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GIS and Early Åland: Spatial analysis in an archipelago of south-western Finland

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12.1 Introduction

The Åland islands form an archipelago which extends from the south-western coast of Finland into the Gulf of Bothnia between Finland and Sweden (Fig. 12.1). This archipelago is a geological and environmental anomaly for several reasons: its proximity to the Gulf Stream has served as a mitigating force upon the climate of the islands and, since the last glacial retreat some ten thousand years ago, it has been experiencing the powerful effects of isostatic rebound. The culmination of these variables has led to a unique pattern of human settlement which has its first traces in the early Stone Age and has been continuous to the present time.

In this paper we are going to show how modern methods of spatial analysis, which in our case will be the application of the ARC-INFO GIS, can further characterise the settlement trends of the early Ålanders and how these methods can be applied in other situations where geological factors of isostatic uplift and shore regression are evident. Our work will be presented in three sections: a geographical and archaeological profile of the region, the project and its methodology, and our remarks and commentary.

12.2 Profile of Åland

12.2.1 The Physical Geography of Åland

The advance of the Fenno-Scandia glacial sheet during the last Ice Age had profound impacts upon the geophysical state of the Åland Archipelago. The land surface was scoured, rendering the landscape undulated, and the repressive weight of the ice mass caused a geological 'submergence' of Åland. A subsequent amelioration of the climate caused the ice sheet to retreat and the regional climate to become hospitable to flora and fauna.

Once freed from the weight of the ice, the land began to rebound immediately. This caused an evolution of the surrounding land and water masses. The land mass, which in the Stone Age has been estimated at 200km^2, rebounded at an initial rate of approximately 60mm a year; a rate which has tapered off by a factor of ten since then. The most direct result of this uplift has been the expansion of surface area which has played a deterministic rôle in the settlement of Åland. The advent of the first fresh water watershed on Åland, occurring about 6500 years ago, satisfied the major prerequisite for permanent settlement.

The climate of the region allowed for a rich variety of marine related fauna. The numerous sounds and skerries around Åland teemed with fish, sea mammals, and waterfowl. The earliest traces of flora consisted of grasses, shrubs, and several species of trees but as the surface area gradually increased so did the agricultural potential of the region. There was also an abundance of marine flora (seaweed) which could be easily harvested on the beaches. These resources allowed for the development of self sufficient settlement (Nuñez 1993).

12.2.2 The Human Settlement of Åland

The first settlers on Åland were members of the Comb Ceramic culture which stemmed from mainland Finland. The dating of the earliest sites indicate that they originated in the late fifth millennium BC. However, the shallow cultural layers of the older sites and the lack of exploitable resources which would have been available at that time indicate that perhaps these dwelling were semi-permanent. It is speculated that the first settlements were bases for seasonal sealing expeditions from the Finnish mainland (Alhonen & Väkeväinen 1980; Welinder 1977). Many of the Stone Age sites are linked to the Pitted Ware culture which came from the Swedish mainland after the Comb Ceramic period. It is during this time that solid evidence of permanent settlements can be discerned.

Agriculture and the domestication of livestock took root in the archipelago sometime in the Bronze Age (Nuñez 1986, 1991). The flat meadows along the

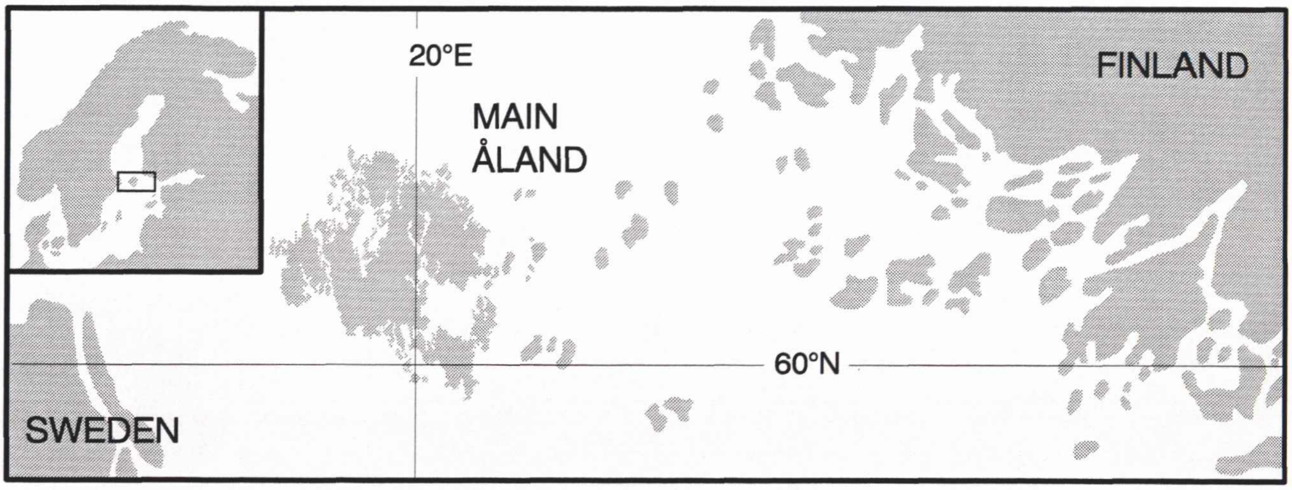


Figure 12.1: The location of Åland with respect to the Finnish and Swedish mainlands. Note the central position of the archipelago.

shores of the sounds provided excellent grazing land and the inland plateau served as land for tillage. The spatial extent of the settlements support the notion that the people were active shepherds. The scarcity of metal resources on Åland meant stone remained the primary material for tool construction.

The Iron Age saw the greatest increase in human population and activity. There was immigration from the west and south west and, by this time, the land surface was more than two times greater than the land surface that the first Ålanders had known. Pollen studies show that by 1500 BP there was extensive use of agriculture (Fries 1963; Roeck-Hansen 1991; Sarmaja-Korjonen *et al.* 1991). The prehistoric settlement reached its apex by the end of the first millennium AD with a population estimated at between 3600–6000 people (Nuñez 1993). It is during this time that Åland lost its reclusive nature and became a hub for the Bothnian maritime. Its locality and inherent nature as an archipelago made it very conducive for seafaring economies.

Furthermore, it should be noted that the constantly changing geographical conditions were not something which greatly changed the spectrum of human activities; 'the environmental zones were seldom destroyed, they merely shifted' (Nuñez & Storå 1995) and with them shifted the people.

12.3 Project Overview

The Åland archipelago case study serves as a unique example for the integration of point feature and landscape oriented GIS. Through the establishment of a point attribute table (PAT) containing information pertaining to the sites' age, type, features, and duration of use, we can use GIS to systematically focus upon points grouped according to selected criteria. Thus, there exists the possibility of querying specific elements of particular sites. An example could sound like 'which sites range from the Stone Age to the late Bronze Age, contain dwellings and stone settings, and are within 10m of the shore line'. This enables us to focus upon sites, establish visual trends, and locate sites which may not fall within the anticipated paradigms and examine why.

Landscape archaeology has traditionally been used to relate the movements and impacts of societies to geographical topology and form (Savage 1990). We intend to utilise temporal landscapes to develop diagnostic views of settlement over time. We are using the factors of time and duration to create these temporal landscapes, which remain geographically accurate in terms of x and y but depend entirely upon time for variance in the z scale. The 'z' factor is then related to point attribute data, which allows us to compare these sites in terms of their features.

This study uses Åland as a model for the creation of diagnostic temporal landscapes with GIS and the examination of known site features in order to achieve three goals. These goals are:

1. To develop and explore theories in creating three-dimensional(x, y, and t) temporal landscapes from point data.
2. To use GIS in examining the relationship of site location with the movement and characteristics of early settlement in Åland.
3. To relate the temporal landscapes to the geographic landscape and analyse the correlation between these developments in the z dimension.

12.3.1 Theory Development

Point data is traditionally used in GIS to indicate locations of interest or importance and to label significant landmarks or nodes. This point data is stored in a PAT where its location (x, y, z) is complimented with attribute data. Our PAT was designed to fulfil this purpose, with items such as site number, name, parish, earliest known date of activity, latest known date of activity, site type(dwelling, mound, cairn, stone setting, hill fort, or church) combined with the number of features, and the duration of the sites activity. However, we are not only using the PAT for the correlation of site attribute data. Our second, and more theoretical, approach to point data management is to use it in the creation of three-dimensional topologies, basing the z-term or elevation of this 'scape' on point attributes rather than geographical elevation. This is achieved in ARC-INFO through the point coverage to grid to triangulated irregular network (TIN) method (the process of creating timescapes will be discussed in Methodology). For these topologies, the slope and features of the 'landforms' (actually timeforms) are related to human activity instead of geographical activity.

The impetus for creating these diagnostic scapes lies in the fact that our test region experienced rapid topological land change in the form of isostatic uplift. Thus the pattern of settlement can be examined in real geographical terms which are directly related to terms of time variability. Examining this point data under both land and time 'scapes' enables us to develop new theories pertaining to the settlement of regions such as Åland.

Another development is spawned from this notion of timescape surface modelling based on variable auspices: topology as a function of site duration. From this we get a picture which doesn't exhibit obvious relativity to the elevation of the physical landscape. In this topology we clearly see sites which, for whatever reason, have served humans for the longest time as topographical maxima, regardless of their real-world elevation. By first analysing the point data in geographical and geo-morphological terms, and then cross referencing these relations with the timescapes and topology of duration, perhaps we can uncover the significance of these locations and their lasting occupation. Ultimately, we should be able to develop characteristic time forms for different eras which can be diagnostic of certain physical and site specific attributes.

12.3.2 Methodology

Establishing a Geographic base

The first step in our methodology was to establish a useful map image in which we could effectively display three dimensional (x, y, z) data and topography while simultaneously integrating point coverage data. ARC-INFO provided us with three methods for the manipulation of our spatial requirements. Starting from a Digital Elevation Map (DEM), we created three different types of geo-datasets: a grid, a TIN, and an ARC coverage.

Our DEM of mainland Åland supplied us with the three dimensions needed for the creation of a grided image. A grid maintains the integrity of landscape's z-term. Within ARC-INFO there are numerous methods of colour and greyscale imaging which depict elevation change within an x, y (2-D) representation. This provided us with an accurate and realistic template for examining spatial aspects of site location. Also, grids are an instrumental bridge in the development of three-dimensional images. Because the z-term maintains its own location in the matrix of the grid, the image can be transformed into a TIN.

The TIN is structurally comprised of 'adjacent, non overlapping triangles computed from irregularly spaced points with x, y coordinates and z values' (ESRI 1991). The TIN is the fundamental format used in surface imaging. The TIN surface provided us with a real-view of the topology, as well as many sub functions such as panoramic views and manually determined relative positioning. Analytically this is significant because, when testing theories pertaining to settlement ideology and the logic of the settlement pattern, we can look at the landscape of that era and examine the conditions right before our eyes. We utilised this in combination with the different surface draping options to produce images from which we can predict and confirm the location of sites and their corresponding features. Most significantly, TINs are the forum for our spatial analysis of time and duration, where we utilize the topological projection of the surface to draw conclusions pertaining to temporal images and diagnostic characteristics.

As an auxiliary view and indicator we created an ARC coverage (*v.* line or point coverage) comprised of elevation contours set to every 10m. From this we can remove and replace contours as the shorelines change depending on the time or era we are viewing. Also, the contours can be labelled for easy z-scale reference so that sites can be located with respect to time or elevation. With these three types of images, we have a comprehensive spread of geographical and topographical views, into which we can insert the site data.

Arrangement of Point Data

The site data are stored as point coverage data in a PAT, the creation of which is a straightforward process. However, the structure of a database is crucial to how it can subsequently be queried; thus, we will briefly explain the thought processes behind the creation of our point database. Since time was the fundamental variable in our case study, the logging of time attributes had to be carefully handled. We are working with sites which are dated in relative terms to their shoreline position, and in some cases, from datable artifacts from the site. We logged the sites with dates according to time blocks which are compatible with the stratigraphic dating of the shorelines. The time blocks utilised are indicated in table 12.1.

The assigned combination of time blocks was determined according to the first and last age of activity. In this way we have a continuous time scale within

Stone Age	Bronze Age	Iron Age/Late Medieval
6000–5300	3300–2500	1500–900
5300–4600	2500–1500	900–400
4600–4000		
4000–3300		

Table 12.1: Time blocks utilised (all ages in years BP).

which different sites can exhibit a multiple combination of ages. For example, some sites may initially be active in the Stone Age and end their activity during the Bronze Age. For a site such as this the PAT will be labelled date1=4600 and date2=2500. From this each site can be queried in terms of its existence, or lack thereof, during any chosen era. We can very clearly see the duration of activity for these sites using the formula (Armstrong 1988):

$$\text{duration} = \text{date1} - \text{date2}$$

After labelling each site with its appropriate age bracket, we then categorised the sites in reference to their type. In this way we are able to look into regional or geographic trends concerning specific site attributes. These include the site code, parish, and site type. The sites range in type from dwellings, to burial mounds, cairns, stone settings, hill forts, and churches (Nuñez 1993). However, for our test model, we are initially using only the items specified and will later add other site attributes in order to make our queries more specific.

Creation of Time Landscapes

The initial methodology used in creating the geo-landscapes was again used in the creation of the time landscapes. However, the distinction is in the concept of integrating the PAT in the construction of these topologies. With a fully calculable PAT, we redefined the z-term of the geographic grid to equal the time attributes of the sites. In this way the x and y terms of the point data maintained their geographic integrity, while the z-term now represented a time dependant variable. Using the previously mentioned '3-D' point to grid to TIN sequence, we effectively created interactive surfaces which have a z scale independent of geographic fixation (Fig. 12.2). Since the surfaces were created from the points which represent the site locations, the topology of these timescapes can be queried in the same way as the PAT. This enables us to compare the similarity or dissimilarity of the site trends in relationship with the geographic landscape and characteristics of the temporal landscape(s).

Querying our PAT and Geo-datasets

The initial stages of the data querying entailed the examination of all the sites in the landscapes of their respective time periods. We rendered the past shorelines of the StoneAge, Bronze Age, and Iron Age Åland according to Nuñez's regression (1993) and reselected points which corresponded to these time periods respectively (Fig. 12.3). These at first included all site types; the points were then colour coded according to their secondary attributes. In this way we created accurate pictures of the sites and could examine the relationships between their features. After creating these separate 'period' maps, we combined them to get a complete picture of the evolution of these sites over the 5500 years in question. The sites were still colour coded according to their attributes, thus we could clearly see sites which appeared irregular. This allowed us to focus on sites and their regions and examine the external factors which may have caused these sites to deviate from the norm.

The second stage of data querying involved the geographic and temporal landscapes. This was essentially the same procedure which was used in the previous stage, only now the focus was on site elevation (z or t) and positioning. With the creation of the time-scapes and the production of an interactive topology, we moved to querying the sites in terms of their duration. By creating a new item containing the calculated duration of site activity, we could select the sites according to their length of occupation. By placing the sites on the timescape, we could test its accuracy and effectiveness in rendering an analytical topology according to time. We repeated the process of reselection according to secondary attributes to see their relative position on the temporal landscape as compared to the geo-datasets.

The final process in our test methodology was the correlation of the timescapes with the positional aspects and geography of Åland and the sites. By using a multiple surface approach and maintaining constant surface-view criteria, we created comprehensive images which contained the geodatasets and points, and their attribute data combined with the drape of a temporal landscape. Our first point of interest is the effectiveness of the time landscapes in rendering the site data according to their known elevational position. Due to the pre-established relationship between elevation and time we could accurately forecast the resulting image. For example, the stone age sites are known to have been active when the surface area of Åland was five times less than the present surface area. Thus, it correlates that the oldest sites should be at the highest physical elevation due to the isostatic activity and at the maximum 'elevation' on the time scape. Thus our querying at this point was more to test the consistency and integrity of the timescape and see its effectiveness under the building parameters

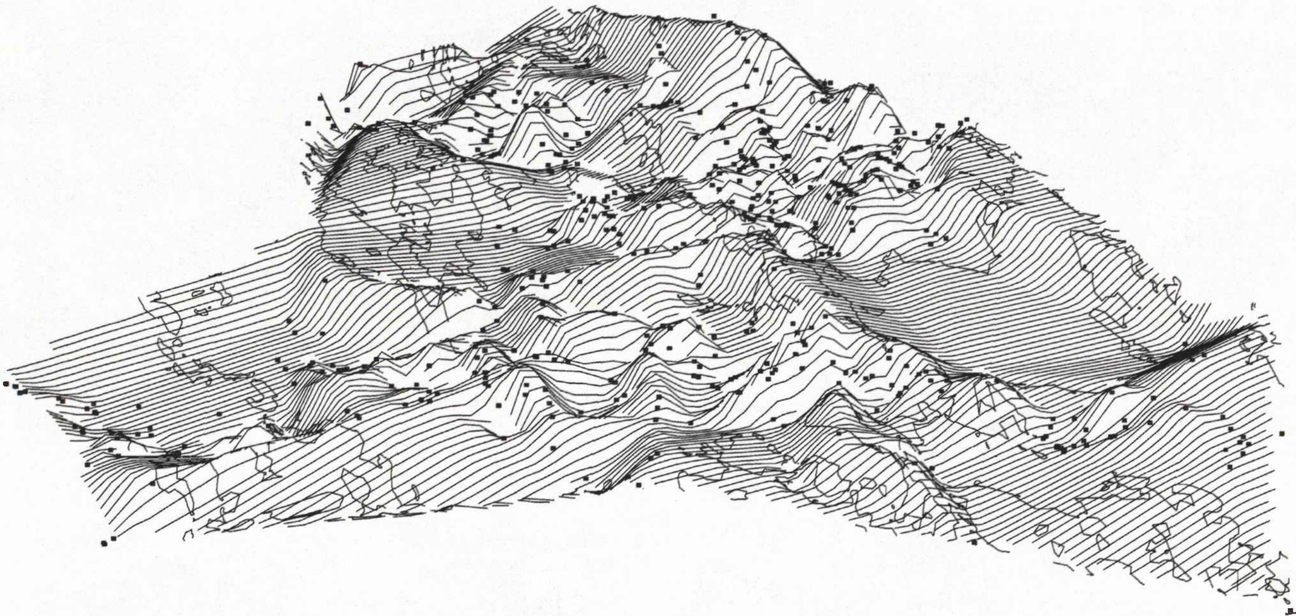


Figure 12.2: A three dimensional 'timescape' where the topology is dependant upon the earliest known date of settlement. The points representing the sites from the Stone Age, Bronze Age and Iron Age are draped over the TIN generated topology using the SURFACEDRAPE command in ArcPlot.

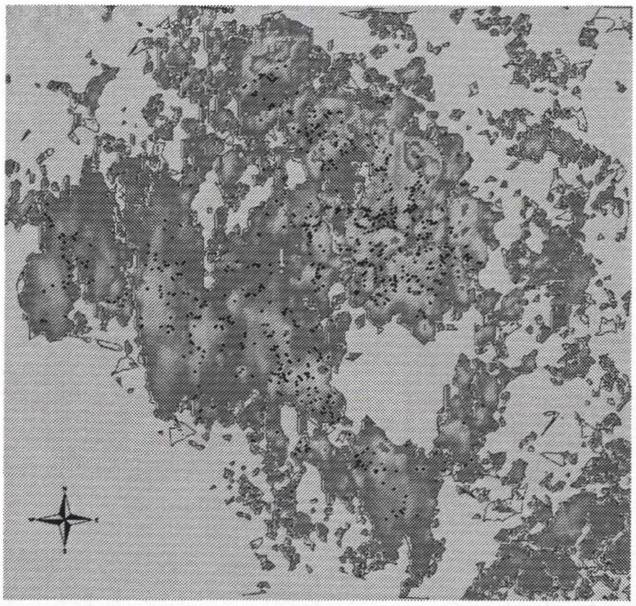
we set. However, when we later created the duration topology, we had no predictable image in mind. With our ability to query the sites and see their topological location compared with their time data (PAT), we detected any differences between these terms. The interactive querying method was used to explain and correct these errors.

12.3.3 Results

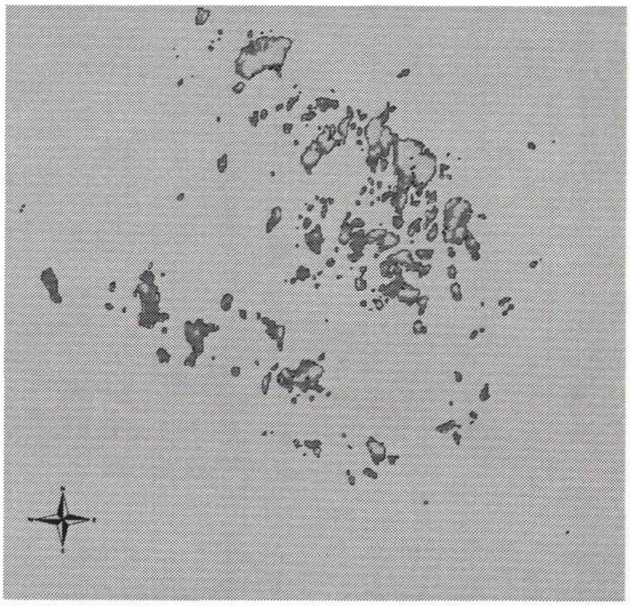
In this project we are testing the utilisation of point attribute data with GIS for establishing a normal method for analysing settlement trends in non-static geomorphic regions. This methodology is easily tested with Åland as a case study due to the controlled nature of the sites and the large body of knowledge concerning the dating of these sites. Also, using Åland as our laboratory and the 785 sites as our control group, we are exploring the procedures of creating diagnostic timescapes and duration timeforms which can ultimately be used as 'era models' to confirm or dispute the dating of other sites for which there is less known empirical information, but which are located in similar geological and geo-positional environments. We will now examine the details of these GIS procedures in relation to our case study and the effectiveness and problems of creating temporal landscapes.

Our methods of investigating the movement and settlement of Åland during the Stone Age, Bronze Age, and Iron Age revealed the usefulness of GIS to visually render the pattern of settlement with the increase of land surface. Our standard querying methodology was very effective in illustrating the documented phenomenon of shoreline settlement (Nuñez 1993). Specifically, the querying and rendering capabilities of ARC-INFO has greatly increased the potential for locational analysis of the settlement patterns and land usage on Åland. Using the grid surfaces and attached PATs, we were able to render the land surfaces according to the surface area of the past environments and the subsequent site locations of these times. Through these, one could see exactly what the settlements of these times looked like in reference to geographical and human influences (Fig. 12.3). The interactive capabilities of the PAT and the visual displays allow for an immense expansion of the queryable attribute information and the potential for in-depth and highly focused studies. The grid, TIN, and coverage images provided us with much more than a simple visual rendering of the sites on a geographic template; they serve as dynamic data display interface with an ever increasing potential.

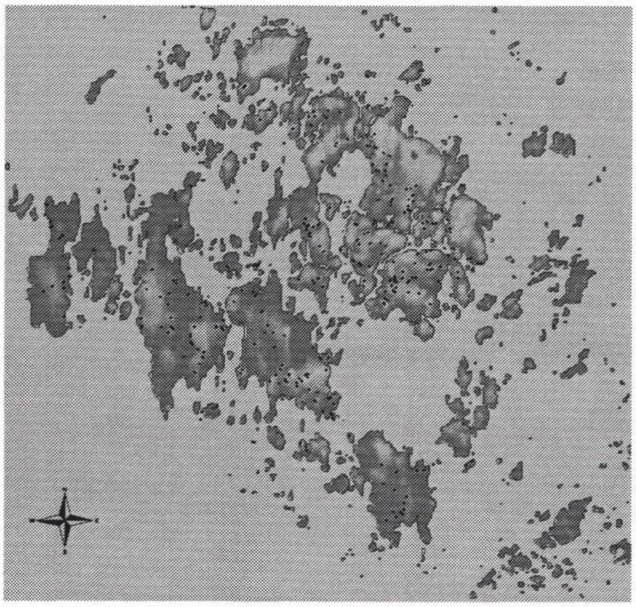
Our point to grid to TIN methodology was also successful in depicting three dimensional time surfaces. However, specifics within ARC-INFO determined the relational capacities of these images with the geographic surface and the point data. First, the 'timescape' (point based) grid is comprised of a matrix of cells, each with a value corresponding to the x and y coordinates of the sites in the 2-d plane and time in the z-plane. However, the effect of choosing the form of the z-term data for locations without x and y terms determined by the PAT is significant. ARC-INFO assigns these other locations within the map boundaries a z value of either 'zero' or 'nodata', the latter being the default. Since the Åland DEM (used to create the geo-grid) logs values for all surface locations as greater than zero according to elevation, and the water surrounding the archipelago with a zero value, the entire



(a) A composite grid image which is based upon the current land surface of Åland and has all of the sites represented.



(b) The land surface as it was during the Stone Age (*c.* 4000 BP)with the Stone Age sites marked in black.



(c) The land surface as it was during the Late Bronze Age (*c.* 1500 BP) with the Bronze Age sites marked in black.

(d) The land surface as it was during the Iron Age (*c.* 1000 BP) with the Iron Age sites marked in black.

Figure 12.3: Past shorelines according to Nuñez's regression (1993).

surface within the boundaries is represented. In order for the timescapes to fully cover the same map extent, and maintain a normal zero baseline, the z-term of the grid must also be created as a 'zero' variable. In this format the surface created maintains its x, y integrity when combined with the geographic surface. However, the image is less topographic in nature and produces a 'tower style' of time representation (Figs. 12.4–12.5). If the 'nodata' option is chosen, an equally accurate time-surface is formed, but its compatibility with the geo-surface is sacrificed due to the 'zero' type surface grid of the geographic landscape. Because each format, 'zero' and 'nodata', is useful in analysis and diagnostic imaging, we created both.

The effectiveness of relating the timescapes with the geo-landscape was excellent. We successfully integrated the queryable PAT with the point based timescape, and correlated both to the geographic locality of the natural landscape. Also, by superimposing both temporal landscapes (earliest activ-

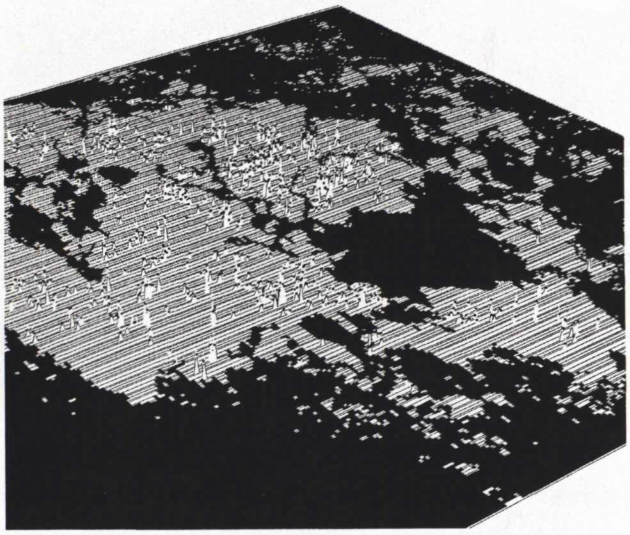


Figure 12.4: The 'tower' style image produced using the 'zero' standard for topology construction. The map boundaries of this scape are compatible with those of the geographic surface images.

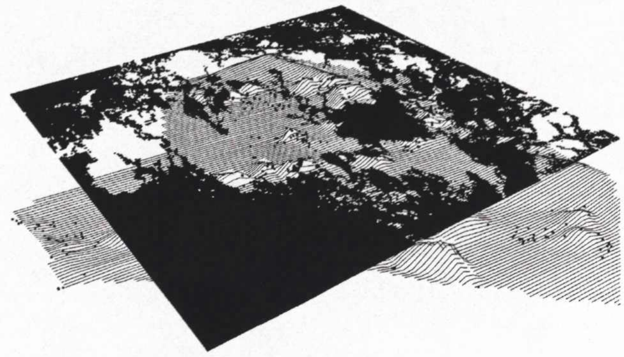


Figure 12.5: The 'nodata' default standard for topology construction. These boundaries are obviously skew from those of the Geodata set, yet a more 'land form' styled image is produced.

ity and duration), we tested the relative positions of the topological maximums of each surface (Fig. 12.6). This was useful in exposing the uniformity or the nonconformity of each surface. Matching these surfaces and point features actually served to correct and update our surface imaging methodology, as we systematically repaired obvious technical errors in the surface formations. We were constantly recreating the temporal landscapes under more accurate auspices, producing images with minimal error.

12.4 Concluding Remarks

It should be kept in mind, that while many of our images depicted interesting scenarios and trends, our goal was not to draw conclusions about the sites' characteristics at this stage of the project. Rather, we are testing the usefulness and value of creating and using these temporal landscapes as a diagnostic method. Therefore, our results are less quantitative and more cognitive or conceptual in nature. In this light, the temporal landscape is one of many types of point attribute based topologies to be tested for effectiveness. In the same way that topographic data is useful in landscape archaeology, we believe that many other forms of 'landscapes' can be used to characterise and predict site features and development. The future direction of this project is to explore the creation and utilisation of 'landscapes' based upon attributes such as site content, physical nature, and proximity to geographic variables (*i.e.*, water, forest, fields, food sources).

The main object of our work is to create a tool which will aid the archaeologist in examining the human and environmental conditions which existed in the past. It is certain that wonderful computer graphics will do little for the pragmatic scientist if there is nothing to substantiate them, but it is our belief that the databases, querying, and images with which we are working will prove very valuable. The utilisation of this tool will shed a great deal of light upon macro scale settlement patterns by allowing the user to examine both individual and multiple site features, juxtaposed with their surrounding environment. It is our hope that our work will provide all archaeologists working with regions which have experienced great geological and environmental change with a tool to aid in their analytical processes. We also hope that some of the ideas we are dealing with contribute to the general theoretical application of GIS in archaeology and any other discipline in which time plays an important rôle.

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References

ALHONEN, P. & L. VÄKEVÄINEN 1980. 'Diatom analytical studies of early Comb ceramic vessels from åland.' *Suomen Museo* 87: 67–77.

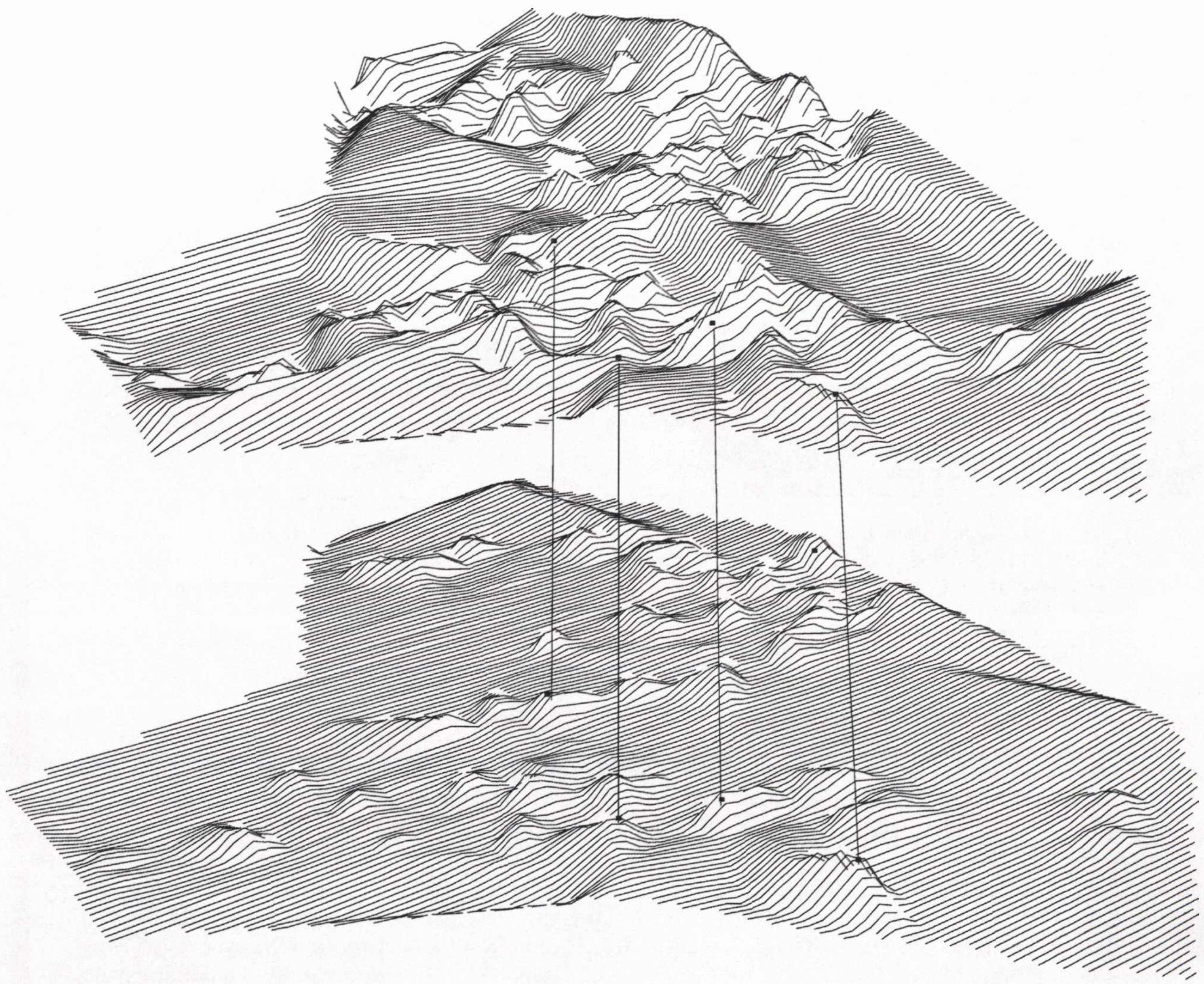

Figure 12.6: Both temporal landscapes. The lower topology is based upon duration. The upper is derived from the earliest date of site activity. We can see how common sites are depicted on each surface.

ARMSTRONG, M. P. 1988. 'Temporality in spatial databases.' In *Proceedings of GIS/LIS '88*, pp. 880–889, Falls Church, Virginia. American Society for Photogrammetry and Remote Sensing.

ESRI 1991. *Surface Modelling with TIN.* Environmental Systems Research Institute, Redlands.

FRIES, M. 1963. 'Pollenanalytisk på åland.' *Åländsk Odling* 24.

NUÑEZ, M. G. 1986. 'Clay figurines from the åland Islands and mainland Finland.' *Fennoscandia Archaeologia* 3: 17–34.

NUÑEZ, M. G. 1991. *On the Food Resources Available to Man in Stone Age Finland.* Vammala.

NUÑEZ, M. G. 1993. *Searching for a Structure in the Late Iron Age Settlement of the Åland Islands, Finland.* Karhunhammas 15. Department of Cultural Studies, University of Turcu, Turku.

NUÑEZ, M. G. & J. STORÅ 1995. *Shoreline Chronology and Economy in the Åland Archipelago 6500-4000* BP. PACT 36. Council of Europe, Parliamentary Assembly, Strasbourg.

ROECK-HANSEN, B. 1991. *Township and Territory. A Study of rural land use and settlement patterns in Åland c.* AD *500–1550.* Acta Universitatis Stockholmiensis, Studies in Human Geography. University of Stockholm, Stockholm.

SARMAJA-KORJONEN, K., Y. VASARI & C. A. HAEGGSTRÖM 1991. '*Taxus Baccata* and influence of Iron Age man on the vegetation in AAland, SW Finland.' *Annales Botanici Fennici* 28: 143–159.

SAVAGE, S. L. 1990. 'Modelling the Late Archaic social landscape.' *In* K. M. S. Allen, S. Green & E. B. W. Zubrow (eds.), *Interpreting Space:* GIS *and Archaeology*, pp. 330–331. Taylor and Francis, London.

WELINDER, S. 1977. 'Åländsk fångststenålder.' *Åländsk Odling* 38.

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