NYE 591 1025.

NZ 1916 0678 NYS 862

NYCC HER	
SNY	862
ENY	591
CNY	1715
Parish	1025
Rec'd	10/1999

GEOPHYSICAL SURVEY OF AN AREA OF LAND AT GATHERLEY MOOR, NORTH YORKSHIRE

A programme of research carried out on behalf of

Block Stone Ltd

by

GeoQuest Associates

1 INTRODUCTION

1.1 This report presents the results of a programme of geophysical research which has been carried out on an area of land NW of Gatherley Moor Quarry Plantation, adjacent to the A66 trunk Road in North Yorkshire. An area of approximately 4.2 hectares was examined with the aim of providing information concerning the presence and character of subsoil archaeological features prior to a proposed extension of the quarry.

1.2 The research was carried out by GeoQuest Associates (GQA) on behalf of Block Stone Ltd, in accordance with a Technical Proposal drafted by GQA agreed by Block Stone Ltd and North Yorkshire County Council.

1.3 Figure 1 shows the location of the survey area on a plan derived from digital map data supplied by The Architectural and Land Survey Partnership. It was not possible to extend the survey up to all field boundaries of the designated area owing to dense vegetation in a number of places. The geophysical survey took place between 3rd and 6th September 1999.

2 LAND USE, TOPOGRAPHY AND GEOLOGY

2.1 The area of geophysical survey comprised a single arable field used for cereal cultivation, bordered on the north, east and south by walls and hedging. The western border of the site comprised the line of an old field boundary shown on the 1:2500 scale Ordnance Survey. A short cereal stubble covered the study area but was not an impediment to the geophysical survey.

2.2 No earthworks were visible in the survey area which generally sloped down gently to the south.

2.3 The solid geology underlying the site comprises Carboniferous sandstone which is overlain by drift largely comprising boulder clay and morainic deposits. Such lithologies are likely to have a low magnetic susceptibility providing a favourable environment for the development of strong geomagnetic field anomalies over cut features infilled with topsoil. There are no rock outcrops within the survey area.

3 THE GEOPHYSICAL SURVEYS

Field Methods

3.1 Measurements of vertical geomagnetic field gradient were recorded using a Geoscan FM36 fluxgate gradiometer. A zig-zag traverse scheme was employed and data were logged in grid units of 20x20m at 1.0x0.5m intervals, thus providing 800 measurements per grid. Appendix A provides further information about the technique.

3.2 Data were downloaded on-site into an IBM Thinkpad computer for processing, printing and storage. These data were subsequently transferred to a laboratory computer for further processing, interpretation and archiving.

Data Processing

3.3 The GeoQuest **InSite®** software was used to process the geophysical data and to produce a continuous tone grey-scale image of the data at a scale of 1:1000. These results are shown in Figure 2 on a plan that has been derived from digital map data supplied by The Architectural and Land Survey Partnership. A convention is used that shows positive magnetic anomalies as dark grey and negative magnetic anomalies as light grey. Figure 2 includes a key which relates the grey-scale intensities to anomaly values in nano Tesla per metre.

3.4 The following basic processing steps were applied to the data:

Removal of striping artifacts in the geomagnetic images caused by alternating changes in level between zig-zag traverses.

Removal of Random 'Spikes' present in the geomagnetic data due to small ferrous objects or fired stone on or near the ground surface. This process replaces spikes with the mean of near-neighbours.

DeShear corrects for apparent shear in strong geomagnetic anomalies surveyed by zig-zag traversing.

Correction for drift in magnetometer calibration with time.

Adjustment of grid mean values to achieve an optimum match along the lines of contact between data grids.

Interpolation of the data, using a bilinear function, to generate a regular mesh of values at 0.25 x 0.25m intervals.

Filtering of the data, using a 5x5m matrix, to reduce noise in the image caused by topsoil magnetic susceptibility variation and plough ridges.

3.5 The geophysical image was printed on a Hewlett Packard HP650C Designjet plotter with 256 grey shades and 600 dpi resolution. A sigmoid function was used to map the data to printed grey tones since this provides a measure of contrast equalisation. Appendix B provides more information about data processing and itemises the algorithms that were applied to produce the grey-scale image in Figure 2.

Key to Figure 3

3.6 A number of significant anomalies have been detected in the data and these are presented on a 1:1000 geophysical interpretation plan using coded colours and patterns (Figure 3). The following types of anomaly have been distinguished:

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

Blue Areas of anomalously low or negative magnetic field gradient, corresponding to features of low magnetic susceptibility, such as concentrations of sandstone rubble.

3.7 An archaeological interpretation plan at 1:1000 is presented in Figure 4 which includes feature codes **f1**, **f2**, etc, to assist in the discussion below.

4 INTERPRETATION

4.1 The most prominent geophysical anomaly detected by the survey comprises a positive lineation that bisects the site along an E-W axis. This anomaly becomes weaker towards the east and cannot be traced into the extreme SE corner of the survey area adjacent to the existing quarry. This geophysical anomaly provide good evidence for the existence of a soil-filled ditch or old field boundary (**f1**) that clearly extends beneath land NW of the surveyed area.

4.2 A pair of positive, linear magnetic anomalies, with SE orientation, have been traced for a distance of 50m close to the western edge of the surveyed area. The form of these anomalies suggests a ditch flanked by a stone-cored bank that may comprise part of an old field boundary or enclosure (**f2**).

4.3 Approximately 20m SW of feature **f2** the survey has detected a further positive magnetic lineation, with similar orientation, that can be traced for a distance of about 30m. Again, the character of the anomaly is consistent with the presence of a soil-filled ditch (**f3**) which (as with **f2** and **f1**) appears to continue NW beyond the study area.

4.4 A pair of weak and diffuse, positive magnetic lineations have been mapped SE of features **f2** and **f3** and may reflect extensions of these ditches (**f4** & **f5**).

4.5 A complex pattern of right-angled magnetic lineations, of positive and negative sign, has been detected in the extreme eastern corner of the survey area adjacent to Moor Road. These anomalies have been examined on a high-resolution computer monitor and are extracted in Figure 3. It seems possible that this pattern of geophysical disturbance may reflect joint patterns in the underlying rockhead.

However, an archaeological interpretation, such as a pattern of minor ditched enclosures and small trackways cannot be ruled out and may warrant further investigation (**f6**, Figure 4). A similar distribution of diffuse rectilinear anomalies of positive and negative sign has been detected in the northern third of the study area and has been marked as feature **f7** in Figure 4.

4.6 It is interesting to note that the line of the old field boundary (a previous stone wall) has not been detected by the geomagnetic survey. This suggests that very little stone debris associated with this structure remains in the subsoil.

5 SUMMARY AND CONCLUSIONS

5.1 A geophysical survey has been carried out on land immediately west and north of Gatherley Moor Quarry in order to identify features of archaeological interest.

5.2 The main feature detected by the survey appears to comprise a linear soil-filled ditch that can be traced east-west through the central part of the study area. This feature may represent an historic field boundary or a ditch of archaeological interest. No other subsoil anomalies appear to be connected to, or associated with this ditch.

5.3 A group of four sub-parallel minor ditches appear to have been detected in the southern third of the survey area.

5.4 The geophysical survey has mapped weak and diffuse rectilinear patterns of geophysical anomalies in the extreme east and northern parts of the area. These anomalies may simply reflect soil-filled joint patterns in the underlying sandstone but may alternatively be of archaeological interest.

6 CONFIDENCE LIMITS

6.1 The following are the levels of confidence which we assign to the features inferred from the geophysical survey:

f1	Ditch	80%		
f2	Ditch	50%	& Bank	15%
f3	Ditch	50%		
f4	Ditch	40%		
f5	Ditch	20%		
f6	Jointing	30%	or Enclosures	20%
f7	Jointing	30%	or Enclosures	20%

7 CREDITS

Survey: A. Newton BA, MA and A.C. Newton
Report: M. J. Noel PhD, FRAS
Date: 1st October 1999

Note: Whilst every effort has been taken in the preparation and submission of this report in order to provide as complete an assessment as possible within the terms of the brief, GeoQuest Associates cannot accept any responsibility for consequences arising as a result of unknown and undiscovered sites or artifacts.

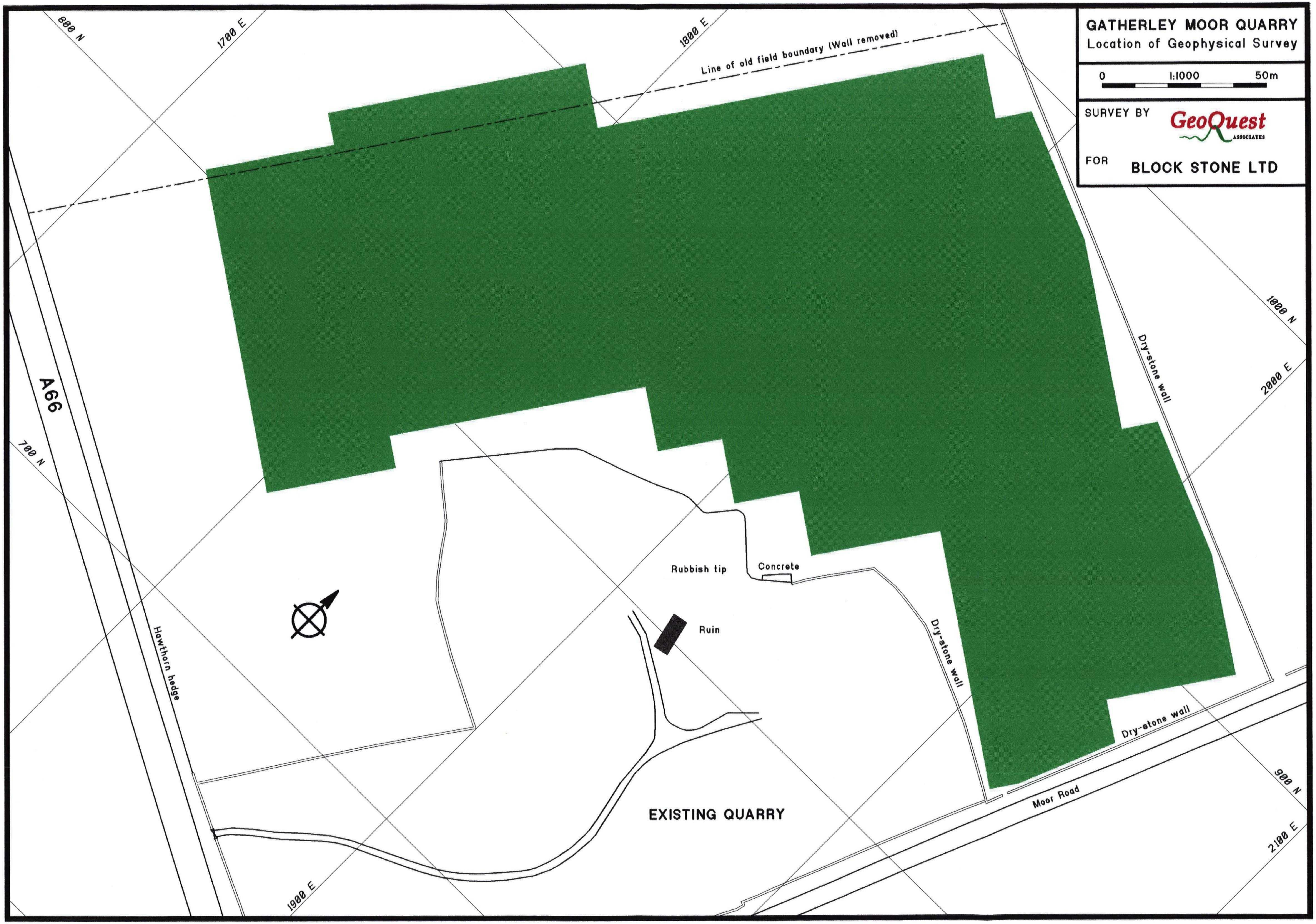

GATHERLEY MOOR QUARRY
Location of Geophysical Survey
0
1:1000
50m
SURVEY BY
GeoQuest
ASSOCIATES
FOR
BLOCK STONE LTD
800 N
1700 E
1800 E
Line of old field boundary (Wall removed)
1000 N
2000 E
Dry-stone wall
A66
700 N
Hawthorn hedge
Rubbish tip
Concrete
Ruin
Dry-stone wall
Dry-stone wall
EXISTING QUARRY
Moor Road
900 N
2100 E
1900 E

FIGURE 1

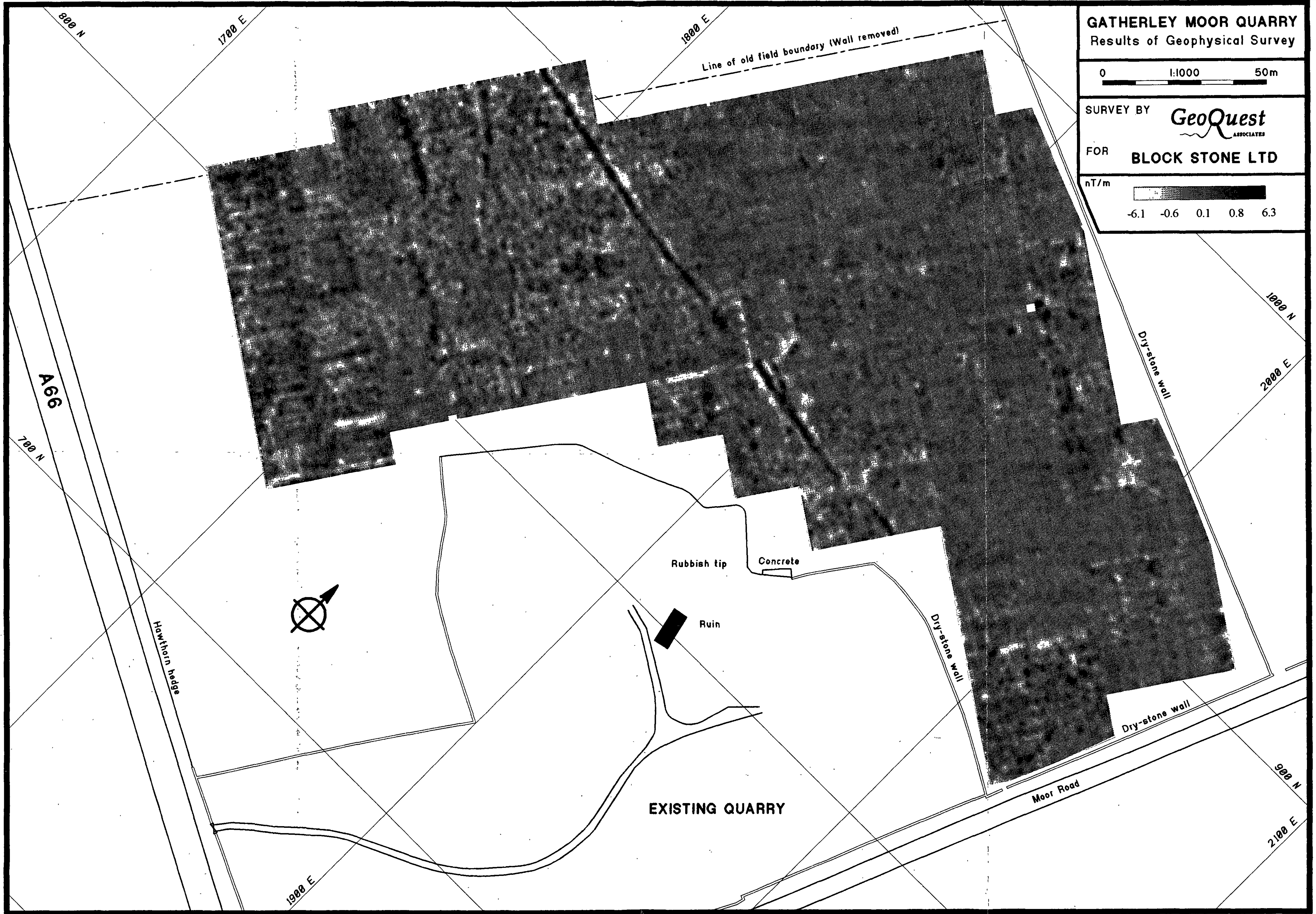

GATHERLEY MOOR QUARRY
Results of Geophysical Survey
0
1:1000
50m
SURVEY BY
GeoQuest ASSOCIATES
FOR
BLOCK STONE LTD
nT/m
-6.1 -0.6 0.1 0.8 6.3
800 N
1700 E
1800 E
Line of old field boundary (Wall removed)
1000 N
2000 E
Dry-stone wall
A66
700 N
Rubbish tip
Concrete
Ruin
Hawthorn hedge
Dry-stone wall
Dry-stone wall
900 N
Moor Road
2100 E
EXISTING QUARRY
1900 E

FIGURE 2

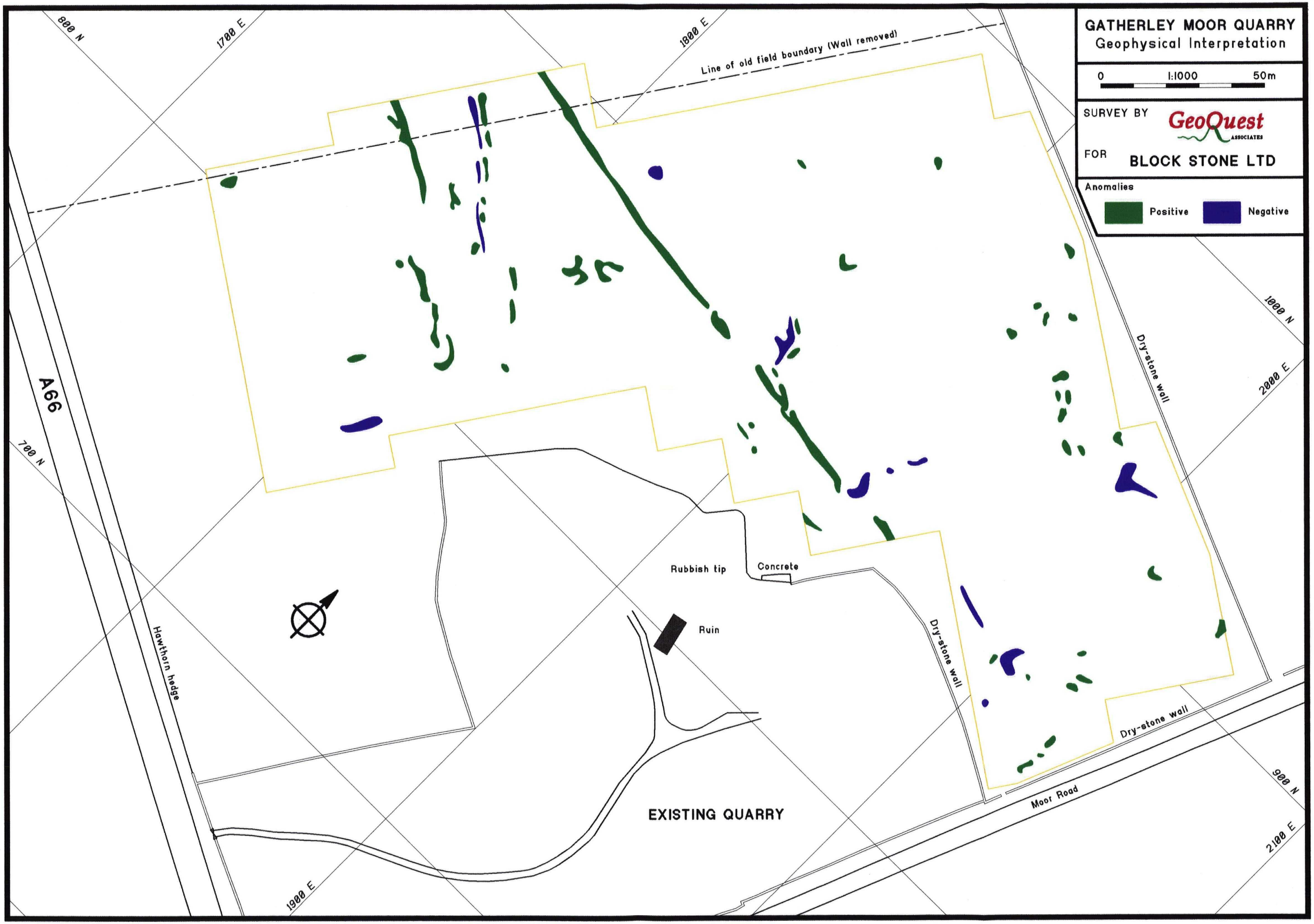

GATHERLEY MOOR QUARRY
Geophysical Interpretation
0 1:1000 50m
SURVEY BY GeoQuest ASSOCIATES
FOR BLOCK STONE LTD
Anomalies
Positive
Negative
800 N
1700 E
1800 E
Line of old field boundary (Wall removed)
1000 N
2000 E
Dry-stone wall
A66
700 N
Rubbish tip
Concrete
Ruin
Hawthorn hedge
Dry-stone wall
Dry-stone wall
Moor Road
900 N
2100 E
EXISTING QUARRY
1900 E

FIGURE 3

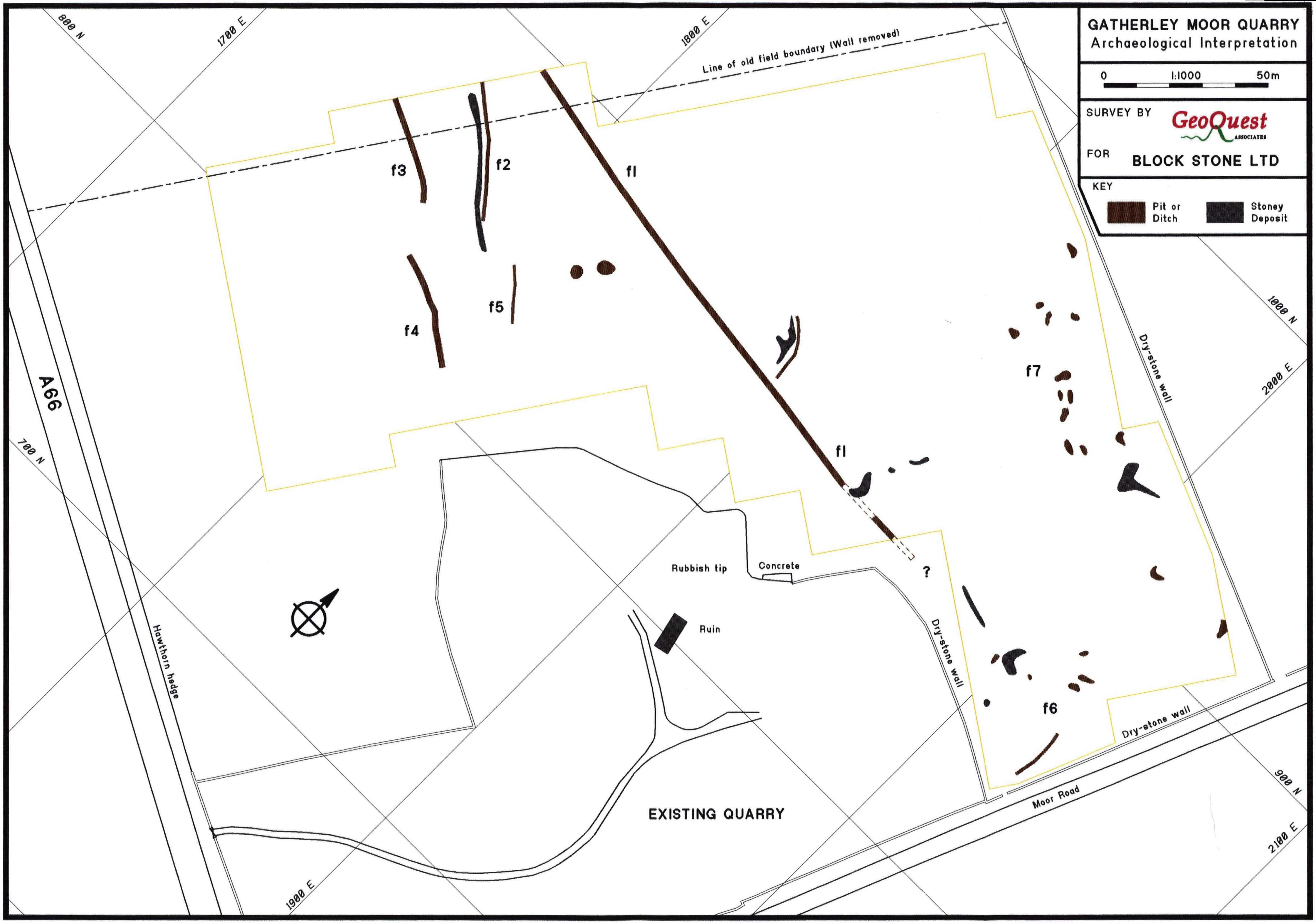

GATHERLEY MOOR QUARRY
Archaeological Interpretation
0
1:1000
50m
SURVEY BY
GeoQuest
ASSOCIATES
FOR
BLOCK STONE LTD
KEY
Pit or Ditch
Stoney Deposit
800 N
1700 E
1800 E
Line of old field boundary (Wall removed)
f1
f2
f3
f4
f5
f6
f7
1000 N
2000 E
Dry-stone wall
A66
700 N
?
Rubbish tip
Concrete
Ruin
Hawthorn hedge
Dry-stone wall
Dry-stone wall
900 N
Moor Road
2100 E
EXISTING QUARRY
1900 E

FIGURE 4

APPENDIX A

PRINCIPLES 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:

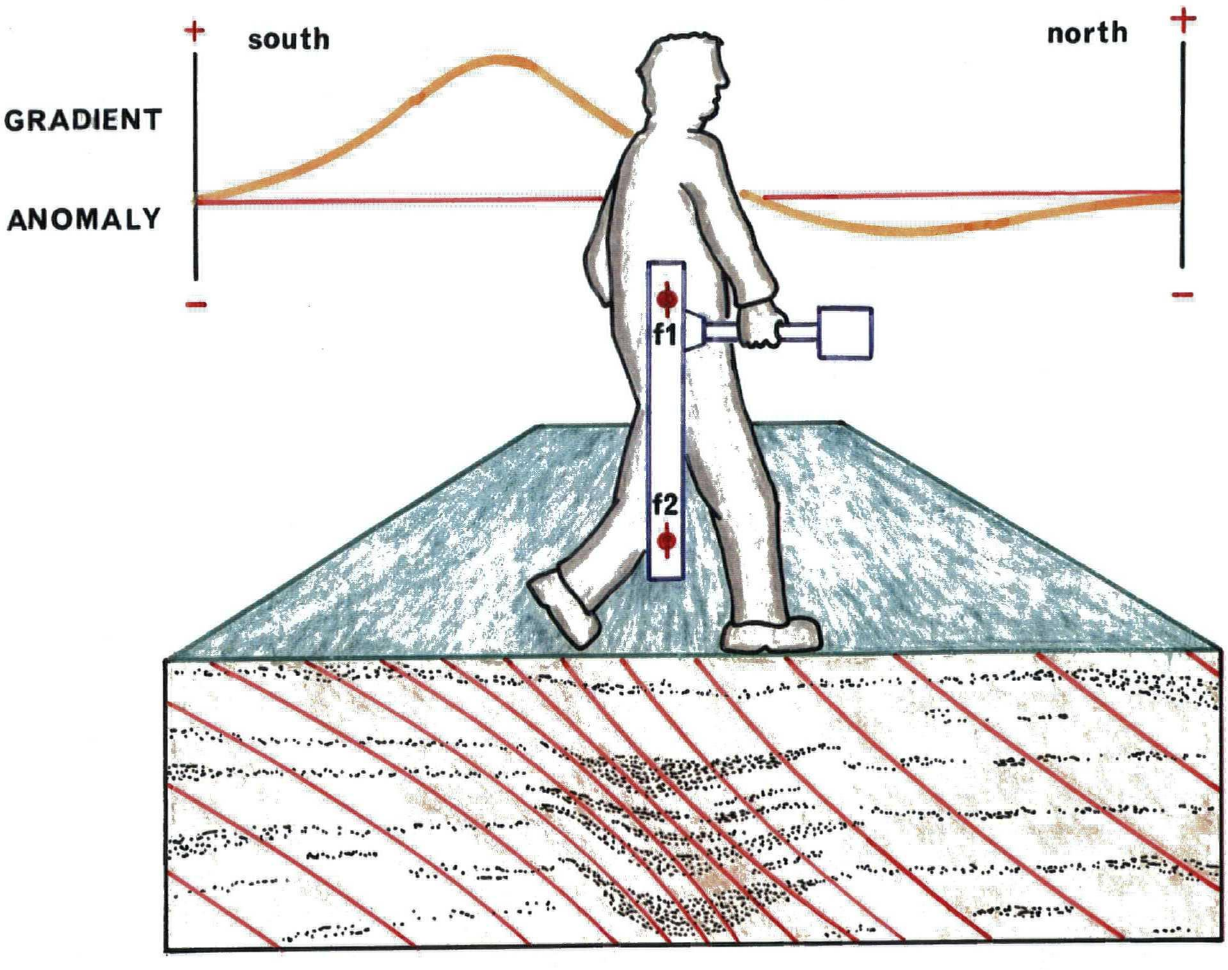
1 Anomalies arising from variations in *magnetic susceptibility* which will modulate the component of magnetisation *induced* in the subsurface by the Earth's magnetic field. For most archaeological sites, this is the dominant factor giving rise to geomagnetic anomalies. In general, susceptibility is relatively weak in sediments, such as sandstones and enhanced in igneous 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.

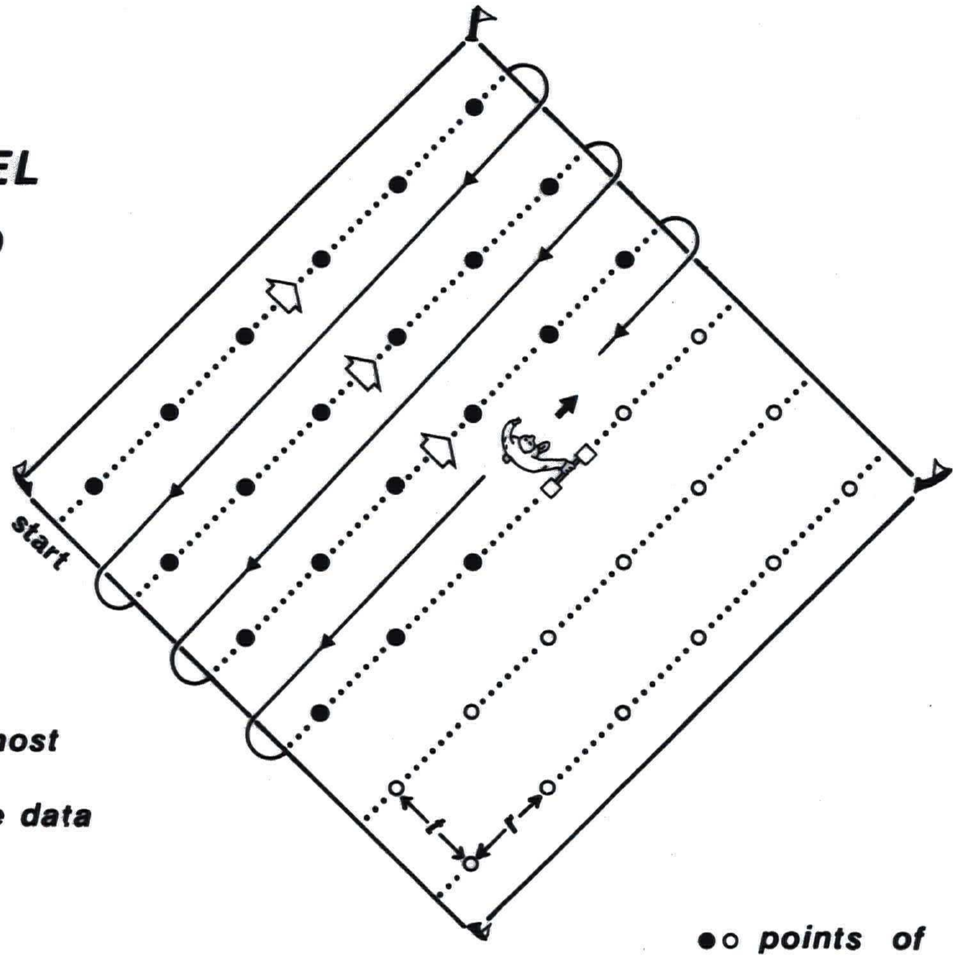
Two techniques can be used to survey gridded areas using the fluxgate magnetometer. In the parallel method the instrument is used to scan the area along traverses which are always in the same direction. This method minimises 'heading errors' due to operator and instrument magnetisation but is time consuming. 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

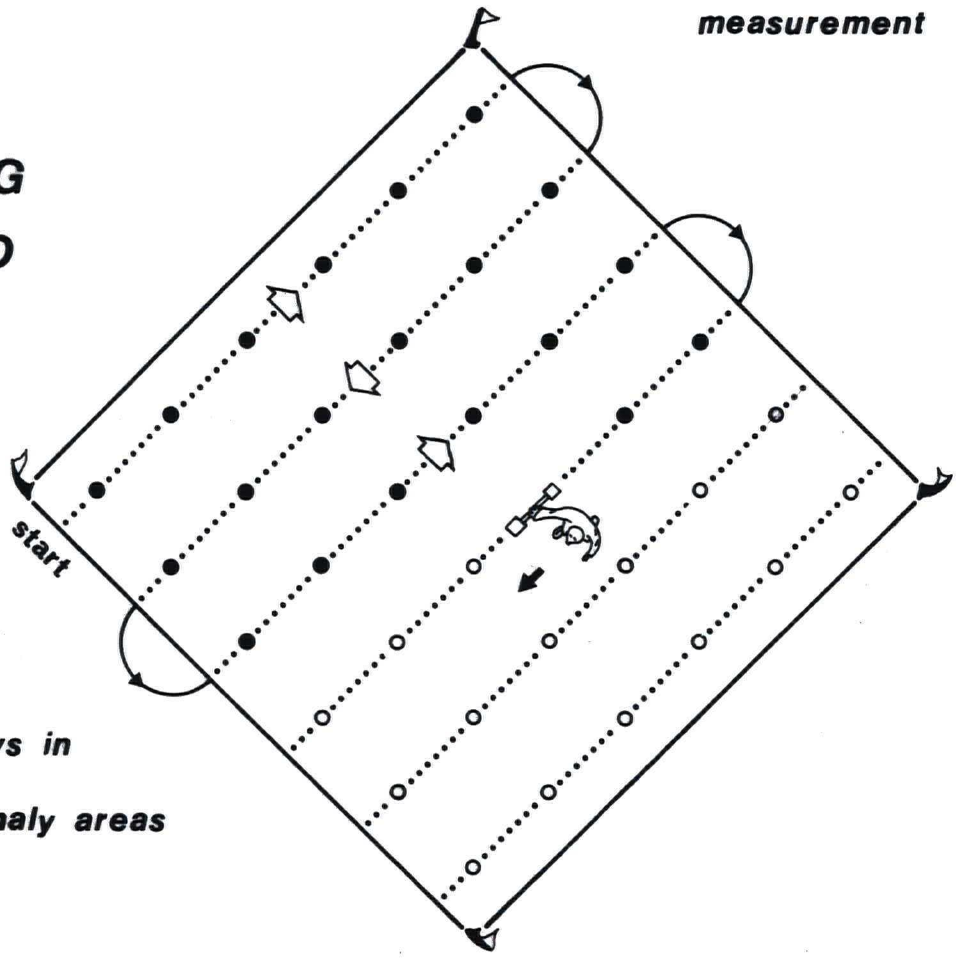
minimises most

errors in the data

●○ points of

measurement

ZIG-ZAG METHOD



suitable for

rapid surveys in

strong anomaly areas

APPENDIX B
DATA PROCESSING

PROCESSING THE SURVEY DATA

The geophysical images contained in this report were prepared within Microsoft Windows® using the **InSite®** program published by GeoQuest Associates. Geophysical images were then placed onto a map which was digitised from the Ordnance Survey, edited and then plotted using a computer aided drafting (CAD) system and colour inkjet printer.

Data were downloaded from the meter to a portable computer in the field for storage, visualisation and quality control (QC) assessment. These data were then transferred to a laboratory computer for final processing, printing and archiving.

A number of process steps have been applied to the geophysical data obtained during the survey and those which have been used are linked to the main flow path by arrows. Steps were applied in the order shown and are designed to reduce artifacts in the data and enhance geophysical features of archaeological interest. The following sections describe each step in more detail.

REMOVE STRIPING

Reduces a data artifact comprising alternating changes in level in readings logged along zig-zag traverses. This artifact is common in fluxgate magnetometer data. InSite uses a proprietary algorithm to reduce this error.

INFILL SMALL BLANK AREAS

Fills isolated blank data cells with the mean of near-neighbours or a suitable approximation entered manually. Small blank areas will have been logged if it was not possible to obtain a geophysical reading over, for example, a manhole cover in the case of a resistivity survey.

REMOVE SPIKES

Replaces isolated, anomalously high or low values with the mean of near neighbours or a suitable approximation entered manually. 'Spike' readings are commonly associated with ferrous litter or poor electrical contact in the case of geomagnetic and resistivity data, respectively.

REDUCE WALK HARMONICS

Reduces a regular oscillation in traverse data caused by walking movements of the operator during a geomagnetic survey. InSite employs a fast Fourier transform to determine the optimum amplitude and phase of the walk-induced harmonic which is then subtracted from each traverse.

REDUCE SHEAR ARTIFACTS

Corrects for apparent shear in geomagnetic anomalies surveyed by zig-zag traversing in a geomagnetic survey. The shearing effect arises from the interaction of the operator + magnetometer with the geomagnetic field and also from the lag in the instrument response to changes in the field. InSite uses a proprietary algorithm to reduce this error.

CORRECT FOR METER DRIFT

Corrects for a linear drift in the meter calibration with time. Such drift is a common problem with fluxgate magnetometers, particularly during periods of rapid air temperature change. InSite uses least-squares regression on the mean of data along each traverse to estimate the change in calibration level across each grid. This gradient is then removed from the data.

ADJUST GRID MEAN LEVELS

Adjusts for differences in the mean level in data grids due to changes in instrument calibration (fluxgate magnetometer survey) or alteration in remote electrode spacing (resistivity survey).

INTERPOLATE AND COMBINE

Combines grids to form an array of regularly-spaced data on a square mesh. InSite uses bilinear interpolation to accomplish this.

LOW PASS FILTER

If this process task is indicated then a 3x3 or 5x5 boxcar filter has been used to smooth the data and reduce noise or 'speckle' seen in the original image.

HIGH PASS FILTER

If this process task is indicated then a 3x3 or 5x5 filter, with appropriate coefficients, has been used to pass short-wavelength information into the resulting image.

EDGE DETECT FILTER

Signifies that a Sobel, Laplace or other specialised filter has been applied to enhance significant lateral transitions in the geophysical image.

DIRECTIONAL FILTER

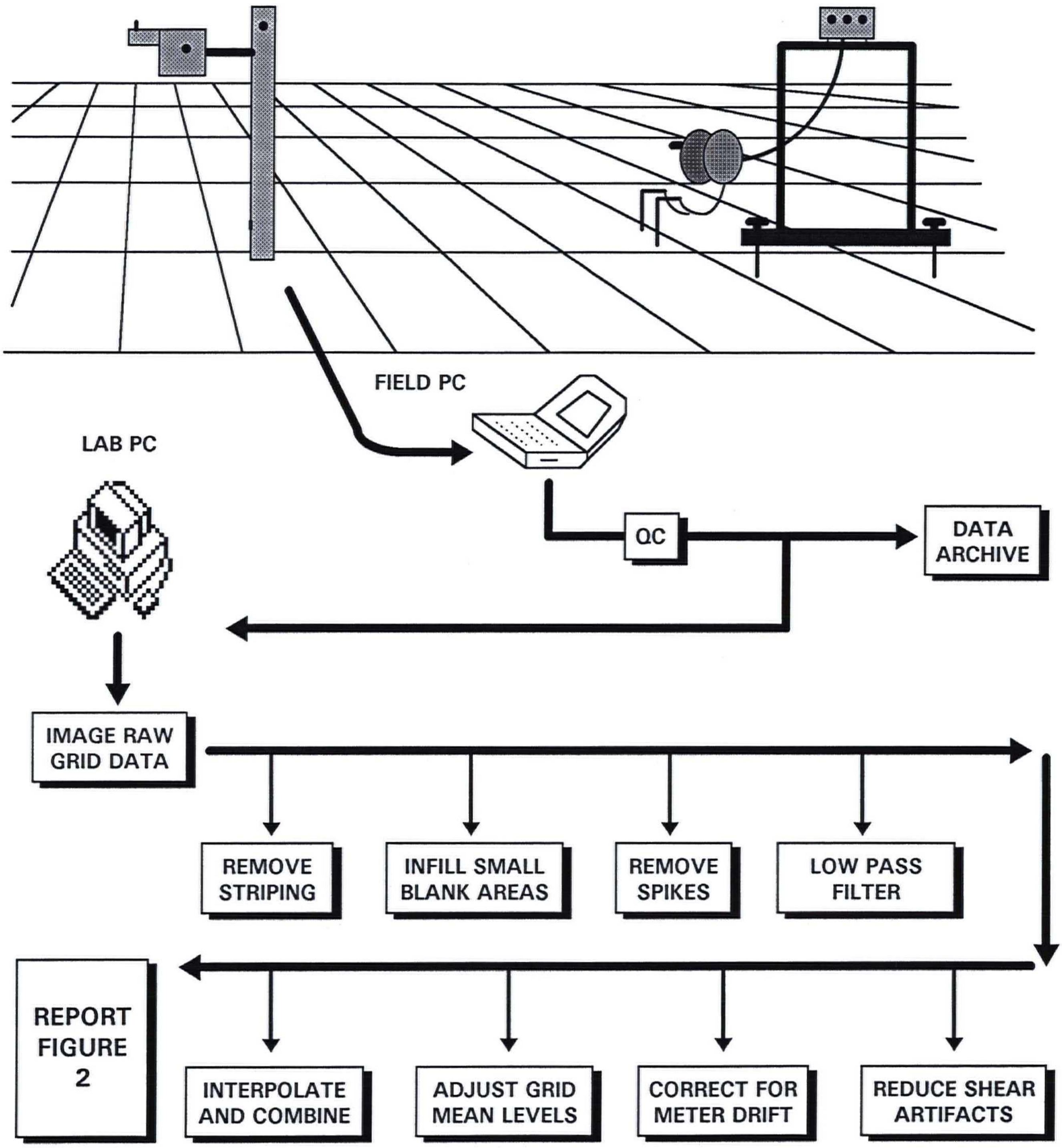
This filter is equivalent to illuminating the data from one direction to produce a pseudo-relief image. Directional filtering is usually employed to aid the identification of subtle anomalies in resistivity data. This filter highlights features trending at right angles to the direction of illumination.

NOTE

GeoQuest Associates can supply the geophysical images presented in this report in a variety of digital formats for visualisation on microcomputers running Microsoft Windows. These formats include the TIF, BMP and PCX standards. Please complete the request form at the rear of this report if you would like to receive such image files.

InSite

APPENDIX B
DATA PROCESSING



PROJECT: GATHERLEY MOOR

SITE: QUARRY EXTENSION