Ilmo T. Kukkonen, Mirja Miettinen, Arto Julkunen & Annina Mattsson

# MAGNETIC PROSPECTING OF STONE-AGE RED OCHRE GRAVES WITH A CASE STUDY FROM LAUKAA, CENTRAL FINLAND

*Abstract*

Magnetic laboratory and prospecting methods were applied in the present study to Stone Age red ochre grave investigations in Finland. With the aid of theoretical and empirical results we demonstrate the possibilities of the magnetic method in this particular field. Laboratory measurements and mineralogical investigations showed that the analysed red ochre samples from six Finnish contexts are all magnetic and their susceptibilites are higher ($1.0 \cdot 10^{-3}$ – $15.6 \cdot 10^{-3}$ SI) than those of typical soils ($< 1.0 \cdot 10^{-3}$ SI). Theoretical simulations of the magnetic anomalies of typical red ochre grave structures indicated that such structures produce anomalies which can be relatively easily detected with common high-precision magnetic field instruments given that the red ochre soil has a susceptibility exceeding about $5 \cdot 10^{-3}$ SI. Field measurements were carried out in Laukaa, central Finland, where a very rich archaeological site with several red ochre graves is known. Magnetic vertical gradient and total field measurements with a 0.25 m line and station spacing in an area of 14 x 15 m showed several anomalies. Some of these were related to graves excavated earlier, but also new potential targets for unknown graves were observed. However, two previously known but unexcavated graves did not show significant anomalies, which can be attributed to either a low soil susceptibility or reversed remanent magnetization in these graves.

*Keywords*: Finland, Stone Age, red ochre graves, geophysics, magnetic methods, magnetic modelling, magnetic minerals.

*Ilmo T. Kukkonen* and *Annina Mattsson*, Geological Survey of Finland, P.O. Box 96, FIN-02151 Espoo, Finland.
*Mirja Miettinen*, National Board of Antiquities, P.O. Box 913, FIN-00101 Helsinki, Finland.
*Arto Julkunen*, Astrock Oy, Jäämerentie 46, FIN-99600 Sodankylä, Finland.

## INTRODUCTION

Applying geophysical prospecting methods in archaeological site investigations provides an indirect means of locating antiquities in subsurface contexts. Under favourable conditions geophysical methods can guide the archaeologist directly to the most critical areas of the investigation site and help to save time and excavation costs. Furthermore, if the geophysical anomalies can be interpreted reliably in relation to archaeological remains it is in principle possible to take such sites under official protection without excavating them or through only minimal excavations. This means that parts of the ancient heritage could be passed on intact to future investigations.

There have been numerous geophysical applications in archaeology. General texts on these topics are provided by Aitken (1974), Scollar et al. (1990) and Clark (1990). The magnetic method has been found to be usually effective in locating forges, kilns, hearths and fire sites (Gibson 1986).

Lavento (1992) describes the first applications of geophysical methods in archaeological investigations in Finland, including magnetic methods. In his experience, magnetic measurements were not found to be very efficient, because recent land-use has often introduced magnetic objects and artefacts into the investigated areas. It has created strong anomalies disturbing the possible magnetic signature from archaeological sources. Furingsten (1985) and Jakobsen and Abrahamsen (1985) have presented case studies of magnetic applications in southern Scandinavia. Their studies suggest that the magnetic method can be relatively effective, particularly if the archaeological artefacts include metal or fired remains.

This study focuses on the magnetic method and its use in within-site surveys for locating Stone Age antiquities in Finland. We take a particular interest in red ochre graves which are the most common grave type known of this prehistoric period in Finland. Red ochre was used widely in undertakings during the Stone Age, and many rich artefact founds are associated with red ochre graves.

The characteristic red colour of the red ochre soils is a sign of iron oxide minerals in the material, and for instance goethite, limonite or hematite may be responsible for the colour. Hematite is a magnetic mineral and if present in sufficient amounts it could alter the magnetic field around red ochre graves. In addition to hematite red ochre may contain also other magnetic minerals.

In this study we present data on the magnetic susceptibility and magnetic mineralogy of red ochre soils collected from six archaeological sites in Finland. We further demonstrate the detectibility of typical red ochre graves with magnetic measurements using theoretical anomaly calculations. Finally we present a case study from Laukaa, central Finland, where new high quality magnetic measurements were carried out in a partly excavated red ochre cemetery dating from the Comb Ware period.

## RED OCHRE GRAVES IN FINLAND

A Stone Age grave in Finland is typically a pit with vertical sides and dimensions equal to the human body. At present there are no indications of the grave to be seen at the surface. Stone Age graves are commonly detected in various land-use operations, such as gravel quarrying or the digging of ditches and therefore they are almost always partly destroyed when found.

The graves can be observed in the cultural layer of the soil on a dwelling site, but their investigations demand excavating considerably large areas. Searching for graves beyond the cultural layer with test excavations is a random, unreliable and expensive method, which cannot usually be applied.

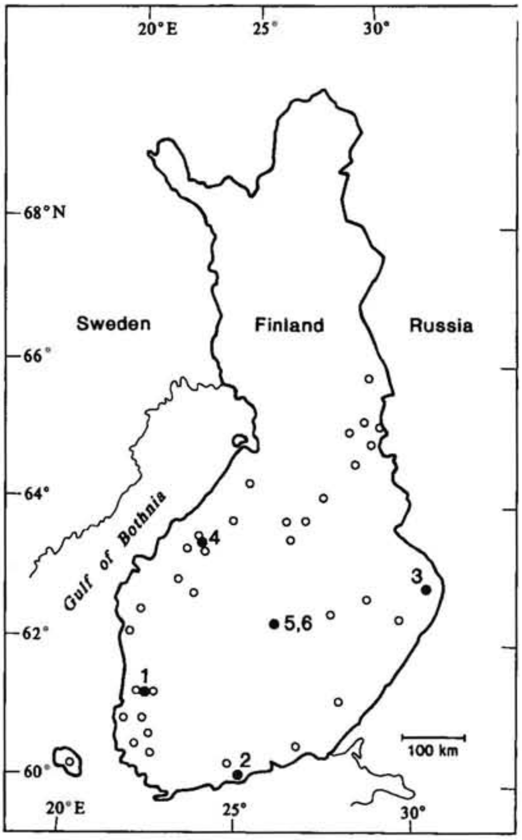


*Fig. 1.* Stone Age red ochre occurrences in Finland. Redrawn from Miettinen (1990). The numbered symbols refer to those sites of samples which were included in the magnetic susceptibility measurements (Table 1).

Therefore, there is a need to find new methods for locating graves without excavation.

Red ochre graves are the best known type of Stone Age graves in Finland, and they have been found at sites of the Comb Ware culture and the Mesolithic Suomusjärvi culture (Miettinen 1990; Fig. 1). A common feature of graves from many different age groups is the presence of red ochre soils which have been used in the undertaking. This soil type is most commonly detected in the grave at the depth of the body remains.

Red ochre graves are usually located in the cultural layer of dwelling sites or beneath it, sometimes beneath the floor level of a house or close to the walls. Graves may also be located in suitable terrain outside dwelling sites. Cemeteries of this kind may contain several dozen graves.

Owing to the typical soil chemistry of Finland, characterized by acidity and low concentrations of calcium, red ochre graves contain very little organic material. With the exception of occasional teeth and bone fragments, osteological material is usually not preserved. Preserved grave-goods in red ochre graves are arrow- or spearheads and scrapers made of flint, ornaments made of amber or slate, as well as fishing hook parts or lash-weights of slate, and sometimes also ceramics. There may be a large number of artefacts in a grave, but graves may also be empty.

## MAGNETIC AND MINERALOGICAL PROPERTIES OF RED OCHRE SOILS

In order to produce a measurable anomaly there must be a contrast in the magnetic properties of red ochre and the surrounding normal soils. Red ochre graves have been found typically at sites where the mineral soil is usually sand or silt with a thin (20–40 cm) podsol layer on top. The soil type possibly reflects the ease of digging pits in these soils. The magnetic properties of sand and silt depend on the origin of the soils before erosion and transport. Typically, their susceptibilities are in the paramagnetic range ($< 1 \cdot 10^{-3}$ SI) since the amount of magnetic minerals is negligible and the magnetic properties are controlled by common silicate minerals (quartz, feldspars and micas).

There are two main magnetic material properties which have an effect on the intensity of the anomalies, viz. magnetic susceptibility and remanent magnetization. Susceptibility is a parameter expressing the ability of matter to produce an anomaly under an external magnetic field, ie. the Earth's field. It is basically determined by the amount and type of ferrimagnetic minerals (hematite, magnetite and pyrrhotite), their grain size and texture. Remanent magnetization on the other hand is "frozen magnetization", a result of permanently magnetized minerals and the common orientation of their magnetic domains in the material. Remanence is also a function of the contents of ferrimagnetic minerals but essentially of their textures and magnetic domain orientations. In order to find out whether there is any remanence in an archaeological soil sample, oriented samples with preserved original soil structures need to be taken. This however, could not be taken into account in our sample material which was originally collected for purely archaeological purposes, and the texture has been inevitably altered. Therefore we are able to present only susceptibility measurements.

To find out the possible variation in the susceptibility of red ochre, six samples were selected from five Finnish sites at which red ochre deposits of either archaeological or natural occurrence are known (Fig. 1, Table 1). The average sample volume was about 38 cm$^3$.

Susceptibility was measured at the petrophysical laboratory of the Geological Survey of Finland. The equipment is described in detail by Puranen and Sulkanen (1985). It has a detection limit of about $0.01 \cdot 10^{-3}$ SI units (volume susceptibility).

The analysed samples have susceptibilities ranging from practically paramagnetic values ($< 1 \cdot 10^{-3}$ SI) to distinctly ferrimagnetic values ($>> 1 \cdot 10^{-3}$ SI). However, all are above the typical mineral soil values in Finland (Table 1).

The mineralogical composition of the fine-grained material of the samples (in particular the most red part of the material) was analysed at the mineralogical laboratory of the Geological Survey of Finland. X-ray diffraction technique was applied with a small Debye-Scherrer camera (K. Lindqvist, Geological Survey of Finland, written communication, 1992).

The mineral composition of the red ochre fine-grained samples is relatively simple. They contain feldspar, plagioclase, quartz, smectite and hematite (Table 1), which was the only magnetic mineral detected with X-ray diffraction. Hematite has a susceptibility of $0.1 \cdot 10^{-3} - 5 \cdot 10^{-3}$ SI, whereas the magnetite group minerals have values as high as $1000 \cdot 10^{-3} - 25000 \cdot 10^{-3}$ SI and pyrrhotite $100 \cdot 10^{-3} - 1000 \cdot 10^{-3}$ SI. No traces of magnetite or pyrrhotite were detected, which may be due to the relatively high detection limit of the x-ray diffraction method (1–5% depending on the mineral species and sample matrix type). However, magnetite or pyrrhotite is quite probably present, since the highest measured sample susceptibilities are of the same order of magnitude as the value of pure hematite. About 0.1–1 % of magnetite would be sufficient to produce the measured red ochre susceptibilities.

The susceptibility of one red ochre sample from an excavated grave in Laukaa, Central Finland (case discussed in detail below), was also measured as a function of temperature with the CS–2/KLY–2 equipment (M. Leino, Geological Survey of Finland, written communication, 1994). Such a measurement reveals the magnetic unblocking temperatures (Curie temperatures) of the magnetic minerals in the sample, and thus provides a means to identify the magnetic minerals. The susceptibility-temperature curve shows two distinct peaks at temperatures of 220–320°C and 560–590°C, which can be attributed to pyrrhotite and magnetite, respectively. Hematite was not detected in this experiment, although it was detected in the X-ray diffraction. This is due to the close proximity of the Curie temperatures of magnetite and hematite, and the low

*Table 1.* Magnetic susceptibility measurements and mineral composition of red ochre samples from Finland.

| Site | Description | Susceptibility ($10^{-3}$ SI) | Mineral composition[1] |
|---|---|---|---|
| 1. Harjavalta | grave | 9.4–12.9 | Hem+Qrz+Smc+Fldsp |
| 2. Vantaa | soil cont. by red ochre | 1.8 | Smc+Qrz+Fldsp |
| 3. Ilomantsi | natural (?) red ochre | 20.8 | Qrz+Fldsp+Smc+ (Hem) |
| 4. Kaustinen | natural (?) red ochre | 1.0–4.5 | Plg+Qrz+Hem |
| 5. Laukaa | grave | 14.8–15.6 | Hem+Plg+Smc+Mag +Pyrr |
| 6. Laukaa | soil cont. by red ochre | 1.1 | n.d. |

1) Mineral composition is based on x-ray diffraction analysis, excluding sample no. 5 which was also investigated with thermomagnetic analysis. See text for details.

Minerals: Hem = hematite, Mag = magnetite, Pyrr = pyrrhotite, Qrz = quartz, Plf = plagioclase, Fldsp = feldspar, Smc = smectite

n.d. = not determined

susceptibility of hematite in comparison to magnetite.

The results clearly indicate that red ochre often is a magnetic material which has anomalous susceptibility in contrast to normal mineral soils. The magnetic mineralogy is complicated and all the main magnetic minerals may be present in a sample. The recorded range of red ochre susceptibilities was also wide. We could therefore expect that the magnetic anomalies of red ochre soils may vary in a wide range as well, but the more magnetic variations can produce distinct anomalies if present in sufficient amounts.

## THEORETICAL MAGNETIC ANOMALIES OF RED OCHRE GRAVES

In the following we discuss the intensity of magnetic anomalies which can be expected at red ochre sites. We calculated theoretical total field intensity anomalies of a shallow red ochre grave structure using the above results of magnetic properties of red ochre materials as guiding values. The theoretical model of a red ochre grave was simplified from the excavation results of Mirja Miettinen (National Board of Antiquities, unpublished data, 1992). They indicate that the graves are often rather shallow structures at about 0.1–1 m below the present ground surface and the red ochre soil is present as a layer 0.2–0.5 m thick. The length of the graves is typically 1–2 m.

The magnetic anomalies of such structures were simulated using the magnetic modelling programs of the Geological Survey of Finland. Two-dimensional modelling was used, and the simulated measurement profiles were set in a north-south direction. The magnetic declination had a value of 5°, inclination 75° and the total field intensity 51 500 nT corresponding to the situation prevailing in Finland. The following parameters were varied and their effects on the total field anomalies were investigated: (I) susceptibility, (II) depth to the red ochre layer, (III) thickness of the layer, and (IV) remanence. The layer was assumed to be 1.0 m wide. The simulation results are presented in Fig. 2.

The theoretical anomalies demonstrate many characteristic features of the effects which are encountered in practical field work. First, the anomaly of a red ochre grave is much wider than the red ochre layer itself. In our model the grave is 1 m wide but its anomaly is about 6 m wide if we take into account the side minima. It is worth noting that the side minimum is considerably deeper on the northern side than on the southern side; it is a consequence of the inclination of the magnetic field. Profiles running in an east-west direction

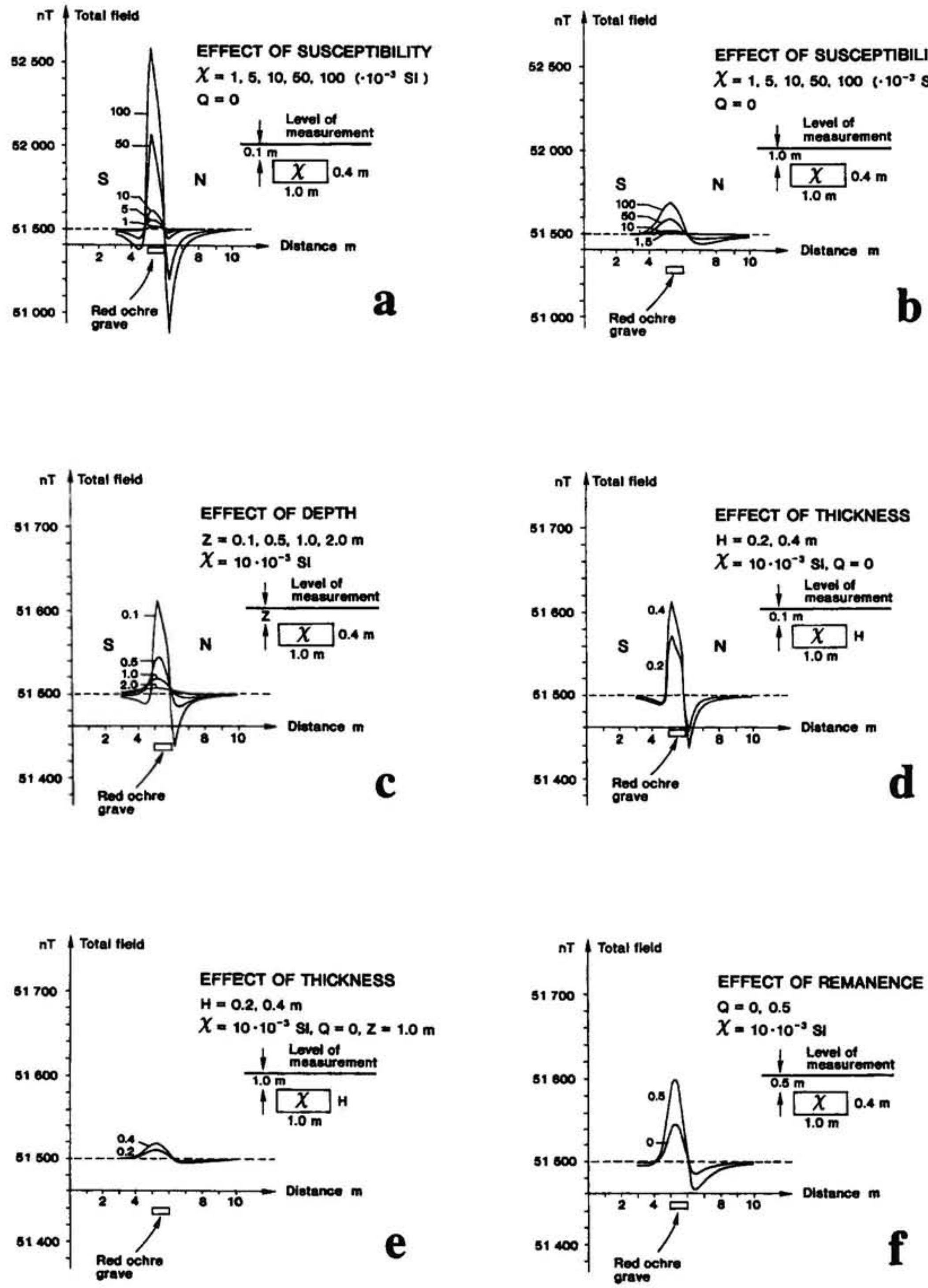


*Fig. 2.* Theoretical two-dimensional anomalies of red ochre graves. The effects of varying the following parameters are presented: (a) and (b) susceptibility, (c) depth to the red ochre layer, (d) and (e) thickness of the layer, and (f) remanence. The parameter Q is the Koenigsberger ratio giving the ratio between remanent and induced magnetization in grave, $\chi$ is magnetic susceptibility, Z is depth to the red-ochre grave and H is its thickness.

would be symmetric with side minima of equal intensity.

Increasing the red ochre susceptibility increases the anomaly amplitude, as can be expected (Fig. 2a). Assuming rather conservatively that the anomaly detection limit is about 10 nT, very shallow (depth 0.1 m) structures could be detected with susceptibilities as low as $1 - 5 \cdot 10^{-3}$ SI. Such values could be represented by our least magnetic samples (Table 1) or alternatively by soils at locations where the red ochre was only processed and handled and the topsoil was merely contaminated with red ochre. For structures at the depth of 1.0 m (Fig. 2b) the susceptibility would have to be about 10 times higher for the anomaly to exceed our detection limit. At any rate, the red ochre layer would produce a measurable anomaly even at a depth of 2.0 m if susceptibility were high (Fig. 2c). The thickness of the red ochre layer would not be a critical factor if the grave is very shallow (Fig. 2d), but if situated deeper, 0.2 m for layer thickness seems to be the approximate limit of producing an anomaly over 10 nT (Fig. 2e). In the presence of remanence, the anomaly could be efficiently modified depending on the orientation of the remanence vector; in our example the remanence vector is parallel to the Earth's field and thus would only enhance the anomaly (Fig. 2f).

These simulations were calculated for total field anomalies. In high resolution measurements the natural time-dependent drift of the Earth's magnetic field may totally prevent the detection of small anomalies. Therefore, the vertical gradient of the magnetic field is often measured instead of the total field intensity, since the vertical gradient is not influenced by the time-dependent changes in the magnetic field. However, total field and vertical gradient anomalies are analogous with each other and of the same shape.

Based on the above simulations we can conclude that red ochre structures may produce magnetic total field anomalies of up to several hundreds of nT's. Thus the magnetic method seems to be a potential tool in their investigations, given that the red ochre material is sufficiently magnetic.

## CASE STUDY: HARTIKKA, LAUKAA, CENTRAL FINLAND

The Hartikka, Laukaa dwelling site and cemetery of the Comb Ware Period was found in an archaeological survey carried out by the National Board of Antiquities in 1986. Investigations carried out during 1987–93 have revealed a large dwelling site consisting of several dwelling pits and a cemetery with red ochre graves of considerable importance. At present, sixteen graves are known as a dense cluster within an area of about 40 m x 30 m. The graves are situated outside the cultural layer on the top of a low ridge (Miettinen 1990, 1992a, b).

All of the seven graves investigated so far are E-W oriented pits dug into coarse-grained sand with depths ranging from 40 to 70 cm. Mixed and red-ochre contaminated soil can be distinctly observed already at a depth of 10–15 cm. The fill of some of the graves is surrounded by an oblate circle of red ochre soil spreading into a 5–15 cm thick continuous layer of red ochre soil in the bottom layer of the grave. The head of the body was (in five graves) at the eastern end of the pit. Most of the grave-goods were excavated in the bottom layers of the graves, in the eastern end of the pits. There were two corpses in two or possibly three of the investigated graves.

The grave-goods discovered at the Hartikka site are typical to the graves and dwelling sites known earlier of the Comb Ware Period. For the most part, the ceramics from the Hartikka site are so-called Typical Comb Ware. The material contains a small amount of ceramics mixed with asbestos, which can be attributed to a somewhat younger age. Carbon-14 age datings made of two hearths in the Laukaa dwelling site support the above age estimates based on the ceramic style. The obtained ages are 4990 ± 110 BP (analysis Hel–2715) and 5060 ± 120 BP (Hel–2716; H. Jungner, Institute of Geology, University of Helsinki, written communication, 1992).

An area of 18 m x 14 m to the southeast of the excavated spots was chosen for magnetic measurements. The instrument used was the Scintrex magnetic vertical gradiometer, type 2.0. In this instrument two proton magnetometers are carried on a vertical bar with a 1.0 m vertical separation. The lower magnetometer is 0.5 m above the ground surface. The magnetometers are read automatically at the same time, which eliminates the problems produced by time dependent changes in the magnetic field intensity. Diurnal magnetic variation may be of considerable magnitude.

The area under study was measured with 0.25 m station and profile spacing, and altogether about 4000 magnetic readings were measured in three days. The results were processed into a map of magnetic vertical gradient (Fig. 4) and profile plottings of total magnetic field intensity and vertical gradient (Fig. 5).

Four soil samples were collected from the topmost soil below the humus layer in order to find out the soil susceptibility at the site of a still unexcavated grave (Fig. 3) which was discovered in a

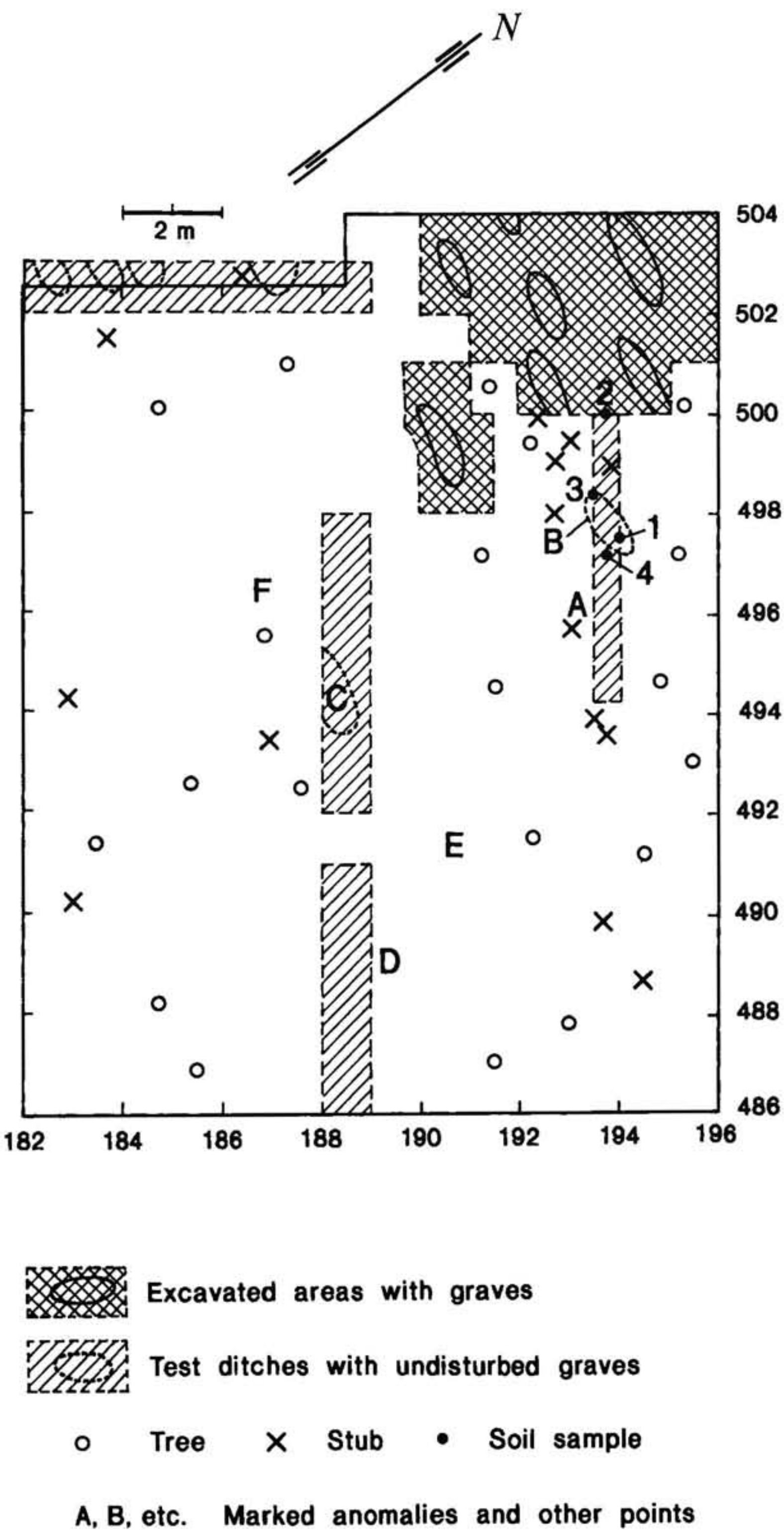


Fig. 3. Detailed map of the Laukaa magnetic measurement area. Excavation data was adapted from Miettinen (1992a).

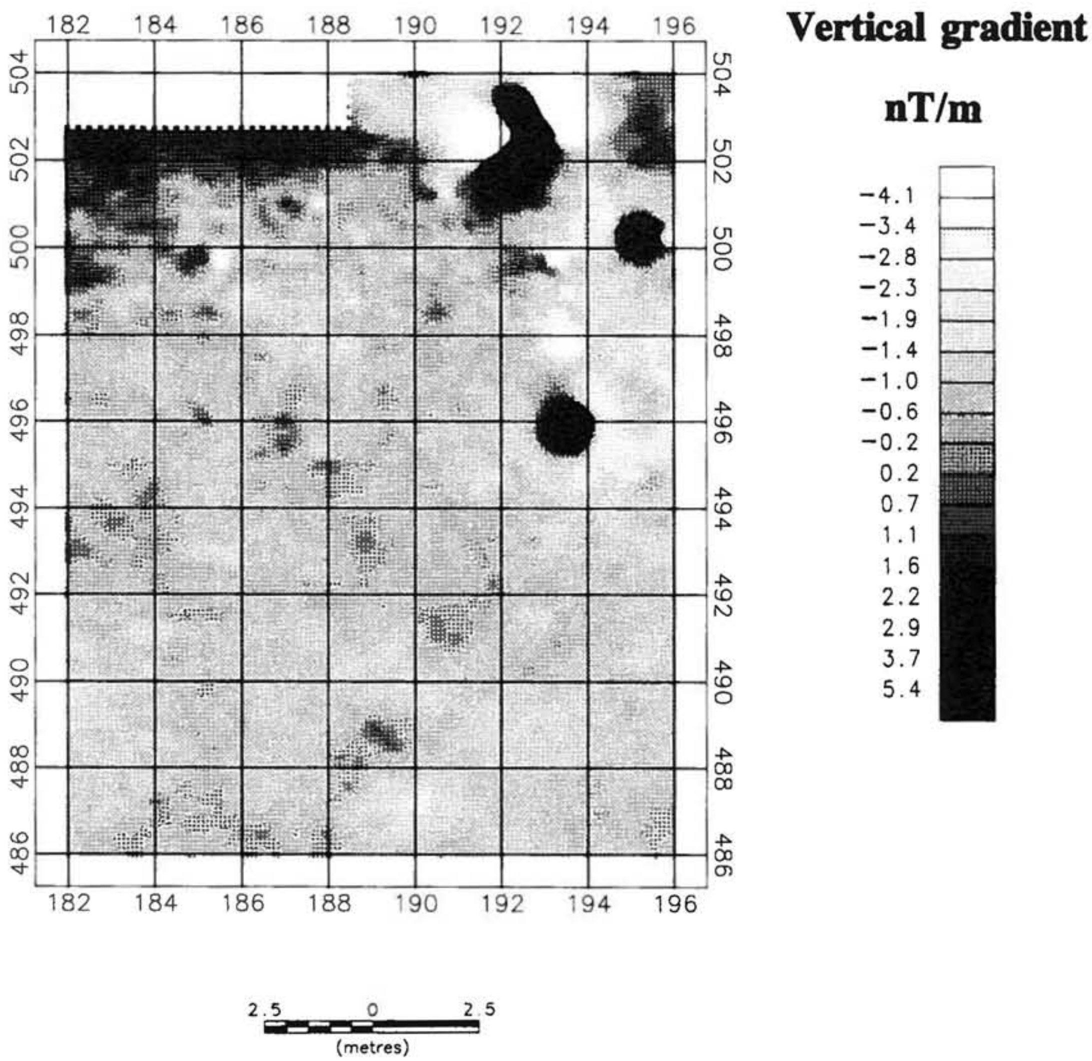


*Fig. 4.* Magnetic vertical gradient map of the Laukaa investigation area.

test excavation section prior to the magnetic measurements, but kept undisturbed. The samples were taken as vertical profiles extending down to around 30-40 cm. Susceptibility values range from $0.01 \cdot 10^{-3}$ to $0.4 \cdot 10^{-3}$ SI (sampling stations 1–3). At one of the sample stations (4) susceptibility increased to $1.1 \cdot 10^{-3}$ SI and already a visual inspection of these samples showed distinct red ochre in them. It should be taken into account that these soil samples do not show the very high susceptibilities measured in the samples taken from one of the excavated graves (Table 1). It suggests that there may be red ochre soils with quite different magnetic properties within the Laukaa site.

The results of the magnetic survey are presented in Fig. 4 and examples of the profiles are given in Fig. 5. The northern corner of the surveyed area has the most intensive anomalies. We know from previous excavations that in the northern corner there are many red ochre graves. The excavated soil was put back into its original position and thus we can still measure considerable anomalies in that area (Fig. 4 and 5a). However, the magnetic signature has very probably been altered. The magnetic measurement also indicates anomalies to the south and southeast of the excavated area.

A particularly strong anomaly was measured at location 'A' (Figs. 3, 4, 5b). There were no observations of red ochre in the test section which crosses the anomaly. The section was dug before the magnetic measurements and it extended to only a depth of 15 cm. It is highly probable that the anomaly is due to a red ochre grave.

However, the unexcavated grave (B), situated 2 m to the NW of the anomaly discussed above, is related to a negative anomaly (Fig. 5c). This feature is very difficult to explain with the magnetic anomalies induced by the Earth's field, since the measured soil susceptibilities were slightly elevated at the site of the anomaly (sample station 4, Fig. 3). Only remanent magnetization with a magnetic orientation opposite to the induced field could produce such a negative anomaly.

Another unexcavated and undisturbed grave (marked C in Fig. 3) has only very small anomalies hardly above the noise level (Fig. 4). This could also be attributed to a low susceptibility of the red ochre soil in this particular grave. In addition to the described anomalies there are several smaller anomalies which may be related to Stone Age antiquities (some of them marked D, E and F), but so far they have not been excavated.

## CONCLUSIONS

The present results demonstrate on the one hand the potential of magnetic methods in investigations of Stone Age red ochre graves, but on the other hand also problems related to the wide spectrum of magnetic susceptibility values of the red ochre. Red ochre soils are magnetic materials but their susceptibilities may range from practically paramagnetic values of about $1 \cdot 10^{-3}$ SI to ferrimagnetic values of about $15 \cdot 10^{-3}$ SI. Therefore, red ochre graves may produce conspicuous magnetic anomalies but they may also be without any magnetic signatures in typical situations encountered in Finland. The magnetic mineralogy of red ochre is complicated and may include all the main magnetic minerals (magnetite, hematite and pyrrhotite) in the same sample as was shown by the mineralogical and magnetic laboratory analyses in the Laukaa case. Theoretical simulations of magnetic anomalies indicated that typical red ochre graves can be detected with magnetic measurements given that the susceptibility is higher than about $5 \cdot 10^{-3}$ SI. In very favourable conditions even lower susceptibilities could be sufficient. The measurements in Laukaa revealed conspicuous magnetic anomalies in an area where sev-

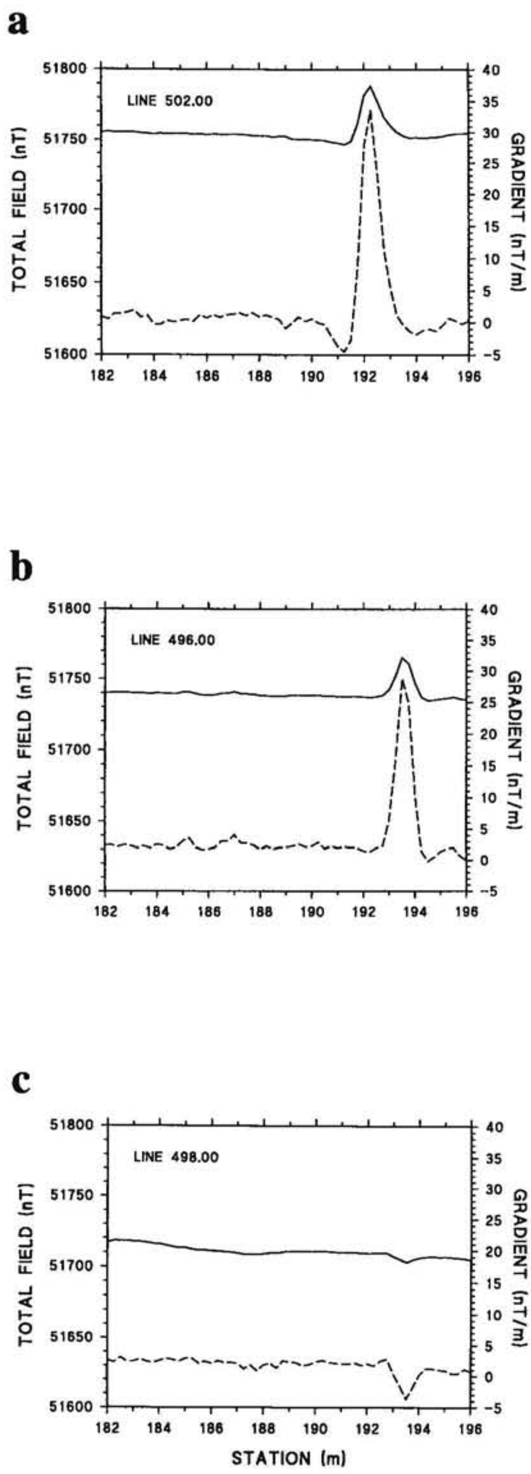


*Fig. 5.* Selected SW-NE profiles of the magnetic results. Solid line: total field anomaly, broken line: vertical gradient, a) line 502.00, b) line 496.00, c) line 498.00.

eral Stone Age red ochre graves are known. The strong peak-like anomalies are similar to the theoretical anomalies calculated and due to red ochre graves. On the other hand, the two known but unexcavated red ochre occurrences in the Laukaa excavation site did not show any distinct positive anomalies. This may be attributed to low susceptibility and possibly to reversed remanent magnetization of the red ochre soil in these graves. Although the field of red ochre magnetism is not free of problems, the present results are encouraging for further research and applying the magnetic methods in investigations of Stone Age remains.


## ACKNOWLEDGEMENTS

We are grateful to H. Manninen, Geological Survey of Finland (GSF), for carrying out the field measurements, to H. Hautaniemi (GSF) for assistance in image processing and to R. Puranen (GSF), for comments on the manuscript.


## REFERENCES


Aitken, M.J. 1974. *Physics and archaeology.* 2nd edition, Clarendon Press, Oxford. 291 pp.

Clark, A. 1990. *Seeing beneath the soil, prospecting methods in archaeology.* B.T. Batsford, London. 176 pp.

Furingsten, A. 1985. Archaeology and geophysics in West-Sweden. T. Edgren & H. Jungner (eds.), Proceedings of the Third Nordic Conference on the Application of Scientific methods in Archaeology, Mariehamn, Åland, Finland, 8–11 October, 1984. *Iskos* 5, pp. 289–298.

Gibson, T.H. 1986. Magnetic prospection on prehistoric sites in western Canada. *Geophysics* 51, pp. 553–560.

Jakobsen, P.-E. & Abrahamsen, N. 1985. Magnetic mapping of kiln remnants at Bistrup, Denmark. T. Edgren & H. Jungner (eds.), Proceedings of the Third Nordic Conference on the Application of Scientific methods in Archaeology, Mariehamn, Åland, Finland, 8–11 October, 1984. *Iskos* 5, pp. 321–328.

Lavento, M. 1992. Arkeologiassa käytettyjen sovelletun geofysiikan menetelmien alkuvaiheista Suomessa. M. Huurre, P. Halinen, M. Lavento & J. Moisanen (eds.), *Kentältä poimittua, kirjoitelmia arkeologian alalta, Museovirasto, Esihistorian toimisto, Julkaisu N:o 2*, pp. 10–20 (in Finnish).

Miettinen, M. 1990. A red-ochre grave of the Comb Ware period from Hartikka in Laukaa. *Iskos* 9, pp. 39–47.

Miettinen, M. 1992a. The Stone Age Cemetery of Hartikka in Laukaa, central Finland. V. Lang & J. Selirand (eds.), *Cultural heritage of the Finno-Ugrians and Slavs. Papers presented in the Soviet-Finnish archaeological symposium, Tallinn, Estonia, 10–16 May, 1990*, pp. 25–40.

Miettinen, M. 1992b. Laukaan Hartikan kivikautinen kalmisto. *Keski-Suomen museon julkaisuja, Keski-Suomi* 19, pp. 8-23 (in Finnish with abstract in English: The Stone Age cemetery of Hartikka at Laukaa).

Puranen, R. & Sulkanen, K. 1985. Technical description of a microcomputer-controlled petrophysical laboratory. *Interim Report Q15/27/85/1, Dept. Geophysics, Geological Survey of Finland.* 252 pp.

Scollar, I., Tabbagh, A., Hesse, A. & Herzog, I. 1990. *Archaeological prospecting and remote sensing.* Cambridge University Press, Cambridge. 674 pp.