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Debatt

Lightning-induced Remanent Magnetisation as Plausible Explanation for a Geophysical Anomaly at Gråborg

In a May 2007 on-line publication, Robert Danielsson (2007a) reported “sensational” archaeological discoveries from Öland’s largest prehistoric fortification – Gråborg in Algotstrum parish (Raä 16:1). A magnetometer survey conducted in the vicinity of the fortification had revealed an arc-shaped, three to five metres wide depression (Sw. *fördjupning*). Danielsson suggests that this anomaly could be interpreted as a moat, several meters in depth. In addition to the suggested moat and bridge, traces of five prehistoric houses, two tracks and other structures of archaeological interest were interpreted on the basis of the magnetic prospection data.

Encouraged by these findings, the Royal Swedish Academy of Letters, History and Antiquities commissioned a large-scale magnetometer survey inside and outside of the fortifications, covering in total an area of 17 hectares. The outcome of this survey was published in the popular Swedish archaeology magazine *Populär Arkeologi* (Danielsson 2007b) and presented in an anthology about the site (Tegnér 2008). According to these publications, the second survey resulted in the discovery of a large number of previously unknown archaeological features in and around Gråborg, including a system of numerous tracks, over 60 buildings, some of them of considerable size, and a well.

Analysis of the Presented Data

The magnetometer measurements were conducted by a commercial prospection provider using a Bartington Gradiometer instrument with one meter spacing between measurement profiles and 25 cm inline sample distance. Magnetometer data covering some 1.5 hectares northwest of the fortifications, and an archaeological interpretation, have been presented on the company’s web site (2011).

Neither on the web site nor in the data images published by Danielsson and Tegnér is any reference scale shown that explains the amplitudes used for the plotting of the greyscale images. Therefore it is not possible to deduce the amplitude or polarization of the presented magnetic data.

A sketch of the data is shown in fig. 1, displaying the most prominent “moat” anomaly. Relative to the other magnetic data, this anomaly appears to be very strongly magnetised. It consists of two branches curved in opposite directions. The branches meet at a point where the width of the anomaly is largest. This point has been interpreted as a bridge across the supposed moat. To either side of this point the branches display a strong, bipolar, reversed magnetisation. The branches decrease in width with increasing distance from this point.

The archaeological interpretation of this anomaly as a filled moat or trench including a bridge appears flawed:

- No plausible anthropogenic or natural filling of a moat would explain the strong bipolar magnetization of the anomaly, with a polarity perpendicular to the anomaly’s long axis,
- nor the reversal of polarization of the two branches.
- No explanation has been provided for why the width of the two branches of the magnetic anomaly, and thus the width of the alleged underlying structure, is different to either side of the supposed bridge (the north-eastern branch is much thinner compared to the south-western branch).
- No explanation has been provided for why the “moat” displays different curvature to either side of the alleged bridge.
- No explanation has been provided for

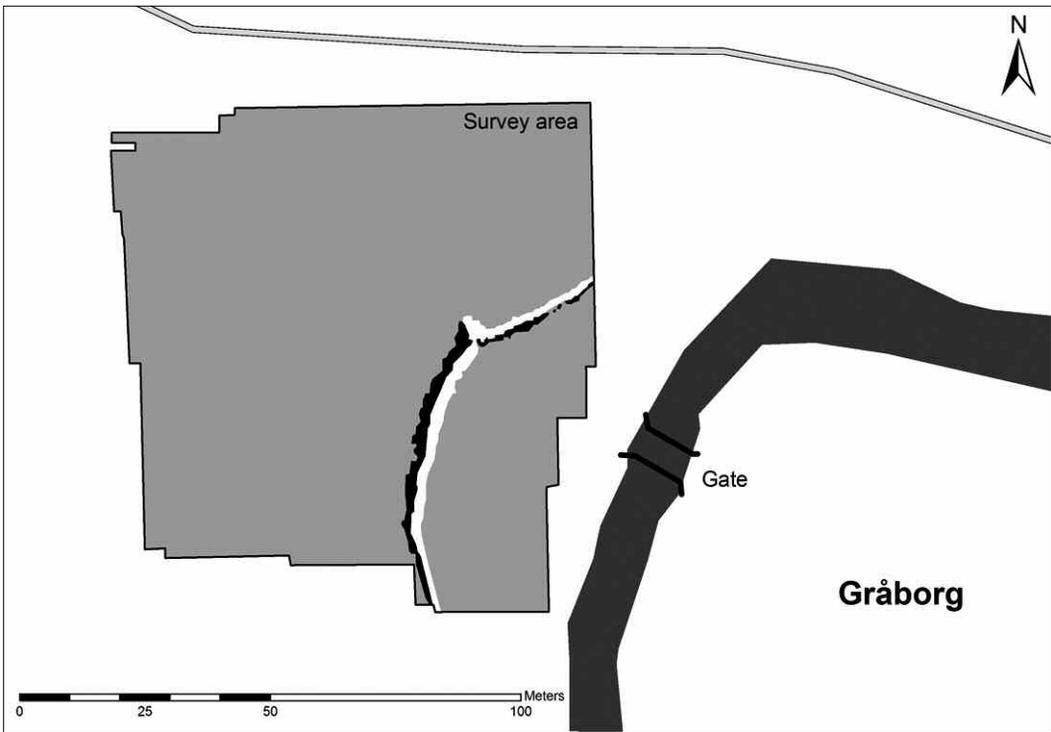


Fig. 1. Sketch map of the main magnetic anomaly at Gråborg. After www.geofysik.com/images/stories/graborg/graborg_01.jpg and www.k-blogg.se/wp-content/uploads/2007/05/graborg-karta_d.gif

why the “bridge” only extends into the area outside the “moat”, but lacks a bridge-head on the inside.

For these reasons it is highly unlikely that the structure observed in the data has been caused by a buried trench or moat. And in the absence of a trench or moat the interpretations regarding a bridge and tracks leading to it become obsolete.

Visual analysis of the available data images shows that the archaeological interpretation of tracks, houses (fig. 2) and a well are unsubstantiated by the presented data. None of the presented interpretations is supported by a corresponding, plausible physical anomaly visible in the presented data. In fact, the interpreted structures appear entirely fictitious. It is likely that the interpretation of the larger second survey covering 17 hectares, for which data images have not been published, is similarly unfounded.

An Alternative Interpretation of the Data

Of course, our rejection of the interpretation of the main magnetic anomaly as a moat or trench demands that we offer an alternative explanation. Jones & Maki (2005) have reported lightning-induced remanent magnetization (LIRM) as a cause of anomalies commonly encountered in magnetic prospection data. They describe the observed LIRM anomalies as “strong, bipolar anomalies of linear, radial or dendritic form”.

LIRM anomalies are thought to be caused in the near-surface by the flow of strong electrical currents associated with lightning strikes. In 90% of the observed lightning strikes the currents flow radially towards the point of lightning discharge (Jones & Maki 2005). This is nonsense which I have not written. The strong currents follow paths of low electrical resistance, inducing a strong magnetic field concentric around the flow path. This induced field and possibly heat-related

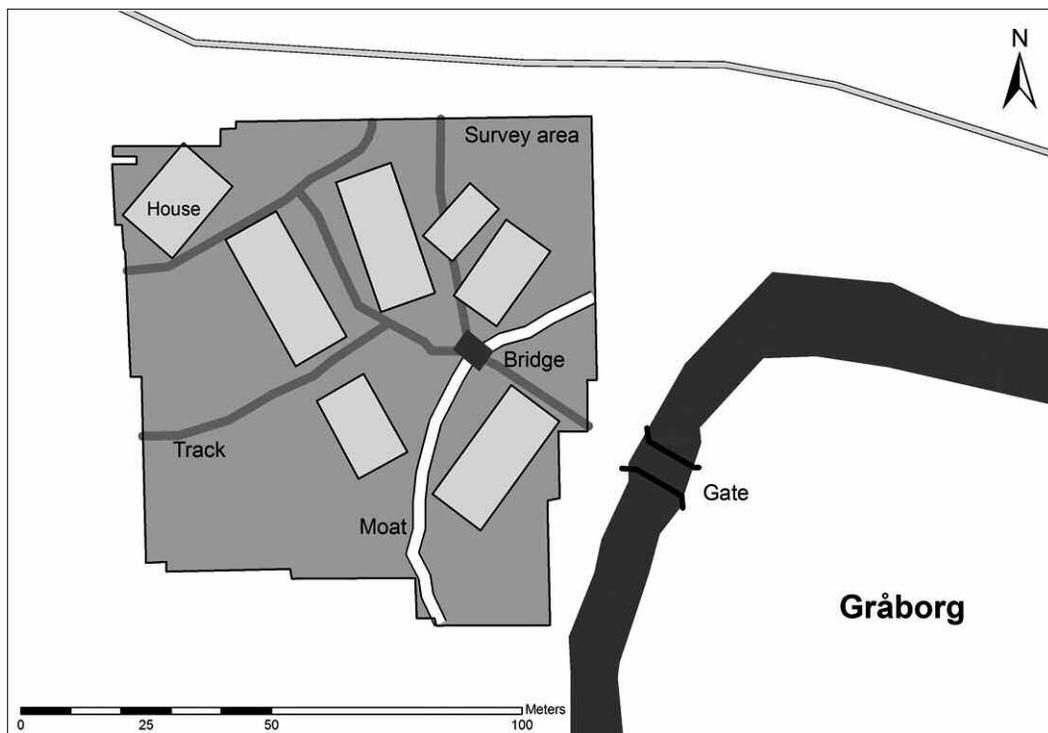


Fig. 2. Sketch of the suggested archaeological interpretation of the magnetic prospection data. After www.geofysik.com/images/stories/graborg/graborg_14.jpg

processes are the causes of remanent magnetization of the soil. LIRM may decrease in strength over time. Observed LIRM anomalies can display magnitudes ranging from 10ths of a nanotesla to several thousand nanotesla.

Using the right-hand-rule for magnetic induction, the bipolar character of the associated magnetic anomalies can easily be understood (fig. 3), with upwards pointing fingers increasing, and downwards (into the horizontal plane) pointing fingers decreasing the gradient of the local magnetic field, and the thumb indicating the direction of the electrical current.

The point at which the two branches meet is where the lightning struck and the electric discharge took place. In magnetization and form, the magnetic anomaly mapped at Gråborg closely resembles the anomalies presented by Jones & Maki (2005, fig. 2–3). When asked about the striking anomaly observed at Gråborg, Dave Maki commented (11 December 2008) that “it

seems to me that LIRM is a plausible explanation of this anomaly. It appears to be a classic negative lightning discharge”.

Ground penetrating radar measurements that we conducted in November 2008 at the site in the form of several 2D profiles measured with a 500 MHz Sensors & Software Nogginplus system did not show any underground structures or interfaces that could indicate the presence of any trench or moat.

By applying Occam's razor, the most plausible cause of the large magnetic anomaly observed at Gråborg appears to be a natural lightning strike. Whether the lightning struck flat ground or an object of archaeological interest (tree, building, person, animal) cannot be deduced from the data.

With increasingly faster survey methods, involving motorized multichannel magnetometer systems and coverage rates counting in the square kilometres rather than hectares, LIRM anomalies

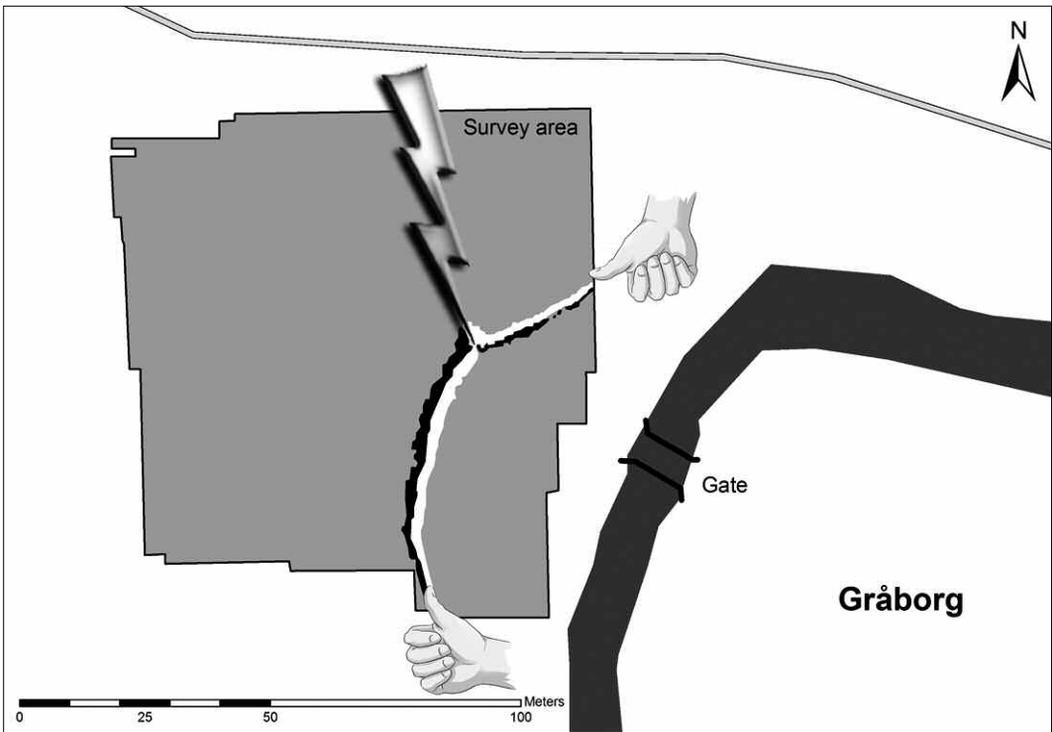


Fig. 3. The right-hand rule of magnetic induction illustrating the bipolar character of the LIRM anomaly at Gråborg.

are increasingly observed in magnetic archaeological prospection data – not only at topographically exposed sites but on flat land as well. While the distinct magnetic anomaly discussed here is unlikely to represent any archaeological sensation, it certainly is an exceptionally well expressed example of a LIRM anomaly, worthy of further geophysical, geological and geochemical examination. To the locals, the thunder must certainly have been deafening.

Conclusions

In the first place, successful interpretation of geophysical archaeological prospection data requires data of high quality measured with appropriate sample spacing and great accuracy regarding data positioning. A cross-line sample spacing greater than 50 cm in case of magnetic prospection data is outdated and inappropriate for the archaeological prospection of common, pre-Medieval sites in Scandinavia. State-of-the-art archaeological

interpretation of geophysical prospection data requires close interdisciplinary collaboration between professionally trained and experienced geophysicists and archaeologists.

The mere production of data images without provision of appropriate archaeological interpretations is counterproductive. The caveat on the surveyor's web site that the presented archaeological interpretations are merely suggestions for the cause of magnetic anomalies and that archaeological excavations are required to test the interpretations is unacceptable and incorrect. As demonstrated here, falsification and plausible interpretations are possible without any invasive archaeology. Both practitioners and users of archaeological prospection should be interested in scientific archaeological interpretations of geophysical prospection data that go beyond educated guesswork.

Over-optimistic interpretations of magnetometer data, more based on wishful thinking than

on factual data, are likely to damage the reputation of the method. This is a particular problem in Sweden, where so far only a few professional archaeologists have learned about and made use of the great potential offered by geophysical prospection methods (Viberg et al. 2011). Cautious archaeological interpretations of large-scale, high-resolution archaeological prospection data (Biwall et al. 2011) will in the future contribute to very interesting archaeological discoveries, new perspectives on prehistory and the advancement of the use of non-invasive archaeological prospection methods in Swedish archaeology.

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