well as field-based mapping with a magnetometer or gradiometer (an array of two magnetometer sensors used to measure changes in the vertical component of the Earth's magnetic field; the dual sensors overcome the problem of diurnal variations in the magnetic field). Typically, such methods are useful for detecting activity such as burning, metalworking, accumulated soil, or magnetic material. For an in-depth description of the magnetic methods, see Gaffney and Gater (2003), Dalan (2008), and Aspinall et al. (2009).

Electrical measurements are taken to map local changes in the ground's electrical properties. Typically, a ditch is conductive as it can retain water, while stones or hard-packed areas tend to be electrically resistive as they do not retain water. By mapping changes in electrical resistance over an area or along depth-sections in the ground, archaeological features can be located. For further information on electrical survey methods, see Clark (1996), Gaffney and Gater (2003), and Schmidt (2013).

Electromagnetic techniques involve use of ground penetrating radar (GPR) and electromagnetic induction (EMI). A GPR transmits electromagnetic energy, often referred to as radio waves, into the ground. By measuring this energy's return time and strength, reflective sources can be mapped in section and plan. A GPR survey is usually performed with traverses laid out parallel to each other with a set spacing. Each measured traverse provides a GPR section of all reflectors along the traverse; by surveying parallel traverses, a three-dimensional data set is established. A map of the magnitude of all reflections at a certain depth is called a time slice. For more detailed information on GPR in archaeology see Conyers (2012; 2013) and Goodman and Piro (2013).

Electromagnetic induction (EMI) is a method of simultaneously measuring both apparent magnetic susceptibility (EMI MS or in-phase) and apparent electrical conductivity (EMI EC or quadrature phase) in the ground. The instrument generates a magnetic field that magnetises particles in the soil. The quantity of this magnetisation is measurable as apparent magnetic susceptibility. The electrical currents in the ground caused by the instrument's magnetic field produce a secondary magnetic field, the strength of which is related to the ground's apparent electrical conductivity. For further information on the principles of EMI, see Clark (1996), De Smedt (2013), and De Smedt et al. (2013).

Pre-excavation survey: Area 1

Excavations in Area 1 revealed building remains from A10 and A14 (see Bauer and Østmo, this vol., Ch.##) and the remains of stone foundations from the post-Reformation rectory at Avaldsnes. In Area 1's south-eastern corner, a medieval ruin (A12) with walls up to 110 cm high lay covered by garden soil from the rectory. Other notable features were a subterranean passageway and a stone-built well of post-medieval origin. Due to the extensive timespan of prehistoric and historic activities in Area 1, many of the archaeological features have truncated and disturbed one another. In addition, there have been massive recent disturbances related to various post-medieval activities as well as the construction of a car park in the area south of the cemetery wall. Among the modern disturbances were a ditch for a high-voltage cable cutting through the area between the rectory remains and building A10/A14 (see Bauer and Østmo, this vol., Ch. ##:fig. #).

Stone walls from A12 (see Bauer, this vol. ##, fig. #) were visible in the GPR data as a linear north–south anomaly breaking eastwards (Persson 2006:fig. 17); see figure 2. The orientation of the building's southern and western walls in the data diverged somewhat from the wall exposed during excavation. This might be because the walls were obscured by stone-filled demolition deposits or, alternatively, due to a grid-positioning error or sources of error introduced during data collection, for instance inconsistent walking speed.

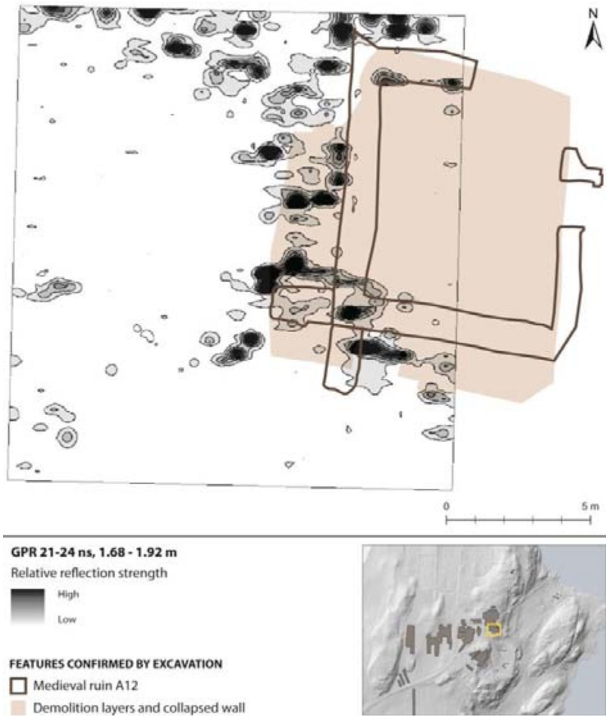

Figure 2: Comparison of Persson's GPR time slice and excavations results. Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from GPR; GeoFysica 2006 (Persson 2006).

In 1986, excavations revealed a medieval subterranean passageway constructed of stone slabs, running across Area 1 towards St Olav’s Church. The re-deposited soil and gravel in the trenches were uncovered during the 2011 excavation. This re-deposited material also showed in the GPR data (Barton 2010). Tracing the passageway in the GPR data, it is apparent that the feature lies deeper in the west than in the east (figs. 3 and 4). In the east, the passageway lies at a depth of approximately 50 cm, while in the west it dips down to approximately 110 cm. This corresponds to the estimated depth based on photographs from the 1986 excavation (see Bauer, this vol., fig. ##[image showing archaeologist, passageway, and top of the excavation area]). It is possible to trace a northward continuation of the passageway in the GPR data (see fig. 4), which is indicated by a strong reflection in the GPR profile at the expected depth that is not visible in the neighbouring profiles (see fig. 5). The reflection probably derives from the flagstones that covered the passageway and the re-deposited material from the 1986 excavation. The hard-packed gravel surface also attenuates part of the signal, yielding a lessened response in this particular area visible in all profiles in figure 5, while still giving a strong response from what we interpret as the northern continuation of the passageway.

A circular, stone-built well with infilling dated to the 18th–20th centuries (Beta-319021) is clearly visible in the GPR data from the central part of Area 1. This feature presents itself as a strong reflection visible at the same place in time slices from multiple depths of the collected dataset (figs. 3 and 6). The excavation showed that the well’s diameter was larger in its upper part, narrowing slightly towards the bottom at a depth of approximately two metres. The GPR data show an area of strong reflections in the shape of hyperbolas and layer disruptions down to similar depths. Stones made up the well’s walls and the backfill within. The backfill was more reflective than the walls, indicating increased water content in the backfill. This is plausible, considering the purpose of a well: to retain water.

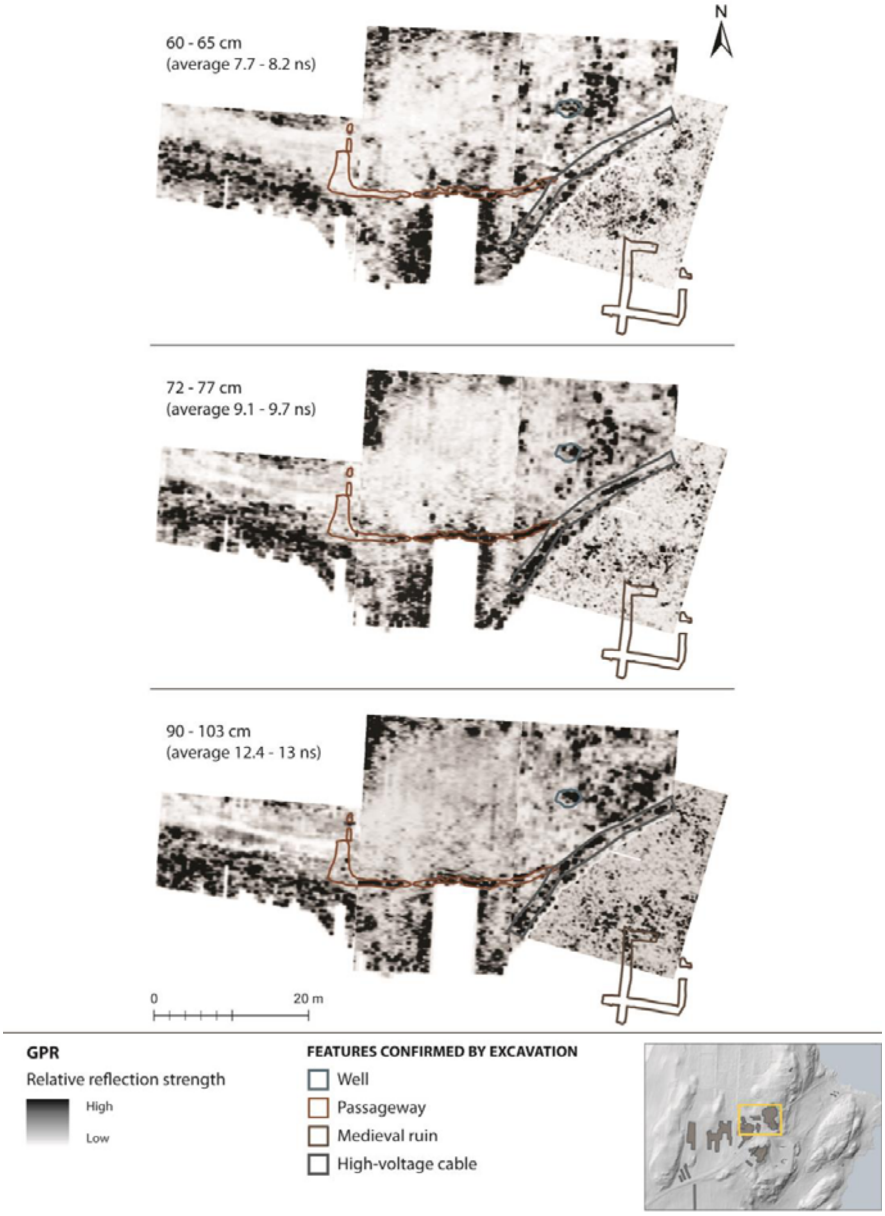

Figure 3: Maps showing GPR reflections of the passageway, the stone-built well, and a high-voltage cable at different depths. Also notice the low reflectivity strength in the central part of the car park in Area 1 (see also Bauer and Østmo, this vol., Ch. ##EXCAVATIONS:fig. #). Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from GPR, Earthsound Associates/NTNU (Barton 2010) and NTNU 2013.

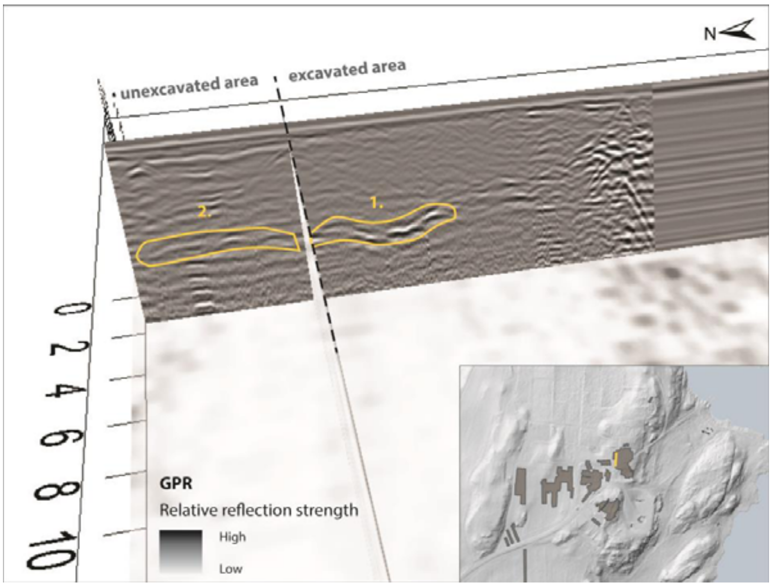

Figure 4: The black line denotes the northern edge of the 1986 excavation. No. 1 is a strong curved reflection coinciding with the exposed passageway from 1986. No. 2 might be reflections from a northward continuation of the passageway. Illustration by Arne Anderson Stamnes. Plot from GPR, Barton 2010.

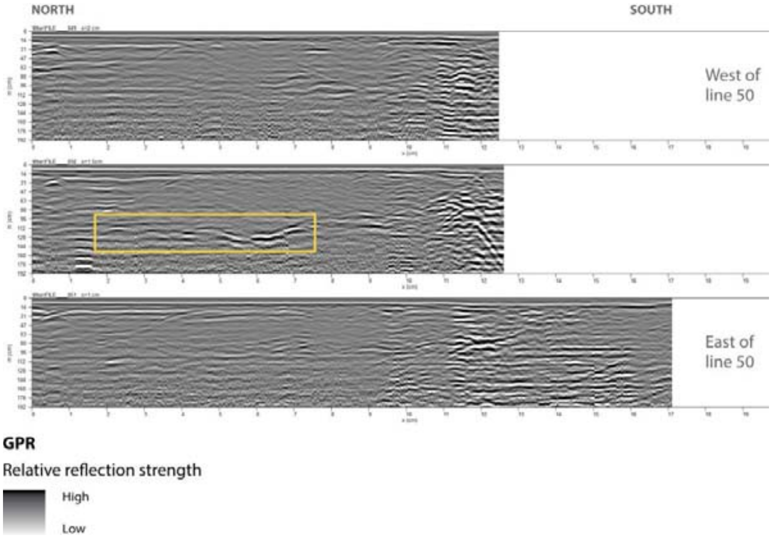

Figure 5: GPR radargram showing the GPR reflection from the possible northwward continuation of the passageway. Illustration by Arne Anderson Stamnes.

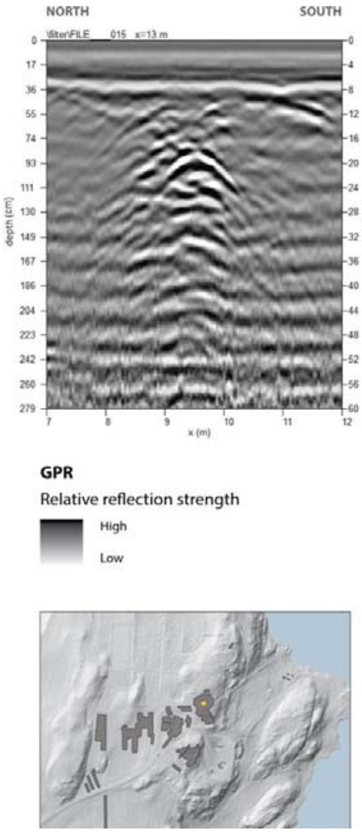

Figure 6: GPR radargram showing the GPR reflection from the stone-built well (A11062). Illustration by Arne Anderson Stamnes.

The Iron Age hall building (A10) (see Bauer and Østmo, this vol., Ch. ##:fig. #) was discovered in the north-eastern part of Area 1, and was identified by a central hearth, several postholes, and a 16.5-metre-long wall ditch cut directly into bedrock. The wall ditch was not observable in the initial processing of the NTNU data (Barton 2010), so several processing steps were attempted to enhance it. The wall ditch ran roughly north to south, while the data was collected both north to south and east to west. Since the ditch lay shallow and was only 30–50 cm wide, the reprocessing focused on a higher frequency range (285–750 MHz) – the processing of different frequency ranges has been suggested as a means of improving image resolution and extracting additional information from GPR data (Grealy 2006). After reprocessing, parts of the ditch became visible as a weak geophysical contrast, seen as a 40–50 cm wide linear anomaly stretching over approximately three meters, which could be seen in three five-centimetre-thick time slices, and only in the dataset collected perpendicular to the feature (fig. 7). This demonstrates how easily certain features can be overlooked in the data interpretation process. While other, more recent features could be seen, such as anomalies relating to electrical cables and water pipes, as well as an older pathway or road leading towards the church, the geophysical contrast of the wall ditch was indistinct under the current survey conditions. The geophysical properties between the cut and the fill were apparently too similar to yield a strong geophysical contrast. The focusing of the GPR signals' higher-frequency range helped identify the wall ditch in the GPR data. As the wall ditch lay relatively shallow, another possibility would have been to test a higher-frequency antenna in the field; this was not done. As seen in figure 5, we observe that the car park has in parts an attenuating surface cover, which reduces the geophysical contrast in the areas beneath it. Survey conditions such as water content or saturation in the ground, surface materials, and salting are all factors that can alter signal attenuation and impact the resulting degree of success of positive identification of archaeological features; these conditions may have played a role for this specific feature. While attention is more easily given to linear, rectangular, and/or repeating observations while interpreting geophysical data, it is possible that an interpreter would not recognize this particular anomaly as an archaeologically relevant feature due to its comparatively weak contrast.

The GPR surveys from Area 1 exemplify the detectability of various feature types, although there were some discrepancies between the survey data and the excavated features, for instance regarding exact location or shape. At similar sites, proper examination of the collected data calls for processing the data at different frequency ranges and/or using a higher-frequency antennae; this practice additionally increases the potential to locate vague or shallow features such as the wall ditch cut into bedrock and leads to a higher survey resolution by decreasing the line spacing between each traverse. As the footprint of the GPR signal from a 500-Mhz centre frequency antenna is approximately 25 cm in diameter under typical survey conditions, a traverse interval of 25 cm or less is needed to avoid spatial aliasing (David et al. 2008). An even higher sample resolution might be recommend depending on the expected size of the archaeological features present; it is advisable to apply a survey methodology that ensures at least two traverses within a single feature. To ensure that two data transects intersect a feature of 20 cm in diameter, two traverses with a traverse interval of 10 cm are needed. The depth of investigation and the potential footprint of the GPR signal are frequency dependent (David et al. 2008; Conyers 2013) and must also be taken into consideration along with the expected size of archaeological features present. Also, if time allows, gathering GPR data in several directions could yield additional positive results. This example shows that perpendicular lines improved the possibility to detect this ditch. As the sample interval is usually lower in the inline direction (i.e. sampling along the survey line) compared to the crossline interval, this method will yield a greater quantity of information along the line than between the lines. In the case of a linear wall, the feature can easily be missed with a course crossline resolution running parallel to the feature. By contrast, the feature has a much higher chance of being detected if the data was collected perpendicular to it. Certain processing software can be used to combine GPR data collected in various survey directions for optimal information gain.

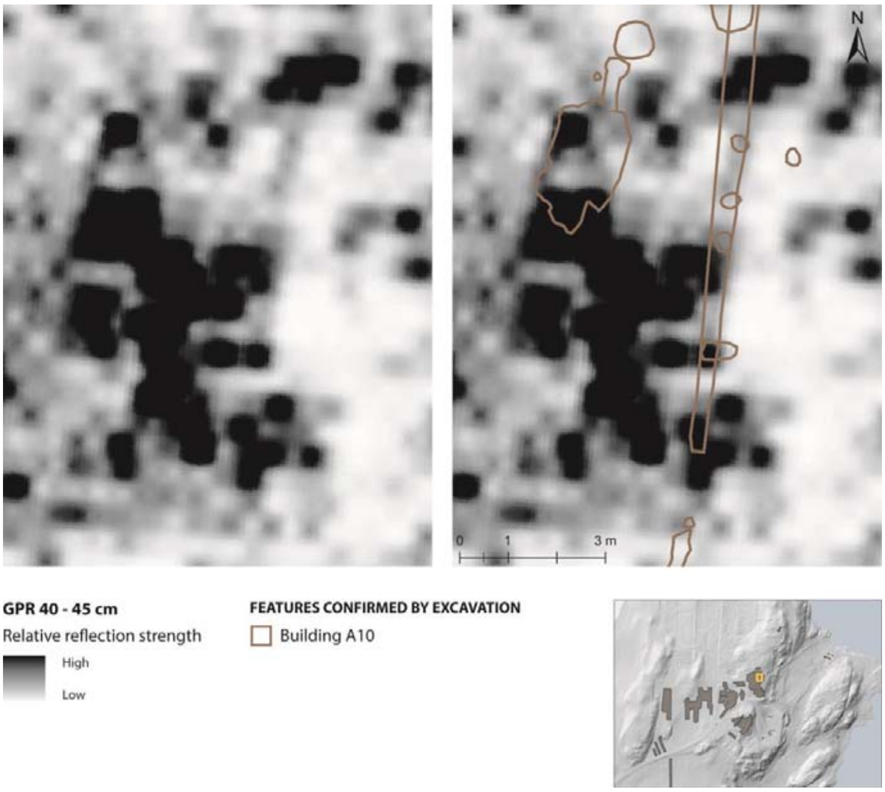

Figure 7: Building A10’s eastern wall in the reprocessed GPR dataset collected east to west. Few of the excavated postholes and none of the hearths are visible in the selected time slice. Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from GPR, Earthsound Associates/NTNU 2009 (Barton 2010).

Pre-excavation survey: Area 2

Excavations in Area 2 showed that colluvial deposits up to 130 cm thick had amassed through centuries of cultivation, forming a large prehistoric field. Micromorphological analyses have demonstrated ploughing and fertilization using animal dung and charcoal, as well as other burnt material (Macphail and Linderholm, this volume, Ch. ##:##). Numerous archaeological features, including cooking pits and postholes, were cut into different levels of the colluvial deposits and the subsoil. The colluvium was homogeneous with scarcely any stones. Thus, stones where present were indicative of archaeological features, for instance cooking pits. The earliest cultural deposits in the field had traces of burning prior to agricultural activity. The wall ditch from a Bronze Age building (A11) was cut into this deposit. In the eastern part of Area 2, the soil was shallow with stony bedrock appearing just below the topsoil.

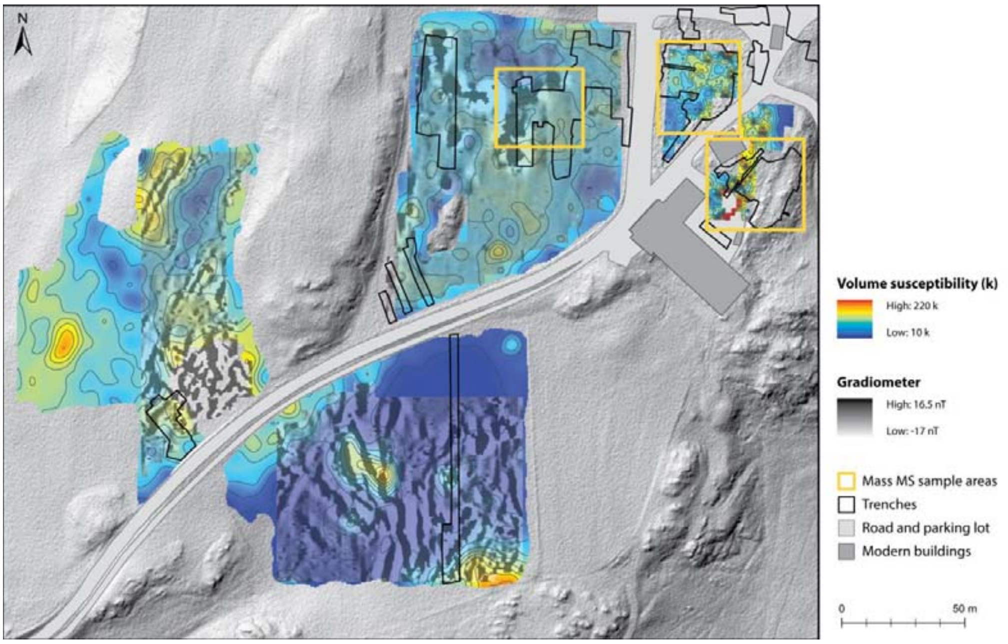

Figure 8: Map showing all topsoil volume susceptibility (K) values measured at Avaldsnes. The red boxes illustrate areas where mass susceptibility samples have been analysed by Linderholm and Wallin 2013 (see also chapter ##). Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from topsoil MS survey, Earthsound Associates/NTNU 2009 (Barton 2010).

The main surveys in Area 2 involved magnetic susceptibility (MS), earth resistance, GPR, electromagnetic imaging, and magnetometry (see figs. 1 and 8). A trend of topsoil MS values elevated relative to those of the surroundings was detected running north-east to south-west in the survey area in Area 2. The values ranged from 60 to 120 K, corresponding closely with the thicker cultivation deposits identified by the VIAS GPR survey and confirmed by excavation as a prehistoric field with thick homogeneous cultivation deposits amassed through centuries of cultivation. The area also included several cooking pits buried at various depths (see Bauer and Østmo, this vol., Ch.##:fig. [time slice from the VIAS GPR survey of Area 2] and fig. 8). The high topsoil MS values continued south-west from the survey area. While the excavation was not carried out further to the south-west, the presumption that the high values are related to thick cultivation deposits has indicated that the area of cultivation deposits did in fact extend further to the south-west from the excavation area. Areas with concentrations of cooking pits were not similarly distinct, despite their presumed high MS values caused by heat-exposed stones. Areas of thinner soil cover above the natural subsoil tended to register low MS values. This is the opposite of areas 3 and 4, where the gradiometer data indicates geological influence closer to the surface in areas with high MS values. This conclusion is supported by the gradiometer data plots from the same areas, which shows a spatial correlation between relatively high MS values and the extremely strong influence from the natural bedrock in the gradiometer data (fig. 8).

It seems likely that the south-west to north-east trend of enhanced MS values in Area 2 is related to prehistoric agricultural activity – especially in areas within this prehistoric field with thicker cultivation deposits above the natural subsoil (Bauer and Østmo, this vol., Ch. ##:##). Factors that are known to enhance the magnetic susceptibility of soils include enhancement of soil by material of increased magnetic susceptibility (for instance fertilizers or the spread of domestic waste on the fields), redox processes, and biological decomposition, which fosters the growth of bacteria capable of altering iron minerals from less magnetic into more magnetic types (Dalan and Banerjee 1996; Dearing 1999; Evans and Heller 2003; Dalan 2006; Linderholm 2007; Dalan 2008). The enhanced MS values observed at Avaldsnes can be explained by the effect of fertilizing where material with an increased magnetic susceptibility has been added to the soil over time. Alternatively, the values may be the result of biological decomposition of plough soil or the ploughing of cooking pits, which caused the mixing of enhanced magnetic material from both cooking pits and redox-altered topsoil into the upper soil strata over time. The southward continuation of this activity into Area 3 is invisible in the MS data, as there is a clear difference in the topsoil MS readings between the northern and southern side of the road separating Areas 2 and 3. No observable change in deposits or features appeared during excavation to explain this. Because the differing values roughly corresponded with the areas separated by the present-day road, the variation in magnetic response was presumed to be the result of activities after construction of the road. Alternatively, the difference might be caused by varying geology or the introduction of soil from different locations in the two areas (Barton 2010:27). The mass MS samples from the excavation showed increased values in the containing cooking pits to the north-west of building A11; furthermore, the samples indicated the possible presence of a ploughed-out hearth within the building. All these samples were taken from the same soil matrix and horizon, at the base of the histic topsoil (MacPhail and Linderholm, this vol., Ch. ##:fig. 8, Cannell, this vol., Ch. ##:##).

Table 3: Calculated correlation between the volume MS and the mass MS from areas 2, 5, and 6, with calculated percentage of the variation in the volume MS that could be explained by the mass MS.

Area	Correlation method	Correlation	Coefficient of determination	Percentage explained
2	Pearson’s product-moment correlation coefficient (r)	-0.30	r^2	9 %
	Spearman’s rank correlation coefficient (ρ)	-0.52	ρ^2	27 %
5	Pearson’s product-moment correlation coefficient (r)	0.36	r^2	13 %
	Spearman’s rank correlation coefficient (ρ)	0.41	ρ^2	17 %
6	Pearson’s product-moment correlation coefficient (r)	0.03	r^2	0.1 %
	Spearman’s rank correlation coefficient (ρ)	0.10	ρ^2	1.0 %

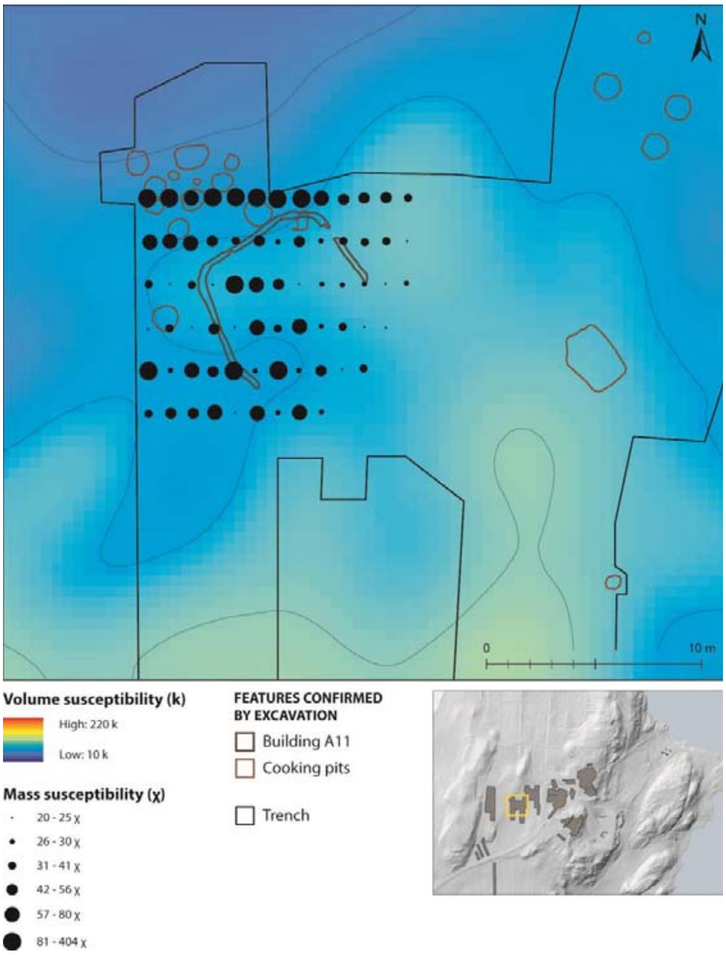

Figure 9: Comparison of topsoil volume susceptibility (k) and the mass susceptibility (χ) samples taken at the excavation. Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from MS survey, Earthsound Associates/NTNU 2009 (Barton 2010) and Linderholm and Wallin 2013.

The various magnetic susceptibility schemes performed at Avaldsnes provide the chance to compare the topsoil MS with the magnetic analysis of soil samples taken from the archaeological deposits, and thereby enable an investigation of whether magnetic soil enhancement observed in the topsoil had a spatial variation similar to that of the archaeological deposits. Comparison between the pre-excavation survey of topsoil MS and the mass MS from the excavations (table 3) showed a modest to moderately negative correlation (Taylor 1990:37), meaning that as the topsoil MS values increased, the mass MS values decreased moderately. This is the opposite of what should be expected if anthropogenic material had been transported up through the deposits by bioturbation and ploughing to be detected in the top 6–8 cm – that is, within the active range of the Bartington MS 2 used to measure topsoil MS. The variation coefficient is low: 9–27% (table 3). A possible explanation is that the overburden's thickness, which in the area with the concentration of cooking pit was approximately 70 cm thick, prevented delimitation of the activity area by means of topsoil MS alone. Furthermore, varying data density from the topsoil MS and the mass MS sampling scheme could introduce additional errors, as data points were not collected from the same geographical position. A proper interpolation with ordinary kriging was performed. Kriging is a method of exact interpolation, returning the same value of the initial measurement at the same location in the resulting interpolation map. This makes the method very well suited for the interpolation at hand (Isaaks and Srivastava 1989); such a method should reduce the impact of dissimilar sample density on the correlation. At Avaldsnes, the survey conditions under which topsoil MS measurements were taken were considered quite uniform, without rough ground or varied vegetation cover. Therefore, the survey conditions should not have any significant impact on the final results. An MS section through the entire sequence of deposits showed declining mass MS values from top to bottom, which is more typical for undisturbed natural soils. Consequently, even if the mass MS sampled from the archaeological deposits indicated a distinction between anthropogenic activities in plan, this was not evident in the section from the same area (Linderholm and Wallin 2013).

Table 4: Measures of magnetic variability of the available fluxgate gradiometer data from Avaldsnes and two reference sites in other parts of Norway (Stamnes 2011; Solli and Stamnes 2013). Original values are in nanotesla (nT).

Location	Mean	Standard Deviation	Variance	Interquartile Range
Avaldsnes – Area 2	2.59	27.44	753	6.2
Avaldsnes – Area 3	-1.47	37.42	1400	27.2
Avaldsnes – Area 4	-1.02	40.38	1631	19.8
Avaldsnes – Area 5	1.46	27.6	762	10
Avaldsnes – Area 6	-0.28	43.22	1868	19.8
Veøy (reference site)	-0.54	13.49	182.0	11.0
Gustad (reference site)	-0.26	2.04	4.2	1.5

Local geology influences geophysical measurements in various ways, with the amount of magnetic minerals in the ground affecting the likelihood of positively identifying archaeological features (Evans and Heller 2003; Aspinall et al. 2009; Bonsall et al. 2014). Different soils and geologies contain various amounts of magnetic minerals that can, in turn, be altered into more magnetically enhanced iron minerals. The background geology in itself can be very magnetic to the point of saturating the sensor, thereby making it impossible to detect subtler, potentially significant archaeological features (Aspinall et al. 2009). A quantification of the magnetic variation in the fluxgate gradiometer datasets is therefore helpful to understanding the local geology's effect on the survey results. Such quantification involves a comparison of statistical parameters for measuring variability, or spread of variables, such as standard deviation (std), variance, and interquartile range (IQR) as explained by Isaaks and Srivastava (1989:16-23). In advance of the 2009 Earthsound/NTNU survey, the geological implications for geophysical magnetic prospectivity were considered uncertain, as the magnetic response from metamorphic bedrock depends on the parent material from which the bedrock has been transformed – that is, the bedrock's original type before exposure to heat and pressure through metamorphic processes. As previous investigations in Norway have shown, a significant magnetic response from the bedrock does not necessarily preclude a magnetic response due to sub-surface archaeology (Barton 2010:8).

Table 4 presents calculated values indicating the relative variation of on-site magnetism at the various areas surveyed at Avaldsnes as compared with two reference sites. Presumably, high variability is caused by background geology or potential anthropogenic activity. The Geological Survey of Norway (NGU 2014) classifies the drift geology at Avaldsnes as shallow moraine material from magmatic bedrock. The bedrock in the area is characterised by the Geological Survey of Norway (NGU) as alkali basaltic greenstone of volcanic origin, volcanic meta-sandstone rich in iron manganese, quartz slate of metamorphic origin, and chert (NGU 2014). Compared with the two reference sites, particularly Gustad, the magnetic variability in the gradiometer data is very high in all areas at Avaldsnes. Veøy's bedrock is metamorphic, and Gustad's is sedimentary. Avaldsnes' bedrock, by contrast, is magmatic and volcanic, which can probably explain some of the variability. The calculated values for magnetic variability demonstrate quantitatively the effect of the bedrock at Avaldsnes on the gathered fluxgate gradiometer information. These values are suitable for use as a reference when planning or analysing magnetic geophysical information from other sites. Evidently, the presence of magmatic and volcanic bedrock of volcanic origin was not known to the surveyors at the time of the survey; rather, they considered it to be metamorphic.

Table 5: Calculated threshold values in nanotesla (nT) for areas 2, 5, and 6 at Avaldsnes, and the two reference locations. The strength categories for magnetic response values follow Hargrave (2006).

Threshold values	Avaldsnes Area 2	Avaldsnes Area 5	Avaldsnes Area 6	Veøy	Gustad
±2 std above mean	-52.3/+57.5	-66.8/+68	-86.7/+86.2	-27.5/+26.4	-4.3/+3.8
±1 std above mean	-24.9/+30.0	-33/+34.4	-43.5/+42.9	-14.0/+13.0	-2.3/+1.8
±1/2 std above mean	-11.1/+16.3	-16.2/+17.5	-21.9/+21.3	-7.3/+6.2	-1.3/+0.8
±1/4 std above mean	-4.3/+9.5	-7.8/+9.1	-11.1/+10.5	-3.9/+2.8	-0.8/+0.25
±1/6 std above mean	-2.1/+7.3	-5.1/+6.4	-7.6/+7.1	-2.8/+1.8	-0.6/+0.1
±1/8 std above mean	-0.9/+6.0	-3.5/+4.9	-5.7/+5.1	-2.2/+1.1	-0.52/-0.01
±1/10 std above mean	-0.2/+5.3	-2.7/+4.0	-4.6/+4.0	-1.9/+0.8	-0.46/-0.06

Interpretation of the fluxgate gradiometer datasets were based on the values presented in table 5, with the shape and size of the fluxgate gradiometer anomalies compared with the visualised fluxgate gradiometer datasets. Out of 213 anomalies within Area 2 with a value stronger than 5.3 nanotesla (or 1/10 std above mean), only five had a shape, size, or position comparable to that of the excavated features. The general impression is that the collected data is highly influenced by the bedrock, which created very high or low readings (figs. 8 and 10; table 4). This consequently rendered it impossible to identify archaeological structures based solely on the gradiometer data, as the magnetic variability resulting from the geology was so strong that the general background noise was much greater than the magnetic enhancement of any archaeological features (see tables 4 and 5). Further analyses of the data – that is, comparison of the excavated features' location with the contour lines visualising change in the measured nT values – allowed the shape of a few additional cooking pits to be outlined. This brought the count of verified anomalies of archaeological origin to 11 – still only about 5% of all the anomalies and 7% of the total number of excavated features.

The maximum nT values from the identified cooking pits ranged from 3.3 to 8.6. As the mean value of the survey was 2.6 nT, the cooking pit values ranged from only 0.7 to 6 above the mean, limiting a proper archaeological interpretation of the dataset. The nT values were not particularly high, demonstrating that even accounting for the descriptive statistics values, the magmatic bedrock of alkali basaltic greenstone, meta-sandstone, quartz slate, and chert creates high background variation. Such background variation reduces the value of gradiometer mapping methods. Thick colluvial deposits further decreased the likelihood of detecting magnetic contrast from buried archaeological features.

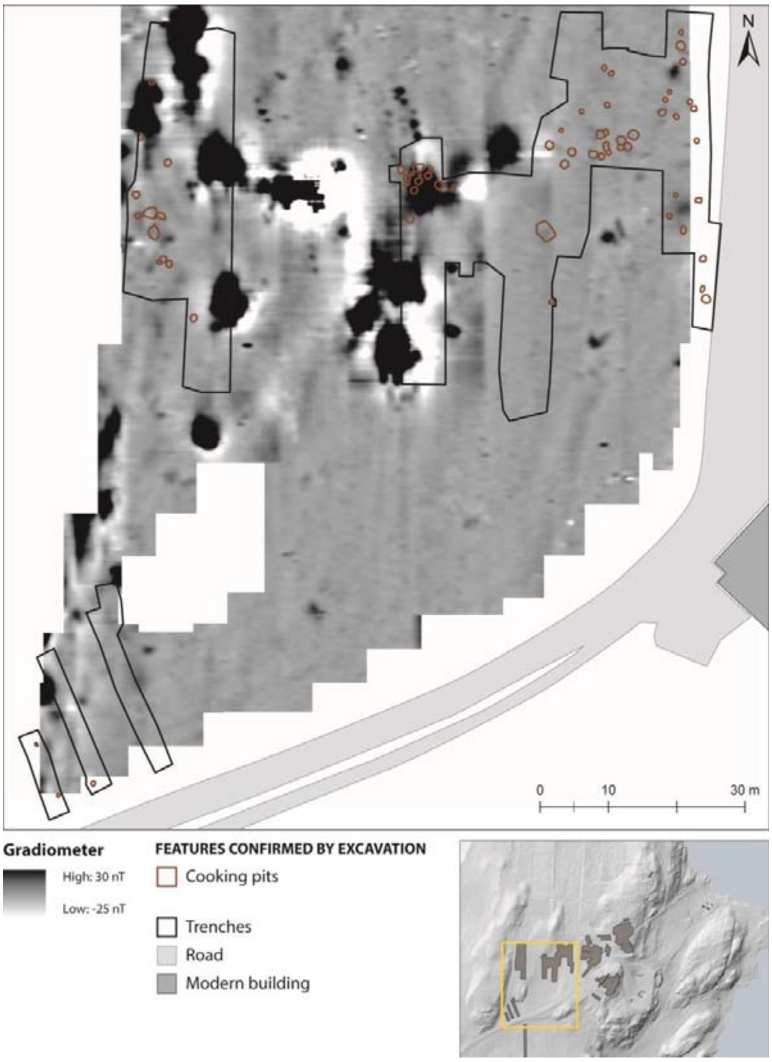

Figure 10: Gradiometer data from Area 2 compared with excavated cooking pits. Plotted in ±1 Standard Deviation (see table 5). Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from gradiometer survey, Earthsound Associates/NTNU 2009 (Barton 2010).

Similarly to the gradiometer data collected by NTNU (Barton 2010), the Moesgård/Geosight magnetometer survey was affected by strong magnetic disturbance from the background geology. The report presents a map of 82 objects in which the potential mass and depth of the anomalies are modelled (Smekalova and Bevan 2009). Of these, 31 anomalies lay within the area excavated in 2011. During excavation, six anomalies were classified as caused by geological variations. Seven of the anomalies corresponded with archaeological features – a 28% co-location. As 123 archaeological features (excluding the stakeholes) were identified within the excavation area, these seven co-located anomalies equal 5.7% of the excavated features within the survey area.

In Moesgaard/Geosight's magnetometer and EMI surveys, which measure detailed magnetic susceptibility, only two anomalies were identified: F1 and F4 (Smekalova and Bevan 2009). F4 lay in the north-eastern corner of Area 2. No archaeological features were exposed in the vicinity of F4 during excavation. Smekalova and Bevan (2009) suggest that the surface could have been burned, thus enhancing the subsoil's magnetic susceptibility. Another interpretation is that the overburden is shallower in the area; hence, the magnetic bedrock is closer to the surface. F1 is visible in the EMI survey, in the magnetometer data from Smekalova and Bevan (2009, the gradiometer data from Earthsound Associates/NTNU 2009 (Barton 2010), and vaguely in the VIAS GPR and earth resistance data from Earthsound Associates/NTNU 2009 (Barton 2010) – the latter constituting reasonable evidence to suspect it to be an archaeological feature (see fig. 11). Smekalova and Bevan (2009) provide a detailed analysis and modelling of the anomaly. It is located within the area of a survey trench from 1992 (Hemdorff 1993) but lay deeper than the exposed level. A reasonable interpretation is that the anomaly is a large cooking pit, similar to cooking pit A3889 (Bauer, this volume, Ch. ##:##) but with a greater magnetic enhancement.

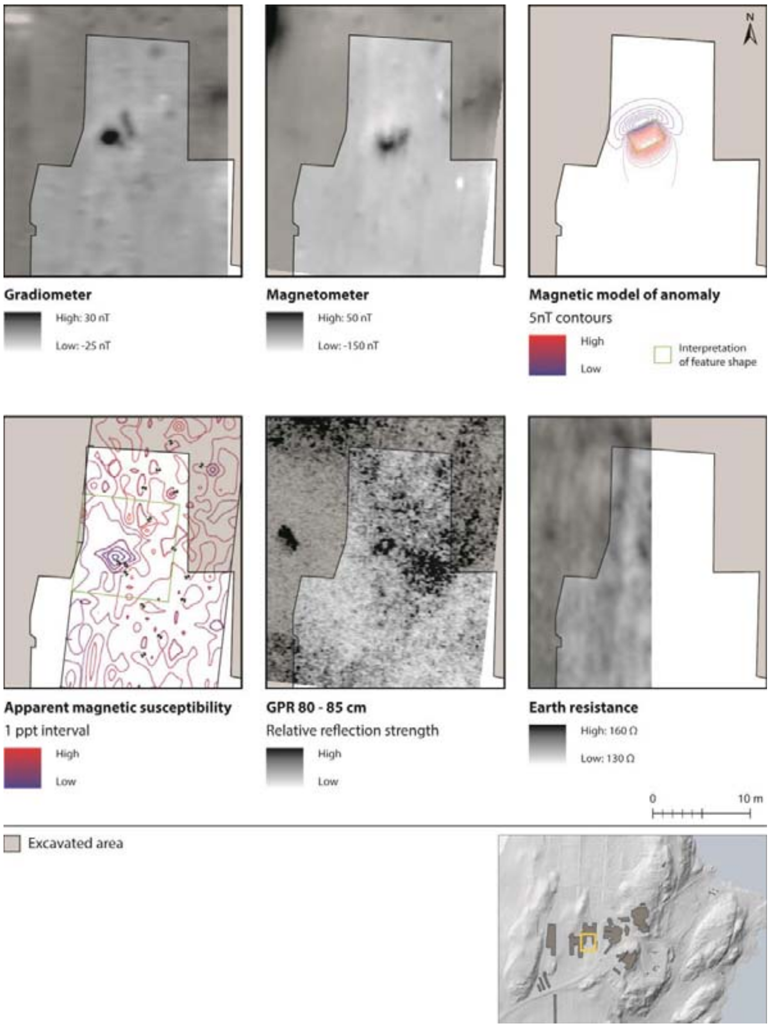

Figure 11: The anomaly denoted as F1 by Smekalova and Bevan (2009) as identified in their EMI (MS) and magnetometer data and modelling, compared with the VIAS GPR data and gradiometer data from Earthsound Associates/NTNU 2009 (Barton 2010). Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes.

The earth resistance data collected with a twin probe array by NTNU in 2009 (Barton 2010) from Area 2 (fig. 12) mainly reflected soil thickness, having low earth resistance values in areas with thick cultivation deposits and relatively high values in areas where the overburden was shallow. A few anomalies coincided with excavated cooking pits – especially the large cooking pit A3889 which yielded a maximum reading of 141 Ω compared with the surrounding soil matrix of approximately 133 Ω. (For information on the cooking pits, see Bauer, this volume, Ch. ##:#.) No clear shapes in the geophysical data were recognised as archaeologically significant prior to excavation. The western edge of the 1992 survey's trench (Hemdorff 1993) was visible. Another resistance anomaly – denoted as F1 in the EMI and magnetometer data from the Moesgaard/Geosight survey – coincided with a GPR anomaly identified outside the excavated trenches (see fig. 11). The earth resistance survey was performed with 1-metre probe separation, which could in theory be affected by features situated as deep as 1–1.5 m, depending on the features' conductivity. Sampling at 0.5 m x 0.5 m is generally considered to provide an adequate spatial resolution (Gaffney and Gater 2003; David et al. 2008; Schmidt 2009). Knowing that the overburden's thickness was ±70 cm in places, any features within this soil volume should still be within detectable depth for a probe spacing of 1 m. The fact that no features were clearly identified indicates either suboptimal survey conditions, poor resistivity contrasts of the archaeological features, or a depth of investigation lower than was indicated.

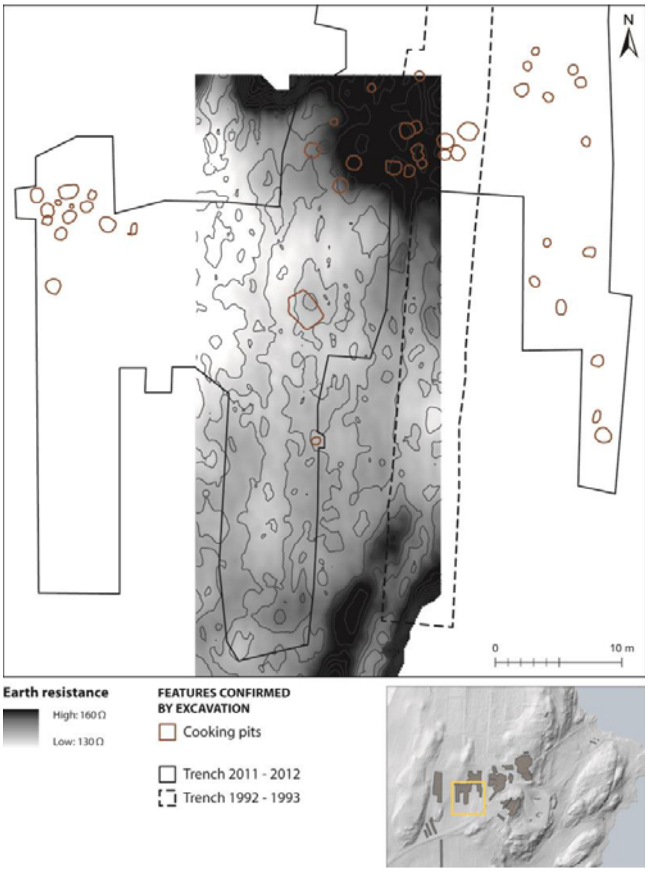

Figure 12: Earth resistance data and the excavated areas, compared with the location of cooking pits. Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from earth resistance survey, Earthsound Associates/NTNU 2009.

Numerous anomalies observed in 36 georeferenced GPR time slices in high spatial resolution from Area 2, supplied by VIAS, corresponded closely with archaeological features discovered during subsequent excavation. Among the numerous geophysical surveys at Avaldsnes, the VIAS survey provided the most relevant results (tab. 6). Twenty-one GPR profiles, collected by NTNU in 2009, were used in tandem with the VIAS time slices for visualizing sections across anomalies. This helped with categorising and understanding the results. The interpretation was made after the excavation ended, but without taking known archaeological features into account when isolating geophysical anomalies (fig. 13).

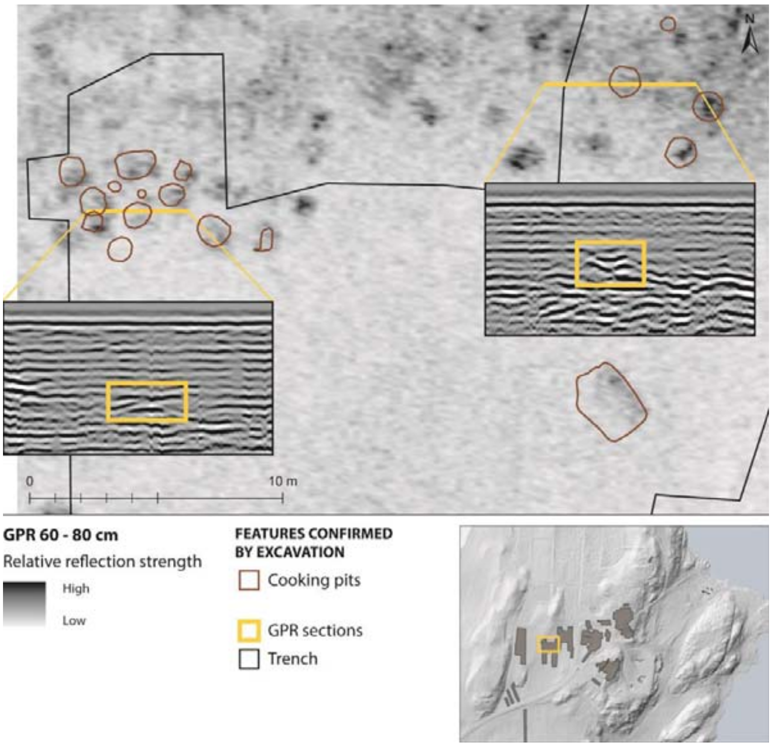

Figure 13: Comparison of the average GPR reflection strength of the VIAS time slices from a depth of 60–80 cm against GPR sections across some of the excavated cooking pits as seen in data collected by Earthsound Associates/NTNU 2009 (Barton 2010).

The VIAS GPR time slices showed 121 anomalies of various sizes and at different depths. The excavation trenches encompassed 78 of these anomalies, while 43 anomalies remain in the ground without verification through excavation. A sharp positive contrast clearly delimited several of the anomalies, especially those situated in areas with thick and homogeneous cultivation deposits. Certain excavated features, such as small stones and stakeholes, cannot be expected to be visible due to their small size (i.e. diameter <0.1 m). Other archaeological deposits were likewise not expected to be visible due to their large and often irregular size, the weak geophysical contrast at interfaces, and the limitation of examining GPR data in time slices alone. Such features are consequently excluded from the statistics. There were 123 excavated archaeological features within the GPR survey area (excluding stakeholes and deposits). Twenty-four of these (i.e. 20%) were identified in the GPR data during initial interpretation made by the authors of this chapter, as mentioned above (table 6 and fig. 13).

Table 6: Comparison of GPR interpretation against excavated features. Numbers are based on the contrast in the GPR time slices and a visual comparison of anomalies and excavated archaeological features to confirm whether the two were of comparable size and shape.

Feature type	Number of excavated features within the GPR survey area	Number of features positively identified in the GPR data	Percentage correlation
Cooking pit	54	23	43%
Charcoal concentration	4	0	0%
Removed clearing cairn	1	0	0%
Stone	24	1	4%
Concentration of stones	2	0	0%
Imprint after stone removal	18	0	0%
Posthole	17	0	0%
Ditch/wall ditch	3	0	0%
Anomalies identified below excavated depth*	0	12	
Total number of archaeological features	123	24	20%
Total interpreted GPR anomalies within excavation area (*anomalies below excavated depth excluded)	66	24	36%

The archaeological feature type proving easiest to identify was cooking pits (see tables 6 and 7, as well as fig. 13). The GPR data showed such stone-rich features as dark anomalies corresponding to the size and shape of the excavated cooking pits. The comparison demonstrated that cooking pits had to be of some size and contain a certain amount of stones in order to be visible in the time slices. Most of the cooking pits cut into homogeneous cultivation deposits cleared of stones, hence the pronounce contrast between the cooking pits and the surrounding soil (see table 7 and GPR sections in fig. 13). The cooking pits lay mainly in the outskirts of the cultivated surface or where the cultivation deposits were rather shallow. Fortunately, the deposits were still thick enough to provide geophysical contrast to the cooking pits. The cultivation deposits' extent and depth were clearly visible in the time slices, mainly due to their sharp contrast to the stony and gravelly subsoil and bedrock below. The same subsoil camouflaged cooking pits and other features dug into it, due to similar signatures. Table 7 demonstrates how easily identifiable cooking pits were when dug into different deposit types. This comparison suggests that several of the 43 anomalies identified outside of the excavation areas might be of archaeological significance, and that it is reasonable to assume that several of the anomalies situated within the cultivation deposits might be additional cooking pits.

Table 7: The visibility in the GPR data of cooking pits dug into subsoil and cultivation deposits, respectively.

Local deposit context of cooking pits	Number of exposed cooking pits	Number of anomalies observed in GPR data	Percentage of excavated cooking pits visible in the GPR data
Subsoil	27	5	19%
Cultivation deposit	27	18	67%
Sum	54	23	43%

We followed up on this by examining the typical features missed in the initial interpretation. Of the 17 postholes, only four contained stones used for bolstering the post, and all 17 had a backfill of sand or silt. A visual comparison left none of the postholes detectable in the time slices, indicating that the backfill of sand or silt did not create a detectable geophysical contrast. The postholes had a diameter of 0.45 m ± 0.2 m and a depth rarely greater than 0.25 m, which typically would be covered by only 1–2 GPR profiles. Of the 31 cooking pits missed in the initial interpretation, at least eight were visible in the time slices, but many were located in the intersection between the bottom of the cultivation deposits and the more stony subsoil. This camouflaged the pits and rendered them less pronounced, as the subsoil generally had a high signal reflection. Eight of the overlooked cooking pits had a backfill of sand, charcoal, and burnt clay – but no stones. The cooking pits indicated in the initial interpretation covered an average area of 0.96 m^2 in plan, and the excavated cooking pits had an average depth of 0.23 m. The missed features had a smaller area on average – 0.65 m^2 – and an average depth of 0.18 m. Both measurements were slightly less than for the identified cooking pits. We were not able to identify the ditches when re-examining the data. We also observed several anomalies outside the excavated areas. Based on size and previous experience, we interpret as many as 25 of these anomalies as cooking pits. Two of the features are of size comparable to that of the large cooking pit A3889.

The geophysical surveys from Area 2 demonstrate that several factors, such as local geology, thickness and homogeneity of deposits, and prehistoric and historic activities at the site, affect the interpretable results. High-definition GPR surveys excel in locating features containing stones within thick cultivation deposits otherwise cleared of stones. MS surveys are better suited to gathering information about activity areas than to locating individual features. While gradiometer surveys usually are used to distinguish and locate individual features than activity areas, this was not the case in Area 2 at Avaldsnes. Here, the magnetic surveys were susceptible to background variation of geological origin, thereby complicating the interpretation of the data. Moreover, thick deposits covering archaeological features decreased the magnetic contrast from such features, limiting their detectability.

Pre-excavation survey: Area 5

The prehistoric field extended into Area 5 from Area 2. The cultivation deposits were shallower in Area 5, however: between 30 cm and 100 cm. A concentration of cooking pits were cut into the cultivation deposits in the area’s western half; on top of this was a stone-paved walkway from a later, medieval complex. A broad ditch running north to south and turning gradually towards the north-east demarcated the prehistoric field from the remains of an Iron Age longhouse (A13). A 19 x 8 m stone packing covered most of the building remains. Two modern ditches for metal pipes were cut through the central part of the excavation area, and recent digging activity and refuse dumping has disturbed the area’s north-eastern part.

The mass MS sampled during excavation (fig. 14) were all taken from the same archaeologically defined deposit and showed two concentrations of distinctly increased value in the north-west and the south-east, respectively. In the north-west, the values increased towards the concentration of cooking pits. The south-eastern area of increased values was located in the south-eastern part of the longhouse and could be caused by Iron Age household activities. Alternatively, these could be traces of the metalwork activity from neighbouring Area 6, approximately 30 m to the south-east, which possibly extended this far. Furthermore, charcoal fertilization – identified in micromorphological thin-sections (MacPhail and Linderholm, this volume, Ch.##) – of the cultivated surface probably contributed to the magnetic enhancement of the topsoil. A heightened response in the eastern part of the area with topsoil MS samples seemed to correspond to the longhouse’s location. Another area of heightened topsoil MS values north-east of the longhouse might be due to modern activity, leaving the collocation with the longhouse a mere coincidence. As seen in table 3, Area 5 showed a correlation of 0.36 to 0.41, which is within the range of a moderate correlation. The relationship between these two measurements is limited, as only 13–17% of the variation in the mass MS could be explained by the topsoil volume MS values. The mass MS sampled during excavation was better suited to identify activity areas, but topsoil MS gave some indication of these areas.

The fluxgate gradiometer data (fig. 15) showed several areas of strong magnetic response, particularly in the eastern part of Area 5. The heightened values can be explained by modern refuse and disturbances and shallow bedrock. The response in the area’s western part was lower compared with that in the eastern, probably due to thicker cultural deposits associated with the prehistoric field. A dipolar, almost beaded linear anomaly in the gradiometer data corresponds with the location of the modern ditch mentioned above. The response accords with what could be expected from the modern metal pipe excavated there. This interpretation was also noted in the geophysical report (Barton 2010:17). A few anomalies were identified within the cooking pit concentration in Area 5’s western part, but the lack of a clear delineation made it difficult to relate any of these anomalies to specific archaeological features. Neither the building elements from the longhouse, the stone packing, the stone-paved walkway, nor the curving ditch were visible in the fluxgate gradiometer data. All values, except the mean, were slightly higher compared to those of Area 2, supporting the hypothesis of modern disturbance and geology influencing the results from Area 5 (see tables 4 and 5). Interestingly, the EMI (MS) data from GeoFysica indicated a possible area of increased response, which in the report was interpreted as an area of burning (Persson 2006). This area coincided well with the excavated cooking pits in the western part of Area 5 (see fig. 16).

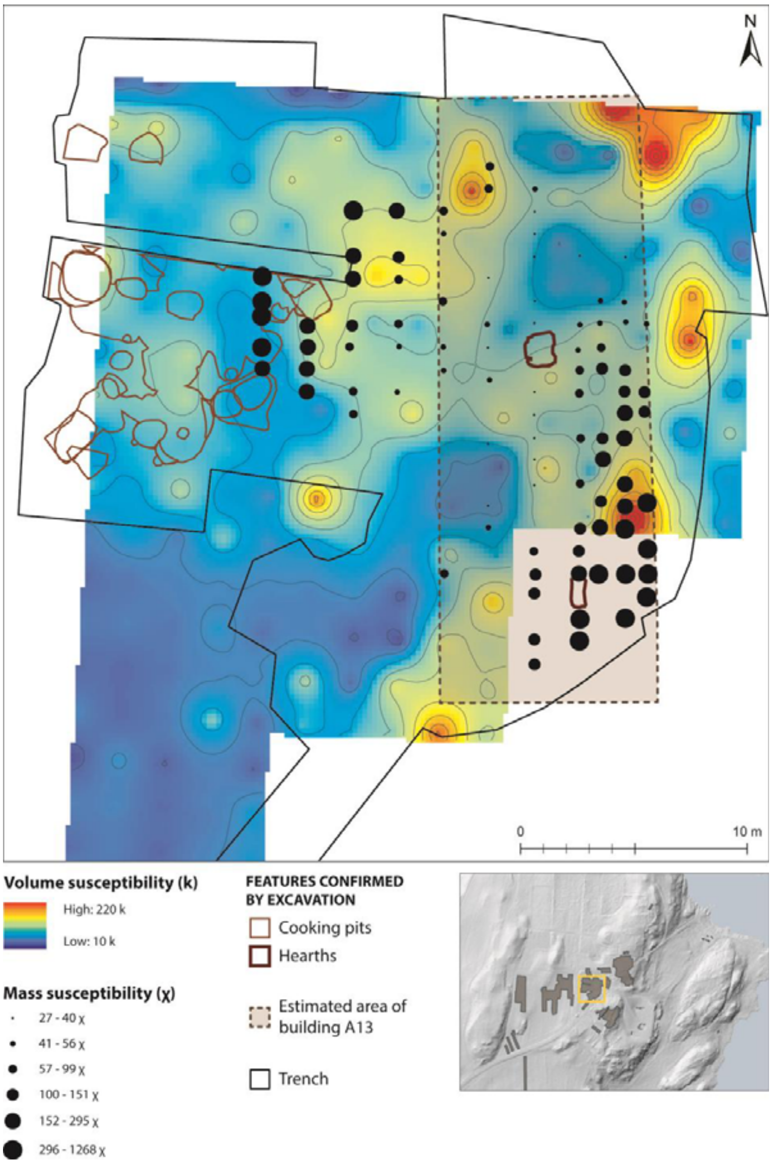

Figure 14: Comparison of topsoil volume MS (k) and the mass MS (χ) sampled during excavation. Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from MS survey reprocessed by Arne Anderson Stamnes, based on samples from the 2009 Earthsound Associates/NTNU survey (Barton 2010), analysed by Linderholm and Wallin (2013).

The earth resistance survey data showed that Area 5's northern part (the northern third of the surveyed area) had low resistance while the southern generally had higher resistance (see ER data in fig. 16). A linear, 1.5–2.5 m wide low-resistance anomaly cutting through both the high and low resistance areas proved to be the same modern pipe ditch as mentioned above. The cut for this pipe was only 0.3–0.5 m wide, however. This reveals how the earth resistance measurements, rather than revealing the ditch itself, indicated the width of the area drained for moisture around the ditch. This demonstrates the potential impact of drainage ditches on the preservation of nearby archaeological features and deposits.

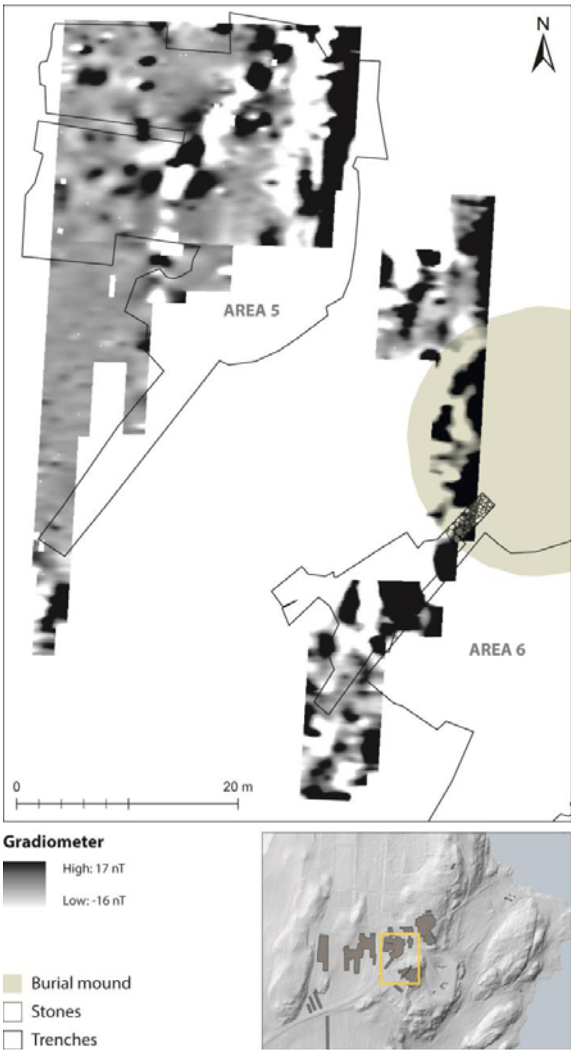

Figure 15: Gradiometer plot from areas 5 and 6, as collected by Earthsound Associates/NTNU 2009 (Barton 2010). Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes.

Neither the stone packing nor the stone-paved walkway were visible in the earth resistance data. The stone packing was exposed 30–50 cm below the topsoil and was 15–20 cm thick. The stone-paved walkway was of similar thickness and lay at a depth of approximately 30 cm. Both features should have been within detectable depth. Stone-filled features are expected to have a relatively high resistance, but hard-packed soil surrounding the features might have created a suboptimal electrical resistance contrast to the stones at the time of the survey. The data showed outlines of old test trenches and pits (see Hafsaas 2006), but none of the ditches or postholes associated with the longhouse were contrasted in the earth resistance data, perhaps due to the overlying stone packing. Neither the cooking pit concentration nor the prehistoric ditches were visible, in the case of the latter possibly because the modern drainage ditch cutting into the ditch drained away moisture, leaving the feature without visible electrical contrast to its surroundings. Some anomalies detected in the earth resistance data were left unexcavated, including a linear, low-resistance anomaly in the area's south-western part and a 9 x 6.5 m rectangular area of high resistance – possibly a compact surface. Further west, five low-resistance anomalies, each approximately 60 cm in diameter, lay evenly spaced (see fig. 17). While these features could be prehistoric pits, it is also possible that they are remnants of removed bushes or other modern-day garden flora.

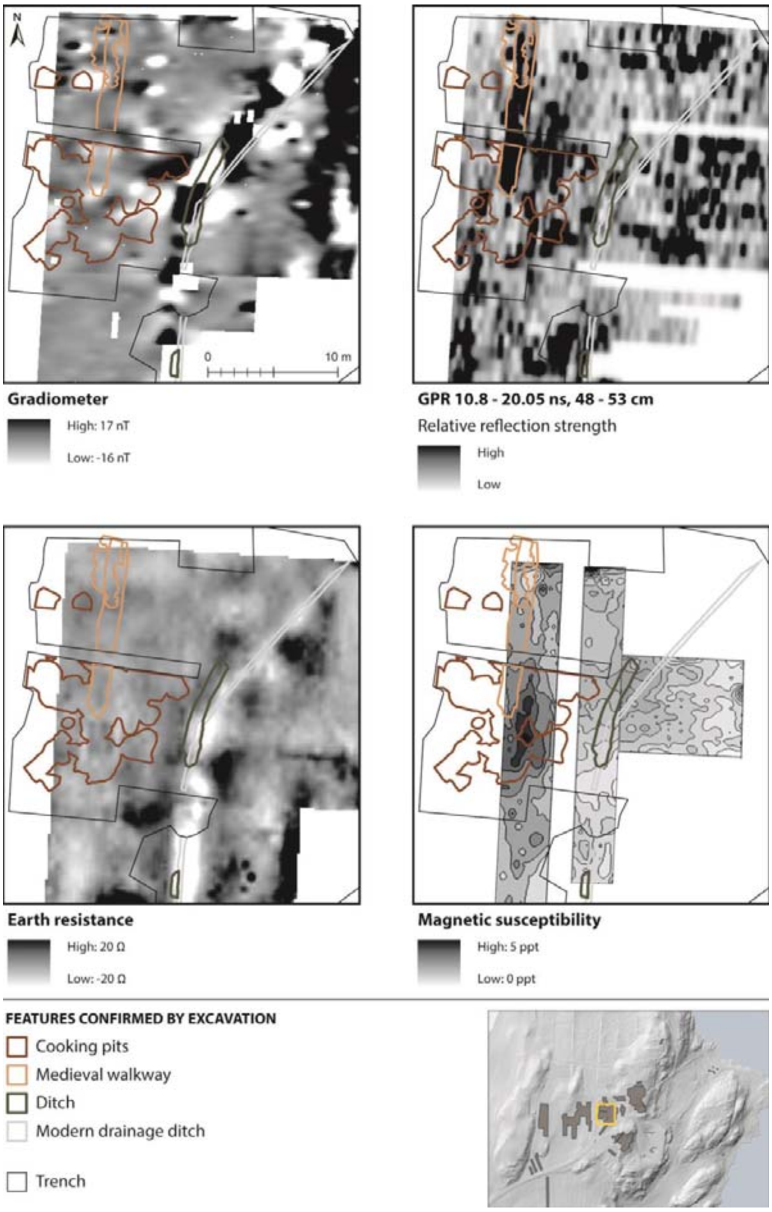

Figure 16: Comparison of various geophysical responses in the north-western part of Area 5. Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from gradiometer, GPR, and ER collected by Earthsound Associates/NTNU 2009 (Barton 2010); EMI (MS) collected by GeoFysica in 2006 (Persson 2006).

Figure 17: Earth resistance plot over the south-western part of Pakterhagen. Data collected by Earthsound Associates/NTNU 2009 (Barton 2010). Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes.

The 2009 GPR survey by Earthsound Associates/NTNU covered only part of Area 5 (fig. 16). The interpretations in the geophysical report focused on the drainage ditch also visible in the earth resistance and gradiometer data, as well as a rectangular feature in the north-west (Barton 2010). The rectangular feature proved to be the medieval stone-paved walkway (see fig. 16). The stone-paved walkway was not visible in the GPR data in the northernmost part of the area, at the edge of the car park. This is difficult to explain, as the feature was clearly visible further south. Possibly, the conductivity contrast within the present-day garden that made up Area 5 was different from that in the gravel-covered car park in Area 1. Alternatively, variation in ground coupling between the GPR antenna and the ground could have altered the amount of transmitted energy, affecting the potential geophysical contrast of features. The data in Area 5 was collected perpendicular to the walkway, while the direction of data collection in Area 1 was oriented parallel to the direction of the walkway.

By reprocessing the data, another linear feature could be correlated with the exposed modern drainage ditch further east. With a traverse interval of 1 m between each mapped GPR transect, features less than 2–3 m in diameter are not expected to be noticeable. Linear features perpendicular to the traverse direction, as well as extensive constructions and coherent continuous deposits, could theoretically be visible. However, for identifying archaeological features such as cooking pits, surveys with a traverse interval of 1 m or more are arguably ineffective. Although described as a Phase 4 GPR survey, intended to further define and refine archaeological features (Barton 2010), the choice of 1-metre transects seems inappropriate when considering the size of typical archaeological features such as cooking pits and postholes that could be expected and were in fact excavated within Area 5. Ideally, a line spacing of 0.25 m or less should have been chosen to identify archaeological features smaller than 0.5 m in diameter (David et al. 2008; Conyers 2013). The reason for the line spacing choice is not known, but may be related to time constraints or lack of information of the size of the archaeological features that were to be expected at the site. In Area 5, ditches and pipes gave clear linear responses in the GPR time slices, while the stone packing was not detectable even though some highly reflective areas were visible in its general location. The examination of the GPR profiles from these areas do not reveal any clear layers that can be easily explained by the presence of this stone packing. Most of the stones in the stone packing were fist-sized or smaller and loosely packed, seemingly not creating enough geophysical contrast to be detectable either by GPR or earth resistance measurements, at least not at the interval spacing used and with the current antenna centre frequency of 400 Mhz.

The surveys carried out in Area 5 illustrate how modern features, refuse, drainage, and disturbances, as well as shallow bedrock make it difficult to discern whether anomalies are related to archaeological features or later activity. This is problematic for sites such as Avaldsnes, which has an extensive history – particularly for Area 5, which is and has been part of the main farmyard for most of the site's history. Interestingly, the EMI survey mapping's apparent magnetic susceptibility produced encouraging results, indicating and roughly delimiting an area of cooking pits, even under such difficult survey conditions.

Pre-excavation survey: Area 6

Area 6's close proximity to the modern-day farmyard, road, car park, and housing was expected to result in spurious, high MS readings. Intrusion into the Kjellerhaugen grave mound is known from historical sources. The topsoil MS showed a low enhancement zone on the central and eastern parts of Kjellerhaugen, interpreted as an intact or less disturbed part of the mound (fig. 18). South of the mound are several zones with high values. The zones are not connected, and the source of these high values could vary. The ground is rough and disturbed, with evidence of modern disturbances (Barton 2010). The measured χ values of the mass MS samples extracted during excavation showed a log-normal distribution with a single extreme reading and a cluster of readings in the range of 1000–2000 χ. A random distribution of sample values would lead to a normal distribution, which is not noticed here. Instead, they are log-normally distributed, interpreted by Linderholm and Wallin (2013) as a sign of human influence as the measured values are skewed. Such high values are usually associated with presence of metal or highly magnetic igneous rock. The mass MS data suggested two areas of particular interest, of which one contained the above-mentioned extreme value. This area coincided with features and deposits containing hammer slag, suggesting that metalworking and dispersion of waste related to this activity caused the high values (Linderholm and Wallin 2013). A furnace and a corn-drying kiln were also excavated in this area (Bauer and Østmo, this volume, Ch.##:##) – features associated with activities that can explain the areas of mass MS enhancement. The areas of enhancement observed in the mass MS data sets are interpreted as reasonable sizes of work zones, and it is plausible that the MS response reflects metalworking and the connected, unintentional spread of waste products in the area (Linderholm and Wallin 2013). The MS survey therefore provided additional spatial information regarding the production and processing activities in this area.

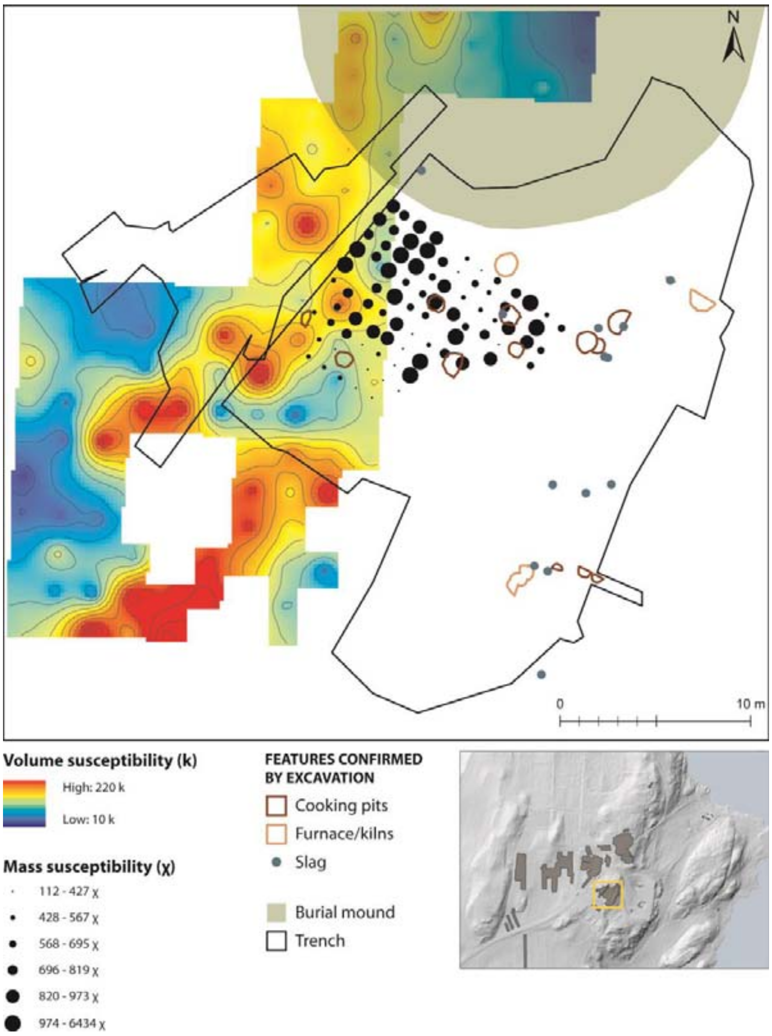

Figure 18: Topsoil volume susceptibility (k) vs. sampled mass susceptibility (χ) in Area 6. Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from MS surveys, Earthsound Associates/NTNU 2009 (Barton 2010) and Linderholm and Wallin (2013).

The correlation between volume and mass MS was very low, only 0.03–0.1, and with a correlation coefficient of only 0.1–1% (see table 2), even though the topsoil MS was sampled relatively densely, in a 2 x 2 m grid. We had assumed that a higher spatial sampling rate would increase the spatial correlation. The correlation between such activity areas delineated by mass MS and the topsoil MS readings was weak or simply absent. In combination with the modern disturbance to the topsoil, this weak correlation made it difficult to use the topsoil MS readings to delineate the production and processing activities that were excavated. The mass MS, on the other hand, was more useful for delineating activity areas.

The fluxgate gradiometer survey covered only a small part of the excavated area, and did not cover significant archaeological features such as the corn-drying kiln or the fortification (see fig. 15; for information on the fortification, see Østmo, this vol., Ch. ##). The exposed stone packing in the southern part of the Kjellerhaugen grave mound was partially included. The rather strong negative magnetic signal observed in this area can probably be attributed to the stones' magnetic properties. A similar signal within the average survey depth of the gradiometer indicated that the stone packing continued to the north-west. The mound's boundary is suggested by the strong negative values occurring roughly where the construction is visible on the surface.

The resistance data did not reveal anomalies related to excavated archaeological features, except for the stone packing in the grave mound, but even this feature did not show a high contrast (fig. 19). By relating high contrast to the presence of stones or compacted soil, it is probable that the rectangular area near the modern building by the south-western edge of Kjellerhaugen represents a disturbance caused by foundation work for the building. Furthermore, a 3.5 x 3.3 m low-resistance area west of the mound's top indicates a filled-in hole from a possible grave-plundering event. The north-eastern part of the mound has very low earth resistance readings, coinciding with the possible location of a potato cellar dug into the mound in the early 19th century.

The lack of correlation between topsoil MS and mass MS in Area 6 demonstrates a limitation of such surveys. Furthermore, magnetic susceptibility can be caused by metal or igneous rock, thus in certain instances necessitating ground-based observations to confirm archaeologically relevant activity areas. Pre-excavation survey areas at any given site do not always cover what subsequent excavation proves to be the most relevant areas for investigation. Small survey areas can furthermore hinder the interpretation of anomalies, as the high- or low-value areas cannot be delineated.

Figure 19: Earth resistance measurements in Area 6. Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from ER survey, Earthsound Associates/NTNU 2009 (Barton 2010).

Post-excavation survey: Area 1

From 4–7 November 2013, post-excavation GPR-surveys were carried out in the northern and south-eastern parts of Area 1 and in Area 8 (see fig. 1) to address some unanswered questions from the excavations. The knowledge of archaeological features in the vicinity facilitated the positioning of the survey areas to cover presumed features in the unexcavated areas.

Area 1's northern part was inside the cemetery partly surveyed with GPR in 2004; however, wet conditions at that time had obscured any possible features, so the 2004 survey was without clear results (Sandnes and Eide 2004:14). In the 2013 GPR survey, we hoped to find remains of a construction extending from the southern chancel wall, towards the medieval ruin (A12) discovered in the south-eastern part of Area 1. Such a feature was suggested by the excavation of the medieval ruin (Bauer, this volume, Ch. ##:##). Another motive for the survey was to attempt to locate an octagonal construction, 6.8 m in diameter – perhaps a vestry – rumoured to have stood 16 paces south of the church (Hansen 1800:259).

The processed GPR data showed a number of high-reflective anomalies from several depths. All anomalies and interpretations are overlaid on a selected time slice in figure 20. The ground was water-saturated after heavy rainfall and yielded little contrast between the soil and low reflective anomalies. Still, three approximately 2 x 1 m anomalies of east–west orientation, presumably graves, lay relatively shallow (40 cm at most). This interpretation is based on the clear geophysical contrast, shape, and orientation of the anomalies. One of the identified graves has a grave slab on the surface, while the two others visible on the time slice in figure 19 do not. Figure 21 shows a GPR time slice through both the visible grave slab and the interpreted grave just east of it. A right-angled anomaly adjoining the chancel's south-eastern corner at a roughly 45-degree angle is probably the remains of foundations for some form of construction. An approximately rectangular area of north–south orientation of high-reflective anomalies just south of the surveyed area's central point could be the remains of a hard-packed surface or stones associated with a foundation. Such an interpretation is difficult to establish without excavation, as the anomalies' size and shape are not continuous.

A line of continuous anomalies extends for approximately 9.5 m at a right angle from chancel's south-eastern corner, before turning westwards for about 5 m and then south again. This line seemingly coincided with a topographic break in the landscape, forming a roughly squared terrace. Another linear anomaly stretched from east to west in the survey area's eastern part. These linear anomalies could represent walls or foundations.

The 2013 survey included the area immediately to the north of the medieval ruin (A12), to discern how far north this construction continued (see map in fig. 1). Excavations had demonstrated that stone rubble from different phases of the post-Reformation rectory buildings complicated the stratigraphy in the area. At the time of the survey, the site had been backfilled to cover and protect the partly exposed ruin. The surfaces exposed during the excavation were covered by 20–40 cm of soil.

The time slices showed large amounts of strong reflective material in the central part of the survey area (fig. 22). As the excavation revealed stone rubble and building material from the post-Reformation rectory, it is reasonable to assume that most of the strong reflective anomalies are related to these building remains. Several rows comprised of individual anomalies indicated foundations. At least one of these rows corresponded with stones left in situ after excavation. This row could be part of a building or a room. Possible building foundations might be traced further outside of the excavated area. The feature's alignment corresponds roughly with the medieval ruin, suggesting that these anomalies might be related to the medieval ruin or constructions associated with it. Apart from these observations, it was generally difficult to discern distinct patterns in the anomalies, even when comparing the excavated features with GPR time slices and profiles. We interpret these observations as indicators of additional building rubble and building material remaining adjacent to the excavated areas. The geophysical response is similar to the known stones left in situ but is still relatively chaotic.

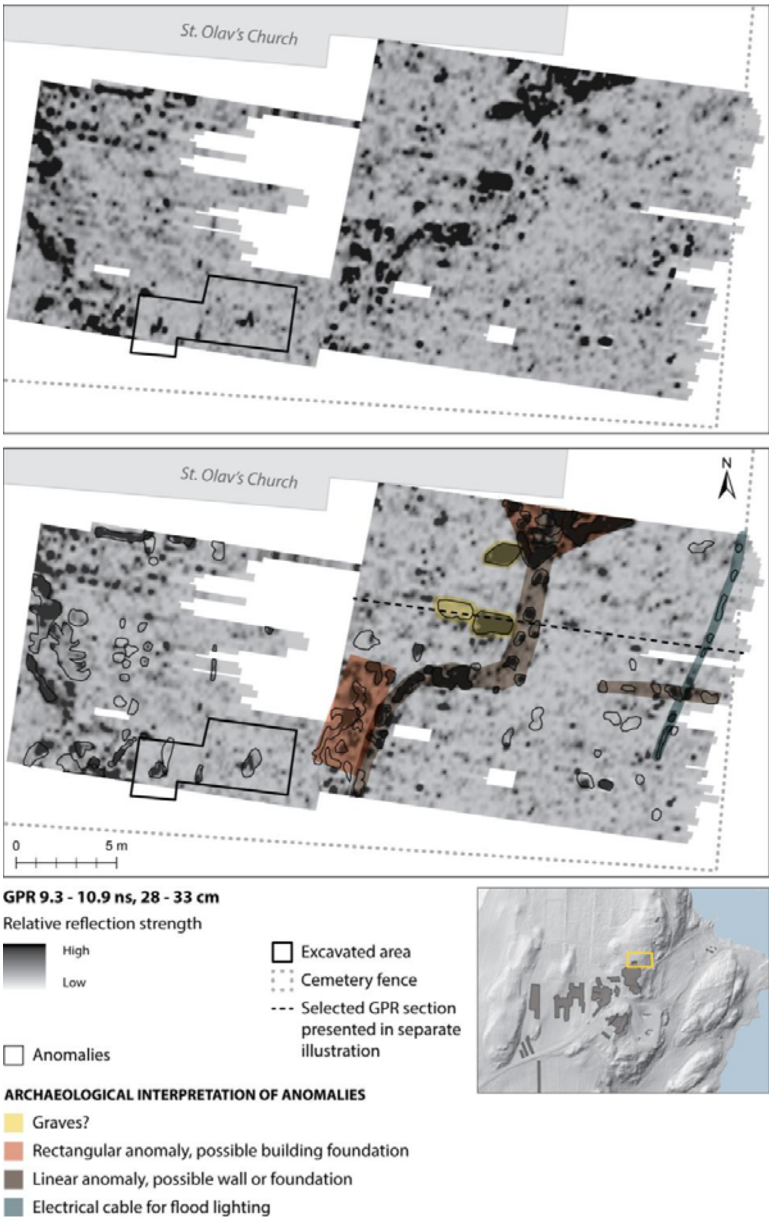

Figure 20: An archaeological interpretation of the GPR data collected in 2013 by the authors. All the anomalies included in this figure were visible in several depth slices, increasing the likelihood that they are man-made constructions collocated at the same spot over several depths. Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes.

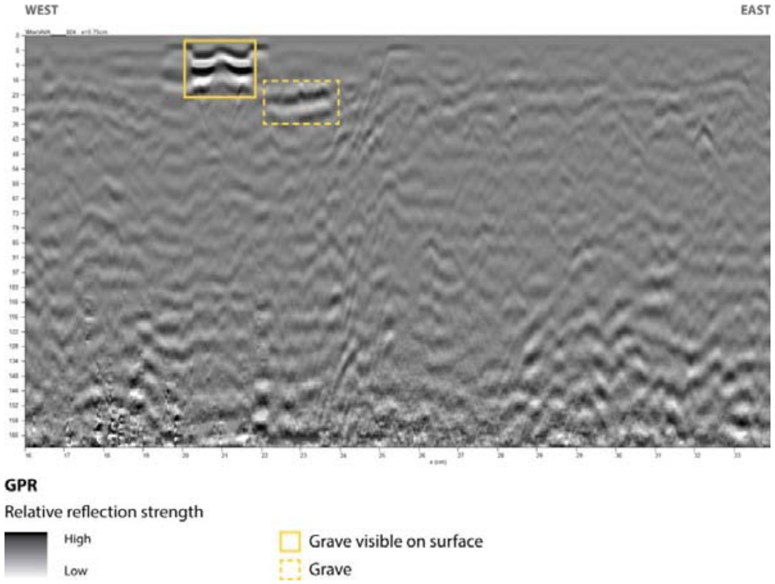

Figure 21: GPR profile showing two of the graves: A shallow grave to the west and a grave at lower depths to the east. Illustration by Arne Anderson Stamnes.

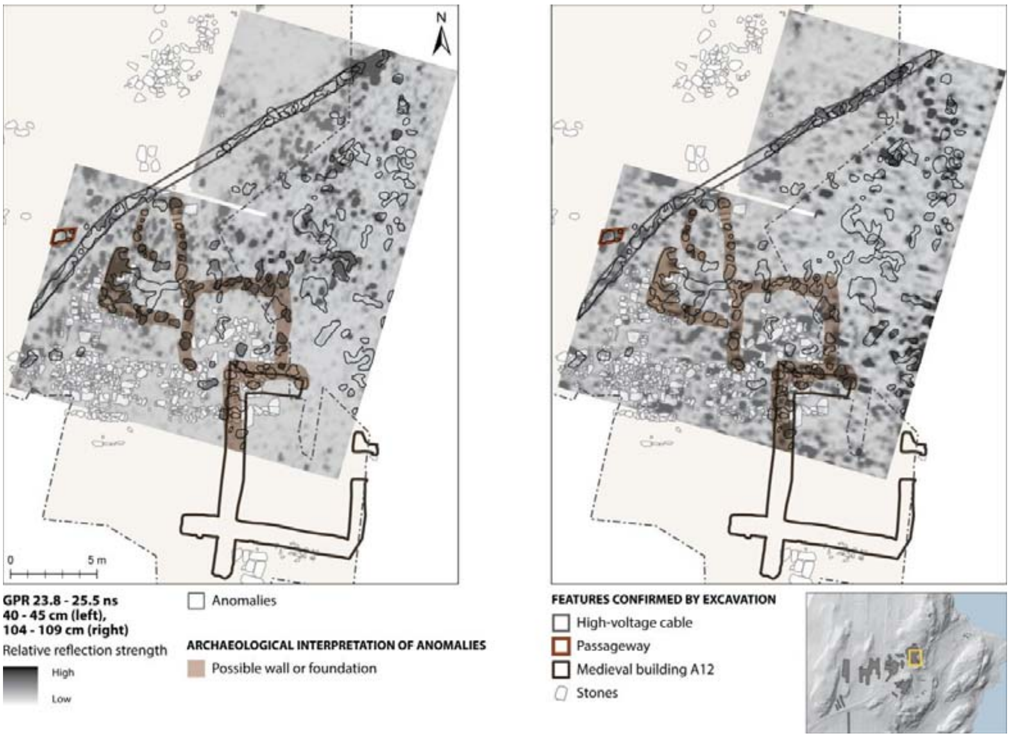

Figure 22: The archaeological interpretation of the GPR data collected by the authors of this chapter in 2013. Two different time slices are overlaid with an archaeological interpretation of the GPR data. Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes.

The only clearly continuous row of anomalies is the high-voltage cable mentioned in connection with the subterranean passageway (above, p. ##). While the passageway's eastern end was visible (figs. 22 and 23, western edge), no linear trend indicating a continuation of the passageway east of the high-voltage cable could be distinguished in the time slices by following the observed response from the passageway into this area in the adjacent GPR sections. This could mean that the passageway actually ended there; alternatively, the high-voltage cable could have been laid in the passageway, effectively camouflaging this feature.

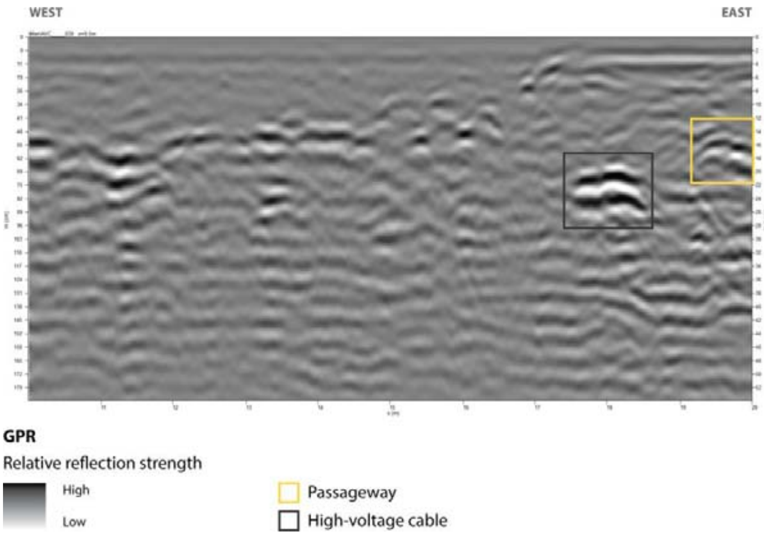

Figure 22: GPR profile showing the geophysical response from the subterranean passageway and the high-voltage cable. Illustration by Arne Anderson Stamnes.

A few anomalies are visible in the GPR sections as very distinct areas of reflection, possibly representing substantial constructions. Alternatively, the heavy rainfall at the time of the survey led to bedrock depressions being filled by water, which in turn can create increased geophysical contrasts complicating interpretation. From the excavation on the terrace in Area 1's eastern part the bedrock is known to lie at approximately 0.2–0.3 metres below the surface, but the GPR profiles indicate increased thickness of deposits down towards the edge of the terrace to the east (figs. 24 and 25). The yellow line in figure 24 is drawn along a layer of strong reflections corresponding with known bedrock depths to the west.

The depth to the bedrock was relevant in order to estimate how far the building remains could extend downwards (see fig. 25). In the survey area's central part, which was not excavated after having stripped away the turf, the depth to the bedrock seems to be 30–40 cm and maybe as little as 20 cm in the northern part. At the area's eastern edge it might be as deep as 65–75 cm, while in the south-eastern corner the depth seems to be as much as 85–125 cm. Earlier excavations with subsequent backfilling of soil have, however, made it hard to judge the depth.

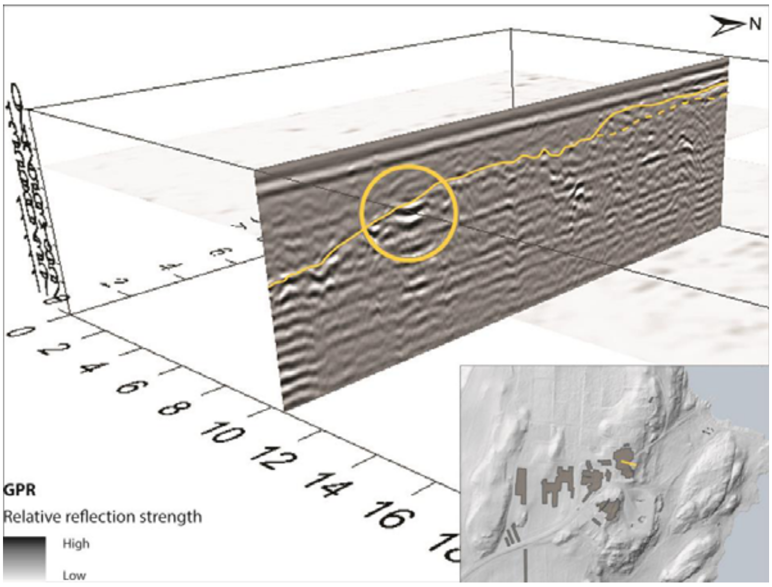

Figure 24: A possible effect of standing water in a bedrock depression. The red line shows an interpretation of the depth to bedrock along the collected GPR transect. Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from GPR survey, NTNU 2013.

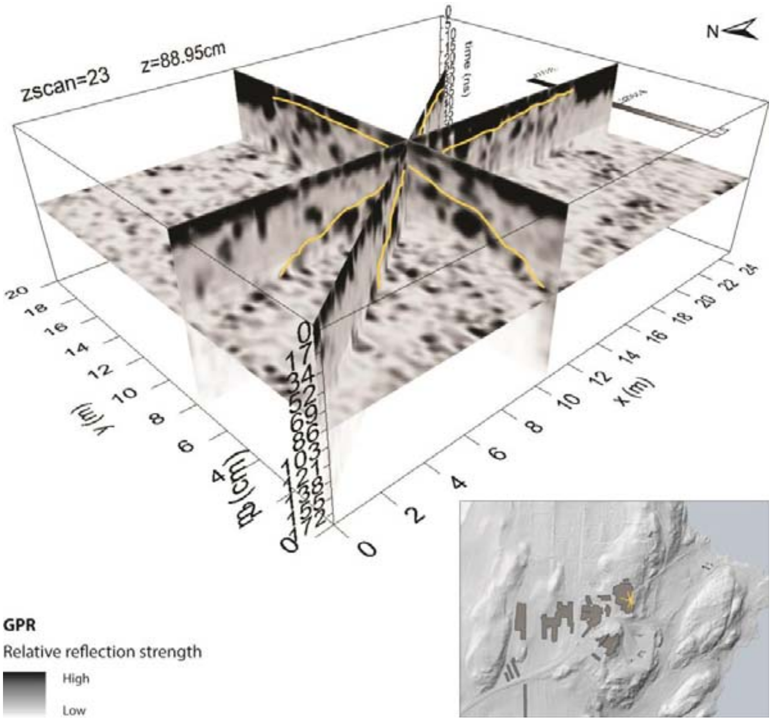

Figure 25: An illustration showing the varied depth down to the bedrock based on an interpretation of the GPR data. North is at right in the illustration. Illustration by Arne Anderson Stamnes. Plot from GPR survey, NTNU 2013.

The post-excavation survey from Area 1 demonstrated that even when information from previously excavated areas and features allows specific hypotheses to be investigated, poor survey conditions, such as water-saturated ground or large amounts of stones in the ground, can result in GPR surveys that are less informative than expected.

Post-excavation survey: Area 8

Area 8 lay at the bottom of the slope below St Olav's Church and was the site for a two-phased boathouse (A40) from the Roman Iron Age and Migration Period (see Bauer, this vol. Ch. ##). The boathouse was investigated in 2012 by digging narrow trenches across the remains, which were covered by colluvial cultivation deposits (Bauer, this vol. Ch. ##:##). A modern gravel path covered the boathouse's presumed opening towards the beach. No pre-excavation geophysical surveys existed from Area 8. The aims of the 2013 GPR survey were to investigate whether any other boathouses could be identified and to delimit and identify additional constructional features of the partly excavated boathouse.

The most distinct results from the GPR survey was the location of four modern ditches (see fig. 26), probably containing plastic tubes similar to the two identified in the excavated trenches (Bauer, this vol. Ch. ##:##). The ditches ran in two parallel pairs, one pair from south-west to north-east and the other pair west-northwest to east-southeast. No other boathouses could be identified within the survey area. It was furthermore difficult to identify any pattern in anomalies possibly representing postholes, as there were many positive reflections. It was likewise difficult to observe already-excavated postholes and stratigraphical observations in the GPR profiles. No stone walls were identified, but in some places the excavated turf walls showed as stronger reflecting areas. In the center of the boathouse was an area with stronger reflection at a depth of approximately 0.5 m, coinciding relatively closely with the depth of the floor deposits. This area extends beyond the relatively narrow excavation trench, but did not form a continuous area of increased signal reflection. Around this area, particularly in the south-west, a curve of slightly stronger reflection seemed to make up the gable end of the boathouse. However, this did not correspond with the location of the excavated wall banks. It is more likely, therefore, that this curvature is a natural formation, or possibly represents the remains of an older boathouse in a slightly different location.

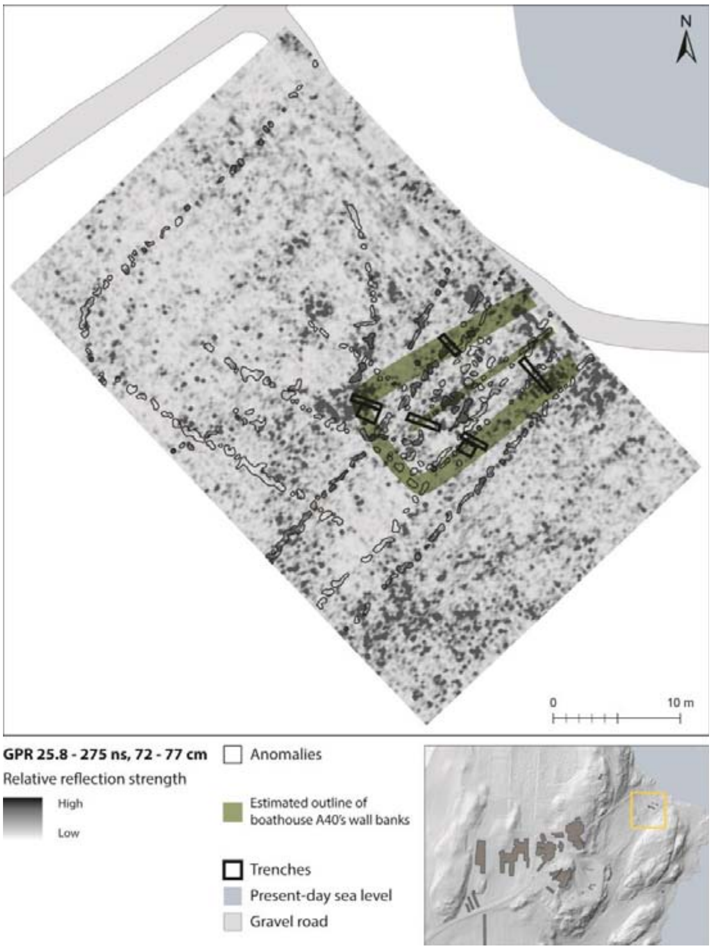

Figure 26: Map showing all identified anomalies interpreted as archaeologically significant in Area 8 on a background of a selected depth slice (72–77 cm below the surface). *Several anomalies are not visible in this presented slice, but appear either above or below the presented depth. All the anomalies included in this figure were visible in several depth slices, increasing the likelihood that they are a man-made construction collocated at the same spot over several depths. The estimated outline of boathouse A40's wall banks is not visible in the data. Illustration by Ingvild Tinglum Bøckman and Arne Anderson Stamnes. Plot from GPR survey, NTNU 2013.*

The post-excavation GPR survey from Area 8 unfortunately was unable to address the unanswered questions from the excavation. The GPR profiles showed only minor geophysical contrasts in areas with known archaeological information, with seemingly high attenuation in the uppermost deposits consisting mainly of water-saturated sand and silt. Drier conditions might have improved the results, but there was not an opportunity to repeat the survey at a later stage under different conditions – a valuable lesson for GPR surveys at similar sites in western Norway.

Evaluation of the geophysical surveys and methods

Generally, the experiences from Avaldsnes show that GPR data was more applicable during excavation than the magnetometer, magnetic susceptibility, and earth resistance data, mainly because GPR anomalies were easily comparable to excavated archaeological features. For field personnel lacking training in interpreting the various data sets, the 'what you see is what you get' nature of GPR time slices is more readily understandable to the untrained eye. The detailed GPR datasets supplied by VIAS from Area 2 were particularly useful during excavation. Following an initial phase of excavation where systematic connections between GPR data and excavated features were discovered, more limited and targeted investigations could be performed, saving work and time.

Certain features, such as stone-free postholes and stakeholes, were invisible in the GPR data; in order to avoid missing entire categories of cultural remains, investigations were based on other criteria as well, such as topography and results from earlier test trenching. By correlating the anomalies' depth within the trench areas with the exposed level of the trenches, the staff could predict with great accuracy the location of archaeological features, which proved to fit well with this dataset. However, stony subsoil or bedrock camouflaged anomalies to a certain extent by providing similar resistance as dug-down, stone-rich features.

For areas with a high density of modern disturbances it was difficult to distinguish archaeological features. This was particularly prevalent in parts of Area 1, where deposits were shallow, compact, and packed with gravel. Certain features, such as the subterranean passageway, stones related to buildings, and several cable ditches, showed clearly in the GPR data. Still, prior to excavation, there was no way of telling whether anomalies were of modern or prehistoric origin. Certain excavated features were even invisible in the GPR data. Such experiences caused the field staff to doubt the surveys' reliability, simply noting anomalies before proceeding with excavation as normal. Other times, the field staff missed certain distinct features in the geophysical data altogether, for example the stone-paved walkway in Area 5. This oversight seemed strange, as the construction was 25 metres long and up to 1.5 metres wide; however, the GPR time slice in the geophysical survey report (Barton 2010:fig. 12.9.1) showed only a single depth slice (no. 10). The walkway was partly visible in four of the other slices (nos. 5–8) not presented in the map. When the GPR data was reprocessed and georeferenced for the presentation of this chapter, the walkway appeared more clearly, as a linear anomaly visible at several depths (see fig. 16). This demonstrates the importance of access to digital files with georeferenced data plots and to an interpretation of the data from the survey, allowing the field staff to continuously select which slices to view, thereby focusing on different depths of the surveyed area, rather than only the depth considered to contain relative features by the geophysicist prior to excavation. It also demonstrates the need for strong communication with trained professionals who can provide adequate data processing and geophysical and archaeological interpretations as well as support and advice throughout the archaeological planning and excavation process.

The data from the survey methods other than GPR were more difficult to interpret for the field staff prior to and during excavation. In the magnetometer data, for instance, the shapes of anomalies do not fit the exposed archaeology. While geophysical responses can be different in size and shape to that of their source features, this is not necessarily a surprise to a trained expert. Rather, it demonstrates the complications in understanding such datasets for field staff untrained in interpreting geophysical data. Often, anomalies corresponded better with geological formations than with exposed archaeological features. Hence, the field staff tended to consider certain data irrelevant when determining the placement of excavation trenches. At Avaldsnes, it was evident that the magnetic bedrock restricted the usefulness of this survey method as well as the magnetometer and resistance data. In Area 2, for instance, the areas of enhanced responses were too large to allow the identification of any relation to specific archaeological features. Heightened signals might stem either from large activity areas or simply from geology, but such conclusions were impossible to draw before excavation. In hindsight, it seems plausible that the heightened topsoil magnetic susceptibility response in Area 5's eastern part corresponded with the area for the excavated longhouse, but prior to excavation it was not possible to discern any occupation area here. The high magnetic susceptibility might equally well have been due to modern disturbances.

The pre-excavation geophysical survey data from Area 6 demonstrated another issue: the survey areas were long and narrow, rendering difficult the attempts to gain an overview of the larger context of the anomalies. The topsoil magnetic susceptibility survey showed high values, but as in the other excavation areas, the meaning of this was unclear. There were high values in the area's northern and southern parts alike; as the latter consisted mostly of modern infilling, there was no reason to interpret the high values in the north as anything else prior to excavation. The general impression is that the topsoil MS at Avaldsnes only partly reflected archaeological observations. Again, geology and modern disturbances probably factored into this, while colluvial deposits in Area 2 would have inhibited the transportation of anthropogenically influenced material upwards towards the topmost deposits. At the same time, the extent of the deeper colluvium and cultivation deposits could be made out in the topsoil MS. Our impression is also that the mass MS collected from soil samples from deposits undisturbed by modern activity was useful in understanding and spatially delimiting past activity areas.

Another potentially problematic factor is the direction of data collection. As seen, for instance, regarding the wall ditch in Area 1, certain features are only visible if the data collection runs perpendicular to them. As it is rarely possible to predict the type and alignment of features and to perform surveys accordingly, performing a GPR survey in only one direction could induce false negatives, leading to important information being missed. Moreover, obstacles and the physical layout of the survey areas often dictate which direction the data collection can be performed. Further, it is essential that the surveys' traverse interval is sufficiently narrow to detect small archaeological features. This boils down to a question of time and money. Good communication between the geophysical service provider and the project management is essential when designing a survey methodology for the site.

Each geophysical survey method has its inherent advantages and limitations, all of which have to be taken into account when planning the survey methodology for a site. In hindsight, some of the choices that were made for Avaldsnes seem inappropriate. GPR traverses with a line spacing of 1 m or 0.5 m seem too coarse to properly detect minor archaeological features such as postholes and small pits. GPR is considered to be the most detailed survey method of all methods applied at Avaldsnes; perhaps for this very reason, the method was not utilized to its full potential. We noticed an improvement in the resolution when reprocessing the data from building A10 in Area 1 to focus on a higher frequency range (285–750 Mhz), but this was a trade-off between potential survey depth and resolution. With GPR, applying a lower frequency will lose spatial resolution but gain potential depth of investigation (Conyers 2013). For magnetic methods using passive magnetometer sensors, any decrease in line spacing will improve the data resolution, thereby increasing the potential to properly characterize and interpret observed anomalies. The choice of inline and crossline spacing should therefore match expected features in detail and size (Schmidt and Marshall 1997). Such details are not always known before commencing a survey, but estimates should nevertheless be taken into account. The magnetometer surveys performed at Avaldsnes had a crossline spacing of 0.5 m, which was deemed sufficient considering that these surveys were performed with hand-carried instruments. Current practice within European archaeological prospecting favours the use of towed magnetometer sensor arrays, which allows for the potential of increased effective spatial resolution and survey speed without losing area coverage.

While magnetic bedrock compromised the magnetometer results at Avaldsnes, we still advocate that geophysical surveys should be performed by utilizing several complementary geophysical methods. At Avaldsnes, we identified in some geophysical datasets archaeological features that were invisible in others. This fact is widely demonstrated and recognized by geophysical practitioners in archaeology (see for instance Clark 1996; Gaffney et al. 2002; Gaffney and Gater 2003; Kvamme et al. 2006; David et al. 2008; Watters 2009; Trinks et al. 2010; Stamnes 2010; Viberg et al. 2011; Gaffney et al. 2012; and Trinks et al. 2014). Furthermore, the use of EMI methods is known to provide positive results within an area of strongly magnetic bedrock, as observed for instance over cooking pits in Area 5 and feature F1 in Area 2. Tests in Ireland have shown promising results from EMI surveys over very wet or dry soils and high and low magnetic bedrock that might otherwise impose difficulties for more conventional geophysical survey methods (Bonsall et al. 2013). This indicates that the future use of multi-depth EMI systems in archaeological geophysical surveys in Scandinavia could compensate for some of the difficulties observed at Avaldsnes, including thick topsoils and magnetic bedrock.

Several of the geophysical survey reports from Avaldsnes accentuate an inherent problem with their usability. As the surveys are usually carried out prior to excavation (several of them even before the Avaldsnes Royal Manor Project was established), the geophysical reports contain unconfirmed interpretations. Data comparison is often complicated by inherent discrepancies with regards to positioning between the surveys, hence the necessity for clear and concise information on survey locations in a digital format. Furthermore, the most apparent anomalies are not always archaeologically significant. It is essential that, along with the report, the geophysical service provider make available depth slices and data plots as high-resolution digital files, thus enabling the excavation staff to study them and quickly alternate between them, consequently increasing the likelihood of spotting anomalies in different areas, both prior to and during excavation. The geophysical technicians should be supplied with excavation plans containing information on the types of features to expect, based on survey excavations, written sources, or previous experience. Communication between the geophysical technicians and the excavation staff should be maintained throughout the excavation phase and even during post-excavation, as interpretations are tested and revised. Such communication, including interpretative assistance, should be included in the standard contract upon entering into collaborative work. Such two-way feedback would facilitate the development of the application and usability of geophysical survey methods for archaeological fieldwork with regard to evaluating initial data interpretations, understanding the influence of background environmental conditions, and reinterpreting the data during and after excavation.

Geophysical survey equipment quickly improves and grows more sophisticated in tandem with archaeologists' experience in interpreting survey results. Thus, while several of the geophysical surveys at Avaldsnes unfortunately proved of meagre importance for locating significant archaeological features, the sheer number of surveys has allowed the methods to be evaluated and put to use for precisely this purpose: to educate archaeologists in the use of these methods.

Conclusion

The main aim of this chapter was to review the applicability of the various geophysical methods under the geological and archaeological conditions encountered at Avaldsnes. This was achieved by comparing the various geophysical data with the archaeological features, as well as with geoarchaeological and geochemical information gathered during the excavation. In this way, the evaluation of the applicability of the various geophysical survey methods performed at Avaldsnes can serve as important reference material for future survey campaigns. The evaluation has demonstrated possibilities as well as pitfalls, highlighting various aspects to be considered in advance of commissioning and planning geophysical surveys – geological information, choice of methods, and survey resolution.

At Avaldsnes, the geological bedrock is mainly magmatic of volcanic origin, with a moraine drift geology derived primarily from this magmatic bedrock. This geological situation created very magnetic subsoil with a high variability, which in turn renders difficult any positive archaeological identification by means of the available magnetometer and gradiometer datasets. Bedrock close to the surface obscured or made invisible any archaeological features; only in a few isolated instances did we notice any semblance of archaeology (for instance feature F1 in fig. 11). Site delineation with topsoil magnetic susceptibility sampling, while difficult at Avaldsnes due to the geological conditions and modern disturbance, did however reveal information of geoarchaeological significance; for instance, the main area of cultivation deposits in Area 2. The mass susceptibility collected from soil samples in less disturbed contexts, on the other hand, created a useful source of information for delineation and understanding of past activity areas.

The mapping of apparent magnetic susceptibility by the use of EMI sensors was more successful in delineating sources of firing; for instance, the area of cooking pits in Area 5 and feature F1 in Area 2. Further investigations on the potential of EMI surveys in areas with magnetically enhanced bedrock are encouraged.

The earth resistance sampling revealed a series of pits in Area 5 as well as information on the drainage effect on the surrounding soils from a modern day pipeline. Earth resistance data could also be used to reveal geoarchaeological information on soil thickness in Area 2, but the stone packing and medieval walkway in Area 5 remained undetected.

Of all methods applied, it is clear that ground penetrating radar (GPR) produced the most usable results at Avaldsnes: data from Area 2 was instrumental in locating cooking pits in an area of thick homogeneous deposits from prehistoric cultivation. The positive identification of these anomalies as cooking pits did not become eminent before excavation, as any magnetic contrast was not detectable. While it is possible that cooking pits might have a clearer magnetic contrast on sites with a less magnetic geological background, it is clear that at Avaldsnes, excavation was the key to identifying geophysical anomalies as cooking pits. The early positive identification of cooking pits within cultivation deposits in Area 2 made it possible to limit excavation areas to those containing such features and to apply the knowledge derived from comparing the geophysical results with field observation during the excavation campaign. While several other observations of archaeological features were visible in other parts of the Avaldsnes site, it also became obvious that interpreting GPR data from stratigraphically complex conditions partly disturbed by modern-day activity was a difficult task. Archaeological observations of stone walls were difficult to distinguish from background 'clutter', as with building A12. The earlier GPR survey campaigns furthermore involved a traverse interval of 50 and 100 cm between each transect, which in hindsight clearly limited the GPR surveys' usability.

At Avaldsnes, the use of magnetometers and gradiometers could probably have been omitted without significant loss to the total amount of geophysical information, had the geological conditions been known at an early date. It might be advisable, however, to explore the potential of other non-intrusive methods such as multi-receiver EMI or high resolution multi-receiver and multi-channel GPR systems.

Generally, clearly communicated objectives for geophysical surveys, including descriptions of expected archaeological features and details of background geology and other information, will facilitate in designing an optimal survey strategy for any given site. Absent such objectives or theses for the site, the large volume of collected data can be difficult to utilise. On the other hand, despite the use of relevant theses and objectives, the site's survey conditions will ultimately play a major part in the produced result.

The communication between the excavation staff and the geophysical technicians should be maintained throughout and after the excavation to help with specific interpretations and for planning and prioritising the excavation work and evaluating results. Such contact would be mutually beneficial for developing geophysical surveys methods for use in archaeological fieldwork. It is the authours' hope that the experiences from Avaldsnes can further improve geophysical survey methods' application in archaeological survey or excavation projects.

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Article IV

Magnetic Geophysical Mapping of Prehistoric Iron Production Sites in Mid-Norway

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Abstract

The *Trøndelagsfurnace* tradition for iron production is a very specific cultural historical tradition in Mid-Norway in the older iron age, but few of these iron production have been excavated in their entirety and there is therefore a lack of information of their size, spatial layout and organization in the landscape. The aim of this paper is therefore to investigate how magnetic geophysical method can be used as a way of locating, delimiting and characterizing activity zones and specific archaeological features associated with this tradition of iron production. The NTNU University museum in Trondheim performed geophysical surveys of four different iron production sites, combining topsoil volume magnetic susceptibility measurements and detailed fluxgate gradiometer surveys. Analyzing and comparing the survey results with sketches and topographic survey results, as well as comparable geophysical survey data from iron production sites elsewhere, made it possible to gain new and valuable cultural historical and methodological knowledge. The topsoil volume susceptibility measurement revealed a strong contrast between the main production areas and the natural background measurement values, often in the range of 7-27 times the median background values. We found that the absolute highest measured values were usually in the area closest to the furnaces, and within the slag mounds. Sattelites of high readings could be interpreted as roasting sites for iron ore, and even areas with known building remains related to the iron production sites had reading stronger than the median. The fluxgate gradiometer data helped to characterize individual features further, with strong geophysical contrast between features within the iron production sites and the areas surrounding them. Also, by analyzing their physical placement, geophysical characteristics such as contrast, magnetic remanence and size, it was possible to gain further insight into the spatial organization by indicate the potential location of furnaces, the spread of slag and handling of iron ore. The latter involved both the location of storage of roasted iron ore, as well as roasting places for the ore. The geophysical characteristics of the furnaces was less uniform than situations reported elsewhere, which can be explained by the reuse of furnaces and slag pits. Also the spread of highly remanent material in and around the furnaces and elsewhere within the limits of the iron production sites, created a disturbed magnetic picture, rendered it difficult to provide an unambiguous archaeological interpretation of all the geophysical anomalies identified. In conclusion, these results showed that the geophysical methods applied made it possible to indicate the physical size, layout and internal spatial organization of iron production sites of the *Trøndelagsfurnace*-tradition.

Introduction

In the mountains around the Trondheimsfjord-area in Mid-Norway, there was a very specific tradition for iron-production in the older Iron Age, with large slag tips, several furnaces and a work practice that involved the reuse of furnaces (Stenvik 1997, 2003). The excavations that have been performed, have largely been smaller excavations focusing on parts of the sites such as the furnaces, pits surrounding the furnaces or remnants of buildings. This has led to a situation where only one known site have excavated with a larger focus on a larger area around the central furnaces area itself (Stenvik 1996).

The actual size of the activity areas related to the iron production sites of the *Trøndelagsfurnace*-tradition remains largely unknown. There is also a lack of knowledge of the location of other activities assumed to present close to the iron production sites, such as roasting places for iron ore, storage of firewood, clay and roasted ore, as well as building remains and traces of food preparation, processing of raw iron or smithing.

Within the latest decade we see an increase in the application of geophysical methods within Norwegian archaeology (Stamnes and Gustavsen 2014), with several surveys performed on Iron Production sites in the southern and eastern part of Norway giving very interesting and positive results (Rundberget 2007; Larsen 2009). Several publications from Great Britain involve the geophysical investigations and analysis of the geophysical response of pyrotechnical industries and iron smelting sites, involving detailed magnetic modelling simulations, gradiometer measurements of a model shaft furnace under controlled conditions, and a gradiometer surveys of a furnace on a test-site (Vernon 2004) as well magnetic susceptibility and fluxgate gradiometer surveys over iron production sites (Crew 1990; Crew and Crew 1995; Powell et al. 2002). Also, investigations from Denmark provide comparable information of the geophysical response of older iron age furnaces and slag pits (Smekalova and Voss 2002; Abrahamsen et al. 2003).

These investigations provides background knowledge on the expected response of various archaeological features that is expected to be present at iron production sites of the *Trøndelagsfurnace*-tradition. The NTNU University Museum, Department of Cultural History and Archaeology at the Norwegian University of Science and Technology (NTNU) have surveyed several iron production sites around the Trondheimsfjord-area with magnetic geophysical methods, providing geophysical data that we can analyze to increase our cultural historical understanding and knowledge of these sites.

The aim of this paper is therefore to investigate how the results from the NTNU University museums surveys with magnetic geophysical methods- combining topsoil magnetic susceptibility and fluxgate gradiometer mapping, can be used to locate and delineate iron production sites. Further, we aim to investigate how the geophysical methods applied can be used as a way of locating, delimiting and characterizing activity zones and specific archaeological features associated with the *Trøndelagsfurnace*-tradition of iron production.

Method

In this section, we will explain the geophysical principles of the magnetic survey methods applied – i.e. magnetic susceptibility sampling and fluxgate gradiometer surveys, and outline survey strategies and field procedures utilized as part of our investigations. We also provide more detailed background knowledge of geophysical characterization of iron production sites in Europe, geophysical mapping of iron production sites in Norway and explain the *status quo* of research on iron production sites of the *Trøndelagsfurnace*-tradition.

Geophysical methods – principles and survey strategies

Magnetic Susceptiblity (MS) is a measure of how magnetized a sample can get when exposed to a magnetic field. An alternating magnetic field is created in a coil, and the change and effect of the sample is measures. MS investigations is therefore considered an active method. Investigations can be conducted in several ways- either by sampling a volume of an exposed surface with a probe which provides bulk measures of volume susceptibility (usually denoted as κ or 10^{-5} SI), or by measuring the magnetic susceptibility of a rock or soil sample- called mass specific susceptibility (usually denoted as Χ or m^3kg^{-1}). By drying, sieving and weighing soil samples, any effects of varying bulk size, inclusions, water content, density etc. is removed. By dividing the k value with the bulk density of the sample (mass divided by volume), a more accurate measure of the susceptibility of the material is estimated. Different soils and parent material have a varying content of magnetic minerals, where iron oxides (FeOx) are among the most magnetic minerals. There are several ways the MS values of a soil can be enhanced, including burning, industrial activity, bacterial activity, reducing and oxidizing processes, deposition of magnetic anthropogenic material, as well as decomposition and fermentation (Fassbinder and Stanjek 1993; Batt et al. 1995; Dearing 1999; Dalan 2008). As several of these activities often are associated with human occupation, systematic measurements can be a way of locating and delimiting anthropogenic activity and further help to distinguish and characterize archaeological features and stratigraphy. In many instances would ploughing and bioturbation help to bring material with enhanced magnetic susceptibility from the subsurface and closer to the upper stratums, where an enhancement can be measured (Fassbinder and Stanjek 1993; Corney et al. 1994; Batt et al. 1995; Clark 1996; Gaffney and Gater 2003; Linderholm 2007; Dalan 2008; David et al. 2008; Aspinall et al. 2009; Stamnes 2011). Within archaeology, the volume susceptibility is usually measured on the exposed earth surface, and when performed on the ground surface the results can be references to as topsoil magnetic susceptibility mapping.

In the examples provided in this article, all sampling were conducted in a semi-systematic manner, using a Bartington MS2 with the D-field loop. Each geographical position and reading from the MS2-sensor were logged with a CPOS-corrected GPS-system, ensuring an accuracy of ±2cm in plan. A good area coverage was ensured by walking with an approximately equal spacing between each sample. When interpolating the values in between each sample point to a raster dataset, a complete raster map is created of the topsoil MS values. It is possible to inspect the quality of the interpolation, as the interpolation software will provide a map over the quality of the interpolation called through the calculated prediction standard error. This map can be used to inspect the coverage and indicate areas where additional samples might be needed (Isaaks and Srivastava 1989). What the necessary sampling density is, is dependent on the size of the target you are expecting (Schmidt and Marshall 1997). When the average distance between each GPS recorded reading is sufficiently low to positively identify the magnetic features you are expecting, and the sampling is performed with the purpose of locating and delimiting archaeological sites, then a grid based strategy is considered unnecessary due to the qualities of ordinary kriging as an interpolation method. Methodological issues related to sampling density when surveying iron production sites will be discussed later.

Fluxgate Gradiometer surveys (FG) is a passive method. FG works by systematically mapping and measuring variation in the Earths magnetic field created by anomalies in the ground. As everything is exposed to this magnetic field at all times, any feature in the ground filled with a material with a higher or lower magnetic susceptibility than its immediate surroundings will be magnetically induced and act as a contrasting local magnetic field, which can be detected. It is therefore the susceptibility contrast between the feature and the surrounding subsoil that governs whether or not this feature can be detected in this way. Burning, settlement refuse and similar actions enhance the MS values of a soil and will increase the chances of archaeological features to be detected as anomalies, since dug archaeological features such as pits and ditches might have been backfilled with more magnetic susceptible material. In addition to induced magnetization, some materials may have an inherent magnetism that remains present even when the induced magnetizing field is removed. This is called remanent magnetization. Several pathways can cause remanent magnetization, but within archaeology, the thermoremanent magnetization can be considered the most relevant pathway to magnetization. This is the heating of materials above the Curie temperature for that specific material, usually between 550-770 °C for iron minerals (Powell et al. 2002:660), which will cause the more or less random magnetic domains within the material to realign itself towards the present day magnetic north when the material cools down below the Curie temperature. Other pathways to remanent magnetization can be chemical, isothermal or viscous. Different geological conditions might mask this effect, if the background variations of rocks and magnetic inclusions are higher than the magnetic contrast of archaeological features. Typically, an induced magnetic feature will have a negative part towards the magnetic north, while a remanent magnetized feature can have the negative part of the signal pointing in any direction- and sometimes also cancelling out the negative part of the signal created by other magnetized features in the vicinity (Clark 1996; Evans and Heller 2003; Gaffney and Gater 2003; Vernon 2004; Aspinall et al. 2009).

All FG data presented here were gathered with a Bartington Grad 601 fluxgate gradiometer. On one site data was only collected with a dual configuration, i.e. with two separate sensors fixed one meter apart, Tromsdalen, in Verdal municipality. Generally, the sensor(s) were fixed on a carrying frame approximately 15-20 cm above ground. The height was increased to about 25-30cm above ground for the Tromsdalen survey due to tree stubs and other obstacles in the survey area, which gave an increased risk of damaging the sensors if they had been positioned lower. The survey direction of each site were planned to improve speed and practical easiness of data capture, and it was therefore decided to angle each traverse so that the surveyor walked straight down sloping ground, instead of having to tackle the topography diagonally or perpendicular. Therefore, none of the surveys were angled directly north-south, which is usually the considerer the best as a north-south traverse gives the characteristic of changes in the magnetic field gradient of the anomalies that you want to study in detail. Grids were staked out using tape markers and the Pythagoras sentence, and prepared ropes with markers for every meter along the ground surface were positioned along each traverse. As the instrument gives a signal for every meter, made it possible to walk each traverse in the same speed- and therefore resolution, by making sure to match each audiosignal with the markers on the ropes. Grid corners were surveyed using a high quality GPS with CPOS correction signal, ensuring a positioning quality of ±2 cm in ideal conditions. Although sloping ground might lead to grids not being exactly 20x20m, the georeferencing of the final result into a map with the GPS surveyed grid corners will correct for this.

Table 1: Overview over survey parameters and areas surveyed

Site and Municipality	FG traverse interval	FG sampling interval	FG Area	MS	MS Samples	MS Area	MS sampling density
Mokk, Steinkjer	0.5m	0.125m	575 m²	No	-	-	-
Storbekken 1, Midtre Gauldal	0.5m	0.125m	1221 m²	Yes	640	7570 m²	3.44m
Tromsdalen, Verdal	0.5m	0.125m	1477 m²	Yes	431	3865 m²	2.99m
Roknesvollen, Levanger	-	-	-	Yes	441	8336 m²	4.35m

Geophysical characterization of iron production sites with magnetic methods in Europe

Research conducted on prehistoric iron production sites in Europe has led to a better insight in the magnetic response of typical archaeological features related to the iron production – such as furnaces, slag tips, tapping channels, roasting and storing iron ore, coal storage, traces of settlement or similar activities. Special attention will here be given to iron production utilizing the shaft furnaces, which is the general technology of which the "*Trøndelagsfurnace*"-technology is based upon.

In Denmark, a typical way of making iron between the last centuries BC to the 6th century was by smelting the iron ore in furnaces made by clay shafts above ground, with underlying slags pits below ground- where the slag ran down and into the pit and solidified to a slag block. Each shaft furnace and slag pit was the result of a single smelt. While remnants of the shaft furnaces are rare due to ploughing and modern activity, the preservation of these slag pits are generally good. At the site of Snorup in western Jutland, excavations and magnetic prospection have revealed more than 4000 slag pits. In the same region, other sites have been found with large amount of slag pits, for instance Krarup (1000 pits), Yderik (1300 pits) and Gødsvang (>1300) (Smekalova and Voss 2002). In southwestern Jutland, over 80 areas with slag pit furnaces have been located (Abrahamsen et al. 2003). The average weight of a slag block is calculated to almost 200kg. Some pits have been found where they were formed, with a magnetic signature that is quite uniform as a magnetic dipole with the negative towards north, while maximum being within quite a wide range, often between 20-2000 nT (Smekalova and Voss 2002). The slags have proven to be too magnetically inhomogenous to be used for geomagnetic dating, as the direction of the frozen-in thermoremanent magnetization is not uniform enough for this purpose (Abrahamsen et al. 2003). The absolute negative value is usually about 1/6 of the value of the maximum, and the negative part of the anomaly being situated north of the positive- where the minimum point is situated at a distance of about 0.5-1m to the North of the maximum (in the latitude of Jutland being at approximately 56°09´ North). How transferable these observations are, depends on the differences in the directions and position of the magnetic north pole at the time of deposition of the cultural historical material we want to study. Also, as the Trøndelag-area is located at 63°24´to 64°N, this influence the geophysical characteristic of an anomaly. The magnetic anomaly over a slag pit is noted to become wider and the maximum value measured decreases rapidly as the height difference between the sensor and the archaeological target is increased. Also, clusters of slag pits situated close to each other can make it difficult to distinguish one from the other, where it was only possible to distinguish two neighbouring objects magnetically if the separation between the objects were more than 1.5 times their depth. In this Danish example, there had to be more than ¾ of a meter between the slags to be able to distinguish them from each other, if they were buried at 0.5m depth below the sensor (Smekalova and Voss 2002; Abrahamsen et al. 2003).

In England, several publications have focused on the magnetic response smelting sites for several types of metal, and different technologies for metal production over time. The PhD-dissertations of Vernon (2004) and Powell (2008) investigate the geophysical responses of British smelting sites and medieval and post-medieval pyrotechnical industries respectively. Vernon (2004) conducted magnetic modelling simulations, gradiometer measurements of a model shaft furnace under controlled conditions, and gradiometer surveys of a furnace on a test-site to understand better the effects of the induced and remanent magnetic response on gradiometer survey-data. When the remanent magnetic north of a target was co-aligned with the true magnetic north, the result was reinforcement of the magnetic signal- with a strong negative response on the north side of the feature. When the remanent magnetic north of the target were pointing towards the true magnetic south, the remanent magnetic part of the signal would be in opposition, and at least in parts weaken the measured negative response. Vernon's tests did show that the magnetic anomaly of a furnace would mainly be due to remanent magnetism, and to a lesser degree induced magnetization. The modelling and simulations showed that the magnetic response of a fired clay furnace would give a distinct positive coaligned between remanent and magnetic north would have maximum south of the center of the source of the anomaly (Vernon 2004). At areas around the Trondheimsfjord-area at 63°24´to 64°N, this would equate to the maximum being somewhere close to 0.20m south of the source of the anomaly, and the lowest minimum part of the signal being about 1.25m north of the source. The measured response would have a negative halo, with the minimum response towards north. When the distance to the target increased, i.e. the target being buried deeper into the ground, the measured positive response would be wider, and the negative halo diminish or become lower positive values. The maximum of the measured signal would still be at the same approximate distance away from the target. Other important observations was that the randomized magnetic orientation of the dumped slag could cancel each other out, leaving the overall remanent magnetic signal of slags smaller than the signal produced by a furnace. Also, a slight 'bulge' on the circumference of the positive data may correspond to the lip of a tapping channel. The lessons learned from the modelling and test-surveys were used to better interpret data from several investigations of archaeological sites with shaft furnaces and activity associated with iron smelting. Typically, most furnaces generated values over 300nT, but the surveyed furnaces were often no more than 30 cm below the surface. Measurements over pockets of roasted iron ore also gave very strong magnetic responses, with high readings as strong as 200-1000nT (Vernon 2004: chapter 4 and 7). Powell (2008) combined the results at several sites that Vernon (2004) investigated with volume magnetic susceptibility sampling and subsequent excavations, identifying both areas of iron roasting ore and furnaces. At the site of Hagg in Bilsdale, North-Yorkshire, Vernons interpretation of a furnace and the direction of a tapping channel proved to be corresponding with the excavation results. At the site of Myers Wood near Huddersfield in West Yorkshire, an area of coal production revealed a relatively "quiet" magnetic characteristic in the gradiometer data, while two anomalies interpreted as potential furnaces by Vernon (2004) proved to be slags deposits with very high susceptibility values (Powell 2008:77).

It has also been suggested that there is a link between high magnetometer readings and the thickness of the slag deposits. Farbregd (1977) illustrates a good correlation between measurements with a proton magnetometer and the thickness of a slag heap at Hoseth in Norway, and the same tendency has been reported at a roman iron production fascility in Hüttenberg (Walach et al. 2011) – where the magnetometerdata was combined with the results of an earth resistivity imaging survey. A mixture of thermanent material partially cancelling out both the induced magnetic properties and pieces of remanent magnetic material randomly oriented would theoretically create a very mixed and random signal overall. The results from Hoseth could indicate that increased thickness might add to the strength of the overall measured strength of the magnetic field over slag tips.

Magnetic susceptibility mapping of the topsoil has proven to be an ideal way of delimiting activity areas on iron production sites in England, and is considered to be a good way to complement gradiometer surveys (Powell et al. 2002; Powell 2008:79-80). In most instances should slags and areas of iron workins produce high magnetic susceptibility readings, even if the contact between the slag and the soil might be compromised. As long as the contrast between the slag and the background geology is sufficient, this should produce good results (Vernon 2004:20). At Crawcwellt West, in Trawsfynydd in Wales, Crew (1990) observed a close correlation between the measured magnetic susceptibility and the volume of slag. In another article it is noted that smaller heaps of slags found at sites in Wales sometimes had as large of a geophysical response as small heaps – suggesting that this was rather linked to the proportion of the magnetic smithing slags deposited (Crew and Crew 1995). Powell et al. (2002) combined magnetometry and magnetic susceptibility survey data, and showed how size and shape of the anomalies are dependent on several parameters, such as furnace operation and the amount of heat-affected material that remained in the archaeological record. By combining the survey results with laboratory magnetic susceptibility investigations and microscopic analysis, they also show a variability in the mineralogy and morphology in the slags, which they use to understand better the operation of an iron production site.

In addition to the various geophysical response of features related to iron production, it is important to take into that various other effects such as heat affecting the surrounding ground, the state of preservation, relining of furnaces and reusable slag pits would complicate the geophysical signature. Also, the physical dimensions of any buried feature would change the geophysical signature.

Short history of geophysical mapping of iron production in Norwegian archaeology

It is assumed that a geophysical mapping of Iron Production sites could help to delineate activity areas and contribute in characterizing specific activity and archaeological features within the sites. Although there is a lack of detailed geophysical analysis and comparison and analysis of the relationship between the geophysical data and archaeological ground observations, there has been some work being done of geophysical mapping of iron production in the country:

The history of geophysically mapping iron production sites in Norway started with a survey in 1973, where NGU (Norwegian abbreviation of Geological Survey of Norway) did a proton magnetometer survey of an Iron Age Production site at Hoset, in Stjørdal Municipality in Nord-Trøndelag. The general outcome was very positive, as the resulting measurements delineated a slag heap of about 45 m². They also compared the strength of the magnetic signal with a section of the slag heap, showing elegantly a correlation between the magnetic total field strength and the thickness of the slag heap, which was 0.9m thick at most (Farbregd 1977:124-125). Although the results from Hoset were very useful, it took 15 years before the next known geophysical mapping of an iron production site. This was at Dokkfløyvatn in Oppland County, where, due to a restricted budget, the survey was commissioned as help in prioritizing which area they should increase their efforts in. The work included both ground penetrating radar and proton magnetometer surveys, and it was especially the magnetometer results which were considered encouraging and indicated the presence and location of furnaces, slag mounds and layers of iron ore (Larsen 1991). Both the Hoset and Dokkfløyvatn-survey were in non-cultivated and forested land. The next survey with the aim of localizing an iron production site were on cultivated land, at Hemmestad in Troms county in the north of Norway. Iron Production sites are scarce in this part of the country, and here a farmer had found a pit with slag quite a few years earlier while working on his field. A magnetometer survey was conducted in 1999 and expanded in 2002, which revealed several anomalies that were considered interesting. Two of these were iron age furnaces, two cooking pits and another anthropogenic pit, and the survey was considered a success as it would otherwise have been very difficult to locate these archaeological features within a large field without the geophysical data (Jørgensen 2010).

Between 2000 and 2002 18 different sites were been investigated in South-East Norway by Tatiana Smekalova from the Saint Petersburg State University in Russia and the Moesgård archaeological museum in Århus, Denmark, on behalf of the Norwegian Institute for Cultural Heritage Research (NIKU) during the initial stages of the location and registration- part of the project. In 2004 and 2005 the Smekalova team returned to Gråfjell in Hedmark County on behalf of the Cultural Historical Museum in Oslo, as well as performing survey campaigns in Tyin in Oppland county in 2005 and Hovden in Aust-Agder in 2006. At the Gråfjell project in Hedmark county in south-east Norway, the usage of magnetometers was included in field campaigns over several years. The surveys were a combination of scanning (also called “free search”) and detailed surveys, and performed in combination with traditional field survey methods. Areas suspected to contain roasting sites were subjected to magnetometer scanning campaigns, or detailed magnetometer survey conducted to help delineate sites. Interesting anomalies were not located on all sites investigated, and this suggested an absence of high-temperature metal-related activity. Not all investigations were subjected to further excavation, but the ones that were showed a good correlation between anomalies interpreted as roasting sites, slag heaps and furnaces and archaeological ground observations. One survey also positively identified a medieval smithy, a rare observation in these forested areas (Risbøl and Smekalova 2001; Risbøl et al. 2001; Risbøl et al. 2002a; Risbøl et al. 2002b). In 2005, the Smekalova team also surveyed at Tyin in Oppland County, performing a detailed investigation of five iron production sites and a scanning campaign. In 2006 they also surveyed at Hovden, in Aust-Agder County and Haglebu in Buskerud County. At Hovden, they did a detailed investigation of two iron production sites and conducting another free search campaign. These investigations resulted in delimiting the sites and locating several roasting sites for iron ore. At Haglebu, they did a detailed survey of three iron production sites. In most surveys, the location of the furnaces gave usually the strongest magnetic response, with a contrast in the region of 800-1500 nT, but sometimes the slag heaps produce just as high response as the furnaces. Coal storage areas was generally elusive in the magnetic data. The roasting sites at Gråfjell often produced a geophysical contrast in the ranges between 180-300nTm but sometimes as high as 650-710 nT (Rundberget 2007). High reponse within the slag heaps could be explained as the result of larger slag blocks with increased iron content being tossed into the slag heaps. Larsen (2009) summarizes the experiences the Cultural Historical Museum in Oslo had with using magnetic non-intrusive methods for locating and investigating iron production sites and places for roasting iron ore. For locating roasting sites, field survey campaigns with magnetometers gave undoubtedly the best results (Smekalova and Voss 2002; Rundberget 2007:279-308; Smekalova et al. 2008; Larsen 2009:206, 221-223). In the southeastern Norway, there is often a close relation between the coal production pits and iron production nearby. Larsen (2009:206) therefore concludes that the usage of metal detectors and/or magnetometers should be mandatory when doing field campaigns to locate slag pits or slag tips, especially when finding pits from coal production, but failing to locate traces of iron production nearby.

In Mid-Norway, there were until recently no geophysical surveys done on Iron Age Iron Production sites, except for the very early test performed at Hoset in Stjørdal Municipality in 1973 (Farbregd 1977). The first event since then was commissioned by Nord-Trøndelag County council at an iron production site in Mokk in Ogndalen in Nord-Trøndelag in 2010, which was one of the authors for The NTNU University Museum and its department of cultural history and archaeology (Stamnes 2010). This initial work was followed up by three more surveys of similar sites of the *Trøndelagsfurnace*-tradition, and are the topic of this article. Before considering the results, a short review of the research on the Iron Age iron production in this area of Norway will be presented.

Iron Age Iron production in Mid-Norway

Results from a dating programme in Mid-Norway conducted in the early 1980s identified trends and variation of the production of iron in the region of Trøndelag over a period of almost 2000 years (Stenvik 1991). Production of Iron in the region started around 400-300 BC in the Pre-Roman Iron Age, using a very specific production technology for this region – usually called *Trøndelagsfurnaces*. This technology lasted until the Migration period, during which it disappeared completely. Typical for this region was a series of shaft furnaces located besides each other and operated contemporaneously, with outputs reaching as much as 100 tons of iron at one site. These furnaces were also much larger than furnaces observed at later periods. Typically, each shaft furnace consisted of a stone built horse-shoe shaped, stone-lined slag pit dug into the subsurface, with an opening that made emptying the product during the production possible – a feature that would have extended the lifetime of production-site. The slag pit is usually 0.7-0.9m in diameter with a depth of 0.7-1m. When encountering slag remains *in situ,* these has been in quantities between 20 and 160 kilos, but usually just under 150 kilos (Espelund 1999; Prestvold 1999; Nordlie 2009). The shaft would probably have been funnel-shaped, and be fired by wood- not charcoal. Usually, each site consisted of four furnaces, but sites with as many as eight are known The associated slag dumps are relatively large, and might contain from tens of tons to as much as 100 tons of slag per iron production site. Usually the furnaces was placed on or close to the edge of a terrace, with the slag dumps downslope of the terrace – creating a fan-shaped slag tip below each furnace. In addition to slag, the tips contain fragments of burnt clay from the furnace shafts, earth and stone. Also, the furnace is often found surrounded by a series of pits of unknown purpose, often encircling the furnaces in a rosette-pattern – a trait that is unique to the *Trøndelagsfurnace*-tradition. These pits are considered to be of some importance to the work carried out in relation to the iron production, the encircling pits never cutting into each other. Additionally, each arrangement of furnace and pits are grouped together without disturbing the other groups of features on the same site. They are circular or oval in plan, between 1-2.4m in diameter, between 0.1 and 1m deep and situated between 0.6 and 0.8m from the furnace (Farbregd et al. 1985; Espelund 1999; Prestvold 1999; Nordlie 2009). Excavations have shown that they may contain roasted iron ore, burnt clay and burnt stone and slates similar to those of which the bottom part of the furnaces are built up of (Farbregd et al. 1985). They have been interpreted as either a container for roasted iron ore, storage for clay and firewood, or places where the extracted iron was postprocessed before transportation (Stenvik 1991; Espelund and Stenvik 1993; Stenvik 2003; Rundberget 2010; Wintervoll 2010). Building remains are known on some of the sites, and might have been used for both lodging for the workers and for ensuring dry storage of fuel and/or iron ore. Lack of archaeological objects and features reveal little of how these buildings were used, but remnants of roasted iron ore and a hearth have been found in some of the excavated examples (Farbregd et al. 1985; Espelund and Stenvik 1993; Prestvold 1999; Nordlie 2009; Wintervoll 2010). In addition to these archaeological features, it is not unusual with other pits a little further back from the edge of the terrace, with an unknown usage and purpose. It could be for instance pits from coal burning or cooking pits (Farbregd et al. 1985). Also, concentrations of roasted iron ore have been identified on some sites, such as the Storbekken 1 site at Tovmoen, Budalen in South-Trøndelag County and Myggvollen (Espelund and Stenvik 1993; Stenvik 1996, 1997). Similar furnaces as these Trøndelagsfurnaces, are found at iron-production sites in Agder in Southern Norway, but then lacking the associated pits and postholes, and nearly as large as the sites in Mid-Norway (Rundberget 2010).

Much of the research focus on the Iron Production sites in Mid-Norway has been from a social and economic perspective (Stenvik 1997) as well as research focusing on the metallurgical processes (Espelund 1999). The sites are often located far from modern day development, so few sites have been excavated. The excavations that have been performed, are mainly focusing on parts of the sites such as detailed excavation of the furnaces, the rosette-pits or remnants of buildings. This has led to a situation where only one known site has been documented extensively, with a larger focus on the terrace and the spatial arrangement of activity away from the central furnace area itself. This is the site of Myggvollen, in Fjergen in Meråker municipality. At this site, activity relating to storage of iron ore and burnt matter were discovered in pits between two ovens, as well as a concentration of roasted iron ore. Further back on the terrace, a layering covering 12x4-5m in plan was identified. It comprised of fire cracked rocks, charcoal and soot, and the bottom parts of this layer consisted of small iron fragments. A pit of fire-cracked rocks and pits with a diameter of 1.6 meters and a depth of 0.35 meter was identified nearby. This pit could be interpreted as a cooking pit, used in the preparation of food for the workers. At the site of Heglesvollen, in Levanger Municipality they identified 12-15 similar pits (Stenvik 1996). The site of Myggvollen indicates that there are remnants of activity near the furnaces, and there are still uncertainties concerning the location of activity such as food preparation, the extraction and roasting of iron ore, settlements, and transportation routes related to these iron production sites. In addition to this, there is a possibility that the iron was processed by hammering or similar treatment before transportation, but this remains largely unknown for the sites in Trøndelag. The actual size of the activity areas related to the iron production sites of the *Trøndelagsfurnace*-tradition remains largely unknown.

Results

We will present the survey results from four different iron production sites below. At Storbekken 1 and Tromsdalen, we performed both a fluxgate gradiometer survey and a topsoil volume susceptibility survey. At the site of Roknesvollen we undertook a topsoil volume susceptibility survey, and at Mokk a fluxgate gradiometer survey.

Storbekken 1 at Tovmoen, Midtre-Gauldal Municipality, Sør-Trøndelag county

A sketch of the site based on visual ground inspections and the usage of a small soil auger, indicates a site of five furnaces with the known pattern of pits around the ovens (figure 1). Letters A-F on the figure gives the position of test pits dug into the slag tip. This investigation indicate presence of an area with a concentration of roasted iron ore, as well house foundations, but no more recognizable features further in from the terrace edge. This edge is indicated by a line just below test pit A. The site of Stoerbekken 1 has been the subject of minor research excavations, focusing on two of the visible furnaces as well as a smaller excavation of 6x7meters over the location of expected building foundations – building number 2 from the right on figure 1. The excavations revealed two stone lined slag pits from shaft furnaces, with an opening towards the terrace edge towards the south-west, as well as a fireplace within one of the buildings. They found 71 kilos of in-situ slag in the bottom of the stone lined furnace and slag pit indicated as “ovn” on figure 1, and charcoal from the bottom of this pit got a 14C-dating to 2050-85 BP – calibrated BC 180-AD 25 (Espelund and Stenvik 1993). The site has id # 122322 in the national monument registry Askeladden.

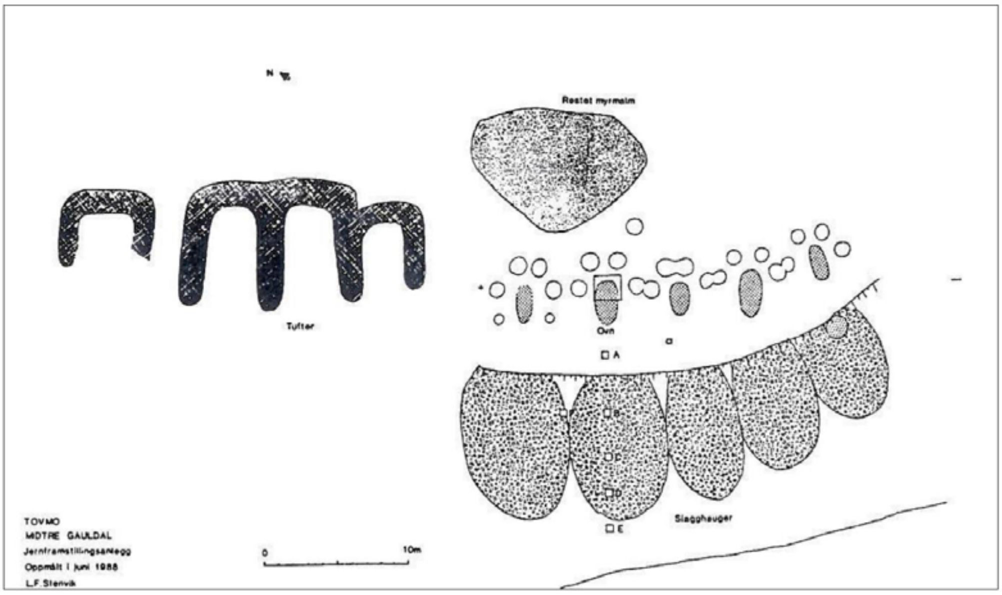

Figure 1: Sketch of the iron production site called Storbekken 1 at Tovmoen in Budalen, made by Stenvik in 1988. On the top of the sketch is approximately north-east.

The site was investigated with magnetic geophysical methods in the autumn of 2014, by a combination of topsoil volume magnetic susceptibility and fluxgate gradiometer data. Some of the pits and furnaces locations were visible as depressions on-site, and were measured in with a centimeter-accurate GPS system. This indicates that the distance between each furnaces is relatively uniform – with about 5-5.5 meters between each of them.

The sample values gives the following statistical distribution:

Table 2: Descriptive statistics for the geophysical survey data collected at Storbekken 1

	*Topsoil Volume MS**	*Flugate Gradiometer (nT)*
Min	**-2**	**-1000**
Max	**3226**	**803**
Mean	**185,41**	**-1,33**
Median	**10,5**	**-2,6**
St.Dev	**420,88**	**79,1**
Skewness	**3,49**	**0,25**
Kurtosis	**17,43**	**29,39**
1st quartile	**2**	**-29,3**
3rd quartile	**110,5**	**6,2**
IQR	**108,5**	**35,5**

*measurements in 10^{-5} SI

Topsoil Volume Magnetic Susceptibility

The sampled area and sample values is presented in table 1.

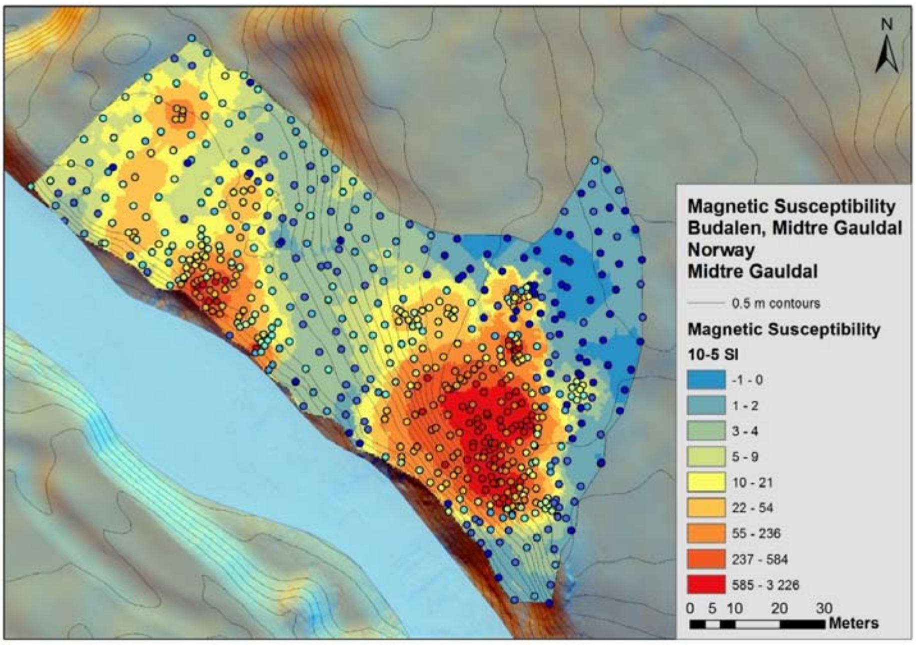

Figure 2: Topsoil volume MS measurements from Storbekken. The older iron age iron production site is in the centre of the image (Storbekken 1). The next area with high readings towards north-west, close to the stream, is a smaller Viking age iron production site, and far north-west is a modern day summer farm.

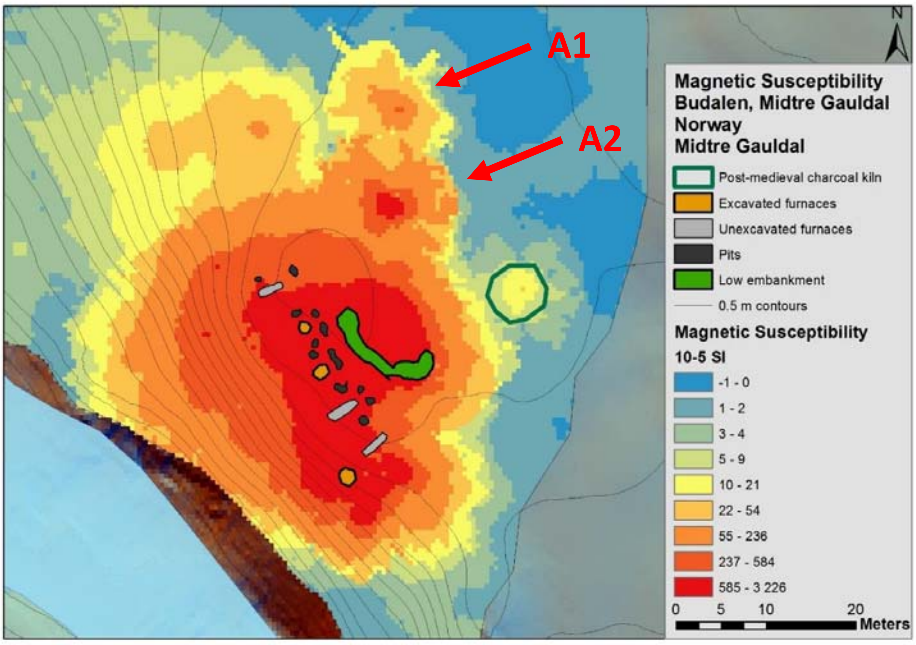

Figure 3: Detail of the topsoil volume MS map. The iron production complex of Storbekken 1 with known archaeology. The slag tips are southwest of the furnaces, down the slope towards the river. Note the hotspots north of the furnace area, and

the area of above median readings extending north-northwest of the northernmost furnace. The southernmost furnace is an "Evenstad furnace", dating to 18th or early 19th century.

This was the only site where it was possible to identify visually and digitally survey associated archaeological features on the ground surface. It is therefore possible to report some general observations on the topsoil volume MS readings intersecting the archaeological features:

Table 3: Topsoil volume MS measurement values over known archaeology at Storbekken 1

*Topsoil volume MS measurements over known archaeology**

	Min.	Max.	Mean
Excavated furnaces	**1184**	**1833**	**1508,5**
Unexcavated furnaces	**339**	**1560**	**929,3**
"Evenstad" furnace	**1180**	**2093**	**1636,5**
Pits	**418**	**901**	**593,5**
Embankment	**824**	**2587**	**1618**
Slag tip	**12**	**3226**	**452,8**
Area with reported building remains	**8**	**131**	**35,3**
Charcoal kiln	**8**	**31**	**15**
Anomalous area A1	**28**	**2014**	**803,2**
Anomaous area A2	**13**	**453**	**150,7**

*measurements in 10^{-5} SI

We see that apart from the excavated Evenstad-furnace, it is the embankment, marked in green, which has very high MS readings – with higher average reading than the exposed and excavated furnaces. The unexcavated furnaces also had higher readings than the pits and the slag tip, all of which had readings well above the median value as reported in table 2. Two smaller areas further north of the main area were possible to delineate, where A2 is furthest to the north and A1 is just north of the embankment. These were previously unknown, and had no surface manifestation. An area protruding to the north where the building remains are reported to be, also had reading well above the median value, but far lower readings than within the main area of activity. Also note high readings south-east of the southernmost known furnace, indicating anthropogenic activity extending this way.

Fluxgate Gradiometer Survey

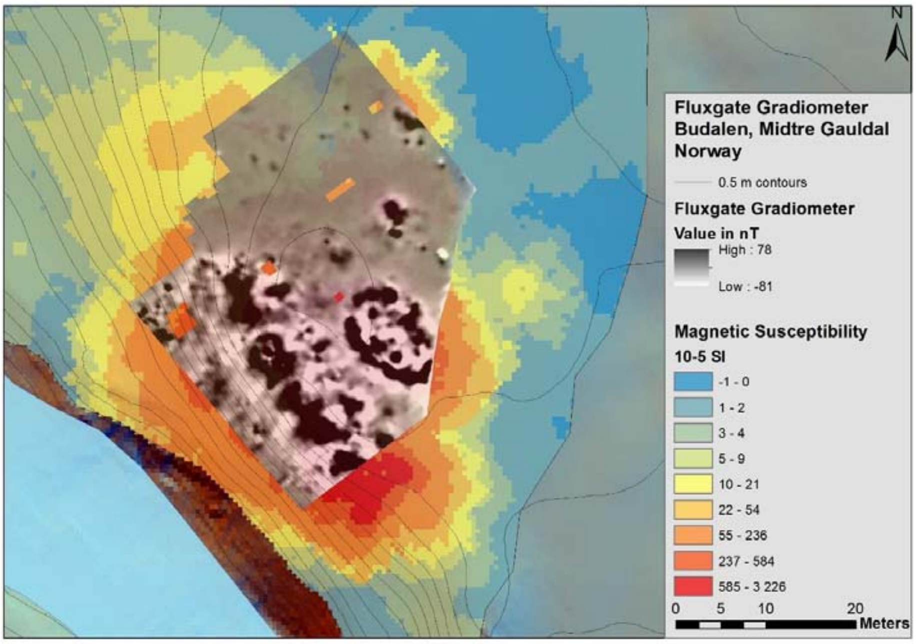

Figure 4: Fluxgate gradiometer survey results over the site of Storbekken 1, overlaid over the topsoil volume MS map. The gradiometer-data is presented at ±1 standard deviation around the mean.

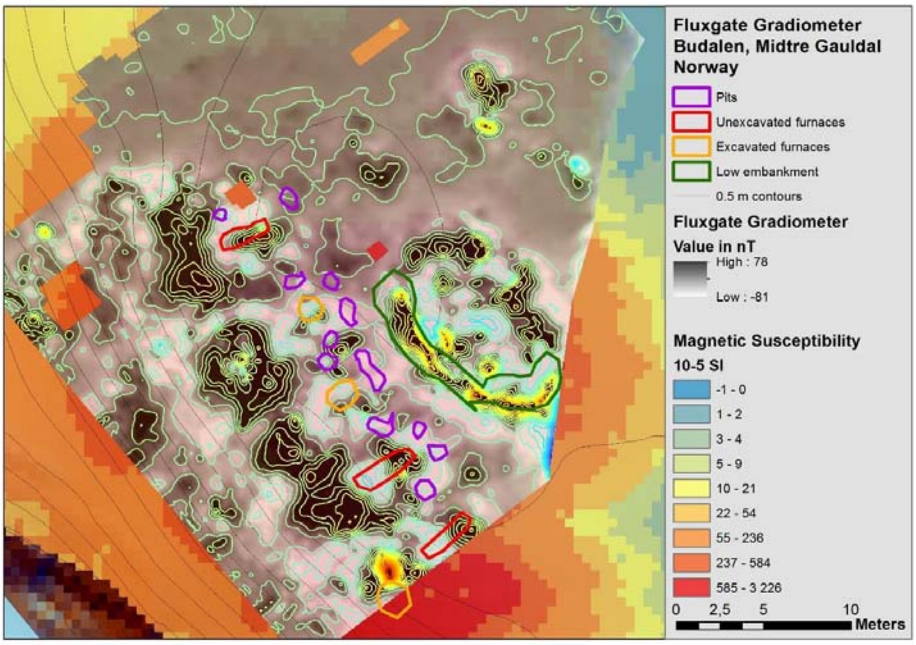

Figure 5: Detailed data plot from Storbekken 1, compared with the position of known archaeology. Contour lines every 50nT, with red lines for positive values and blue lines for negative values.

The comparison with the known archaeology indicate that the features denoted as an embankment, visible as a small ridge on the surface, is an very symmetrical oval of 12x7,5 meters oriented north-west/south-east. Inside this anomaly, there are several smaller anomalies with strong reading. On the sketch, figure 1, this area was interpreted as an area of roasted iron ore. There are high readings with the maximum just south of the unexcavated furnaces, and strong readings related to the slag tips which gives a fan-shaped pattern outside- and down-slope of each furnace. The excavated anomalies still reveal a magnetic response, but much smaller than the unexcavated furnaces. There are also anomalies within the two minor separate areas of high susceptibility readings north of the main area. Some general observations on the strength of the magnetic response can be summarized as follows:

Table 4: Observed strength of the magnetic response over known archaeological features at Storbekken 1. Values are in nT

	MIN. NEGATIVE	MAX. POSITIVE	SHAPE	POSITION OF NEGATIVE	DISTANCE TO CENTER OF FEATURE	CORRELATION
UNEXCAVATED FURNACE 1	-139	277	Oval	NNW	0,45m	Very good
UNEXCAVATED FURNACE 2	-128	318	Amorph	W, WSW, N and NE	0,7m	Good
UNEXCAVATED FURNACE 3	-103	260	Circular	NNW	0,7m	Very good
PITS	-77	238	Semi-oval	NW	0,7-1,1m	Poor
EMBANKMENT	-277	555	Oval	Mainly N	0,75-1,1m	Very good
SLAG PITS	-210	300	Fan-shaped	Various	Difficult to assess	Good
ANOMALOUS AREA A1	-87	363	Semi-ovals	N, NW	Unknown	Very good
ANOMALOUS AREA A2	-62	320	Amorph	Various	Unknown	Good

Unexcavated furnaces are numbered from north-west to southeast, with the one farthest to the north-east is given the lowest number

Tromsdalen in Verdal Municipality, Nord-Trøndelag county

The site at Tromsdalen was discouvered by the land owner in the 1970s when a road was constructed through the area: pieces of slag were noted after bulldozing a path for the road. No sketch exists of the site. The was first made known to archaeologists during an archaeological assessment survey conducted in 2011 and 2012. The site was then interpreted as consisting of one slag mound, and probably up to four ovens associated with the production site. They did not find any traces from the iron production on the other side of the road (Arnkværn 2013).

Figure 6: Overview over the Tromsdalen site. The slag mounds are between the large tree just right of center of the image and the fence to the left.

The sample values gives the following statistical distribution:

Table 5: Descriptive statistics for the geophysical survey data collected at Tromsdalen

	*Topsoil Volume MS**	*Fluxgate Gradiometer (nT)*
Min	**0**	**-124,8**
Max	**1673**	**446,7**
Mean	**86,37**	**-1,13**
Median	**19**	**-0,1**
St.Dev	**192,15**	**-26,8**
Skewness	**3,97**	**2,02**
Kurtosis	**22,634**	**28,11**
1st quartile	**10**	**-3,55**
3rd quartile	**41,75**	**2,2**
IQR	**31,75**	**5,75**

*measurements in 10^{-5} SI

Topsoil Volume Magnetic Susceptibility

The sampled area and sample values is presented in table 1

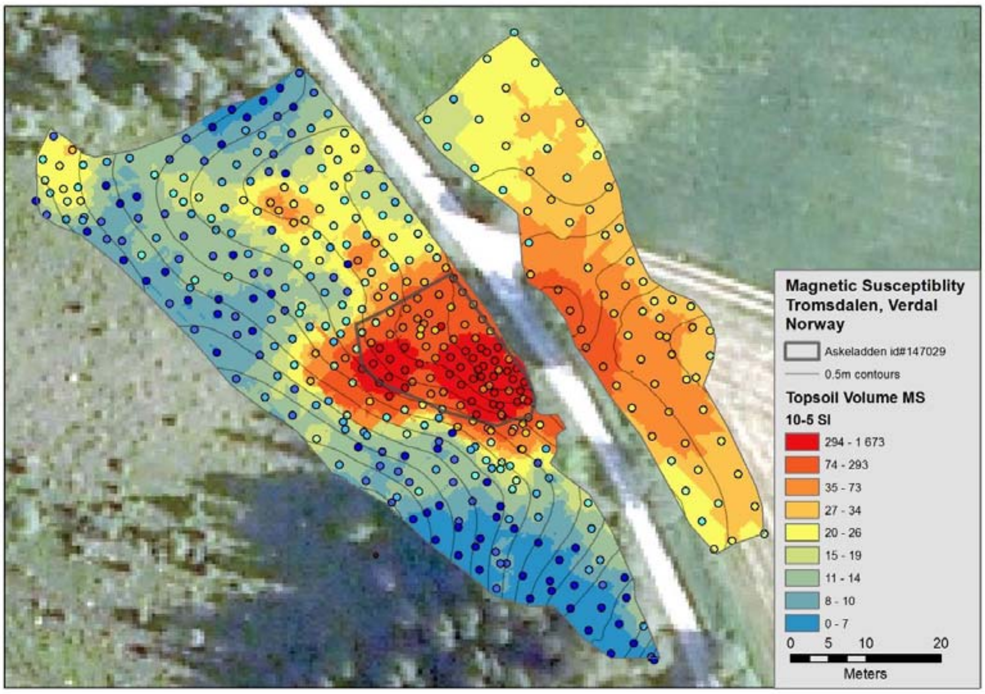

Figure 7: Topsoil volume magnetic susceptibility survey results from Tromsdalen, Verdal municipality in Nord-Trøndelag.

The main area of maximum values coincided well with the borders of the monument as entered in the national monument registry of Norway- askeladden id #147029 , which was delineated by test pits (Arnkværn 2013). The topsoil volume MS readings indicates that the spread of slag is slightly larger than the registered site borders, and that the site extends to the eastern side of the road. There are also relatively high readings north-west of the main area, indicating potential activity associated with the iron production in this direction.

Fluxgate Gradiometer

A visual inspection of the data showed very large minimum values along the road caused by a metal fence. It was therefore decided to remove all values below -125nT before calculating the descriptive statistics, as all values below -125nt were concentrated along this fence and clearly influenced the measurements. The sensor height was increased due to the risk of damaging the instrument by knocking it into tree stubs or similar obstructions, something that would decrease the measured geophysical contrast of any magnetic anomaly in the ground, and widen the geophysical signature (Vernon 2004).

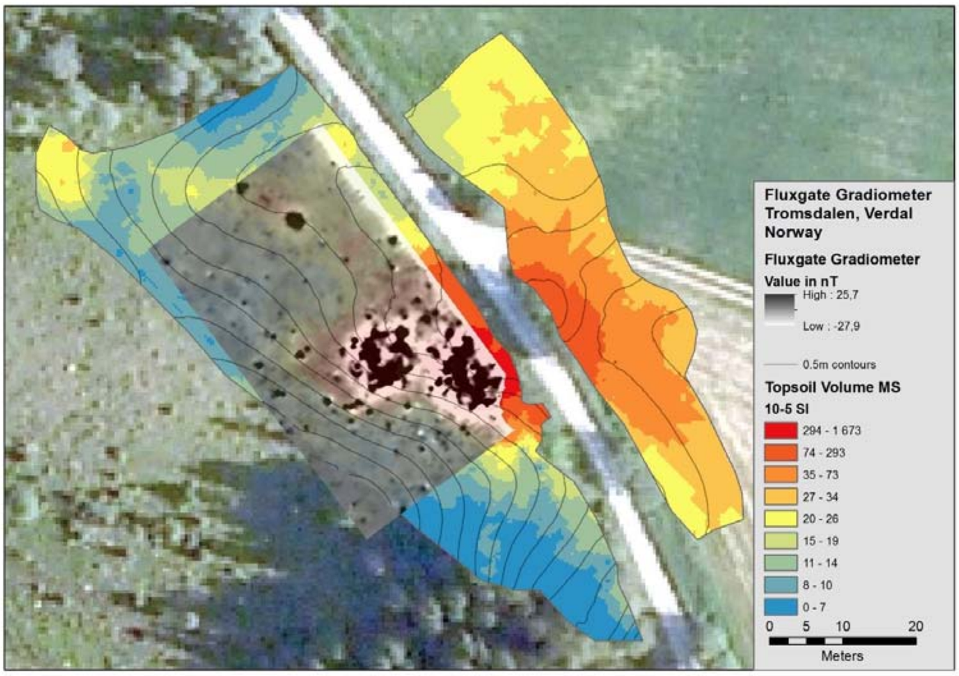

Figure 8: Fluxgate gradiometer survey results. The gradiometer readings are presented in ±1 Standard Deviation around the mean, after removal of large negative values.

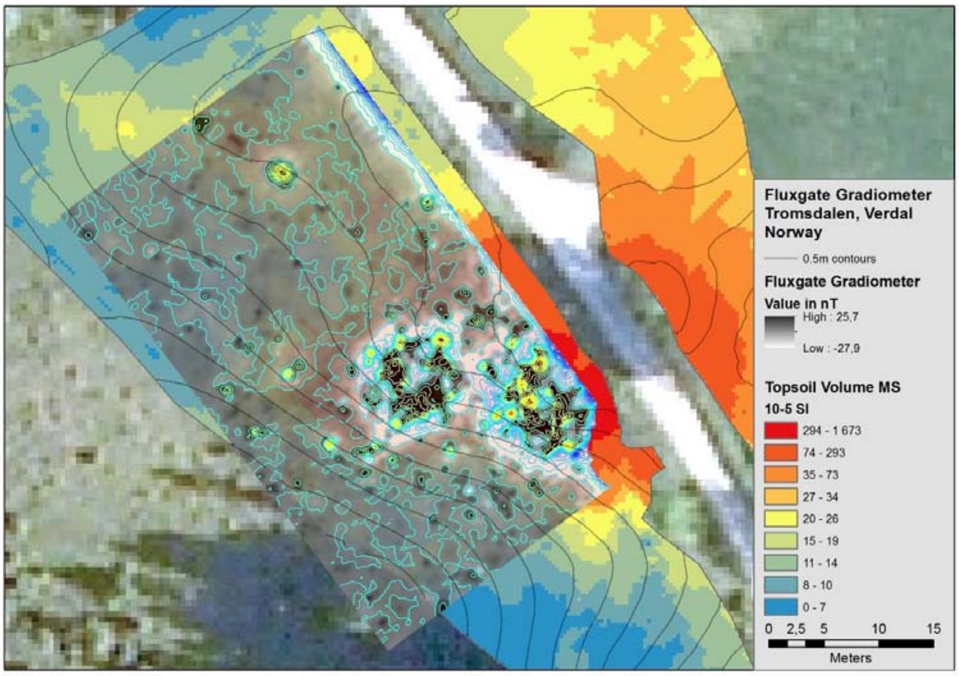

Figure 9: Detailed fluxgate gradiometer results with added contour lines for every 20nT. Red contours equals positive readings, blue contours equals negative readings.

The fluxgate gradiometer-data show large positive anomalies with a negative halo in areas of high magnetic susceptibility readings. The location of these larger anomalies coincides well with the spread of slag, as indicated by test pits in 2011/2012 (see figure 8 and 9). Within these larger positive anomalies is a range of high positives and negatives, and several localised hotspots. A couple of more distinct strong anomalies occur northwest of the main area. No linear anomalies are visible in the data.

Roknesvollen, Levanger Municipality, Nord-Trøndelag County

The site of Roknesvollen is located at a summer farm at approximately 400 meters above sea level. The site was discovered by Bjarne Berre in the 1980s, and is according to the national monument registry (askeladden id. # 103631) known to be south of a stream and east of the summer farm, approximately 15-20m from the stream. He also noticed roasted iron ore downstream from the furnaces, as well as a bit closer to the stream, but the records do not say how far. Pollen analysis taken from peat cores approximately 200m east of the summer farm indicated temporary human presence in the area from 1775-1590 BC, at the 60cm level of the core sample. Iron ore particles are continuously present from the 40-10cm level, and the 40cm level coincides with the onset of a decrease in the pine pollen curve and an increase in the charcoal curve. The 40cm level was not dated, but the observations here is assumed to indicate the onset of the iron production at Roknesvollen. The summer farming is indicated to have started around the 25cm level (Solem 1991), possibly indicating that the iron production and summerfarming had a period of mutual coexistence. During the topsoil volume MS survey in September 2014, we also found two house foundations and a cairn – possibly a clearance cairn or a prehistoric grave monument.

Topsoil Volume Magnetic Susceptibility

The sampled area and sample values is presented in table 1

The sample values gives the following statistical distribution:

Table 6: Descriptive statistics for the geophysical survey data collected at Roknesvollen

	*Topsoil Volume MS**
Min	**2**
Max	**1450**
Mean	**65,38**
Median	**10**
St.Dev	**148,84**
Skewness	**4,74**
Kurtosis	**33,11**
1st quartile	**3**
3rd quartile	**53,25**
IQR	**50,25**

*measurements in 10^{-5} SI

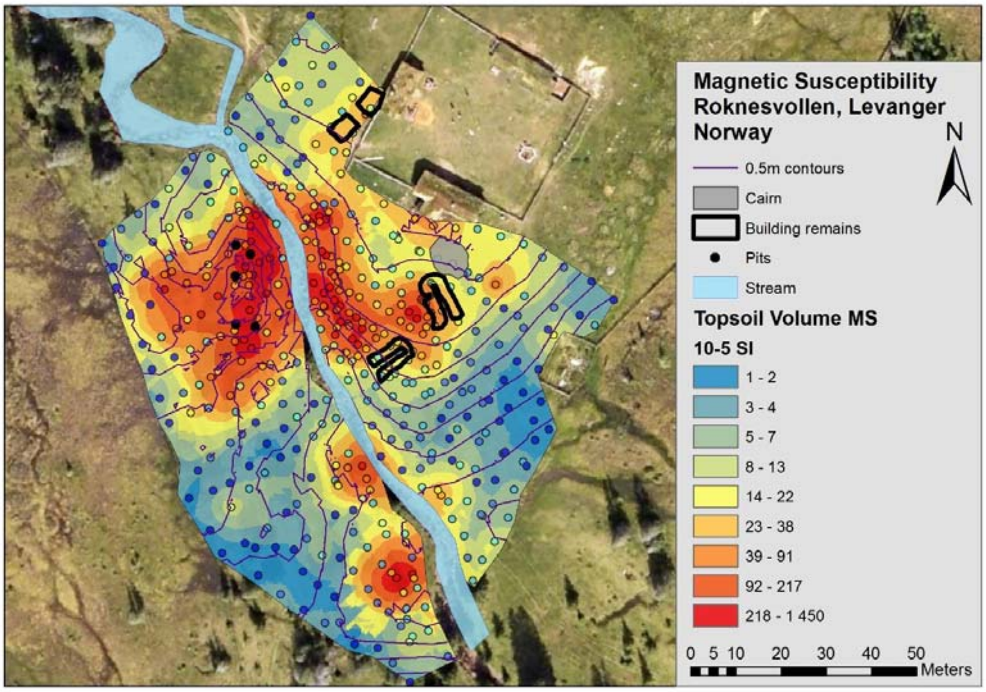

Figure 10: Topsoil volume magnetic susceptibility survey results from Roknesvollen, Levanger municipality in Nord-Trøndelag.

The most prominent observation at Roknesvollen, is the high readings at both sides of the stream. There are some outlying high readings on the western side of the stream, south of the main area of high readings. There are high values just outside of the western wall of the building remains located immediately south of the cairn, but relatively low readings within both this building and the one just south-west towards the stream.

Mokk in Steinkjer municipality, Nord-Trøndelag County

The site was visited by the archaeologist Lars Stenvik in 1989, who made a sketch of the iron production site and took a charcoal-sample from one of the slag pits. This 14C-sample was to BP 1875±90, which equals a calibrated age of AD 25-235. The site was surveyed on behalf of the Nord-Trøndelag county council in October 2010, and is located between 285-295 meters above mean sealevel. This site has id # 103787 in the national monument registry.

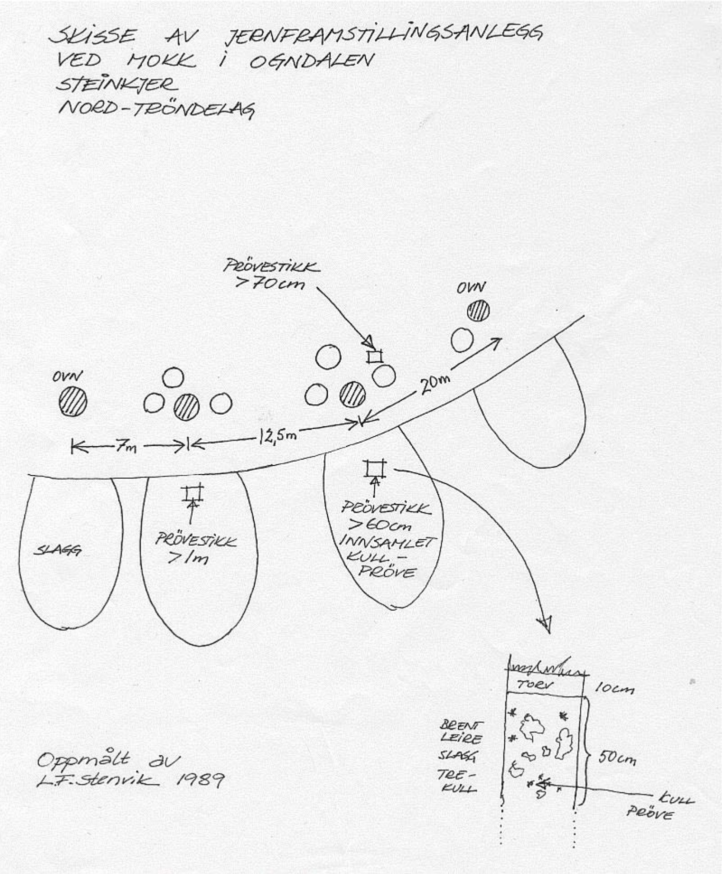

Figure 11: Sketch of the iron production site made by Lars F. Stenvik in 1989

Fluxgate gradiometer scanning and area survey

This is the only site where we tested scanning with the magnetometer and recording high values. While full-area survey clearly is the preferred strategy, the vegetation cover and time-constraints did not make this possible.

Table 7: Descriptive statistics for the geophysical survey data collected at Mokk

	Fluxgate Gradiometer (nT)
Min	**-290**
Max	**1000**
Mean	**10,59**
Median	**-0,3**
St.Dev	**76,66**
Skewness	**2,50**
Kurtosis	**25,32**
1st quartile	**-17,5**
3rd quartile	**21,55**
IQR	**39,05**

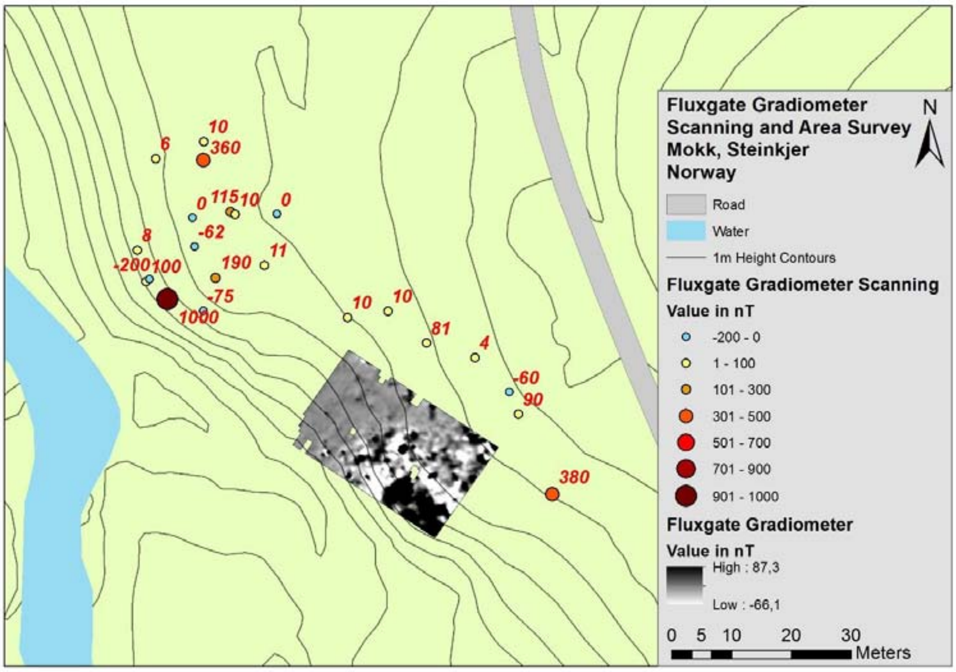

Figure 12: Results of scanning and full-area survey. The fluxgate gradiometer area survey data is visualized in 1standard deviation around the mean value.

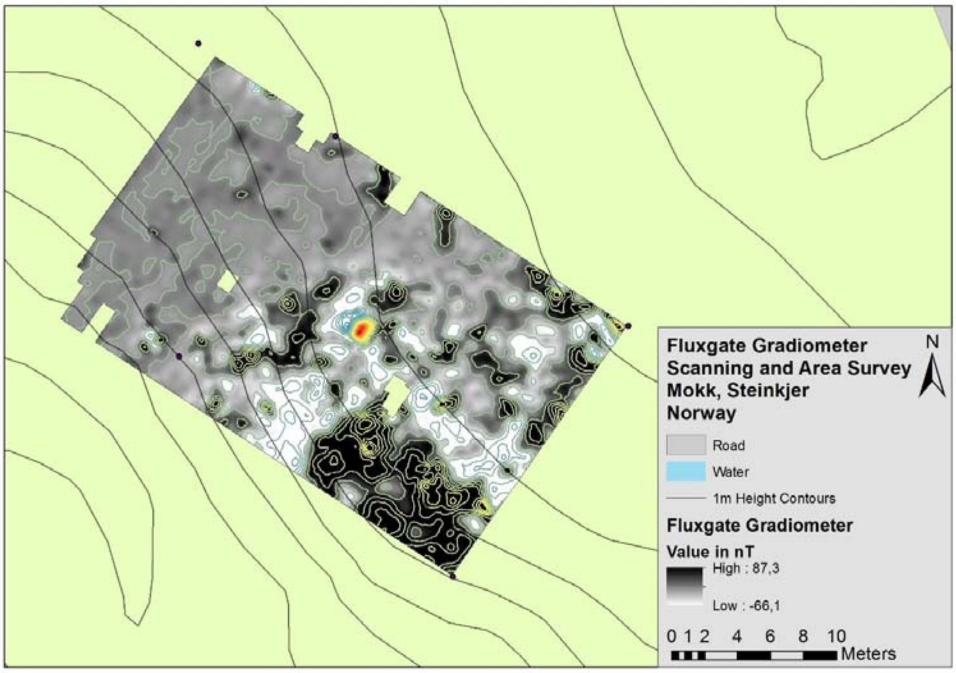

Figure 13: Detailed plot of the fluxgate gradiometer area survey results. The coloured contoures are for each 50nT, where contours in blue colour shades are negative values and red colour shades are positive values.

It is assumed that the area the fluxgate-survey covered, includes the furnace to the far left on Stenviks sketch, figure 11, and probably the next furnace to the right as well as the associated slag dumps downslope towards the southwest. The scanning test revealed a hotspot east of the main survey area, as well as several mid-high readings north of the main survey area. The western part of the area survey gave relatively low readings, while approximately 40-70 meters further east very high readings were measured. We observed several slag blocks in this area, indicating the presence of another iron production site.

Discussion

The general impression is that topsoil volume magnetic susceptibility measurements with the Bartington MS2 with a D-loop is very applicable to locate, delineate and partly characterize activity on and relating to the iron production sites. On the basis on the median value for each site – which we regard as a good indication of the natural background value at each site, we could estimate the approximate area size of each site, including the younger Iron Age iron production site at Storbekken in Budalen. In addition, we extracted some additional descriptive statistics from the interpolated raster datasets:

Table 8: Descriptive statistics for the delimited iron production sites

	M²	MEAN	RANGE	MIN *	MAX	STD
STORBEKKEN YOUNGER IRON AGE	531,5	118,0	1413,0	10,5	1416,0	157,7
STORBEKKEN 1 OLDER IRON AGE	1940	287,5	2391,0	10,5	2392,0	348,4
TROMSDALEN	1152	144,9	1537,8	19,0	1551,9	175,5
ROKNESVOLLEN	3020	94,5	680,3	10,0	686,4	88,2

*Equals the median value for the test area. At Tromsdalen, the median value was different on the cultivated surface east of the road, so an interpreted eastern edge was utilized for estimating the area size.

Being able to indicate the approximate size of the iron production areas is of considerate scientific value, as only one site of the *Trøndelagsfurnace*-tradition have been fully excavated previously and the size and activity zones relating to the iron production has remained largely unknown. This information can therefore be taken into account when new sites will be investigated in the future, to ensure proper delineation when entering the sites into the national monument registry or budgeting for future excavations. Although this statement is not considered to be valid for all archaeological types, our results show a clear correlation between the areas of iron production we surveyed and the MS readings we got at these sites.

At Storbekken 1 enhanced values were observed as far back as 30 m away from the furnaces, extending into on the flat terrace behind the furnaces. The highest readings were in the vicinity of the furnaces and the closest area towards east. At Tromsdalen the same was noticed some 15 meters northeast on the opposite side of the road, and about 30 meters north-west on the flatter part of the terrain extending in this direction. At Roknesvollen, we got high values about 20-30 meters westwards, away from the edge towards the stream, which also divided the site in two. The division is based on the susceptibility-measurements alone and it is difficult to assess if the activity on either side of the stream was coexisting in time, or the result of activity separated in time and by function. An interesting observation here, are the lower values within the identified house foundations, but also an area of increased values just west of the building oriented NNW-SSE; this observation can be interpreted as the result of potential smithing or pre-processing of the raw iron produced on site. Generally, there are low readings within the southernmost building, which is surrounded by relatively high values. The buildings have either been kept intentionally clean of any susceptibility-enhancing material, or it is masking magnetically susceptible deposits that might have been removed when building it or remain stratigraphically below the construction. The origin of these enhanced values outside the building, or the reason for lower values within the buildings, have not been investigated by intrusive archaeological investigations. At Storbekken 1 we also observed heightened values compared to the median value of the measurements on site, where Lars Stenvik identified house foundation – indicating that the activity within the houses at least to some degree led to magnetic enhancement of the subsoil. At Storbekken, an additional strong measured susceptibility-contrast was noticed as a low embankment – which in combination with the fluxgate gradiometer-results proved to be an oval feature measuring 12x7.5 m; this is interpreted as a very intentional and manmade shape. This feature had some of the strongest susceptibility readings – even stronger than the exposed excavated furnaces and measurements within the unexcavated furnaces. Roasting iron ore is a necessary stage on the pathway to producing usable iron, and is a process that increases the magnetic susceptibility of the iron ore. It is possible that this feature is a storage area of roasted iron ore. The fact that the measured contrast within the building area was far lower, can be used as an argument against these buildings being a storage area for roasted iron ore, but rather used for residential purposes and/or the storage of unroasted iron ore, firewood or clay used for constructing the furnaces. At Storbekken 1, the mean value within the slag tip-area was 452,8 10^{-5} SI, which is approximately 43 times the median background value – i.e. a very strong contrast is expected on slag tips or heaps. Some very high readings within the slag tips can be explained due to measuring more or less directly on a very susceptible piece of slag such as a larger piece of a slag block with high iron content. At Tromsdalen, it is expected that the furnaces should be located at the higher point in the landscape, with the slag heaps or tips downslope from the furnaces. If this assumption is correct, then the highest maximum readings at Tromsdalen were within the slag tip as well. Figure 14 illustrates data along a 22m long line from the excavated furnace on figure 1, across the five test pits and continuing five meters further downslope. There is a clear correlation between the depth of the slag tip and the topsoil volume MS readings, which is highest at the furnace on the edge of the terrace, and with a tendency of reducing MS-values and decreasing thickness down the slope. The amount of slags found within these test pits does not indicate the same trend. A possible explanation is that the heavier and/or larger pieces more easily fall further down the slope, which might explain the large amount of slag found in testpit D.

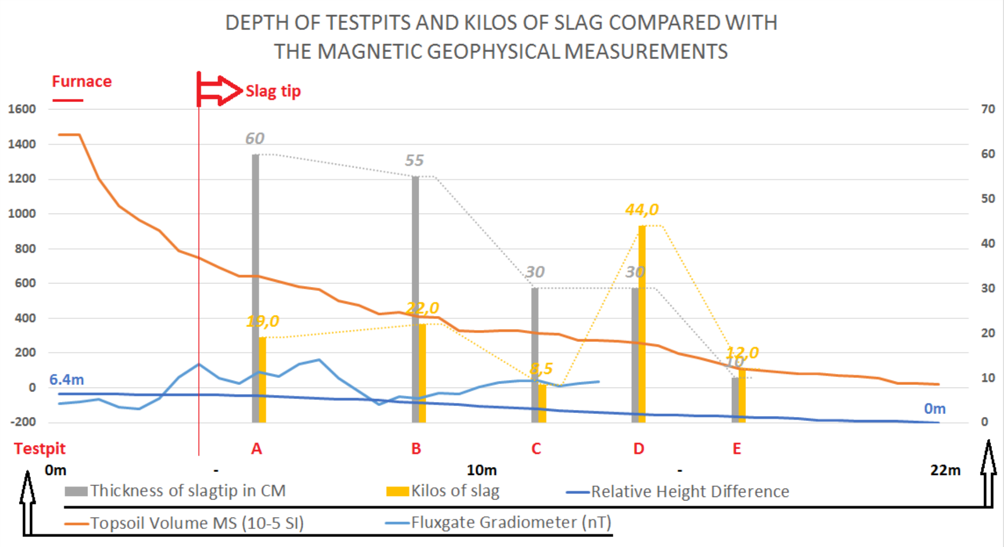

Figure 14: The relationship between depths of the slag tip and the amount of slag found in testpits, compared with the magnetic geophysical measurements at Storbekken 1. The median MS value was 10.5 10^{-5} SI

Although there are some variation in the average, range, maximum measured value and the standard deviation when we consider all measured values within the estimated site area, the mean measured values within the sites is from 7-27 times the median value. This indicates that the main areas of the iron production sites have a very strong contrast with respect to the natural background, suggesting that topsoil volume susceptibility sampling is as a very useful method to apply if we intend to locate and delimit additional iron production sites in the future. The resolution applied, i.e. a sample between 2.99m to 4.35m between each measurements, proved detailed enough to identify additional activity areas – for instance the areas denoted as A1 and A2 at Storbekken 1 (figure 3), areas south on the eastern side of the stream at Roknesvollen (figure 10) as well as northwest of the main area at Tromsdalen (figure 7). The smallest of these areas were approximately 5x6m, equal to 30m^2 . This means that to get to measurements within this area, a sample density of maximum 3.87m between each measurements should be regarded as a minimum requirement. We interpret these areas as potential roasting site for iron ore- an interpretation strengthened by the fluxgate gradiometer response within these areas of increased magnetic susceptibility response. This will be discussed later. Also, by indicating the approximate size of the iron production areas, we can use this information to calculate the approximate survey resolution needed to identify similar sites in the future. As we can assume that we will have readings somewhere between 7 and 27 times the median in average, with extreme values sometimes over 200 times the median (see table 8), relatively few measurements are necessary to ensure some measurements fall within the target area. As soon as points with extreme measurements are located, the average sample distance around this anomalous point can be decreased and the sample resolution increased. A good rule of thumb is that the sample resolution should not exceed the size or the depth of the expected feature (Schmidt and Marshall 1997), but more sample points within the feature might be necessary to properly characterize the geophysical properties of the feature you want to investigate. If we assume that we want a sample density with 3-5 points within the iron production sites, this would then give a minimum sample density as follows:

Table 9: Table over maximum sample density required for a minimum sample resolution of three and five samples within the main area of iron production

		MAX SAMPLE DENSITY		**MAX SAMPLE DENSITY**	
SITE	m²	3 samples within main area	Sample covering in m²	5 samples within main area	Sample covering in m²
STORBEKKEN YOUNGER IRON AGE	531,5	13,3	177,2	10,3	106,3
STORBEKKEN OLDER IRON AGE	1940	25,4	646,7	19,7	388
TROMSDALEN	1152	19,6	384,0	15,2	230,4
ROKNESVOLLEN	3020	31,7	1006,7	24,6	604

This means that to positively identify the smaller younger iron age site at Storbekken- which is 531,5 m², a maximum sample density of at least 10-13 meters between each sample should be used. To locate the smallest of the surveyed *Trøndelagsfurnace*- sites, Tromsdalen at approximately 1152 m², a maximum sample density of 15-20 meters between each sample would have been necessary. This resolution estimate is only valid for indicating the site, and not the internal characterization of activity sones within the site. If you were to survey 400 sample points in a day with a 15m sample interval, it would be possible to survey 9 hectares in one day of surveying. This does not take into account any additional detailed investigation of areas close to the hotspots themselves. A sequential approach is of course possible, by going back and resurveying areas of hotspots with increased resolution at a later stage.

The fluxgate gradiometer data from the surveyed sites gave additional information of the structural layout and activity within the sites. Also, the very strong magnetic response of the measurements, could in itself be indicative of the main areas of iron production related activities in the landscape. While gradiometer-surveys gave us more detailed information of the activity on these sites, the data is also has a more complex geophysical signature making them inherently more complicated to interpret than the MS data.

When encountering satellites of high magnetic susceptibility measurements such as the A1 and A2 area at Storbekken 1 or within the area extending north-west of the main area at Tromsdalen, the fluxgate gradiometer measurements confirmed the presence of strong magnetic anomalies, and helped delineate and characterize these. At Storbekken the anomaly A1 had a maximum of 363 nT, and the anomaly A2 had a maximum of 320 nT (see figure 4 and 5). The anomaly at Tromsdalen had a maximum of 198 nT (see figure 15); it issemi-oval in shape and approximately 2.7x2.2m, being the longest in the SE-NW-direction. This anomaly had a distinct negative with a minimum value of -16,4 nT due north – suggesting a composition of mainly induced magnetism. This can be interpreted as traces of burning, which has largely been left undisturbed in-situ. The anomaly A1, the southernmost of the two areas at Storbekken 1, has a similar shape and dimensions – semi-oval and 3.2x2.0 meters roughly aligned SSE-NNW. This anomaly has the strongest negative due north, but has a negative halo surrounding it. The minimum measured value was -86,5 nT. The anomaly A2 had more of an amorphous shape stretching at least 4.2x1.8m, also with a negative halo, and some strong negative hotspots both to the south and north – indicating the composition of both induced and remanent magnetism. This might be interpreted as a more disturbed context than A1 and the anomaly at Tromsdalen. The fact that all these three anomalies occur a short distance from the main area and from the terrace edges, but with a strong magnetic signature still within the areas with MS readings above the median, could indicate that they are the result of a similar activity. The size and the geophysical signature indicate that these anomalies might be roasting sites for iron ore, and their geophysical contrast is comparable with observations at Gråfjell – where they often were detected with a geophysical contrast in the range of 180-300 nT (Rundberget 2007). They could be storage of roasted iron ore, but the presence of the semi-oval with extremely high MS-readings mentioned earlier which has been interpreted as just such a storage site, indicate that the expected gradiometer-readings for a storage area of roasted could be even higher than the values observed at the hotspots A1 and A2, as well as the one at Tromsdalen. The maximum nT reading of the larger oval at Storbekken 1 was 555nT, with the strongest negatives mainly towards north, but with more of a mixed signal of positives and negatives within and also surrounding the anomaly. There is a clear correlation between the visible embankment and the geophysical anomaly, but the gradiometer-results also show the remaining layout of the feature- composing a complete semi-oval.

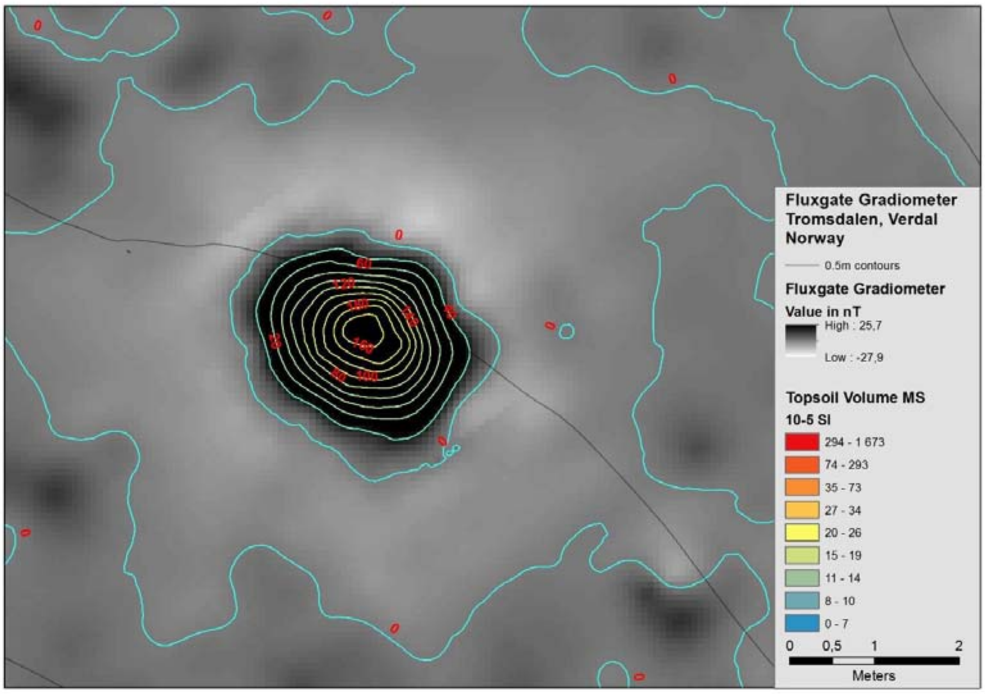

Figure 15: The possible roasting site for iron ore at Tromsdalen. Contours are for every 20nT, where red colours are positive values, and blue colours denote negative values.

We can see the slag mounds at Tromsdalen very clearly in the fluxgate gradiometer-data from the same site (figure 8 and 9). The maximum responses of topsoil volume MS coincided with the strong readings from the slag mounds identified on site. The strong positive gradiometer-results are surrounded with a halo of negative readings. Within and around the main areas of high gradiometer readings are some relatively random hotspots which could be the response from larger slag blocks being removed from the furnaces and tossed into the slag mounds. The response from the Storbekken 1 site is different, with fan-shaped strong positive readings oriented around the perceived opening of the known furnaces and about 2-8 meters away from the known locations of the furnaces. From visually surveying the site, Stenvik's sketch and the topsoil volume MS-results we can suggest that the slag heaps extends further downslope towards the east. Further away from these fan-shaped strong positive anomalies is a combination of both strong negative and positive readings with a clear contrast to the natural background, but without a clear shape or pattern. Plotting the response in nT along a line with known depth of the slag heap and quantification of the amound of slag, also show this varied response across the slag-heap (figure 14). This is somewhat a different response than Farbregd (1977) and Walach et al. (2011) reported from other slag tips, but is also different to what was observed at Tromsdalen. Within these fan-shaped slag heaps are random strong hotspots, equal to the ones interpreted as larger pieces of slag blocks observed in the slag mounds at Tromsdalen. At Mokk, the larger positive signal down slope to the south has a maximum reading of 313 nT, and is interpreted as a slag mound. A band of higher magnetic material further west, and the areas of magnetic response clearly delineate the limits of the iron production towards the west and northwest. The slag heaps extends further south and east than the area covered by this survey (see figure 13).

The results of Vernon (2004), Abrahamsen et al. (2003) and Smekalova and Voss (2002) indicate a relatively easily identifiable shaft furnace when the slag blocks are remaining in situ. The geophysical signatures when measured with a magnetometer are often strong circular positives, with the negative part of the signal mainly to the northern side and potentially with a negative halo. When the furnace is further away from the sensor, i.e. that the furnace is buried at additional depth, the negative halo around the central part of the signal diminishes. At Storbekken 1 we known the location of the furnaces, and the unexcavated furnaces have maximum values between 260 and 318 nT (see table 4 and figure 16).

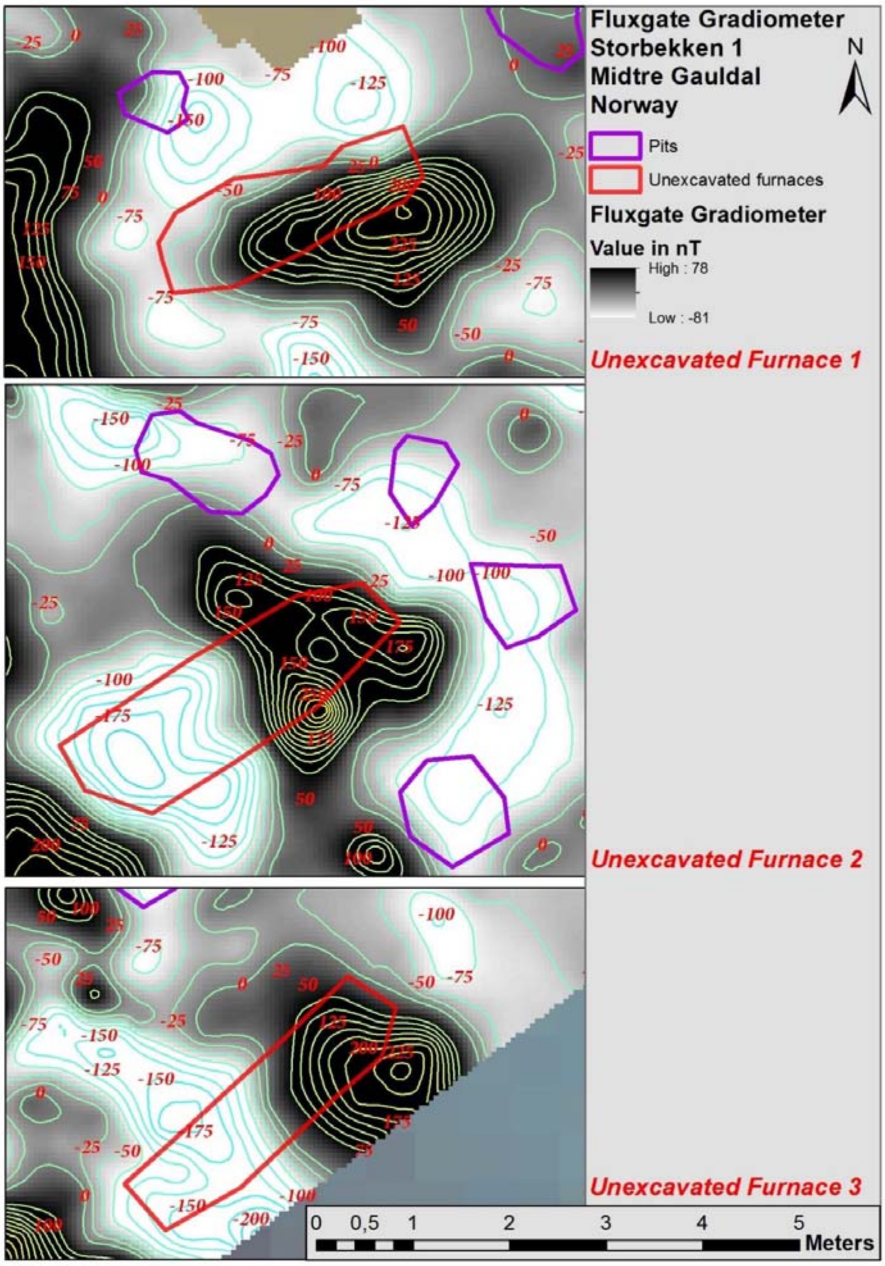

Figure 16: Detailed illustration of the fluxgate gradiometer response of the unexcavated furnaces at Storbekken 1.

The maximum response is relatively high (between 260 and 318 nT) , but not as high as readings reported from the Gråfjell-project and at Haglebu – where readings with a maximum of 800-1500+ nT have been reported (Rundberget 2007). This could be due to the depth of the *trøndelagsfurnaces,* which is known to be up to 0.7-1m (Espelund 1999; Prestvold 1999; Nordlie 2009), where increased depth decrease the geophysical contrast of the feature. The unexcavated furnace 1 has an elongated ENE-WSW reponse, with the maximum of 277nT just south of the elongated ditch – indicating the location of the most magnetic response within the feature as being on the eastern end of the visible ditch (see figure 16). The negative part of the signal is strongest due north, but surrounds the anomaly. The other unexcavated furnaces have the same tendency when it comes to the location of the most magnetic response, but they lack the elongated shape. The unexcavated furnace 2 have several hotspots of approximately 150, 175 and 318nT, and lack an elongated or round/oval shape of the positive part of the signal along with being surrounded by various strong negative responses – indicating a more disturbed context. The unexcavated furnace number 3 have a more round and symmetrical geophysical response of the positive part of the signal, with its maximum reading of 260nT just south of the eastern edge of the visible ditch on the surface. The negative values are strong due north and to the east, indicating a mixture of remanent material. The geophysical response at Storbekken 1 is not uniform, but the physical placement just in from the terrace edge, the strong geophysical response and the size of the anomaly makes it possible to separate these anomalies from the slag tips at this site.

At Tromsdalen there is a strong positive and relatively circular anomaly located in the north-western edge of the slag mound, on higher and flatter part of the ground (figure 17). We would expect the furnaces to be located in the higher and flatter part of the terrace edge, although the terrace edge is less pronounced at this site than at Storbekken 1. This anomaly has a maximum of 204 nT with a small outlier protruding towards south (Anomaly A on figure 17), surrounded by a negative halo with the strongest minimum values at several directions. If this anomaly is the furnace, then the outlier bulging out towards south may indicate the opening of the furnace. Anomaly B is elongated and semi-oval, oriented roughly perpendicular to the slope, with a maximum of 148 nT surrounded by negative values to the north-west and south-east. Anomaly C has a higher maximum with strong negative readingsdue east indicating strong remanent magnetism, with a maximum reading of 226 nT. Compared with the results from Storbekken 1, there does not seem to be a clear separation in space between the maximum values interpreted as potential ovens on figure 17, and the slag tips or heaps downslope. It is, although, possible to see Anomaly B as a similar phenomenon as Unexcavated furnace 1 at Storbekken 1 with anomaly C as being the result of a larger slag block within the slag heap. The distance between anomaly A and B would then be similar to the distances between the furnaces at Storbekken 1. If anomaly B is a furnace, then there is a reasonable chance that there had been another furnace further east that either falls just outside of the investigated area or have been removed by the construction of the road in the 70s.

At Mokk, there are three anomalies that can be interpreted as potential furnaces (figure 18), all close to the flatter bit of the terrace. Anomali A is a very strong positive, with a maximum of 1061 nT, and a minimum of -358 nT towards north-east. The strength of the positive is above the measurable range of the instrument, which is ±1000nT for the Bartington Gradiometers in full scale setting, indicating that the actual maximum reading in nT at this feature can potentially be even higher. There is another strong positive due north. The shape is semi-oval. Anomaly B has a maximum of 248nT, and the slag mound is encircling it 2-3 meters downslope from the anomaly, a pattern that is similar to the Storbekken 1 observations. The distance of approximately 6.5 m between Anomaly A and B is also similar to the distance reported between the westernmost furnaces on Stenviks sketch (figure 11). Anomaly C is a strong anomaly with a maximum of 314 nT, but is further in from the edge and not surveyed in its entirety due to dense vegetation at the time of the survey.

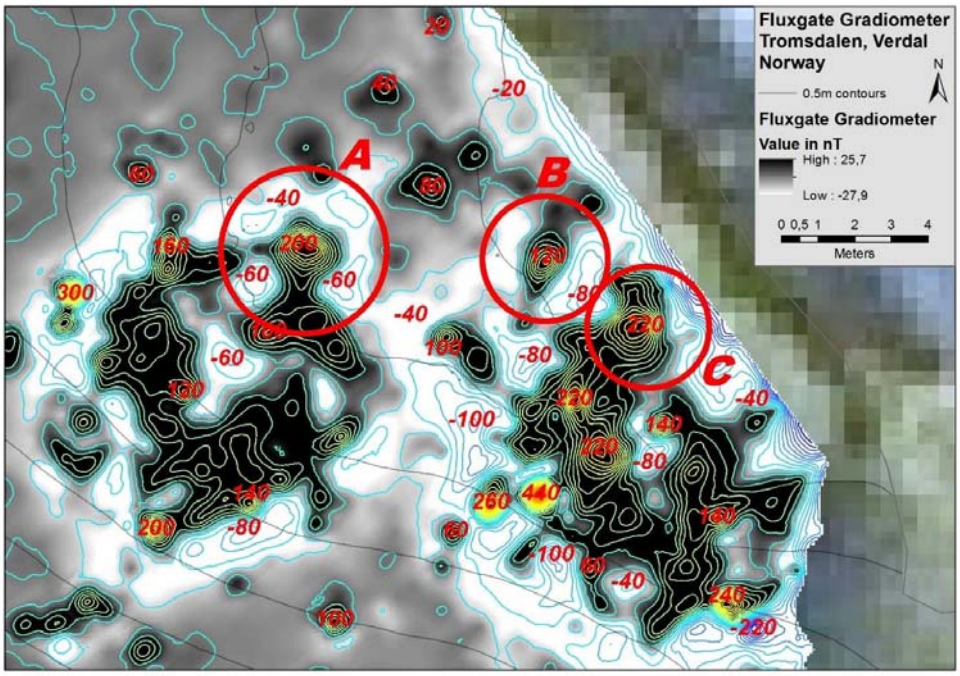

Figure 17: Possible furnaces at Tromsdalen. Fluxgate gradiometer data. The contours indicate every 20 nT, with red colours as positive values and blue colours as negative.

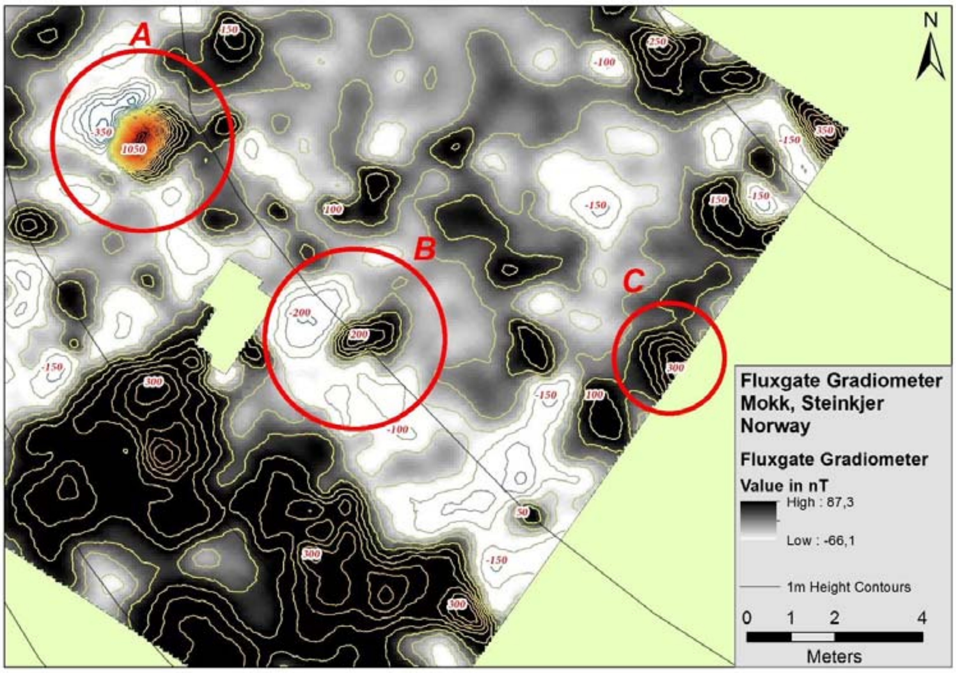

Figure 18: Possible furnaces at Mokk. Fluxgate gradiometer data. The contours indicate every 50 nT, with red colours as positive values and blue colours as negative.

Our results indicate a more complicated geophysical response than what is reported by Vernon (2004), Abrahamsen et al. (2003) and Smekalova and Voss (2002). While strong anomalies were reported, there is a variation in the shape and geophysical contrast – both in relation to strength and the position of the negative values associated with the strong positives. This might be explained by the fact that the *Trøndelagsfurnace*-tradition is based on the *reuse* of the slag pits, instead of the furnaces and slag pits below them being the result of a single firing. Also, the construction of a stone lined, horseshoe-shaped back wall under the furnace, can contribute to a more complicated magnetic geophysical response. In additional to this, post depositional processes such as ploughing, modern disturbance or other human activities from the time of the construction and use of the site and until today, could alter the geophysical response from these sites. In fact, there are evidence of intentionally placing burnt shaft material into the slag-pit (Berre 1999) and covering the slag pit with a large slab of slate – interpreted as an act to hide the knowledge associated with the iron production (Rundberget 2002).

One of the typical characteristics of the *Trønderlags-furnace* tradition is the systematic appearance of pits encircling the furnaces. They have been shown to contain roasted iron ore, burnt clay and burnt stone and slates, and have been interpreted as possible containers for roasted iron ore, storage for clay and firewood, or places for postprocessing the extracted iron (Farbregd et al. 1985; Espelund and Stenvik 1993; Stenvik 2003; Rundberget 2010; Wintervoll 2010). If we study the pits surrounding the unexcavated furnaces # 2 on figure 16, we notice a lack of correlation between the gradiometer-results and the location of these pits. Although the susceptibility values are high for the pits (see table 3) – the high susceptibility values can be explained by the most intensive part of the iron production activity area- an area with high spread of burnt remains from furnaces, slag and burnt clay from the furnaces. Although some hotspots with high readings are roughly co-located with the known location of the pits at Storbekken 1, this appears more coincidental than deliberate. The fact that they are located so close to the actual furnace, often not more than 0,7-1,5 meters, might result in a situation where the gradiometer-readings could be cancelled out by strong remanent effects from the furnace and any other highly remanent or otherwise magnetic material around the furnaces.

The general spread of magnetic material such as slags, iron ore and burnt clay is expected to create a generally magnetically disturbed situation, which explains the overall high values around and within the main activity areas of the iron production sites. There might also be a situation where the latest stage in the iron production is cutting into earlier activity, as known from the site of Heglesvollen, where one of the rosette-pits cut into an older furnace (Farbregd et al. 1985); this further complicates the geophysical response. A possible example of this from Storbekken 1 is presented on figure 19. Although they might very well be the result of cultural historical activity related to the general work logistics, food preparation or otherwise associated with the iron production in general, it is difficult to provide an coherent cultural-historical interpretation of all anomalies.

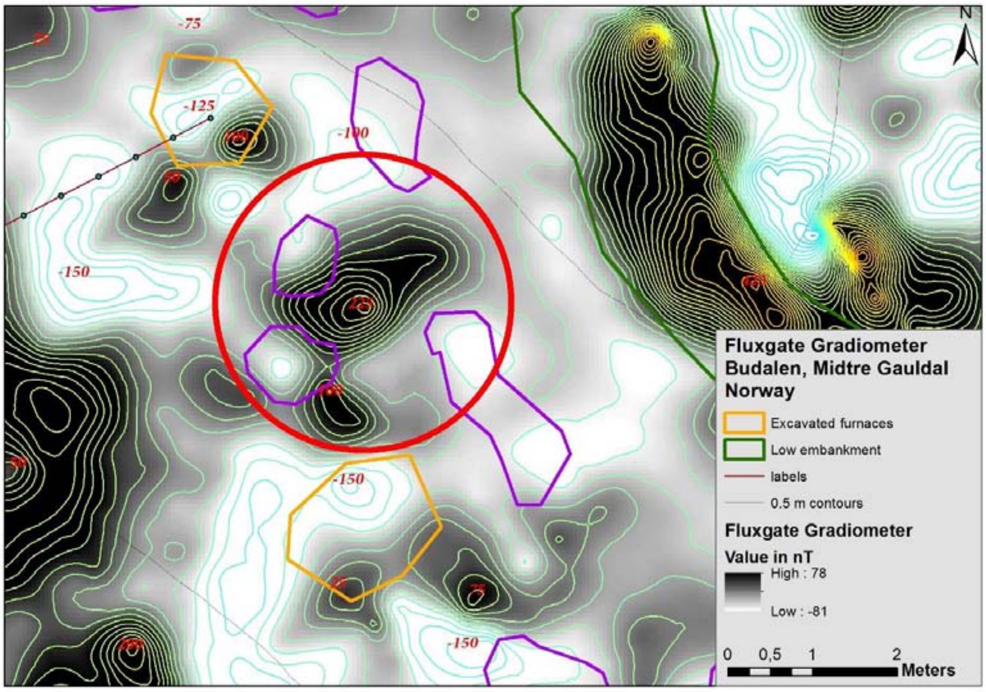

Figure 19: A semi-oval anomaly placed perpendicular to the edge of the terrace, with a strong maximum reading of 237 nT. This anomaly is situated between the two excavated furnaces. Could this be traces of a furnace from an earlier phase of activity?

Conclusions

The aim of this paper was to investigate how the results of magnetic geophysical methods, combining topsoil magnetic susceptibility and fluxgate gradiometer mapping, could be used to locate and delineate iron production sites – and be used as a way of characterizing activity zones and specific archaeological features associated with the *Trøndelagsfurnace*-tradition of iron production.

Topsoil volume susceptibility mapping proved to be a good way of delineating the main activity areas at such sites. The areas with highest mean values were the main areas of production closest to the furnaces and the activity in their immediate surroundings, as well as within the slag tips. All sites had traces of magnetic enhancement extending back several tens of meters into the flatter terraces behind the furnaces, which themselves are usually found a few meters back from the edge of the terrace, with the slag tips downslope from the terrace. There was also a close relationship between the measured susceptibility values and the thickness of the slag tip, and an area with known building remains at Storbekken 1 also showed enhanced values – higher than the median but not as high as the main activity area. We found satellites of heightened values connected to- but placed a little away from the main areas. We interpreted these areas as possible roasting sites for iron ore. We consider the median value for the whole areas surveyed as indicative of the natural background values. The average susceptibility values within the iron production site was somewhere between 7-27 times the background median values, indicating that these types of cultural historical sites yield a very strong magnetic susceptibility contrast. This information made it possible to indicate the approximate size of the iron production sites, and derive an estimate of the necessary sample resolution for locating such sites with topsoil volume magnetic susceptibility when performing a rapid assessment of a survey area. We notice a variation in the descriptive statistics between the sites.

The fluxgate gradiometer results led to several interesting observations, which helped characterize the iron production sites even further. Although a more detailed picture emerges, the data sets resulting from these surveys also had a more complicated response. The site at Storbekken 1 indicated several interesting observations:

- Strong magnetic response from the unexcavated furnaces, with maximum values between 260-318 nT.
- The shape of the anomalies from the furnaces were varied- an elongated oval perpendicular to the terrace edge, amorph shape with several higher remanent peaks, and roughly circular. They were all in the eastern part of the elongated depression visible on the surface, furthest away from the terrace edge
- Strong magnetic response from the upper-lying parts of the slag mound, where the slag tip is thickest, with maximum values up to 286 nT, and generally higher response closer to the furnaces
- Varied response with strong positive and negative values from the slag tips, with increasing variation further downslope and away from the furnaces
- Very distinct and strong remanent magnetic signal shaped as an oval, just behind the furnaces. Possible storage area for roasted iron ore.
- Possible roasting site for iron ore further back onto the terrace, coinciding with areas of increased magnetic susceptibility

Many of the same observations was noticed at Tromsdalen, such as the presence a strong anomaly with induced magnetical geophysical properties a small distance away from the slag tips- which was interpreted as a roasting site for iron ore. We also indicated the potential location of three possible furnaces with strong remanent magnetic contrast, with maximum readings of 148-226 nT. The sensor at this survey was about 10 cm further away from the ground than at Storbekken 1, which would decrease the maximum values. The response from these possible furnaces was therefore comparable to the unexcavated furnaces at Storbekken 1. The response from the slag tips was more uniform than at Storbekken 1, where the spatial distribution in the strong geophysical anomalies in the fluxgate gradiometer-data was comparable with high readings in the the topsoil volume magnetic susceptibility. We also highlighted the location of three possible furnaces at Mokk, where the fluxgate gradiometer data helped indicate the limits of the iron production site towards north-west. It was clear that this survey did not cover the site in its entirety, and several strongly magnetic anomalies indicate further activity on the terrace behind the slag tip and furnaces. The typical response from the furnaces were different from observations reported by Vernon (2004), Abrahamsen et al. (2003) and Smekalova and Voss (2002). There is a variation in the shape and geophysical contrast of the furnaces – both in relation to strength and the position of the negative values associated with the strong positives, creating a less uniform geophysical response from the furnaces than previously reported. The magnetic geophysical mapping of the iron production sites presented here made it possible to assess the physical size of the iron production sites of the Trøndelagsfurnace-tradition, something that has not been achieved before. Also, it was possible to prove additional activity relating to the iron production at these sites as far back as 30 m away from the furnaces – an observation that should be taken into account when investigating new sites in the future. We believe the geophysical observations presented and discussed here can function as important reference material for future geophysical mapping of iron production sites in Scandinavia, both in relation to the quantification and identification of various associated archaeological features in the geophysical data, but also from a methodological point of view.

The combination of topsoil volume magnetic susceptibility measurements and fluxgate gradiometer surveys provided the possibility of both locating, delineating and characterizing the main activity areas as well as additional activity in the vicinity of the iron production sites. While topsoil MS was well suited for the purpose of outlining the activity zones, fluxgate gradiometer data provided valuable additional detail, both geophysically and spatially – and helped provide new and valuable cultural-historical knowledge of these site – including details of size, spatial layout and extent as well as methodological experiences concerning spatial resolution and sampling strategies.

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