Excavating the Digital Landscape

GIS analyses of social relations in central Sweden in the 1st millennium AD

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Abstract
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This thesis presents four GIS-based landscape analyses that together aim to explore aspects of the social development in Iron Age Västmanland, central Sweden. From a perspective where nature and culture are seen as integrated in the landscape, differences in the relations to the physical landscape are interpreted as reflecting social organisation. Hydrological modelling of watersheds is used for understanding the development of territories and regions that are recognisable in the outlay of the medieval *hundare* districts. Statistical modelling of burial grounds together with variables describing their situation in the landscape is used to calculate a chronology for unexcavated sites. The setting of burial grounds in the landscape can reveal different trends in claims to land and property rights. An extensive renegotiation of property rights took place after the climatic catastrophe in AD 536 and the years after. This is interpreted as having caused a substantial population decline in different areas of Scandinavia. The social development after this includes an increasingly stratified social hierarchy in the Late Iron Age, which is reflected in the construction of grave monuments. New GIS methods are introduced for interpreting the perception of different locations in the landscape, in terms of local topography and soil.

A central focus is the analysis of large datasets of archaeological information in combination with other sources of geographical information. Geographically Weighted Regression is used to predict the representativity of the registry of graves for the whole landscape. It is argued that the increasing availability of archaeological information in digital format, and improved analytical techniques, will facilitate working with the large amount of data produced by rescue archaeology in a structured manner.

Keywords: landscape archaeology, GIS, Iron Age, Västmanland, burial grounds, Vendel Period, Viking Age, spatial analysis, territorial organisation, watersheds, statistical analysis, chronology, discriminant analysis, GWR, perception, topography, AD 536, Fimbulvinter, property rights, crisis, historical ecology.

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Cover image is an overlay of a modern topographical map, a hillshade relief and a 17th century map of the province of Västmanland.

"Six by nine. Forty-two."
"That's it. That's all there is."
"I always thought something was
fundamentally wrong with the universe."
- Douglas Adams
The Restaurant at the End of the Universe

List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

I Watersheds as a Method for Reconstructing Regions and Territories in GIS. In: Clark, J. T. & Hagemeister, E. M. (Eds.) *Digital Discovery. Exploring New Frontiers in Human Heritage: CAA 2006 Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 34th Conference, Fargo, United States, April 2006.* 2007: p. 143-149. Budapest, Archaeolingua.

II Landscapes of death: GIS modelling of a dated sequence of prehistoric cemeteries in Västmanland, Sweden. *Antiquity,* 2009. 83: p. 1134-1143.

III Using Geographically Weighted Regression to Predict Site Representativity. *In press. Making History Interactive: CAA 2009.*

IV Digital Perceptions of the Landscape: A GIS based analysis of the location of burial grounds in Västmanland, Sweden. *Submitted.*

V The Iron Age Shock Doctrine: What were the mechanisms behind the social changes in Scandinavia at the middle of the first millennium AD? *Submitted.*

Contents

Acknowledgements

The journey of writing this book has taken me through landscapes and to places I never thought I would see, but at the destination it seems clear that all the stops on the road have served some purpose. There is no doubt that the final product would not have been the same if it were not for all the minor and major events that I have come across in order to get here. Most of all, writing this book would not have been possible without the help and support by numerous friends and colleagues who have provided ideas and knowledge, and also made it a memorable and joyful journey. Most of what is presented here would just not have been possible without my fellow travellers, and to acknowledge them I would like to dedicate the different results in the thesis to those who have meant the most.

I have been exceptionally fortunate to have two supervisors who have shared their knowledge and experience with me. My aim at the outset was to combine their different approaches to landscape. Therefore, I would like to dedicate the paper about *hundare* and watersheds, where settlement districts and environmental water catchments come together in territorial divisions, to Paul Sinclair and Stefan Brink. Thank you both for all your support and encouragement!

My second paper is a statistical analysis of graves and burial grounds, which makes up the data for several of the further analyses. These results I would like to dedicate to a number of colleagues, teachers and friends who through their aid and support made this possible. My mentors and teachers in my first real encounter with the world of statistical analyses, Dag Sörbom and Rolf Dalin, deserve many thanks for their valuable support. Many thanks also to Franco Nicculucci and Sorin Hermon for inviting me to a year as a Marie Curie fellow in the CHIRON project at the Università di Firenze. This was a great opportunity to develop my skills and get to know the European scene of archaeological computing! Thanks to Björn Ambrosiani, Jonas Gustavsson and Hans Lidén for sharing their important work on burial grounds with me. Robert Sjöö was also helpful in sending me his great dissertation, thanks! Many thanks indeed to Henry Simonsson for sending me a copy of his excellent map which has been a great inspiration. My teachers in Leicester, Mark Gillings and Neil Christie, helped me to an extremely valuable year of landscape studies as an MA student. There I had my first encounters with GIS and the concept of watersheds. Cheers mates! I especially treasure the memories from the fieldwork with the Wadi Faynan project in Jordan, and the learning experience in great company out in the desert. Good fieldwork was also enjoyed in Bjärtrå, Ångermanland, under the guidance of Leif Grundberg who taught us undergraduates from Umeå University our first lessons of the practice of archaeology. Sophia Malm, Pinn-Janne Selin, Linda Lidström and the rest was a good gang to share a muddy pit with! Many thanks to everyone, past and present, at FMIS RAÄ, for doing a great job This book could not have been written without you and all the archaeologists who have been out surveying for the registry. Thanks to you all!

I first heard of GWR at the ESRI UC in San Diego. GWR turned out to be a great tool that I enjoyed testing out for predicting how many sites that are missing from my data. With the third paper I would thus like to acknowledge all the instances that have provided financial support enabling me to travel and take part in conferences to keep in touch with the development in GIS and archaeology and do some fieldwork myself. The GIS scholarship from the Stefan Stenlund Foundation got me to the ESRI UC. The Berit Wallenberg Foundation has provided financial support for different projects, for which I am much grateful. The Anna Maria Lundins Foundation from Smålands student nation generously helped me to two CAA conferences. I have also had support from the Royal Gustav Adolf Academy, Mårten Stenberger's Foundation, the Rydeberg's Foundation and the Valsgärde Foundation, for which I am sincerely thankful. The travel bursaries from CAA have also contributed to the fact that I have been able

to attend my favorite conference each year since 2005. Meeting so many archaeologists with similar interests from all over the world has been important to me.

The fourth paper presents the actual landscape analysis of the location of the burial grounds and how the landscape can be perceived. This was the hardest and most painful paper to write. Therefore I would like to dedicate this paper to all my wonderful friends and colleagues who have made the whole experience of doing a PhD something fun and exciting. Getting to know all of you have been a major profit, which has made it all worth while. Lotta Hillerdal and Kristin Ilves have helped ease the pains of academic life over several well deserved pints. Now it is just one of us left to go – best of luck Kristin! At the department there has always been much laughter about archaeology combined with discussions about everything between heaven and earth. Åsa Larsson, Thomas Eriksson, C-G Ojala, Karin Bengtsson, Anna Gatti, Lotta Mejsholm, Fredrik Hallgren, Magnus Alkarp, John Ljungkvist, Cia Holmberg, Anders Biwall, Svante Fischer, Sara Hagström, Pierre Vogel, Gunilla Larsson, Anna Karlström, Alexandra Sanmark, Helena Victor, Erika Lindgren, Marjaana Kohtamäki have all made the department a place where it is always fun to be, and no matter how late, there is almost always company. Julia Mattes has an amazing way of always being there with encouragements and support for everyone, no matter what, and she is always a source of joy. Annika Larsson has been a great companion to many excursion and archaeological adventures, always full of inspiration and curiosity. Ragnar Hedlund and Henrik Berg have provided excellent company for many lunches at Fugu. Henrik has also been a great support in so many ways, and a great chess opponent! Thanks also to Frands Herschend, Kjel Knutsson, Anne-Sofie Gräslund, Anders Kaliff, Ola Kyhlberg, Gullög Nordström and everyone downstairs. Torun Zachrisson has generously provided much valued advice which has had a substantial impact on my work. My friends from CHIRON and CAA have also been great mates – Go Sugimoto provided true samurai skills in fighting the rat in Prato and many laughs. Holly Wright, Kasia Bronk-Zabrowska, Ladislav Šmejda, Lars Gustavsen, Kristina Martinelle have been excellent company. Lotta Fernstål and Björn Hjulström were great company for excursions to Västmanland. Kalle Lindholm has been awesome in so many ways and a true source of inspiration. Kim von Hackwitz has been a great companion in the adventures of GIS and archaeology. Cheers to Carmen Bem and all my friends at cIMeC in Bucharest, hope to see you all soon!

The fifth paper is my attempt to see the society behind the data. This is put in the context of the AD 536 event and the *Fimbulvinter*, as suggested by Bosse Gräslund. The whole paper is of course dedicated to Bosse, with warm thanks for cheerful support and encouragement.

The thesis as a whole, with my thoughts on GIS for the future of archaeology, is dedicated to my mother Martha Persson and my father, Kjell Löwenborg, for everything throughout the years. And most of all of course to my Mona, for always being there and making me smile. The best that has come out of my landscape studies is getting to know you!

Introduction - research objectives and background

Archaeology is fascinating since it is a nexus of many disciplines and makes use of many different ideas, methods and theories in order to understand past human societies from whatever minute traces they might have left behind. The material available often seems to be too fragmented or distorted for us to be able to understand the processes and societies through the centuries and millennia. As new pieces to the puzzle are added sporadically, archaeologists are constantly kept on their toes, always having to readjust ideas and previous knowledge. Focus and aims shift with ideas in contemporary society and with the theories and methods available for interpretation, and the very reason to have an interest in past societies varies both over time and from individual to individual. By putting the pieces together differently the whole picture can change quite markedly, encouraging new directions of thought. For questions that concern whole societies it is often necessary to apply a broad perspective, and it can thus be useful to start with the concept of the landscape, as a frame for much of human activity. Archaeological landscape studies is a field where many new technologies and methods have become available in recent times, and the ways in which this can contribute to an improved understanding of past societies is at the core of this thesis.

Aims and questions

At the outset of my PhD studies I decided to start from a landscape perspective of the province of Västmanland. Much of my previous archaeological experience had a landscape element to it, and I felt that a landscape perspective presented an interesting and rewarding starting point representing aspects of the society that otherwise would be difficult to analyse. Västmanland was new to me, and although I had limited knowledge I also hopefully had fewer preconceptions. The initial idea was to examine special places that could perhaps be understood as central or important for the region. I intended to discuss what constituted such places and what their role would be in the landscape and the society. A second ambition I had was to try to use GIS to see if it was possible to combine this new and promising technology with the traditional, well established kind of landscape archaeology. In addition the post-modern discussion has had a considerable impact on landscape studies and discussions of space and place, and how to insert humans into a constructed landscape (Ingold 1993; Tuan 1977). By combining these perspectives I hoped to understand some aspects of social development, primarily in the later parts of the Iron Age.

Lacking the kind of well defined, limited and accomplishable aims and questions that PhD students normally are equipped with from the outset, I instead went about building my geodatabase in GIS. This was fascinating and great fun, especially since I fortuitously began my work at the same time as *Riksantikvarieämbetet* was completing the digitalisation of the Swedish sites and monuments record, FMIS (http://www.raa.se/cms/fornsok/start.html). This enabled the fast and accurate display and query of the locations of the archaeological sites that had been recorded, including some information on excavations and links to more information. Around the same time *Lantmäteriet* launched their application *Digitala Kartbiblioteket* (https://butiken.metria.se/digibib/index.php), which gave universities access to a range of maps at different scales as both raster images and vector shapefiles that could be used at will to manipulate the maps. An elevation model at 50 metres resolution (cells or pixels) was also included, and together this provided a great material for testing ideas and "playing around with" a wealth of cultural heritage information from the desktop. I enjoyed this immensely and included additional information such as placenames, historical maps, soil data, archaeological finds, and other sites of historical interest, without worrying too much where it was taking me in terms of research. As I was working with the material, there were things that caught my interest and influenced where I put my attention and how I approached the material, which led to new questions. In that way, the question that I ended up working with was to a large extent derived from interacting with the material.

It is probably more a rule than an exception that the focus of a PhD thesis changes over time, and for me that has been a good thing. This is perhaps especially true when working with large materials and with technologies such as GIS that can incorporate enormous amounts of data and analyse these in a wide range of ways. This allows for explorative data analysis, which is a powerful way of feeding results back into the questions and discussions, and since analyses can be rerun fairly easily the material can be allowed to guide much of the research process. While this might be dangerous and could result in a dead end, if successful it might lead to unexpected paths and results that could not have been predicted from the start. I would never have foreseen that I would be working with the *hundare* districts or the Migration Period crisis, yet some of the things I noticed in my data led me in these directions. Of course, it is necessary to approach the material with a question to begin with, but I think it is a good thing if the orientation of the research can be guided by the material. Working with GIS provides an excellent platform for structuring the research, and the control of information that this provides can be a great advantage at all stages of the research process. This could be related to the ideas of Grounded Theory, which emphasises the transition back and forth between inductive and deductive analysis (Glaser & Strauss 1967; Starrin et al. 1997). The collection of empirical data is seen as fundamental to generating theories, while the theories must go beyond the mere description and summary of data. This, it is argued, should allow creativity since research is not being predestined to follow a certain line of thought but instead is enabling new and unexpected perspectives of the material. A similar idea is the "scientific circle" that can be approached at different positions, sometimes taking a starting point in empirical observations and sampling, and other times starting from theories and deduction (Gibbon 1984). At some stage of the research, all aspects of the scientific circle need to be addressed in order to gain a deeper understanding of the questions at hand.

As the work progressed, I became increasingly fascinated by GIS and the possibilities that GIS technology provided the field of landscape archaeology. Apart from simply using GIS to structure my own ideas and material, I also wished to explore some of the general potential in working the GIS together with datasets of archaeological material. Over the last few years there has been an increase in archaeological research that uses GIS in some way, from simple maps to advanced analyses. Swedish archaeologists have (after some initial hype followed by certain scepticism) come to embrace the new technology and it is now part of standard archaeological practice. I am sure that the use of GIS in archaeology is something that will continue to develop and gain in importance. To explore some of the benefits that GIS technology can give archaeological landscape studies and promote more analytical use of GIS thus became an explicit goal of my work. With this came the necessity of dealing with different datasets of both environmental and archaeological material, to ensure that they were possible to analyse together. Much work thus went into things like building a geodatabase with all the data needed, and rebuilding the FMIS database using the FME Workbench application (Löwenborg 2007). The schema created in FME in order to redesign the data structure of the data from FMIS was presented at a workshop in 2006, and has since then been available on my university webpage.

The main questions of the thesis can be summarised as:

- What major trends in the social development in Iron Age Västmanland and the Mälaren basin can be derived from the analysis of burial grounds from a landscape perspective?

- How can landscape archaeology benefit from the use of GIS for integrating environmental and cultural data?

Each of the articles deals with different aspects of these questions and is presented as a case study. The papers build on each other and the landscape analyses presented in Papers 4 and 5 are based on the chronological classification of burial grounds presented in Paper 2. The exception is Paper 1, concerning the study of *hundare* in relation to watersheds. These results are brought together in the concluding discussion below. The purpose of the present thesis is thus to cover some of the aspects that have been left out of the papers and to discuss some general conclusions from all the papers together with some future perspectives.

Period and area

From an initial perspective where both Bronze Age and Iron Age burials are considered

chronologically, the main focus of the analysis is on the shift from the Early to the Late Iron Age and some of the developments during the Late Iron Age. As the analyses are implemented from a landscape perspective the processes discussed are drawn with broad strokes and the overview is usually prioritised at the expense of detail. Geographically, the main focus is the modern county of Västmanland, which is not the same as the traditional province of Västmanland that extends further to the west, see Figure 1.

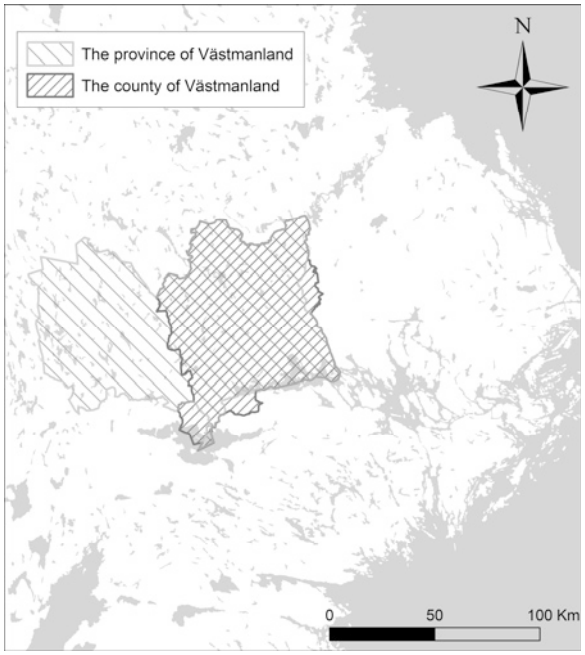

Figure 1. The difference between the province of Västmanland and the county of Västmanland.

When referring to "Västmanland" it is usually the county of Västmanland that is intended unless otherwise stated. The western part separates itself somewhat from the eastern, with markedly fewer ancient monuments. The eastern part on the other hand resembles more the Mälardalen districts of Uppland and Södermanland in archaeological appearance. There has been some debate as to whether or not it is possible to distinguish cultural or administrative borders that would divide Västmanland into an eastern and a western part, where the river Kolbäcksån often is seen as a border zone. Differences can for instance be seen in the frequency of rune stones, which are very rare in the western parts. There are also differences in the dialects, discussed in connection to an old debate on the relation between Västmanland and the easternmost *folkland* of Fjärdrundaland in the province of Uppland (Lindström & Lindström 2006). The *folkland* were the medieval territorial units of Uppland, also including the *folkland* Tiundaland and Attundaland (see map in Figure 5). Sometimes Fjärdrundaland has been understood as including parts of Västmanland (Schück 1949). The landscapes of the northern part, including Bergslagen, and the southern part around Lake Mälaren are also significantly different in terms of topography and natural geography. The fertile clay is primarily on the plain in the south and along the valleys. These valleys and a number of marked eskers give the landscape a special character that connects the northern and southern parts. Apart from the valleys, the northern part is dominated by forested areas on moraine with a large number of lakes (Lundqvist 1956; Welinder 1974).

Material

As mentioned, this thesis relies greatly on materials available in digital format. FMIS/Fornsök is most important as a source of spatial and antiquarian information. The web application is open to the general public and enables queries that can be defined spatially or by categories. For professional archaeologists and those involved in heritage management, it is also possible to download the data so that it can be included in a GIS and combined with other geographic information for advanced analyses. Although the data in FMIS still have some problems and the quality of the information is being checked and improved, FMIS represents an important resource for fast and, from a landscape perspective, accurate overviews.

Apart from FMIS data and digital maps, soil data from the Swedish Geological Survey (SGU) were also included. For elevations, the database provided by *Lantmäteriet* was not detailed enough. Therefore the contour lines from a vector version of a 1:50 000 topographical map (*Terrängkartan*) was coded for elevation values. These contours, together with hydrological features, were used to calculate an elevation model with a resolution of 20 metres. A large part of the work on this thesis has consisted of analysing the digital material. This is often a very time consuming process, where it is necessary to ensure that data is in the right format for the analysis at hand, and often analyses need to be rerun several times in order to work as intended.

To complete the data from FMIS, information from the results of excavations was gathered from a number of sources for the analyses. The table accounting for the excavated burial grounds in Paper 2, however, does not match the tables used in Papers 4 and 5. The reason for this

is that different selections were made for the material presented. In Paper 2 only the burial grounds used in the chronological analysis were accounted for. These are notably fewer than the total number of excavated sites in Västmanland since they had to meet a number of criteria in order to be included. The main part of the sites that was left out was those that were not known before the excavations started, so that there was no information on how the graves appeared in the landscape. Since this is the key variable for estimating the chronology of the other sites, they could not be used. Sites where the location was classified as "uncertain" (Swe: *osäker*) were also excluded from the analysis, since the location in the landscape was the other set of variables used in the analysis. Unfortunately this reduced the number of sites considerably, which is a disadvantage for statistical analysis. A few single burials were also included to complement the material, even if only burial grounds were being analysed. The reason is that none of the excavated burial grounds had cairns registered in them before excavation, and since this category of grave is seen as an important chronological indicator it was included in the chronological analysis.

The output of an analysis is also dependent on the quality of the data on which the analysis is based. FMIS is based on the field observations of archaeologists, and there is of course much interpretation involved in categorising archaeological sites into the formalised vocabulary used to describe different features. Written accounts might still contain a certain amount of ambiguity in order to stress that interpretations are often somewhat uncertain. Most of those reservations would, however, be lost when information is digitised and entered into a database that is not designed to handle fuzzy definitions (Crescioli, D'Andrea & Niccolucci 2000). As terminology and interpretations also change over time, it is unavoidable that there would be some issues in a dataset like the monuments registry which has been created over a long period of time. Examples of possible misclassifications are Kolsva 136:3 and Björksta 145:2. These are classified as stone settings, ship shaped and rectangular respectively. In the description of them they are mentioned as possible house foundations, which also is the interpretation given by Helena Victor (2002:88-89). This is, however, not reflected in the database, and most likely there would be more examples of uncertain definitions.

Archaeological settlement history in the Mälaren area

A project initiated by Knut Stjerna in 1907 aimed at studying the development of regions during the time of the first settlements on the basis of the distribution of Stone Age artefacts (Arwidsson 1964:21-26). A team of archaeologists was formed, where each member was assigned a district from which all relevant information should be collected in order to investigate the first traces of settlement. Although the ambition was to investigate all of Sweden, the area of Mälardalen – which comprises the Lake Mälaren basin – was prioritised first. With a large number of archaeological remains available, and a rough spatial chronology as a consequence of land rise and shore displacement in the area, Mälardalen was often seen as a model in which it was possible to build and test different ideas. From an early stage this line of research was connected to other disciplines such as geology, geography, anthropology, the history of agriculture, and place-name studies in order to understand the social developments from a broad perspective.

The project initiated by Stjerna was followed by a number of small-scale settlement historical studies of different regions, especially on Öland and Gotland. A new approach was introduced by Björn Ambrosiani's highly influential work *Fornlämningar och bebyggelse. Studier i Attundalands och Södertörns förhistoria* from 1964, where he builds on a large amount of archaeological excavations carried out between 1956 and 1962. Innovative methods of excavation meant that larger areas of the burial grounds were being excavated and not only the actual graves that were visible from the start. As a result of this, the number of burials found was considerably larger than expected. An increasing number of excavations also enabled quantitative approaches to interpreting the historical development of regions through estimated dates of burial grounds that were known only from surveys. This was possible due to schemas constructed for chronological descriptions of the different types of graves, such as cairns, mounds, standing stones, and stone settings of different forms and shapes. The number of graves at a site was seen as an important variable in determining the age of a burial ground. This marks the starting point of what was to be known as the Mälardalen tradition of settlement historical research. By studying the burial grounds the spatial extent of the settlement could

be understood, enabling the researcher to analyse the development of the region. The main focus of Ambrosiani's analysis was the settlement historical development in seven small areas in eastern Mälardalen which were interpreted as being defined as a region by natural conditions (Ambrosiani 1964:17).

Ambrosiani concludes that it is possible to follow the development closely, often in terms of the individual farmsteads and how they were established, expanded and gave rise to new settlements around them. He also interpreted the development of the region as a whole, where in the Early Iron Age there were few settlements, followed by a substantial expansion in the Late Iron Age. This was seen as an internal colonisation, where new land that previously was uninhabited had been settled. It was suggested that it was possible to distinguish original and secondary settlements through comparisons with the dated burial grounds.

At the end of his thesis Ambrosiani points to some future prospective investigations, for example concerning the administrative organisation of the area and the *ledung* in medieval times. This thought is expanded on by another important work in the settlement historical school, Åke Hyenstrand's *Centralbygd – Randbygd. Strukturella, ekonomiska och administrative huvudlinjer i mellansvensk yngre järnålder* from 1974. By applying Ambrosiani's method of quantitative investigations of chronology of settlements based on visible burial grounds to the whole of the Mälardalen area, Hyenstrand aims at analysing the settlement structure and the *hundare* organisation in combination with an analysis of the importance of iron production in the area north of Mälardalen. One of Hyenstrand's aims is to test the possibility of computerised statistical analysis of the large material that is the result of the extensive surveys of the archaeological sites in the area (Hyenstrand 1974:14). This large dataset is classified into different subsets based on the combination of grave forms that are registered, and the classes are then related to different periods. His results concerning the settlements are much in line with those of Ambrosiani, where a strong continuity is assumed from Late Iron Age to medieval settlements.

With a chronological understanding of the prehistoric settlements of the Mälardalen area, Hyenstrand proceeds to compare the settlement structure to the administrative organisation. A model for the organisation of the *hundare* is constructed based on comparisons with examples from England and Western Europe where the number of settlement units in each region is used as the basic unit of the analysis. After examining all the *hundare* of Mälardalen, a territorial division into *hundare* is suggested based on the number of primary units that could fit in the different territorial units. The primary function of the *hundare* is seen as a fiscal organisation based around *thing* sites and *Tuna* place-names, something that is also linked to the formation of parishes during the introduction of Christianity. This development is seen in part as a consequence of a newly established aristocratic elite in the area, which took advantage of the new land that became available due to land rise, in combination with control of trade, especially by the northern parts of the region which had a great deal of iron.

Both Ambrosiani and Hyenstrand consider the problem of how representative the known register of burial grounds is in light of such factors as lack of visibility and the possible removal of some burial grounds through agriculture. They conclude, however, that although some graves clearly are missing, the material as a whole is complete enough to study the development of the settlements in detail. The question of just how complete the register of burial grounds is was brought up again by Agneta Bennett (Lagerlöf) in relation to the large number of excavations in the 1970s and 1980s (Bennett 1987). Against the background of a larger number of excavated graves and further developments in the methodology, Bennett discusses the previous idea of a high survival rate of complete burial grounds. One problem is how antiquarian considerations of heritage management have added bias to sites selected for excavation. Large and imposing burial grounds are preserved, especially if they contain graves of more elaborate shapes and forms, and consequently the sites chosen for excavation might not reflect the whole variation in burial grounds. This makes it problematic to interpret the settlement structure and continuity. The differences in the rate of urban expansion in different areas have also resulted in an unbalanced knowledge base of archaeological sites. Analysis based on the registered material thus needs to be cautious; and Bennett suggests that the prehistoric settlements which produced the burials were not as homogeneous as previously thought but instead showed greater variation in the size of settlements, with both single farms and groups of farms. Especially the Early Iron Age might be underestimated since it is not as well represented, and she

argues that the difference between the periods and the large expansion in the Late Iron Age has been overestimated because of this (Bennett 1987:148). It is also clear that the number of individuals for whom surviving burials were prepared has varied considerably over time, and there are major gaps in how the population is represented by the burial practice (Johnsen-Welinder & Welinder 1973).

It should be noted that my use of the concept "landscape" is based more on the Swedish definition of *landskap* than the English counterpart. The Swedish *landskap* with its roots in the north European use (expressed in terms such as *landschaft*, *landskap* and *Landskab*) has a longer history than the word's insertion into the English language, which makes its first appearance together with landscape paintings at the turn of the 16th century (Olwig 1996). The term was simultaneously an expression of a territorial unit and the cultural and judicial institutions that linked the local community with it. This would differ somewhat from the English understanding of the concept, which puts much focus on landscape as a "way of seeing" and perception (ibid, Jones 1991, Tilley 1994). The different readings of the landscape are, however, seen as a benefit that enriches the concept and makes it more dynamic and useful.

Research papers – overview

Paper I

Watersheds as a Method for Reconstructing Regions and Territories in GIS.

The administrative *hundare* units are compared to watersheds, or water basins, which are the topographically and hydrologically defined maximum extent of river systems. Rivers and water courses are important communication routes that tie regions together. By expanding the scope to the whole landscape, focus shifts from the core of the communication system, i.e. the water courses, to the edges, i.e. the watersheds. Thereby natural regions are delimited, and these correspond to a high degree with the extent of the *hundare* boundaries. For a society where water is central for communication and transportation, the watershed areas constitute intuitive regions that are experienced in the landscape, both from the topography and from the common point where all the connected water courses drain. Hence it is suggested that watersheds are useful for the study of naturally grown regions that can develop into formalised regions, thus shedding some light on the question of how the *hundare* might have developed and some of the background to their spatial extent and appearance.

Paper II

Landscapes of death: GIS modelling of a dated sequence of prehistoric cemeteries in Västmanland, Sweden.

A chronology is estimated for all burial grounds and single graves in Västmanland that have not been excavated, by comparing them to the sites that have been archaeologically investigated. Apart from the description of the sites in FMIS, how the sites are situated in the landscape in relation to soil and topography is also analysed to test whether the landscape context could provide information useful for chronological estimations. A statistical method is then applied that puts all the sites into the chronological class they resemble the most. A variable that estimates whether sites have been in use during more than one period is calculated in the same way. The outcome is a dataset of dated sites that can be used for analysing spatial changes and distributions of where burial grounds are constructed. How well each site resembles the statistical profile is also defined, as an estimate of how reliable the prediction is.

Paper III

Using Geographically Weighted Regression to Predict Site Representativity.

In order to get an estimate of how large an amount of burial grounds and single graves are missing from the FMIS record, the outcome of a number of large archaeological projects in Västmanland and Uppland are analysed. Differences in how many new sites that are found in different parts of the landscape are used to create a model that aims at applying the results to the landscape as a whole. A range of variables that characterise different aspects of the landscape are analysed and compared to the locations where previously unknown graves were found during excavations. Two methods are used: one that only considers similarities in the variables in order to predict the amount of missing sites, and another that also analyses spatial trends in the material to account for regional differences. The results suggest that a considerable amount of the sites that might be found in excavations are missing in the registry. Landscape analyses of the known number of burial grounds thus need to accept that the image they present is incomplete.

Paper IV

Digital Perceptions of the Landscape – A GIS based analysis of the location of burial grounds in Västmanland, Sweden.

The chronological estimates from paper II are used for analysing differences in how the sites have been located in the landscape. Different methods for describing how sites relate to their surroundings are tested, including descriptive statistics, correspondence analysis and multivariate raster analysis. The locations of burial grounds are compared to the locations of settlements, hill forts, and a sample of randomly generated points for reference. Depending on how the chronological classification is handled the results can be interpreted in different ways. For instance, one can see a general tendency for Late Iron Age burial grounds to be located in less prominent locations than earlier sites, closer to clay and resembling the settlements. But an alternative interpretation is that the Vendel period sites are in a markedly different location, very much like settlements, whereas the Viking Age sites are back in a location that is similar to sites from the Early Iron Age. The methods for analysing the landscape are suggested to reflect some aspects of how the landscape could be perceived at different locations. The spatial differences could thus represent different preferences for where to locate burial grounds, which in turn might reflect varying social purposes.

Paper V

The Iron Age Shock Doctrine. What were the mechanisms behind the social changes in Scandinavia in the middle of the first millennium AD?

The dataset of burial grounds is considered in relation to the question of a probable demographic crisis in the 6th century AD, as a consequence of the cosmic event in AD 536-7. Although indications of an extensive crisis can be seen in a wide range of sources, it is still not possible to make any estimate of the extent of the crisis. Some hypothetical social consequences are, however, discussed and compared to the Black Death in the 14th century AD. For the 6th-century crisis, a widespread upheaval and renegotiation of property rights for land that has been abandoned is suggested, together with a possible redefinition of the nature of property rights. After the crisis there seem to be increased possibilities for private ownership of land, which enables the acquisition of large landholdings among a limited number of people. This is related to an increasingly stratified social structure in the Late Iron Age, where an elite is thought to have been able to take advantage of the crisis for their own benefit. It is argued that this is reflected in the Late Iron Age/Vendel Period burial grounds and their locations, as these might have been used to manifest renewed property rights.

Discussion

Graves – concept and definition

Being among the most central categories of archaeological investigations, graves and burials are far from straightforward to define and use as analytical entities. The most common mistake would probably be to apply a modern westernised concept of what a grave is, which could lead us astray in many ways (Parker Pearson 1982; Kaliff 2007). An obvious example is when no human remains are found in a construction that we otherwise would interpret as a grave. Is it still a grave, or should we call it something else? This phenomenon has been increasingly observed and discussed lately, as it seems that human remains indeed are quite rare for long periods, even considering the effect of taphonomic processes (Renk & Appelgren 2007; Engström 2007). As our preconceptions and how we choose to name what we see usually determine how we come to think about an ancient construction, calling it a grave implies considerable interpretation that is not always made explicit (Kaliff 2007:26). As there often is great ambiguity in what to call graves or burial grounds, and sites with several burials might lack features that are visible on the surface, this will have implications for any investigation using burial grounds as analytical entities.

Mortuary rituals would probably have both secular and religious motives, often intertwined (Kaliff 2007:28). Therefore graves should be understood as means to convey a whole set of ideas of ideological, religious and practical implications, to commemorate relatives and confirm social status, relations and heritage (Parker Pearson 2002, Jonsson 2009). As such, graves have become a node for archaeological interpretation, and our interpretations of graves are fundamental for our understanding of prehistoric societies (Gatti manuscript). Accordingly it is important to reflect on our definitions of graves, to avoid contemporary biases about the purpose and functions of graves and instead acknowledge the complexity of the phenomena. Burials and human remains often even seem to have been of secondary importance for constructing graves, something that needs to be incorporated into archaeological interpretation (ibid).

For my analyses I have focused on the graves as a deliberate signal of presence in the landscape, associated to claims to land (Zachrisson 1994). Although important, the aspects of heritage, economy and more or less juridical purposes are only part of the multitude of meanings that a grave represents. Certainly religious and social meanings would be relevant for how and where graves are constructed, but these would be integrated with more profane functions. Graves can thus be studied in a range of ways, but to my analyses it would not really matter whether the monuments in the landscape were built on a burial, if cremated fragments of ancestors were added to a sacred monument that already existed, or if there was no association between human remains and the monument whatsoever (Kaliff 2007:80). By graves and burial grounds I am solely referring to the manifestations in the landscape that are analysed in order to interpret social changes. The landscape component of graves is something that I think has not yet been used to its full potential in Scandinavian archaeology. The landscape of death and graves is thus relevant for the living by creating a historicity where references to forefathers and heritage are active in establishing rights to land.

Environment and society

Mere mention of the word “environment” can be like waving a red cape at some archaeologists, as it is often immediately associated with a notion of determinism. This is somewhat surprising, since no one who follows the news today can be a stranger to the fact that human societies are affected by their environment in many ways. At the same time humans affect their environment, and through technology this is occurring at an increasing scale and pace today. The problem is how to describe and understand this relationship in a way that can be of benefit for archaeologists investigating prehistoric societies, without being bound to deterministic models of simplified causal connections. Examples in this thesis in-

clude both radical social changes in the wake of a climatic and environmental crisis, as well as how social organisation might be structured around hydrological watersheds that also are highly significant to ecology. A key to approaching these questions is the advances in the natural sciences which stress that processes are far from linear and deterministic (McGlade 1995). Instead of assuming stability and a cumulative evolution towards increasing complexity, reality must be understood as non-linear and dynamic. The factors that influence the development are often so unpredictable or even chaotic that the result might be described as structured disorder (ibid:121). This applies both to ecosystems and human societies, as it is indeed a false dichotomy to separate "human" and "environment". McGlade suggests a move towards a true, interactive, human-ecological theory: "human ecodynamics", where environment is no longer seen as a passive background (ibid:115). Humans are part of the natural world in a reciprocal dynamic where "the social informs the natural and the natural informs the social" (ibid:114). In studying social development we are thus forced to consider the environment, not as a separate entity, but as part of the whole. This conception is mirrored in current discussions of the new field of historical ecology (Crumley 1994).

As more and more environmental data are becoming available through the advances in the natural sciences, archaeologists are presented with the possibility to compare environmental and social development with increasing detail. This shows that the process is one that involves complex developments as society and environment influence each other (Costanza et al. 2007). It has often been suggested that archaeology provides a unique opportunity to observe this interplay in the kind of long-term perspective that is necessary for understanding slow processes. With this experience archaeology could provide valuable insights into future human ecodynamics, as suggested by the IHOPE project (ibid, ref). It is not possible to predict what will happen in the future, but knowledge of past human-environmental interplay could help us in giving some idea of what to expect and prepare for. There are many challenges to this, since the factors at play are intertwined from different spatial and temporal scales that continuously change, adapt and resist development in non-linear ways, as outlined in the Panarchy theory (Gunderson & Holling 2002). Introducing human ecodynamics and historical ecology will thus not provide any simple and straightforward answers, or any answers at all, but might help us address some of the complexity involved in the human environment interplay. Not least does this apply to how systems can be both resilient and vulnerable at the same time, and how small deviations can cause very large effects that can be difficult or impossible to reverse when thresholds of resilience are passed (Liu et al. 2007:641).

The social effect of climate often is thought of in terms of *longue durée* and gradual shifts and adjustments (McGovern 1994, Eriksson 2009). Catastrophes are often considered to be events that can be managed and overcome by society, as there would be flexibility within systems that ensured resilience (McAnany & Yoffee 2009, Tainter 1988:52). However, if a certain threshold is reached, that triggers a crisis, than this would result in cultural response (Crumley 1994:10, 1998:xiii). It is thus important to consider the scale of events. The AD 536 event is suggested as an exceptional event that for parts of Scandinavia would have had consequences beyond the boundaries that could be managed. It is still debated whether the dust cloud should be ascribed to a volcanic eruption or a cosmic impact (Abbott et al. 2008, Larsen et al. 2008), but the effect can be traced in sulphates in ice cores from Greenland and in the growth of tree-rings in many parts of the northern hemisphere. These show extremely low growth in oak from Ireland, Scotland, England, Holland, Germany and Poland, and on other kinds of wood from northern Sweden, northern Finland, Austria, northern Russia, Siberia, Mongolia, southwest USA, as well as in Argentina and Chile on the southern hemisphere (Gräslund 2007:106-109, with references). The growth of tree-rings is almost nonexistent in AD 536, and continues to fluctuate at low levels for the period AD 537 to 545, indicating that this would have much more extreme than any historically known volcanic eruptions like Tamora 1815, Krakatau 1883 or Pinatubo 1991 (ibid.). For areas such as the Mälaren basin and Hälsingland where ecological thresholds were overshot, extensive impact could be expected that would result in considerable change on several levels. Modelling the linear and non linear socio-ecological system dynamics of climate effects on societies is the current focus of intensive research and archaeological applications. This has considerable potential, especially when dealing with large data sets and integrating extended time periods and

specific events (McIntosh, Tainter & McIntosh 2000, Redman 1999).

Questions of the environment would also be closely interlinked with economic considerations, and, if treated with caution, economic theory would have much to offer archaeology. A problem with analysing social, economic, political and related ecosystems is that the disciplines have developed independently and do not combine easily without a general framework (Ostrom 2009).

Landscape Archaeology 2.0

GIS technology has great potential for archaeology in general and landscape archaeology in particular. However, the use of such a technology is by no means theoretically unbiased, and much debate has focused on the issues and problems that might be introduced by relying on computational and statistical models (see Crescioli; D'Andrea & Niccolucci 2000; Wheatley & Gillings 2002). There is a real danger that the analytical capabilities of GIS can come to steer the questions being asked by archaeologists by limiting the scope to the tools available in GIS packages. This can be seen in the extensive use of viewshed analysis and cost surfaces that often are used to stimulate human interaction with the landscape. The efficient and powerful manipulation of environmental data might have the result that these aspects are stressed at the expense of cultural factors. It has been suggested that GIS in archaeology is used to best effect in holistic investigations that aim to explain phenomena by means of broad generalisations, by looking for time and space patterns (Voorrips 1996). Large amounts of information can be dealt with in order to examine aspects of the data that might otherwise be impossible to observe. At the same time there is a risk of generalising the variation so that important exceptions are missed. There is an ongoing debate on the relation between archaeological applications of GIS and archaeological theory, and there are motivated concerns (Evans & Daly 2006). Together with greater confidence in the technology and awareness of the dangers, there also seems to be increasing maturity as to how the results of the analyses are incorporated into archaeological interpretation.

There is no doubt that the use of GIS in archaeology will continue to grow and open new opportunities and questions that will enrich the discipline in many ways. This should not be at the expense of qualitative methods applied to individual sites or types of artefacts. Instead, I think it is clear that the different methodological approaches used in the archaeological discipline complement each other. Ideally some of the means of including large datasets from the ever growing archaeological material might even help to comfort some of those who have despaired as archaeology seemed to end in epistemological relativism, and to provide some hope for those of us who wish to study prehistoric societies.

One of the really powerful aspects of GIS is that we now can include the physical landscape in archaeological analyses in a structured way that can give rich and detailed information. This is an opportunity to develop a "Landscape Archaeology 2.0", which would enable archaeologists to analyse the landscape together with the social and cultural aspects integrated. This would continue to improve our understanding of social and environmental development as integrated, without being stuck with deterministic explanations. The "2.0" refers to "Web 2.0" which stresses information sharing, interoperability, user-centred design and collaboration (http://en.wikipedia.org/wiki/Web_2.0), Wikipedia being one of the most obvious examples. As archaeology embraces more and more of the advances in information and communication technologies (ICT), there is a need for an understanding of the inherent benefits and dangers. The benefits include fast and easy sharing of data, ease in incorporating data from different sources, refining the information by further research and making the results available again.

I have tried to make sure that the results of my analysis will be available for future research. A table with the results of the classification is available by contacting me, and the table can be combined with spatial information from FMIS in order to do further analyses in GIS. Without having to use a GIS, some aspects of the results can be explored through a layered PDF with burial grounds that gives the user the possibility to choose what periods to display. The comparison between watersheds and *hundare* and the results of the GWR analysis are similarly made available as layered PDFs, as digital appendices of the thesis through the DiVA library system. Naturally, the results of the statistical estimation of chronology for the graves should in no sense be regarded as final, as they will be made obsolete by future excavations, both in terms of which sites are excavated or not and their estimated dates. The results presented here should, of course, be understood as statistical estimations which are always flawed. With the weak-

nesses of the material in mind, some of the ways that the information might be used for analyses are presented here in Paper 4. Other research approaches that include burial grounds in Västmanland would be welcome to use this data for reference or analyses and to correct and develop the material further as necessary. I am well aware that the methods suggested for including all the burial grounds known from surveys could be developed further, and a larger material of excavated sites from other areas as well would probably yield better results

As more and more archaeological information is becoming available in digital format – from assessment to excavation, publication and archiving – it is time to fully address the implications of this situation. The wealth of information has a huge potential and should be made available so that it can be included in research in the best way. In line with this, a good initiative by the archaeological excavations department at the National Heritage Board was to publish GIS files with some of their excavation reports (http://www.arkeologiuv.se/rapporter.htm), and this will hopefully become standard for all excavating agencies. In fact, something like this should become a requisite for obtaining a permit to excavate, since archaeological practice is so information intensive that other media usually are insufficient. With time this would facilitate nationwide overviews of house typologies and collections of ^{14}C samples that could be used to study trends, as suggested by Thomas Eriksson (2009:263-273). A positive side effect might be a closer and mutually beneficial collaboration between the research at the university departments and the excavating agencies. This would also be in line with the ambition that research should be available through Open Access agreements, as is often argued for now.

The availability of GIS data would also be of great value for evaluating the results of excavations in relation to what was previously known from surveys. This would be very useful for the interpretation of burial grounds that are known only from surveys (Bennett 1987). The data could also be used to ensure quality control and evaluate excavation methods. When there is a system of negotiating rescue excavation contracts, as there is in Sweden, it is important to be able to have some sort of measure of quality in the process. Otherwise there would often be a situation where the contractor that agrees to do the excavation at the lowest price gets the job, regardless of the methods proposed to ensure quality (Petersson & Ytterberg 2009). This is a very complex and difficult problem, and there is no easy solution, but a structured utilisation of existing and newly recovered excavation data might be one way to start addressing this issue.

In a long-term perspective, there are also considerable problems concerning aspects of format and the archiving of digital information that need to be addressed. This is a general concern for all of society at present, as ICT is becoming an integrated part of everyday life. Much effort is needed to make sure that information is stored in such a way that it will not be lost as hardware when, for instance, file formats change. A good starting point for these questions is the UK Arts and Humanities Data Service's *Digital Archives from Excavation and Fieldwork: Guide to Good Practice* (Richards, Robinson & Austin 2000). Ideally there should be national initiatives to provide such services, so that much of the efforts spent in creating the information will not be in vain. The hope is that these kinds of databases will eventually be international, to enable analyses across borders that were of little or no relevance during prehistoric times. There are several obstacles to achieving something like that, however, not least of which is getting archaeologists to agree on what concepts to use to describe different archaeological phenomena and how to structure the information (Huvila 2006). How to establish responsibility for providing data from excavations for further research is a question that will have to be solved. The Swedish National Data Service (http://www.snd.gu.se/), founded by the Swedish Research Council and the University of Gothenburg, is a service organisation that probably could play an important part in this. Their function is to assist research within the humanities, social sciences and health sciences in the collection and dissemination of data, both with advice and support in how to develop the data and how to give access to data for research.

Large datasets and quantitative methods hold promise of revealing some of the general tendencies of the historical development that otherwise are easily lost in the details. This will hopefully make it possible to learn more about the average man, woman and child during prehistory that did not leave imprints in archaeological materials like exclusive objects or impressive burial monuments. A project that is currently being developed, called LANDBOFOLK, aims at calculating the population dimensions during prehistoric times in actual numbers for the districts of Västmanland and Uppland. This would be possible by utilising the results of the exten-

sive rescue excavations since the 1980s. As a first step a database would be collected of all houses, their dates and sizes, together with estimations of duration of use and the number of people living in the houses in different periods. This information would then be compared to the total extent of the excavations, e.g. the areas where no houses were found. A range of landscape variables that could be relevant for how many houses that would be expected to be found if the whole of the landscape was excavated need to be defined and analysed. The database could then be used to predict values of house area and population using Geographically Weighted Regression, in a similar mode as presented in Paper 4. The outcome would certainly have considerable error margins, since there would be no absolute correlation between landscape and population. The results would, however, be much more reliable than previous estimates of the population in Mälardalen that have been based on registered burial grounds, which are inadequate for such interpretations (Edgren & Herschend 1982). With a rough estimation of population size, much would be gained for further interpretation of prehistoric societies, for example when discussing how common or uncommon it was to erect rune stones in the Viking Period.

Another promising future prospect is the use of airborne laser scanning for elevation data (LiDAR - Light Detection And Ranging). This is currently commissioned by *Lantmäteriet* for all of Sweden (www.lantmateriet.se). When this project is completed the elevation data will be an extremely valuable resource for archaeological analyses of the landscape, as detailed models of the terrain can be made for large areas. This can be used for the modelling of shore displacement where even small differences in elevation might have a considerable impact on the complex process. Another possibility is to use the data in order to identify archaeological remains in the landscape, especially in forested areas with poor ground visibility and in areas where surveying has been summary. Some tests of how LiDAR data can be used to recognise archaeology have already been carried out, where the impact of vegetation coverage and the intensity in scanning were evaluated (Alexander 2009; Alexander, Jonsson & Söderman 2009; Devereux et al. 2005). This has produced some very promising results (Figure 2). Ideally the identification of archaeological remains should be possible to implement with automated image analysis, so that large areas could be covered. Especially in the northern parts of Sweden this could probably produce much new information and open for interesting perspectives on the use of forested areas.

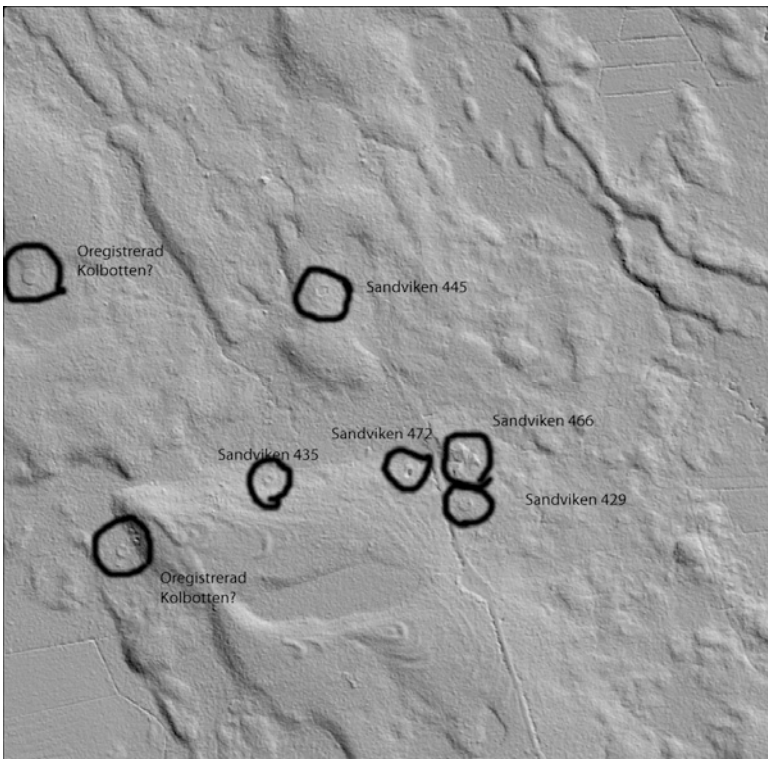

Figure 2. Archaeological sites visible in LiDAR data, including some previously unregistered possible remains of charcoal production sites. From Alexander (2009).

Further benefits of GIS technology include the possibilities to present complex information with both overview and detail where the user can have control of what to display and how. Through different means it is possible to indicate usually would be a mix of fact and fiction. Virtual reality applications have often been suggested as both a means to present archaeology and a tool for research, although this still has some way to go (Pujol Tost 2008).

As GIS is increasingly being used for every aspect of archaeological work there is also a need to develop the skills of archaeologists in the technology, since GIS is still fairly new in archaeological training. In order to contribute to this I have, with support from Uppsala Learning Lab and the Department of Archaeology and Ancient History, developed a course that aims at giving professional archaeologists training in basic GIS skills as well as some familiarity with more advanced techniques for analysis. This course has been given as a long-distance course since 2008. It builds on the facilities of the GIS lab founded by Paul Sinclair as part of the Africa project activities and courses which were developed by Markku Pyykönen, Karl-Johan Lindholm and me, and which have been taught to first-year archaeology students at the department since the late 1990s.

The Iron Age landscape in Västmanland

What can we learn about the Iron Age landscape in Västmanland from the analyses presented? The distribution of burial grounds suggests that the plain along the shore of Lake Mälaren was fully settled by the end of the Early Iron Age. The shift from the Early to Late Iron Age is assumed to coincide with a climatic crisis that results in a demographic decline. As burial grounds are seen as a manifestation of presence related to claims to land, it would not be possible to say much about changes in the proportions of the population from the number of burial grounds in the landscape. This would probably not be feasible to do even if it was possible to give more detailed estimations of chronology, since grave monuments are primarily constructed for other reasons than the burial of deceased individuals. In fact there is a rather high ratio of new sites being founded in the Vendel Period (see Paper 5, Fig. 1). This indicates a need to establish or renegotiate property rights. There also often is a break in continuity with burial grounds from the Early Iron Age. New burial grounds are often in a different location ranges of certainty in the material, so that it is possible to separate what is known from excavations and what are interpretations and suggestions. Ideally this would give the user insight into the research process and how the end result and in a different landscape situation, which is interpreted as signifying differences in how land is claimed. A general renegotiation of property rights is suggested to be behind many of these changes.

For studies that aim at interpreting general changes within whole communities, it is advantageous to use large datasets that can represent as wide aspects of society as possible. New archaeological excavations are producing an ever increasing body of information that will make these kinds of broad interpretations of society more relevant, but the information produced is still rather difficult to access. A more accessible material would be the graves and burial grounds that are visible in the landscape. These do not represent all the strata of society, and they have considerable ideological connotations with regard to their construction. Still, they represent such a large and important material that it is essential to utilise the information they provide in the best way possible, for integrated interpretations of the social development.

Limitations to the material of burial grounds that affect the way they can be used for analyses are primarily their representativity. It has been established that there are many sites missing from the registry, which is important for how this category of archaeological sites is investigated. Since the ratio of how many sites are missing has been estimated for the whole study area, this information could have been used in order to try to compensate for sites that are missing. This has not been done in the analyses presented here, since the large standard errors of the estimation and conceptual difficulties in how the compensation might be calculated would introduce considerable uncertainties.

Another concern might be with the use of landscape variables calculated for the burial grounds, and how these were used for the analyses. To avoid having the same dataset in the chronological classification (in Paper 2) and for the analysis of how the sites are located in the landscape (Paper 4), the variables were recalculated differently for the two analyses. It would, however, still be similar aspects of the landscape that are at the focus of the analysis, i.e. how the sites are situated in relation to topography and soils. This raises the question of whether the location in the landscape should be understood

as a chronological or social indicator. In my interpretation I would see the landscape primarily as a social indicator, which might have been used in all the periods studied to signify presence in the landscape in different ways. This would be reflected by the fact that there are examples of sites that have values throughout the range of possible values for each of the periods. Similar ideas might thus have been expressed though the landscape during the whole period of study. What the results signify is instead how there might be general variations in the social motivations for constructing graves over time, where property rights would have been one of several motives. Thus, the chronological and social aspects of where graves are constructed are both integrated parts of the material, where the landscape can be an important complement to the design of the graves in order to predict chronology.

Watersheds are suggested as a good model for understanding how the landscape can influence societies, not by absolute limitations that humans are bound to adjust to, but by creating an ecological structure that humans are part of. Similar relations between regions and watershed have been suggested in other parts of the Mälaren area both for the Viking Age and the Middle Neolithic (Wijkander 1983: 31; von Hackwitz 2009:208). In my example, the watersheds should be understood as a natural structuring aspect of the landscape which unites the settlements contained within the watersheds into natural regions. The starting point is thus the settlements, where the watershed divide is a natural, docile, border.

In an attempt to illustrate a hypothetical early development of the *hundare*, Figures 3 and 4 shows the relation between *hundare*, watersheds and land settled in the Late Iron Age. As many sites are missing from the registry, the settled area is slightly exaggerated, and the map should only be read as a rough estimation that stresses how both the human and environmental input are influencing the outcome in the landscape.

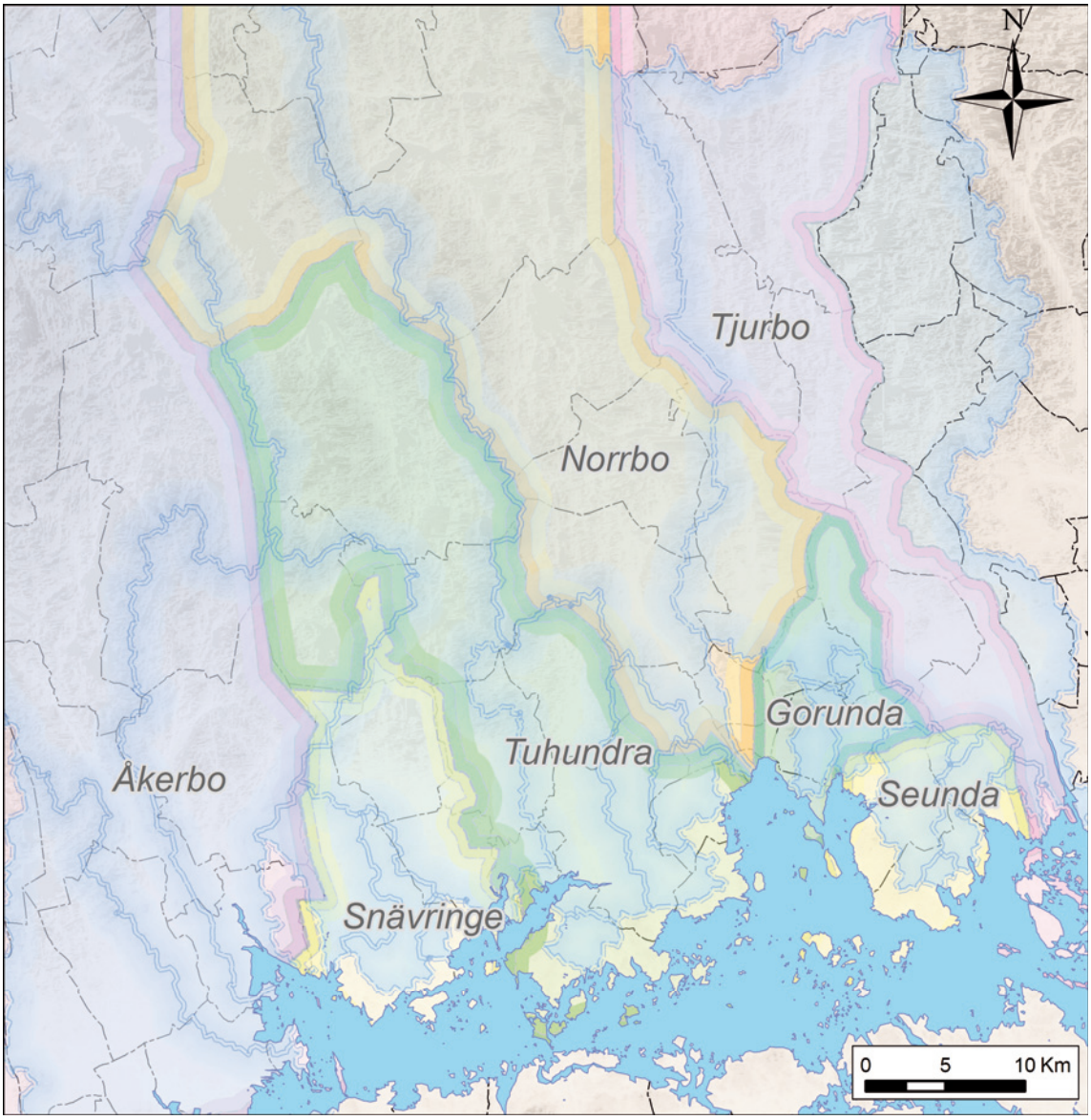

Figure 3. The medieval *hundare* and the watersheds, shown as blue gradients. Elevation data for the background map published with permission: © Lantmäteriet Gävle 2008. Medgivande 2009-21576.

Since it is difficult to compare different overlying areas in an image, the watersheds for the northern side of Lake Mälaren together with a map of medieval *hundare/härad* is also provided as a layered PDF in the digital appendix. The watersheds in the appendix are provided by SMHI, the Swedish Meteorological and Hydrological Institute. As these are not confined to Västmanland, they show the entire extent of the watersheds, which start further to the north then suggested in Paper 1. These are also shown for parts of Uppland, where especially the *folkland* of Tiundaland seems to relate to watersheds.

It would probably not be possible to determine a chronology for the development of regions around the communication system based on rivers and water courses. The Late Iron Age would, however, seem likely, since land transportation became increasingly important during the Middle Ages. Especially the *Svear*, the people living in the Mälaren area, have been characterised as having an explicitly maritime culture during the Late Iron Age that is reflected both in maritime expeditions and in the organisation of society (Larsson 2007). By uniting the people that belong to a natural region, using the same water courses for communication, it would be possible to increase control over population and extend that control to the corresponding land. These regions would be transformed into the medieval *hundare* system, as discussed in Paper 1. For a system based on water courses, it would seem natural to interpret the boat-graves of the same period as representing administrators of some kind, who exercised control over the regions and over the transportation of iron

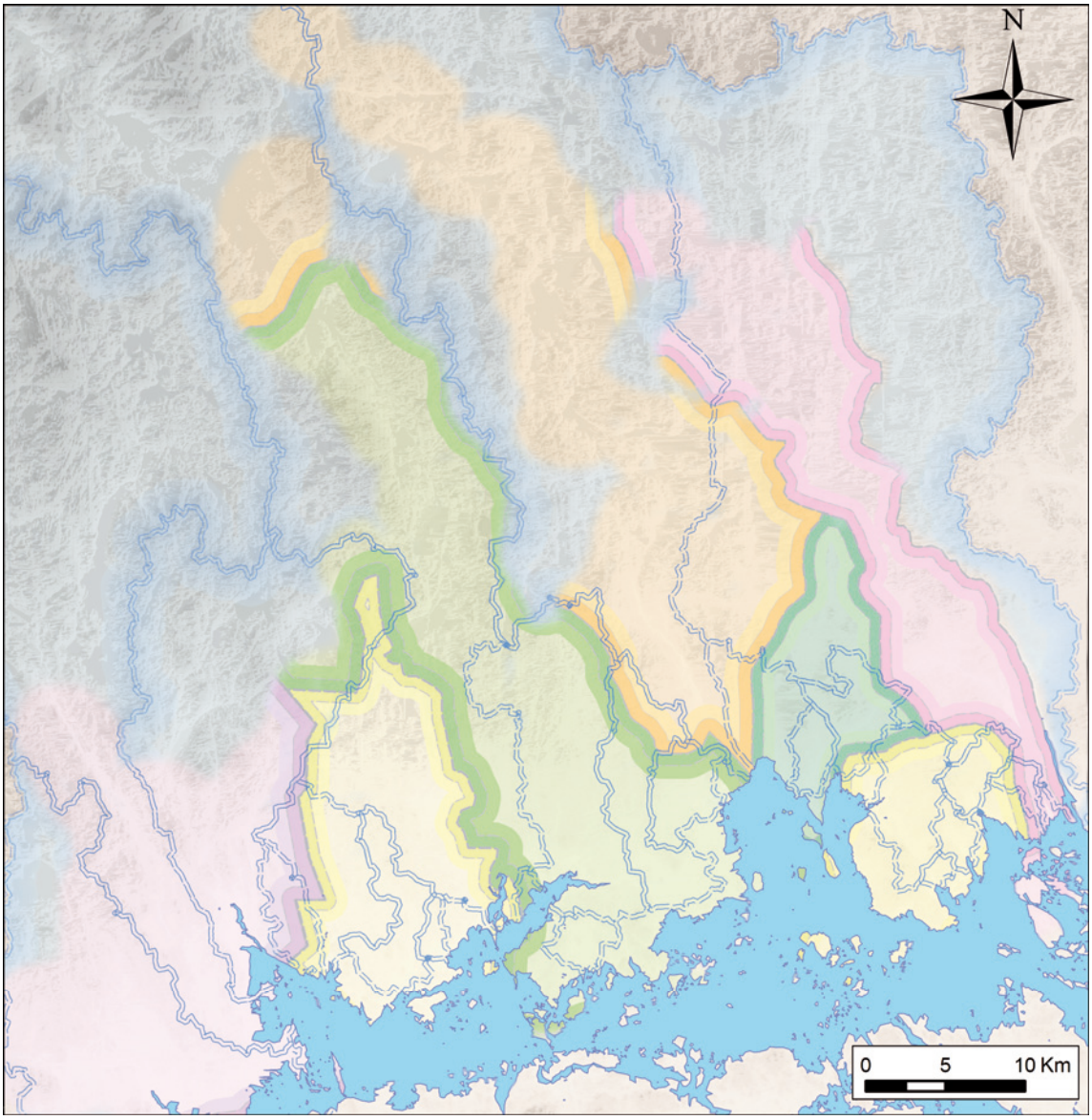

Figure 4. An overlay where the *hundare* are only visible for the parts where there are Late Iron Age graves, as a suggested extent of the prehistoric regions in the area. The section in the eastern part of Norrbo that belongs to the "wrong" *hundare*, judging from the watersheds, consists of one parish (see Figure 3), called Romfartuna. This parish has previously been interpreted as belonging to the *hundare* of Gorunda (Hyenstrand 1974). Elevation data for the background map published with permission: © Lantmäteriet Gävle 2008. Medgivande 2009-21576.

and other resources (Hyenstrand 1974). The boat-graves in the Mälaren basin, which deviate markedly from the otherwise dominating practice of cremation graves, could thus be understood as a mark or sign of this function, as a kind of emblem of office, often somehow connected to *Tuna* place-names. This would thus mean that the person who held that office also could be a woman, as there are several examples of females being buried in boat-graves, especially in Västmanland (Schönbäck 1994). Such an administrative functionary would probably also include religious and cultic aspects, as these would be different attributes of the same role.

The main watershed of the Mälaren basin drains to a point in present-day Stockholm. This has not always been the case, since there were a few more outlets both to the south and to the east. During the first centuries in the second millennium AD the other outlets would have dried up, leaving the only permanent access to the open sea through Stockholm (Risberg et al. 2002). That would have made this point important for communications to and from the region, and an obvious place for controlling the area, something that contributed to the locating of Stockholm to this place. Even before this point became the sole outlet, the main part of the inland watershed here would have had some relevance for the region. Figure 5 shows the modern watershed together with the map of *hundare*. Several points of interest might be noted, and a fascinating question would be to what degree this region was of significance for

uniting the people of *Svitjod* (Old Norse *Svíþjóð*), the early origin of which developed over time into Svealand and eventually into a central area for the country of Sweden (Hyenstrand 1996; Lindström & Lindström 2006). Svitjod would represent a rather highly structured political organisation, making it possible to talk about some kind of pre-Christian kingdom or kingdoms (Lindkvist 2008:669). Iron Age Svitjod would, however, also have included much of Södermanland, which falls outside the modern watershed but would have been well connected to the Mälaren area through the previous strait by Södertälje. Notably, Svitjod is mentioned on a rune stone in Rönö (*Röna hundare* in Figure 5) in Södermanland.

Figure 5. The modern watershed of Lake Mälaren on top of a map with medieval *härad* and *folkland*. Watershed provided by SMHI, map from Westin (1953-1971:133).

Conclusions and the way ahead

In this study I argue that the landscape was used in an active way to signal presence and claims to land through the construction and positioning of graves. The manner in which this was done could be interpreted as indicating differences in social organisation during the Iron Age. This would especially be the case after the probable climatic catastrophe in the 6th century AD, which gave rise to extensive renegotiations of property rights in the wake of a population decline. By constructing new graves, possibly on top of previous settlements, land could be claimed by new families, enabling the large aggregations of land and wealth that became the basis for the Late Iron Age elite. This is also seen in relation to a shift in how land could be owned, and it is suggested that there were increasing possibilities for private ownership in the Late Iron Age compared to previous periods. The AD 536 event is seen as an important factor for understanding the cultural development in the Late Iron Age. Crises, climatic or otherwise, and the trauma that followed after a social shock could thus be used for both economic benefit and the political restructuring of society.

How human society and environment come together as a holistic landscape can also be illustrated by the natural regions, analysed as watersheds, which gain social meaning from how they influence movement in the landscape and through this can be transformed into formalised administrative units. That hydrological modelling of the topography can produce results that can be interpreted in terms of the development of social organisation highlights how humans are part of the landscape in intricate ways that go beyond simple descriptions of land use and resources.

As human society must be understood in relation to the landscape, the possibilities to do integrated spatial analysis of different datasets as offered by the GIS technology have great potential for archaeological research. We are still at a fairly early stage of this development, and just as the scientific communities in other disciplines are readjusting to new opportunities for information sharing within the digital media, so must archaeology readjust. While some parts of the analyses presented here might have been done on a pen and paper basis, others would not have been realistically possible at all without the use of GIS. Therefore it is argued that GIS has an important value for the future of archaeology and can contribute with new information. In order to make the most of this situation it is necessary to strengthen the use of ICT in archaeological research, both in terms of access to data and by establishing research communities where methods and theories are developed further. The computer applications and quantitative methods in archaeology conferences (http://www.caaconference.org/) are an excellent international example that also has national chapters. Applications and datasets that are developed should be made available for further research, and there is a need to take a comprehensive approach to how the information that is created should be maintained and disseminated.

The huge amounts of complex information generated in archaeological practice must be combined with equally complex information from a range of other disciplines and theoretical frameworks that allow interpretations of different aspects of human society. New theoretical perspectives together with the development of improved technologies and methods will enable new kinds of questions at wide ranges of both spatial and temporal scales. This will enrich the subject of archaeology, and it might also contribute to an enhanced understanding of how to perceive humans and culture as embedded in the environment, together creating the living landscape.

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Appendices

The results of some of the analyses in this thesis are presented in three appendices that are only available in digital format from the DiVA system. Each appendix is a PDF file with layers, that can be accessed with Adobe Reader 8 or later. By choosing the menu View > Navigation Panels > Layers, it is possible select which layers to show or hide, in order to facilitate comparisons.

By choosing the menu Tools > Object Data > Object Data Tool, it is possible to double click objects to retrieve information for each object.

For more information, see the help function in Adobe Reader.

The appendices are:

1. Map with burial grounds and estimated dating
2. Map with watersheds and *hundare*
3. Map with estimated representativity of burial grounds per parish

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