The Application of Magnetic Methods for Dutch Archaeological Resource Management

Kattenberg, A.E.

9 Conclusion

The aim of this study was to assess the possibilities of the application of magnetic methods for mapping and evaluating archaeological remains in The Netherlands. This conclusion sets out with a short summary of the principles that underlie magnetic archaeological prospection. It is followed by a description of the most important findings of this study and its implications for the use of magnetic methods in ARM in The Netherlands.

9.1 Principles of magnetic prospection

The principle of magnetic prospection lies in the contrast between archaeological features and objects to the matrix that they are embedded in. This contrast can be remanent, being caused for instance by subjecting soil material to high temperatures, or induced, depending on differences in magnetic susceptibility. If there is a magnetic contrast, a magnetic field will be present around the feature or object. This magnetic field will interfere with the earth's magnetic field and create anomalies in it. These anomalies can in theory be detected with a magnetometer, which is a passive instrument that can measure the local strength and direction of the earth's magnetic field, but can not be adjusted to take measurements 'at a certain depth'. In this study the archaeological feature is the smallest unit of investigation. Buried features with a magnetic contrast can obtain a magnetic field around them, which, depending on the volume, depth of burial and contrast of the features, can be measured on the surface.

There are several processes that can cause a *magnetic remanence* in a material, but thermoremanence which occurs after a material has been heated to high temperatures, is the process that is most relevant to archaeological prospection. Features and objects with a remanent magnetization will always cause a magnetic anomaly in the earth's magnetic field. In archaeological terms these features include brick walls and foundations, kilns, hearths, and feature fills that consist mainly of brick or tile. The only constrains for the magnetic detection of these features are their contrast, their size and their depth of burial. A material that has not been directly investigated in this study is natural stone with a magnetic remanence, for example basalt and tufa. Archaeological features made up from these materials are likely to cause a magnetic anomaly that may be detected in magnetic surveys, depending on their size and depth of burial. The certainty of the presence of a magnetic anomaly that is caused by the above mentioned features and materials alone could be an incentive to use magnetic methods more frequently in archaeological prospection in The Netherlands.

All materials can obtain an *induced magnetization*, which depends on the presence of an applied magnetic field like the earth's magnetic field. All archaeological features can become magnetized in this way, and can cause an anomaly in the earth's magnetic field. The strength of the induced magnetization depends on the contrast in the magnetic susceptibility between the fill of negative archaeological features like pits and ditches or of the material of which the feature consists like natural stone and the undisturbed matrix that they are embedded in. Whether of not this anomaly can be detected by means of magnetic methods is depending on its strength at the surface, which is related to the contrast in magnetic susceptibility and the depth, shape and volume of the feature. In this study it was shown that a wide range of archaeological features can be detected, for example pits, ditches, wells, walls and roads. Without detailed knowledge about the magnetic contrast, however, it is hard to predict which features can be detected.

The general detectability of archaeological features on a certain site can be partly predicted, however, because the formation, preservation and deletion of magnetic contrasts depend for a large part on the geological circumstances. This is the reason why for this thesis, the research area was divided into three parts.
In order to assess the use of magnetic methods in The Netherlands for mapping archaeological features and sites, which was one of the objectives of this study, three geogenetic environments were considered; estuarine, wind blown and fluvial. It was found that for induced magnetic anomalies (caused by magnetic susceptibility contrasts) the magnetic contrast depend not only on material properties like grain size, organic matter content and pH, but also on post depositional processes, which may have altered the primary magnetic contrasts into the contrasts that we observe today.
It must be stressed at this point that the magnetic detection of objects that have a remanent magnetism is independent to their geological environment. Furnaces and brick walls for example can be detected up to a certain depth, depending on their volume and the strength of magnetization, in any geological environment. The only post depositional process that could affect these objects would be mechanical weathering.
The possibilities for the magnetic detection of induced magnetic anomalies will now be discussed per geogenetic environment.

9.2 Magnetic contrasts in different geogenetic environments

Magnetometer surveys on estuarine deposits did not prove successful in mapping archaeological features. A number of younger features could be detected, but archaeological pits and ditches did not cause a magnetic anomaly. Neither could archaeological deposits clearly be distinguished from the undisturbed matrix based on their magnetic susceptibility values. It is thought that the magnetic similarity of the archaeological and the non-archaeological deposits is the result of post depositional processes like gleying, leaching, waterlogging and sea waterlogging, which is discussed in more detail below. Because of these conclusions, magnetometer surveys on estuarine soils are not recommended as an archaeological prospection tool. One exception is archaeological sites that are buried under saline or brackish groundwater, as the preferential formation of iron sulphides in organic deposits could make these sites very good targets.
The Weichselien cover sands of the eastern and the southern part of the country is a further geological environment in which the use of magnetometer surveys in archaeological prospection is not recommended. On the archaeological sites that were investigated in this study magnetic susceptibilities and contrasts were very low. The reason for the lack of differentiation in these sandy soils is likely to be found in the fact that magnetic susceptibility enhancement is difficult to achieve and easily lost in coarse grained sediments.
Only one site was studied on loess and one on coastal dune deposits, both of which had very good magnetic susceptibility contrasts. The data that has been collected in this study is too limited to judge the suitability of these environments for the use of magnetic methods as an archaeological prospection tool, but the results are promising and these areas should certainly be selected for a follow up study.
The fluvial environment gave mixed results. In the central river area sites with and without clear magnetic contrasts were observed, but further investigations are needed to assess what factors have enabled the formation, preservation and deletion of magnetic contrasts on these sites. For the Meuse valley, consistently good magnetic contrasts were detected, which makes this valley the most suitable starting point for the integration of magnetic methods into the current suite of prospection methods.

9.3 Masking and variability

Two processes that may hamper the detection of any archaeologically relevant magnetic anomalies in any geological environment, masking and variability, are discussed here. Masking is the increase in distance between the surface (and the magnetometer) and the archaeological deposits by the deposition of sediments or other deposits over older archaeological levels.

This is common in fluvial, estuarine and marine areas where sedimentation is or has until recently been an on-going process. Peat and secondarily deposited wind blown sands can also have covered archaeological levels.
Plaggen soils are man made soils, thick layers of organic soil superimposed on the Weichselien cover sands in the eastern and southern parts of The Netherlands. The presence of these soils over archaeological sites on the one hand increases the distance between the archaeological levels and the surface from which the survey is conducted in a similar way to alluvial layers that can cover archaeological sites. On the other hand, the variation of magnetic susceptibilities and magnetic moments within the plaggen soil may be larger than the magnetic contrast between archaeological features and the cover sand underneath. In this case the archaeological features may have been magnetically detectable under a homogeneous cover, but they cannot be distinguished under a magnetically variable cover. The variation in magnetic susceptibility and magnetic moments within the undisturbed matrix in which the archaeological features are embedded can also hamper the detection of these features. An example of this is the occurrence of red sand in the eastern and central parts of the Netherlands, the magnetic contrast and the shape of the red sand features are similar to the contrast and shape that would be expected from archaeological features, which makes it difficult to distinguish between the two.
Magnetic variations in the layers underneath the archaeological levels are well known from surveys over for example igneous geology in Ireland and the United Kingdom. The Netherlands lack superficial bedrock, but during this study it was found that large magnetic variations can also occur in unconsolidated, estuarine deposits. On the sites of Harnaschpolder and Smokkelhoek highly magnetic anomalies of a geological nature were mapped during a magnetometer survey. As the interpretation of magnetometer data is often only based on the shape and size of magnetic anomalies, these features were initially assumed to be man made. The magnetic investigation of these large magnetic variations however, showed that the features causing them were in fact natural, ferrimagnetic, deeply buried features. The presence of these could confuse the interpretation of the response of the archaeological features in the magnetometer data in a similar way as the red sand does, but the structures are generally larger and more consistent and the magnetic contrast stronger.

9.4 Iron sulphide formation

In this study the hypothesis is posed that one of the reasons for the observed lack of magnetic contrast on archaeological sites under marine or estuarine deposits in the Netherlands is caused by a soil chemical change during sea water logging. Magnetic contrasts in the soil depend mainly on the type and abundance of iron oxides. If a marine inundation takes place after an archaeological site has been abandoned, the iron oxides can dissolve if the sea water logging is persistent. The iron is liberated to form iron sulphides, accumulations of these can be preserved in anoxic conditions, causing the magnetic anomalies that were observed in the magnetometer data of the surveys carried out in the former estuaries. It is thought that any magnetic contrast that would have been present on these archaeological sites is ‘erased’ during this process, making magnetic methods unsuitable for prospection on archaeological sites with a post-abandonment estuarine phase, not only in The Netherlands but in general. For example, this study also incorporates an investigation into the magnetic properties of an archaeological site in the Fenlands, United Kingdom, where both the presence of highly magnetic iron sulphides and a lack of contrast in the archaeological deposits could be identified. In The Netherlands, most of the archaeological levels that were inundated with sea water during a marine transgression are presently above the groundwater table. The soil contains iron oxides most likely of a different type and abundance than before the marine inundation. The observation of younger features being magnetically clearer than older features on estuarine soils does fit into this hypothesis, the divide not being old-young but rather pre- and post-transgression.
If valid, the hypothesis may in part explain the absence of a detectable magnetic contrast -both on- and off-site- as was observed on archaeological sites in Zeeland and Noord- and Zuid-Holland. The deletion of the archaeological magnetic contrast remains a hypothesis, however, and more research is needed to investigate the soil processes that take place during and especially after marine transgressions.

9.5 Returning to the objectives

Now that the areas in which magnetic methods can and cannot be used as an archaeological prospection tool have been outlined, the other objectives of this study need to be re-entered into the discussion. The objective of assessing magnetic methods as a tool to map the archaeological landscape has not been fully investigated because of an unfortunate choice of the first two, largest survey areas (see Chapter 8). A study into a quick soil sample based method in order to assess whether a magnetometer survey could prove successful in mapping archaeological features, the fourth objective of this study, has been conducted. The best sampling method has been used throughout this study, sampling archaeological and undisturbed deposits and measuring their magnetic susceptibility contrast is a good way of assessing the suitability of a site for magnetometer surveys, if such samples can be collected. The difference in magnetic susceptibility between the topsoil and the subsoil did not prove to be an indication of the presence of archaeologically meaningful magnetic contrasts. Almost all of the successful magnetometer surveys, i.e. surveys in which a number of archaeological features could be mapped magnetically, have had a high magnetic susceptibility topsoil, however, of more than 30 x 10^{-8} m^3/kg. Topsoil magnetic susceptibility could be a rough indication of the suitability of a site for magnetic prospection if samples from the subsoil are not available.

9.6 The integration of magnetometry into ARM

The knowledge that was gained during this study is aimed to be the basis for the integration of magnetometry into the archaeological prospection toolkit. In this conclusion the strengths and limitations of the methods have been described, and at this point a proposal for the phased introduction of magnetometer surveys in Dutch Archaeological Resource Management is proposed.

<u>Phase I</u>

- include magnetometry in the KNA as the method of choice for the prospection of metal working sites and sites at which kilns or furnaces are expected to be present,
- propose geophysical guide (leidraad geofysica) for the KNA,
- magnetometer surveys to be conducted alongside other archaeological prospection methods in all Meuse valley surveys in which archaeological remains are expected to be possibly present in the top meter of the soil.

In this first phase magnetometry is embedded in the framework of the KNA in which ARM work is usually conducted. Consistent magnetometer surveys in an environment that is expected to show good results can create a (local) base for the integration of magnetometry as a prospection tool.

<u>Phase II</u>

- magnetometer surveys to be conducted alongside other archaeological prospection methods in all surveys on loess in which archaeological remains are expected to be possibly present in the top meter of the soil.

<u>Phase III</u>

- magnetometer surveys to be conducted alongside other archaeological prospection methods in all surveys on dune sands in which archaeological remains are expected to be possibly present in the top meter of the soil.

In phase II and III the application radius of the magnetometer is increased, again using areas in which good results are expected.

9.7 The application of magnetic methods

The magnetometer is not a miraculous instrument that overshadows traditional prospection methods, but its strengths have to be recognized in order to strengthen the methodology of archaeological prospection as a whole. Its merits are not yet to be found in finding previously unknown sites but in assessing the value known archaeological sites. Used along side hand augering, magnetometry can obtain a much better resolution in the same time (approximately one hectare per day on a resolution of 0.25 x 1 meter). Another big advantage is that it maps archaeological features on a horizontal plane, 'as a map' as opposed to a vertical stratigraphy. For example the features of those archaeological sites that are found during a hand augering prospection can be made visible in a magnetometer survey. At present, traditional prospection methods like hand augering and test trenching are often used in cases where a magnetometer survey would produce better data as compared to the hand augering, and would be less intrusive as compared to the test trenching. It is in the investigation and validation of individual features and on known archaeological sites that magnetic methods can be readily employed

On extensive sites magnetometer surveys can be used next to excavations in order to gain information from the unexcavated part of the site, or to plan future excavations. Archaeological or geological features like ditches and creeks that have sufficient magnetic contrast can be quickly mapped over great lengths.

Modern or ancient disturbances in the archaeological record can be mapped magnetically in order to assess their size and location. Annual or bi-annual surveys on scheduled archaeological sites can be used to monitor any change or disturbance in the archaeological record.

More work is needed to get a better insight into the application of magnetic methods in Dutch archaeology. The investigation of the iron mineralogy of archaeological features in fluvial environments would be a logical continuation of this study.

In conclusion, magnetic methods have proved to be a welcome addition to traditional prospection methods. It is not a magical method, it can be successfully used in some situations, but not in all. With this study it has become much clearer under which circumstances a magnetometer survey can be successfully applied, which will give a focus to the integration of this novel technique into the existing archaeological prospection toolkit.