PARISH 4003

S9594
E2876 (MAG)
E2877 (RES)

GEOPHYSICAL SURVEYS OF CARR NAZE, FILEY NORTH YORKSHIRE

A PROGRAMME OF RESEARCH CARRIED OUT ON BEHALF OF

YORK ARCHAEOLOGICAL TRUST

By

GeoQuest Associates

INTRODUCTION

This report presents the results of geophysical surveys along the crest of Carr Naze, a promontary 1.5km northeast of Filey in North Yorkshire. This landmark is the site of a Roman signal station which was discovered in 1857 following a landslip and preliminary investigations at the time produced the plan of a stone tower. The structure was excavated in 1923 by Simpson who was able to show that the tower was enclosed by a 30m square curtain wall with an outer ditch and bank.

Local history records that during WWII Carr Naze was bombed in mistake for a naval vessel and the evidence for this can still be seen in the form of deep craters. Exacavations were also carried out during the War for the construction of lookout posts and several concrete foundations and steps for these can be distinguished.

Referring to Simpson's excavation plan, it is evident that the cliff edge adjoining the signal station has retreated by up to 10m since 1923. The present research was therefore carried out as part of an effort to locate and record the surviving archaeological remains on Carr Naze.

GEOLOGY AND TOPOGRAPHY

Carr Naze is composed of Corallian limestones which present a more resistant finger to coastal erosion than the Kimmeridge Clays that outcrop to the south (all Upper Jurassic). The Corallian rocks are thinly bedded and well-jointed giving rise to steep seaward cliffs and the promontary is capped with 1-2m of boulder clay which also erodes rapidly. From its landward connection near Filey Country Park, the spit narrows from a width of ~80m to less than 10m at the signal station, expanding to a width of ~40m above the rocks of Filey Brigg. The maximum elevation is ~101m (Figure 1).

THE GEOPHYSICAL SURVEY

Geophysical surveying provides a rapid method for the detection of subsoil features within archaeological landscapes. Two methods are most frequently used. *Geomagnetic* surveying employs a portable magnetometer to detect small perturbations in the Earth's magnetic field caused by changes in soil magnetic susceptibility or permanent magnetisation. The *resistivity* method, on the other hand, maps differences in soil electrical resistance which mainly reflect variations in water content.

The primary aim of the geophysical survey at Filey was to detect the stone foundations and ditches of the Roman signal station. However, the survey was also designed to detect further archaeological activity for which the site may have been a natural focus and these might include minor ditches, fired structures and stone features. It was therefore decided to carry out a geomagnetic survey of the entire peninsula with an additional resistivity survey of the signal station site.

Measurements of vertical geomagnetic field gradient and electrical resistivity were made at 0.5x0.5m intervals on the central part of Carr Naze which includes the signal station, as shown in Figure 1. This measurement scheme will detect geophysical anomalies on a scale of 0.5-1.0m and this approximately equates to the archaeological resolution. The remainder of the promontary (with the exception of a narrow section with railings) was surveyed geomagnetically at a resolution of 0.5x1.0m, enabling the detection of subsoil features on a scale of 1.0-2.0m. The instruments used were a Geoscan FM36 fluxgate gradiometer with ST4 sample trigger and a Geoscan RM15 resistance meter with 0.5m electrode spacing. Both parallel and zig-zag traverse schemes were employed according to the terrain. Appendices **A** and **B** provide more information about these methods of archaeological geophysical surveying.

The geophysical results were processed into grey-scale images showing the residual geomagnetic and resistance anomalies and these are presented in Figures 2 & 3. Appendix **C** describes the computer processing of the field data in more detail.

DISCUSSION

General

The promontary is characterised by very weak geomagnetic and electrical resistance anomalies, (standard deviations of the order of 0.8nT/m and 6 Ohms, respectively). This presumably reflects weak soil magnetic susceptibility and moisture contrasts. Absolute values of soil resistivity were very low due seawater infiltration. The surveys were carried out during a period of high winds which causes a component of tilt-error noise in the magnetic data; this has been reduced by applying a 3x3 box filter.

As a first stage in the interpretation, the geophysical and resistivity maps have been classified into characteristic styles of geophysical terrain (Figure 4). These are illustrated in the graphical foldout key contained in the rear of this report and are defined as follows:

1 Significant regions of anomalously *high magnetic field gradient* which might be associated with high susceptibility, soil filled structures such as *pits or ditches*.

2 Areas of anomalously *low magnetic field gradient*, corresponding to features of low magnetic susceptibility, such as Jurassic limestone. Some strong negative anomalies corellate with *bomb craters*.

3 Strong *dipolar anomalies* (paired positive-negative) whose most probable source in this context are dumps of material with very high susceptibility or metallic *iron contamination*.

4 Significant regions of anomalously *high resistivity* which probably correspond to stone features or regions of more *stoney soil.*

5 Areas of anomalously *low* resistivity. The most likely candidates are soil filled *pits or ditches.*

The key provides examples of the geophysical appearance of archaeological features as geomagnetic and resistivity anomalies. Note that solid colour fills, rather than patterns have been used for clarity in some instances. A list of graphical symbols which we have used to represent interpreted archaeological features is also given.

West of Signal Station

The dominant geophysical anomaly comprises a linear chain of magnetic dipoles due to iron objects (reinforced concrete?) along the main cliff path. Other minor paths can also be traced from their similar magnetic signatures while Figures 2 & 4 show that iron objects are abundant throughout this part of the study area. Strong magnetic disturbances have also been caused by metal notices.

A number of pronounced negative, sub-circular geomagnetic anomalies correspond to depressions (presumably craters) and bunkers, some of which contain concentrations of iron objects. The presence of such strong geophysical disturbances has, in places, hindered the detection of more subtle features of possible archaeological interest. However, several pits may have been located, as indicated in Figure 5.

Signal Station Area

This area was surveyed at 0.5x0.5m resolution using geomagnetic and resistivity methods. Again, the dominant feature in the geomagnetic data are linear disturbances associated with footpaths and scattered magnetic dipoles caused by surface iron objects. A crater and metal notice add further strong disturbances. The resistivity survey has revealed no recognisable archaeological or geological features (Figure 3); the main anomalies comprise subtle positive and negative features near the cliff edge which probably reflect lateral changes in soil moisture content. Thus unfortunately, it has not been possible to detect any geophysical features which add detail to the signal station archaeology.

East of Signal Station

Several linear or curvilinear chains of magnetic dipoles reflect branching footpaths which traverse this part of the study area (Figures 2 & 5). A massive cluster of small magnetic dipoles are aligned in a N-S band suggesting that a fence or ditch containing iron objects transects the headland at this point. East of this feature the landscape is characterised by a network of 1-2m wide linear and curving positive anomalies, several of which define partial circles (Figure 5). The geometry of these features seems inconsistent with geological origins as joint-controlled fissures or camber cracks although patterned ground developed under permafrost and drift structures are tentative explanations. Archaeological origins for these anomalies can also be considered in the form of small enclosure-drainage ditches or the silted trenches for wall footings.

SUMMARY AND CONCLUSIONS

The results of this study can be summarised as follows:

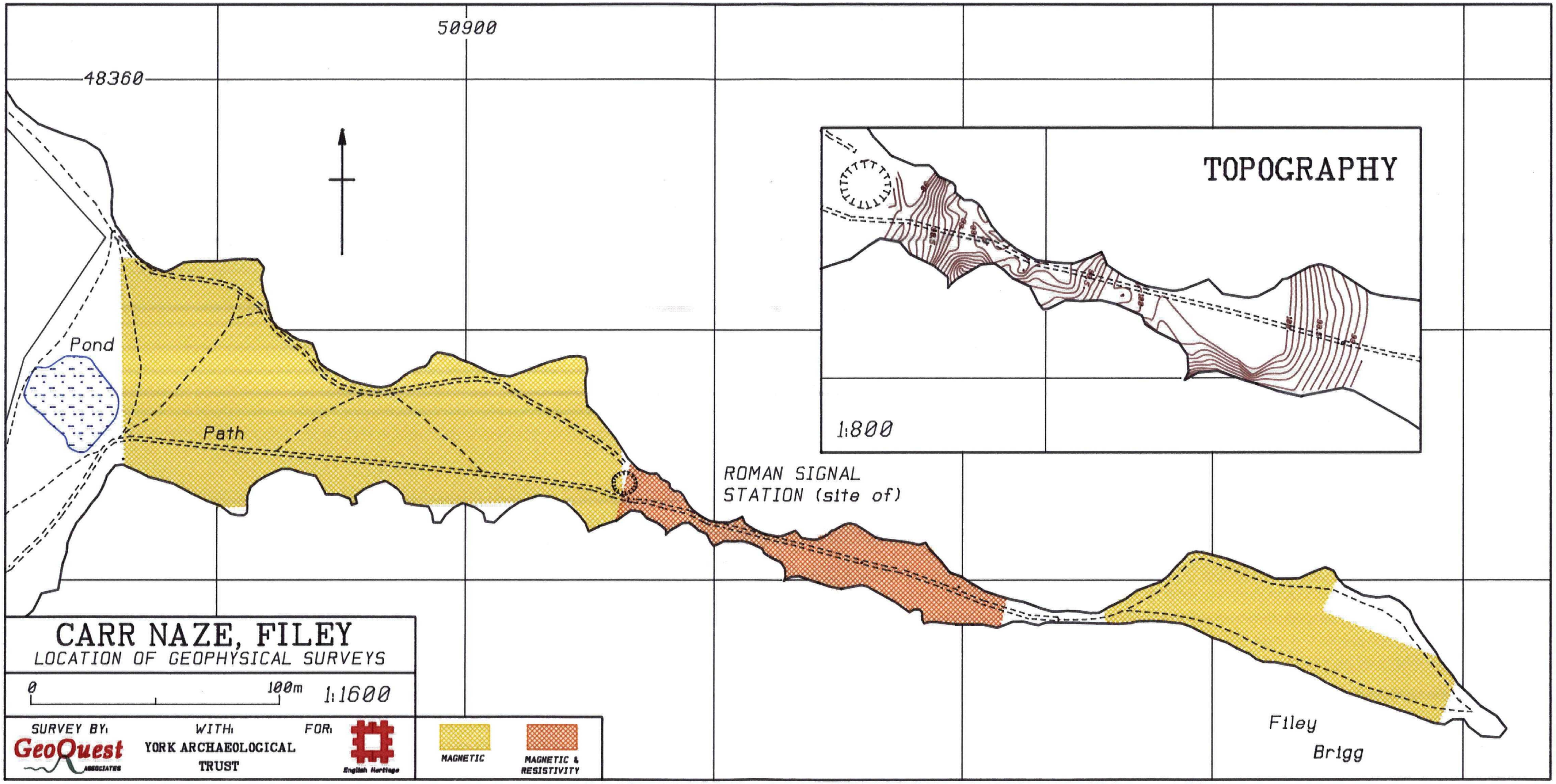
1 Geomagnetic and electrical resistivity anomalies arising from the subsoil were found to be very weak with the former being dominated by pathways, iron contamination and deep hollows.

2 The geophysical mapping provides no evidence for archaeological structures in the vicinity of the Roman signal station. However, a pattern of linear and curvilinear magnetic anomalies near the eastern extremity of Carr Naze possibly reflect a series of pits and ditches which may warrant further archaeological investigation.

Credits *Field survey*: D.N. Hale, C. Thompson, M.J. Noel
Report: M.J. Noel

FIGURE 1

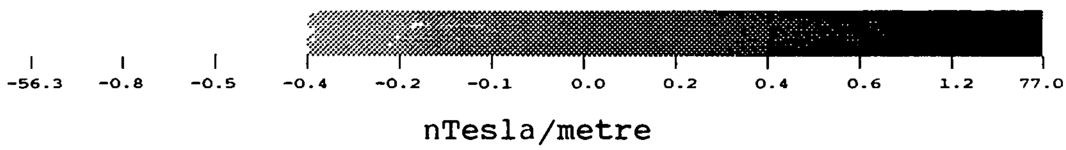
Map showing the location of areas on Carr Naze surveyed by geomagnetic and resistivity methods. Inset is contour survey by York Archaeological Trust. Coastline has been derived from the YAT survey and a digitised 1:50000 OS map.



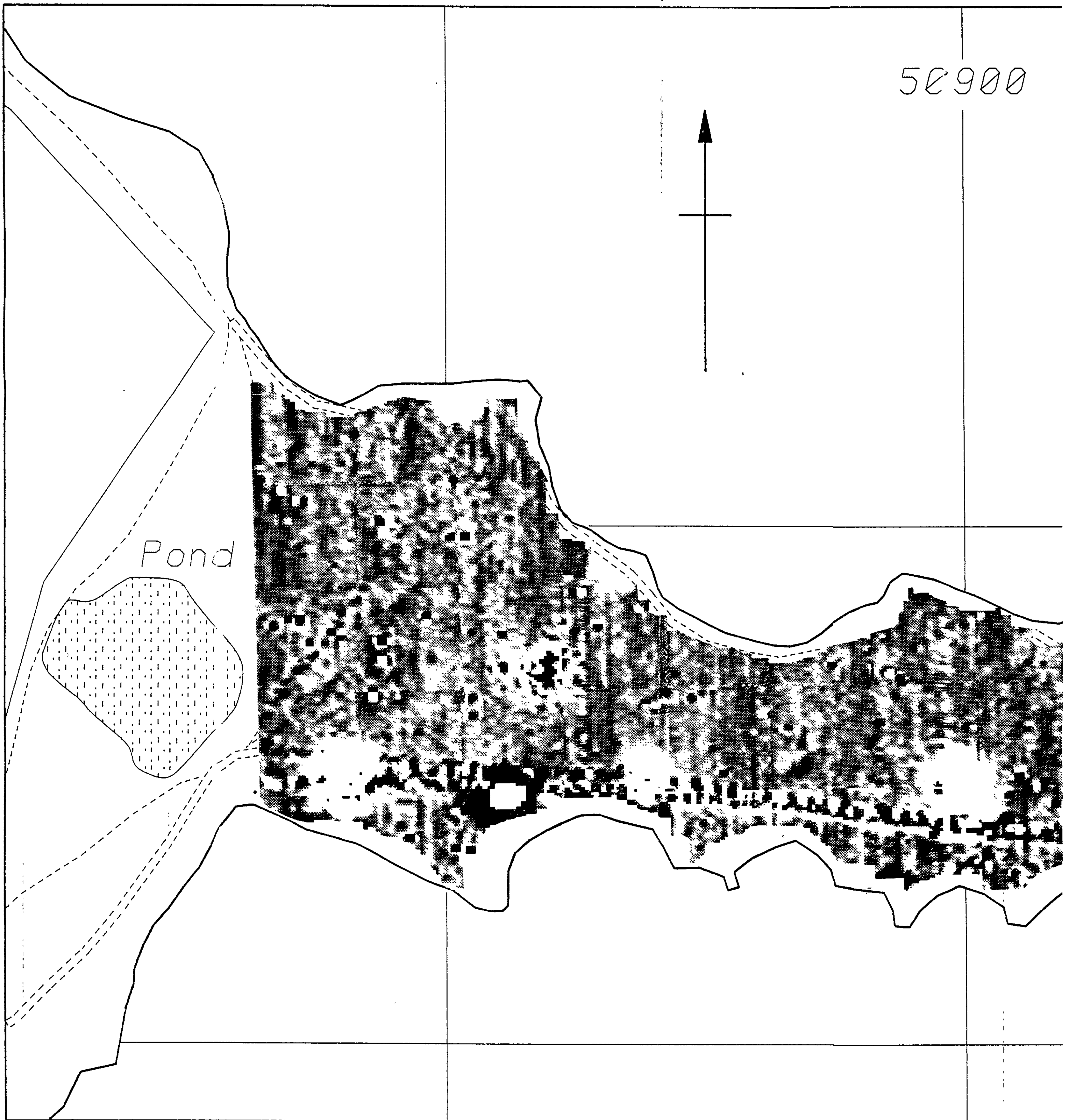
50900
48360
TOPOGRAPHY
1:800
Pond
Path
ROMAN SIGNAL
STATION (site of)
Filey
Brigg
CARR NAZE, FILEY
LOCATION OF GEOPHYSICAL SURVEYS
0
100m
1:1600
SURVEY BY:
GeoQuest
ASSOCIATES
WITH:
YORK ARCHAEOLOGICAL
TRUST
FOR:
English Heritage
MAGNETIC
MAGNETIC &
RESISTIVITY

FIGURE 2

Results of the geomagnetic survey of Carr Naze The narrow section was not surveyed because of the presence of iron railings. Data have been filtered to reduce noise Refer to the scale below for absolute values.



SNY9594 part 1 of 3



CARR NAZE, FILEY

RESULTS OF GEOMAGNETIC SURVEY

0 100m 1:738.2

SURVEY BY: GeoQuest ASSOCIATES

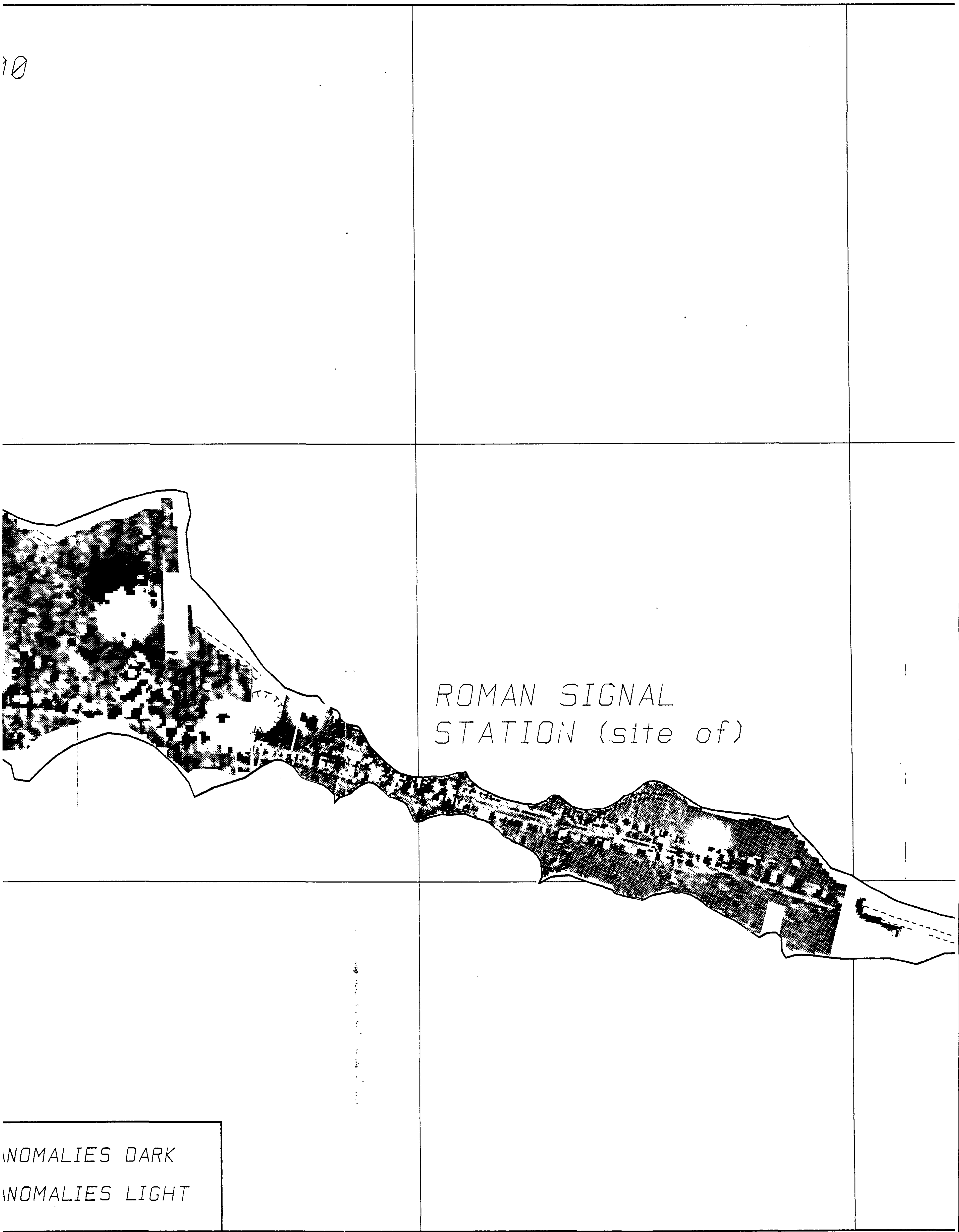
WITH: YORK ARCHAEOLOGICAL TRUST

FOR: English Heritage

+ve ANOMA

-ve ANOMA

Smy 9594 part 2of3



SNY 9594 part 3 of 3

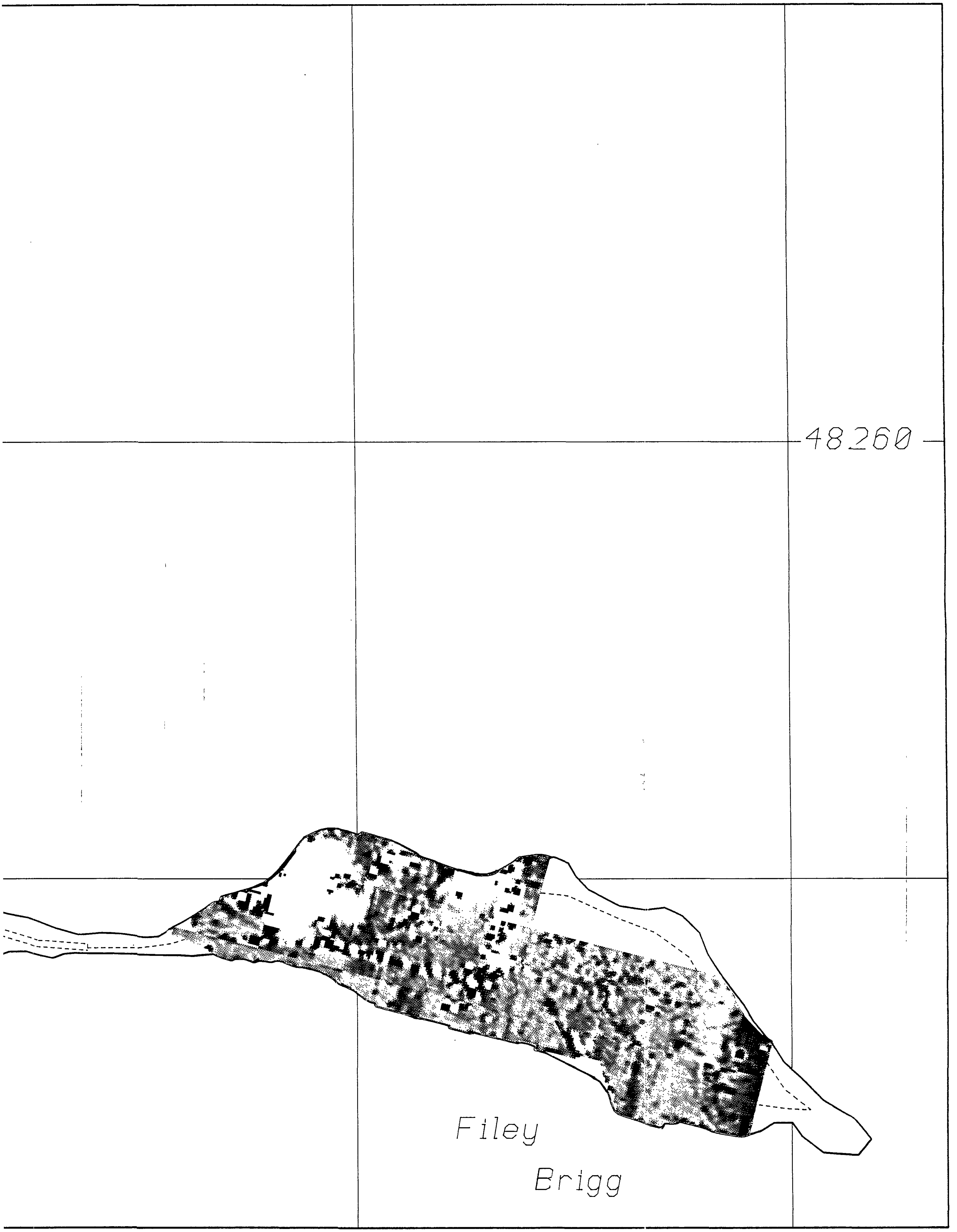
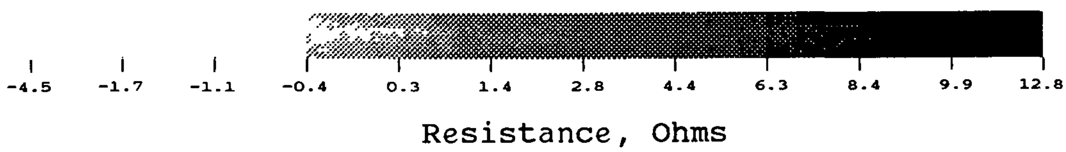


FIGURE 3

Results of the electrical resistivity survey in the vicinity of the Roman signal station. Refer to the scale below for absolute values.



CARR NAZE, FILEY: RESULTS OF RESISTIVITY SURVEY

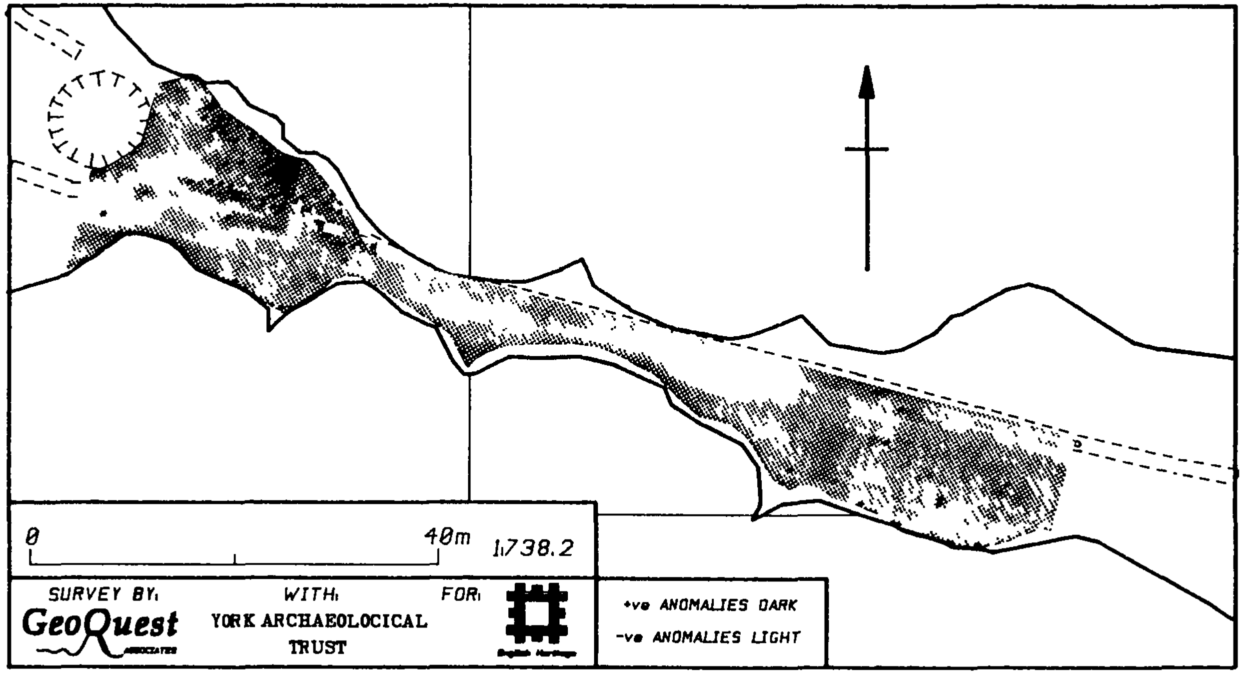


FIGURE 4

Geophysical interpretation of the survey results obtained on Carr Naze
Refer to the foldout key for an explanation of the symbols used

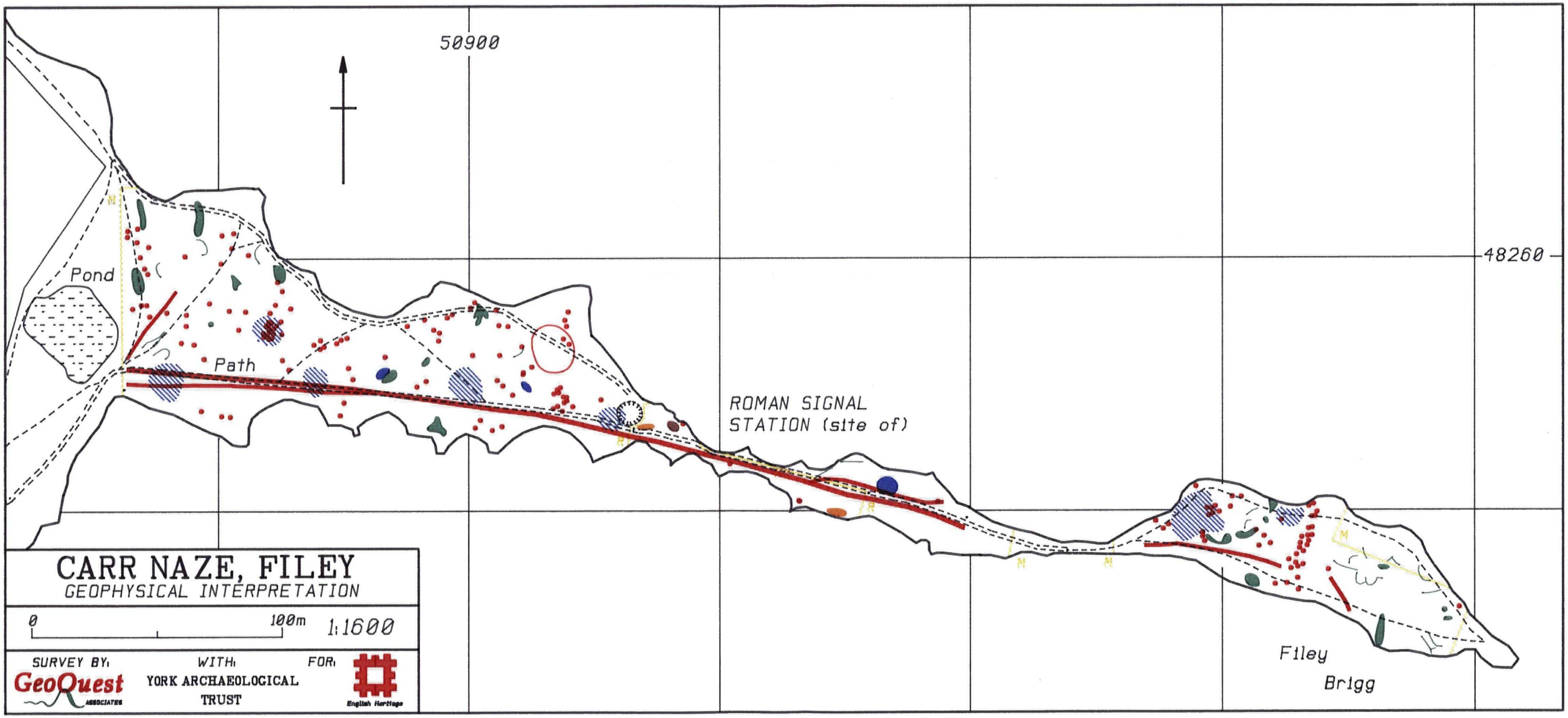
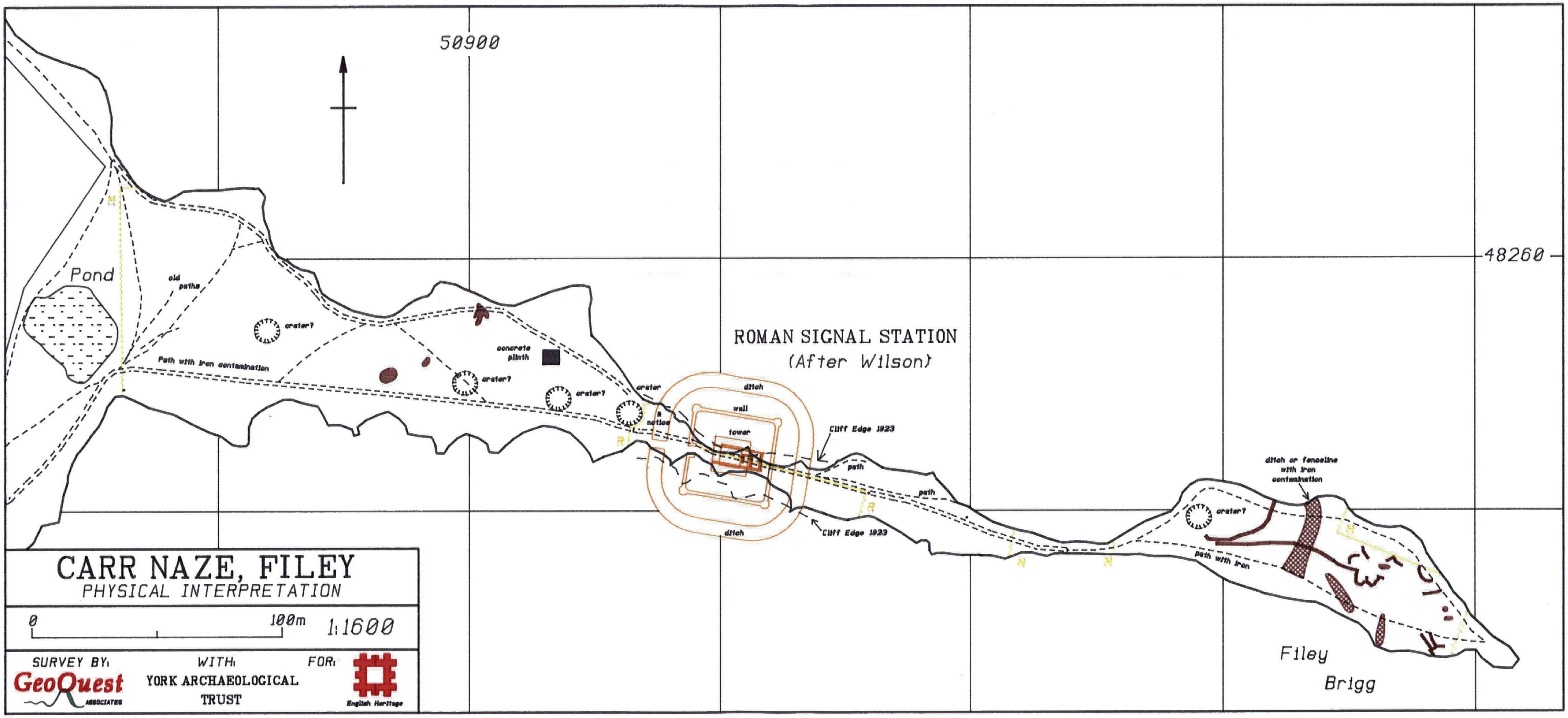

50900
48260
Pond
Path
ROMAN SIGNAL
STATION (site of)
Filey
Brigg
CARR NAZE, FILEY
GEOPHYSICAL INTERPRETATION
0
100m
1:1600
SURVEY BY:
GeoQuest
WITH:
YORK ARCHAEOLOGICAL
TRUST
FOR:
English Heritage

FIGURE 5

A physical interpretation of the geophysical survey results from Carr Naze Refer to the foldout key for an explanation of the symbols used.



50900
48260
Pond
old paths
crater?
Path with iron contamination
concrete plinth
crater?
crater?
crater
R notice
ROMAN SIGNAL STATION
(After Wilson)
ditch
wall
tower
Cliff Edge 1923
path
path
ditch
Cliff Edge 1923
ditch or fenceline with iron contamination
crater?
path with iron
Filey Brigg
CARR NAZE, FILEY
PHYSICAL INTERPRETATION
0
100m
1:1600
SURVEY BY:
GeoQuest ASSOCIATES
WITH:
YORK ARCHAEOLOGICAL TRUST
FOR:
English Heritage

GEOPHYSICAL ANOMALIES

- +ve MAGNETIC AREA
- +ve MAGNETIC LINEATION
- -ve MAGNETIC AREA
- -ve MAGNETIC LINEATION
- MAGNETIC DIPOLES
- CHAINS OF DIPOLES
- +ve RESISTIVITY AREA
- +ve RESISTIVITY LINEATION
- -ve RESISTIVITY AREA
- -ve RESISTIVITY LINEATION
- BOUNDARY OF SURVEYED AREA

INTERPRETIVE SYMBOLS

- WALLS (interpreted)
- WALLS (part inferred)
- DITCH (interpreted)
- DITCHES (part inferred)
- PITS
- PIPES OR DRAINS
- ROADS AND YARDS
- KILNS AND HEARTHS
- RIDGE (r) AND FURROW (f)

GEOPHYSICAL EXAMPLES

(RESULTS MAY DEPEND ON TIME OF YEAR)

- WALL OF SEDIMENTARY ROCK
- DITCH WITH MOIST INFILL
- POTTERY KILN
- IRON PIPE

N

TOPOGRAPHIC SYMBOLS

- CONTOUR
- SPOT HEIGHT
- SLOPES
- WATER

APPENDIX A

Theory of Geomagnetic Surveying

Geomagnetic prospecting detects subsurface features in terms of the perturbations or 'anomalies' that they induce in the Earth's magnetic field. In contrast to resistivity, seismic or electromagnetic surveying, no energy is injected into the subsoil and hence this is one of a class of *passive* geophysical techniques that includes gravity and thermal surveying. In an archaeological setting two types of magnetic anomalies can be distinguished:

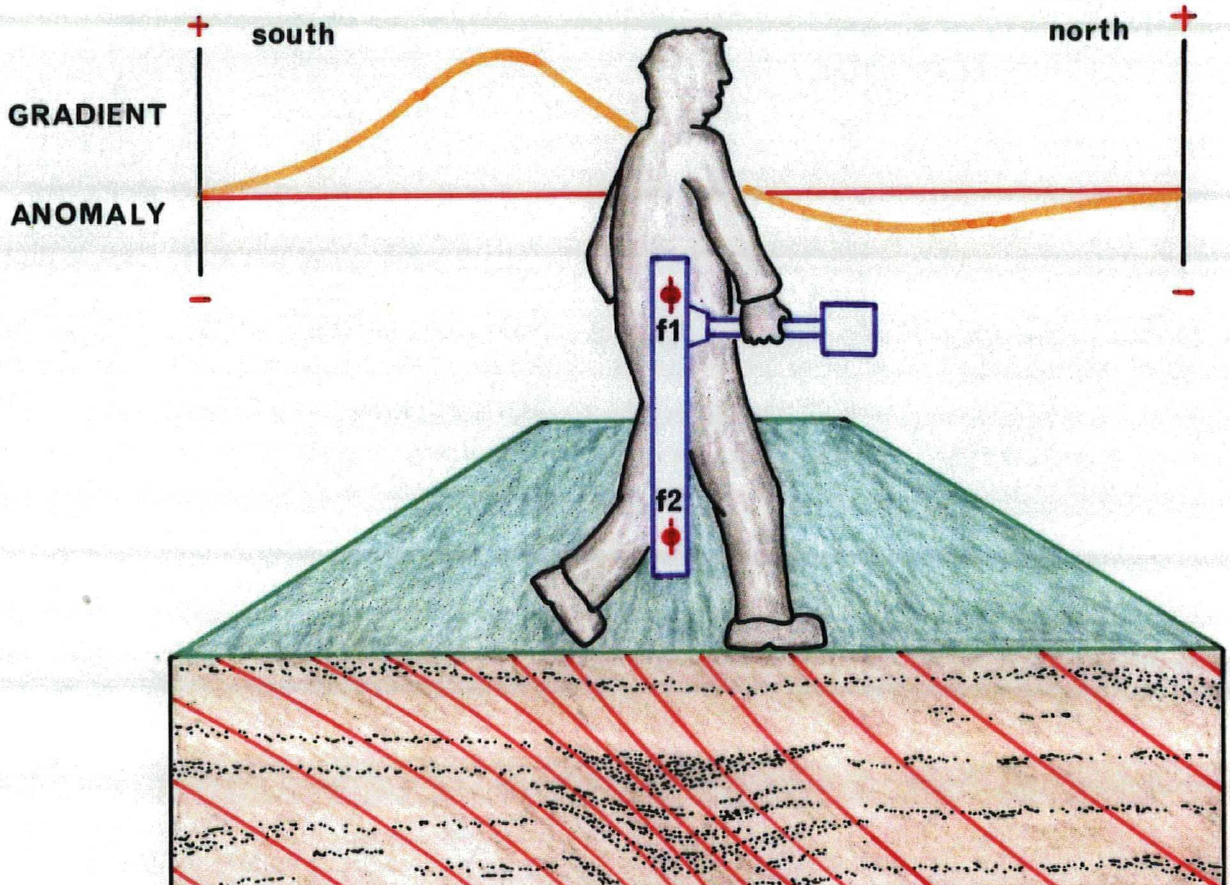
1 Anomalies arising from variations in *magnetic susceptibility* which will modulate the component of magnetisation *induced* in the subsurface by the Earth's magnetic field. For most archaeological sites, this is the dominant factor giving rise to geomagnetic anomalies. In general, susceptibility is relatively weak in sediments, such as sandstones and enhanced in ingeous rocks and soils, especially those which have been burnt or stratified with organic material.

2 Anomalies due to large, *permanently magnetised* structures. Such permanent magnetisation or 'remanence' arises when earth materials are heated to above ~600°C and cooled in the geomagnetic field. Thus kilns and hearths are often detected as strong permanent magnets causing highly localised anomalies that dominate effects due to background susceptibility variations. Remanence can result from other physical and chemical processes but these give rise to anomalies that are usually unimportant for geophysical prospecting.

There are several approaches towards the practical measurement of geomagnetic anomalies. In this study measurements were made using a Geoscan FM36 fluxgate gradiometer which records the change with height in the vertical component of the Earth's magnetic field, as shown overleaf. This method has the advantage of being insensitive to diurnal variations while the Geoscan instrument also benefits from an integrated data logger. Note that in mid northern latitudes the magnetic anomaly will be asymmetric with the main peak displaced to the south of the archaeological feature. Thus, a ditch filled with a soil of enhanced susceptibility, for example, will generate a positive anomaly to the south, mirrored by a weak negative anomaly north of the feature. When portrayed as an area map of grey tones this gives rise to a 'shadowing' or pseudo relief effect which must be borne in mind when making an archaeological interpretation.

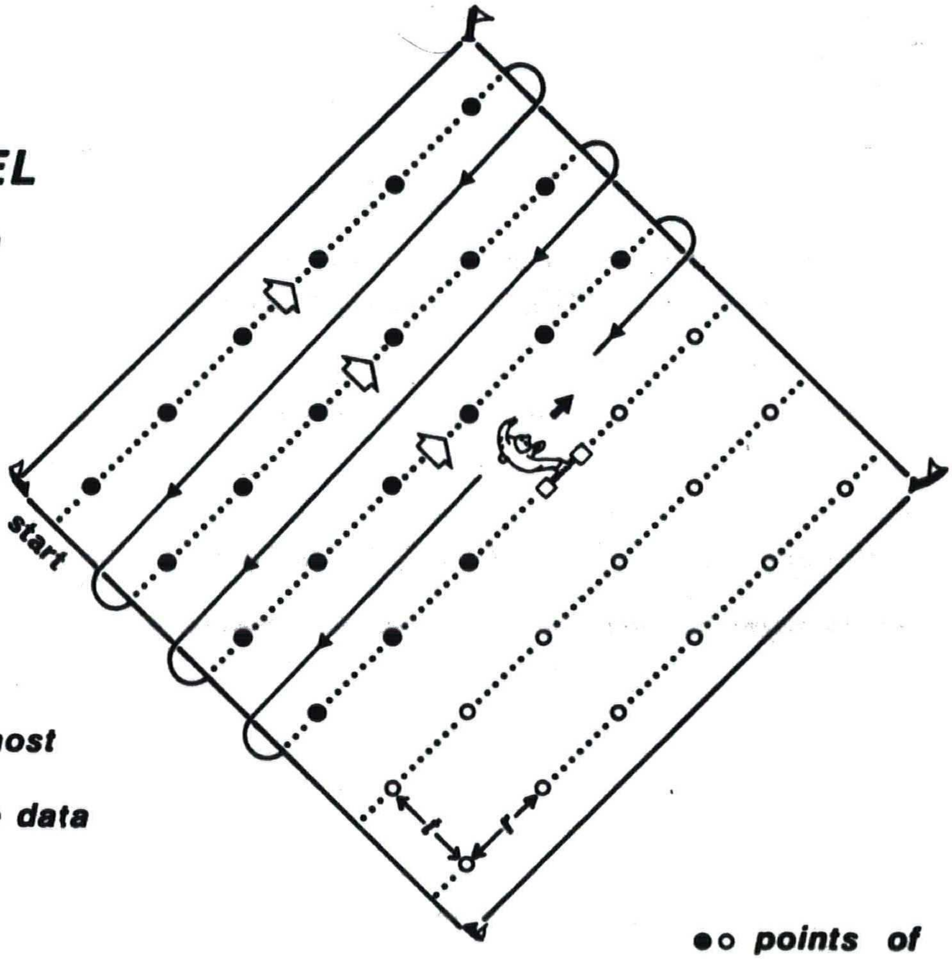
Two techniques can be used to survey gridded areas using the fluxgate magnetometer. In the parallel method the instrument is used to scan the area along traverses which are always in the same direction. This method minimises 'heading errors' due to operator and instrument magnetisation but is time consuming. The alternative zig-zag method is significantly faster and suitable for areas where anomalies are large compared to these and other sources of error.

MAGNETIC SURVEYING



SURVEY SCHEMES

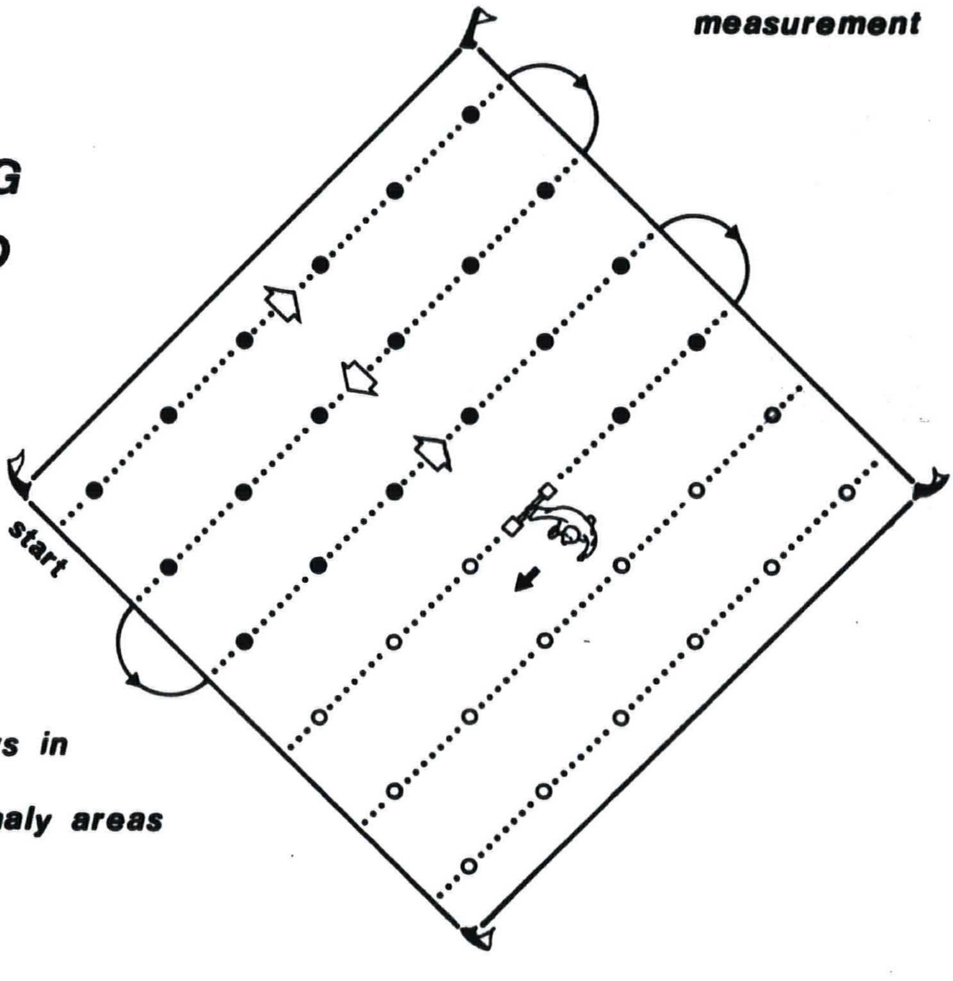
PARALLEL METHOD



slower but minimises most errors in the data

●○ points of measurement

ZIG-ZAG METHOD



suitable for rapid surveys in strong anomaly areas

APPENDIX B

Principles of Electrical Resistivity Surveying

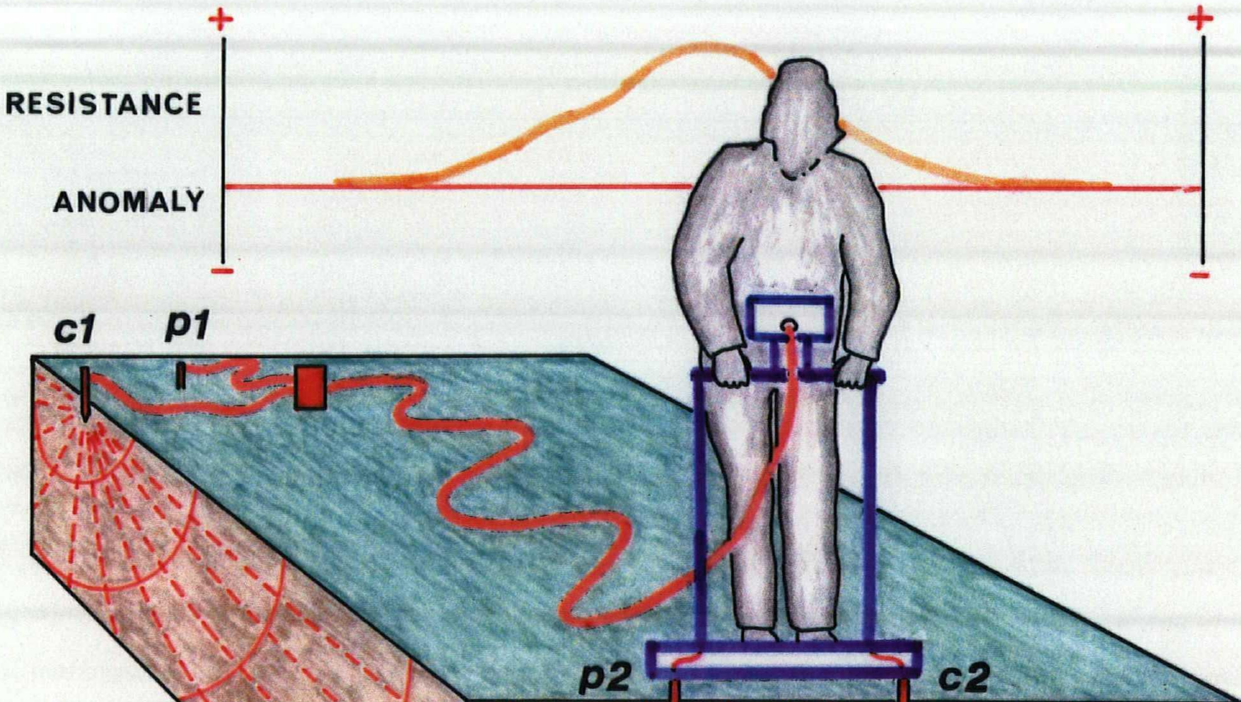
This is an *active* geophysical prospecting technique which detects subsurface features in terms of the resistance they present to the passage of an artificially induced electric current. In the dry state, most soils and rocks are insulators but, when they become moist, electric currents are able to flow through the movement of ions which are always dissolved in the porewater. As the soil or rock absorbs more water the conductivity increases since more ions become available for conduction and their mobility is enhanced. Hence electrical resistivity surveying primarily maps the volume concentration of ground moisture which varies according to lithology, porosity and time of year. Temperature fluctuations can also be important although in mid-latitudes this effect is insignificant.

To record the soil electrical resistivity an alternating current is injected into the ground through a pair of metal electrodes and the surface potential detected between a second pair. This arrangement is needed to minimise errors arising from contact effects, earth currents (usually of mains origin) and polarisation potentials. Several configurations have been evaluated for archaeological use but the 'twin electrode' scheme shown overleaf has proved popular for this purpose. A mobile frame is used to carry one potential and one current electrode (**p2** and **c2**) which are connected, via the meter, to their respective **p1** and **c1** soil electrodes. Alternating current is passed between **c1** and **c2** and the potential measured between **p1** and **p2**. The presence of a zone of anomalous resistivity modifies the distribution of current flow (dotted streamlines) and also the contours of constant potential (curved solid lines) and is depicted for the case of a high resistivity structure such as a wall. The instrument thus senses a maximum (or minimum) in the apparent soil resistance which is centred over the feature.

Through good instrument design, resistivity surveying is now a rapid technique although the need for soil contact and cables makes this a slower method than magnetometry. Our surveys employed a Geoscan RM15 instrument with variable spacing between the mobile electrodes which enables the sensing depth to be optimised.

Measurements are generally taken at regular intervals on a grid. Both parallel and zig-zag traverse schemes are used; the first method is slower but minimises systematic errors in the resulting data.

RESISTIVITY SURVEYING



APPENDIX C

Data Processing Procedure

The various stages involved in gathering and manipulating the field measurements are summarised in the flow diagram overleaf. Data are downloaded from the magnetometer or resistivity meter to a portable computer, via a serial cable, inspected graphically and then stored on disc. Once the survey is completed, the data from individual grids are corrected for instrument drift (typically a few % per hour for the magnetometer) and then their dynamic range reduced if they contain highly variable values. This is often necessary where an area contains strong dipole sources if one is to make the best use of the grey scales available from the printer. Next, the area image is constructed by 'tiling' together adjacent grids. To achieve this, a special graphical technique is applied that minimises 'seams' in the image which would otherwise mask the anomalies of archaeological interest. If enlargement of a selected area is required, then this is achieved by expanding the data with bicubic splines; an approach which helps to reduce blurring. Finally, the data are numerically mapped to a set of 33 grey levels (true half tones) which are programmed to have a normal distribution in the printed image. From experience, it has been found that such a distribution is pleasing to the eye and by adjusting the mean density and variance the appearance of the anomalies can be optimised. All processing is carried out by proprietary GeoQuest software.

DATA PROCESSING