Denbigh Quarry, Denbighshire

Geophysical Survey Report
(Total Magnetic Intensity – Archaeology)

Version 1.0

Project code: DQD191

Produced for: Andrew Josephs Associates

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Environmental Geophysics – Survey, Research and Consultancy

TIGERGEO

Denbigh Quarry, Denbighshire

Digital data

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TIGERGEO

Non-Technical Summary

TigerGeo was commissioned by Andrew Josephs Associates on behalf of Breedon Southern Ltd. to undertake a magnetic survey of about five hectares of land to the west of Denbigh Quarry to inform subsequent archaeological evaluation. Survey was undertaken using an array of caesium vapour magnetometers towed by an ATV, covering all available area within the proposed expansion footprint.

Little of archaeological interest was seen, however, there is reasonable evidence for former enclosures and also cultivation, some of which may be of medieval or earlier date. There may also be an enclosure defined by a low magnetic intensity structure like a stony bank, however, a natural origin cannot be completely discounted.

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1 Introduction

TigerGeo was commissioned by Andrew Josephs Associates on behalf of Breedon Southern Ltd. to undertake a magnetic survey of land to the west of Denbigh Quarry to inform subsequent archaeological evaluation. The Till Deposits contribute to the magnetic susceptibility of the soil although there are presumably changes within this, or of the depth of soil, to account for the NE to SW transition from base rich soils to loamy ones. This change appears to be present in the magnetic data with the more variable texture apparently associated with the loamy soils. It is possible, indeed likely, that the cover of Till is not continuous and where it is absent the base-rich soils predominate; this would correlate with the magnetic result.

Survey was undertaken across three fields, covering an area of approximately 5.1 hectares. A few small gaps in the coverage in the southern fields were necessitated by the presence of trees but otherwise coverage was total.

Country	Wales
County	Denbighshire, Sir Ddinbych
Nearest Settlement	Smithfield
Central Co-ordinates	304700, 367000

2 Context

2.1 Environment

Soilscapes Classification	NE - Freely draining slightly acid but base rich soils (6), SW - Freely draining slightly acid loamy soils
Superficial 1:50000 BGS	Till, Devensian – Diamicton (TILLD)
Bedrock 1:50000 BGS	Clwyd Limestone Group (CLWYD)
Topography	Principal slope eastwards
Hydrology	Assumed free draining, but land drains seen in S
Current Land Use	Mixed Agricultural
Historic Land Use	Mixed Agricultural
Vegetation Cover	Grassland - Pasture
Sources of Interference	Nothing unusual, so wire boundary fences, etc.

2.2 Heritage

A Scoping Opinion by Pleydell Smithyman (2018) was consulted for archaeological background and this has identified that there are no known heritage assets within the site boundary or immediately adjacent to it. The site has been identified as within an area of low archaeological potential although this could reflect a lack of previous investigations.

The Clwyd Powys Archaeological Trust are the local advisors to the Mineral Planning Authority and may have been previously consulted.

A rapid due-diligence desk based assessment by TigerGeo prior to survey revealed nothing depicted on old OS map editions or publicly available aerial imagery that could be of archaeological interest.

3 Discussion

3.1 Character & Principal Results

3.1.1 Data Character

The data is of good quality throughout with reasonable magnetic contrast. At first glance the intensity data looks fairly complex but in combination with the result of a pseudo-gradient transformation the underlying magnetic structures become more evident.

Data character varies across the site with smoother texture to the north and east and a much more variable one to the south with an obvious strong geological input. Magnetic intensity varies by multiple nano-Tesla within a metres in this region but overall anomaly strength is also higher. Contrast is good throughout.

3.1.2 Geology

The Till Deposits contribute to the magnetic susceptibility of the soil although there are presumably changes within this, or of the depth of soil, to account for the NE to SW transition from base rich soils to loamy ones. This change appears to be present in the magnetic data with the more variable texture apparently associated with the loamy soils. It is possible, indeed likely, that the cover of Till is not continuous and where it is absent the base-rich soils predominate; this would correlate with the magnetic result.

The BGS G-BASE soil iron content is 3.4% at 5 km resolution, against a 3.8% 15 km regional average. Although this does not indicate site-specific conditions it does show that overall the soils have a high potential for magnetisation by artificial processes.

3.1.3 Land use

There is little direct evidence for past land use although there are some examples of cultivation reminiscent of narrow ridge and furrow, with a 4 – 5 m separation rather than the more common 6 – 7 m, at [7] and [11]. This does not obviously relate to the present field boundaries so may predate these.

No obvious former field boundaries are apparent within the data and none are known to have been removed since the 1890s OS map edition.

At [10] a spread of debris might indicate the former site of a small hollow, e.g. a pond or similar.

3.1.4 Archaeology

There is little conclusive evidence for features of archaeological interest but there are hints at former systems of enclosure. Seen against a strongly variable background, a wide (3 – 4 m) band of reduced magnetic intensity [3] and perhaps also [9] might be interpreted as a stony bank with a possible entrance at [4]. If so, its southeast flank would run along the contour. There are no direct indications of date but such a construction could be medieval or earlier. However, such an anomaly can also be generated by discontinuities in the limestone bedrock and hence there is a degree of ambiguity about this.

Elsewhere there are possible narrow ditch fills at [6] and [16], although these are uncertain and [6] in particular could relate to adjacent cultivation [7].

At [12] there may be a small diameter ring ditch, no more than 4 – 5 m across, however, this is as likely to be an artefact of juxtaposition of other anomalies including cultivation [12].

Further, less distinct, linear enhanced intensity anomalies at [8] may be natural in origin but there remains a small possibility that they could be ditch or gully fills.

3.2 Catalogue

Catalogue ID	Data Class	Anomaly Class	Form Class	Feature Class	Feature Sub-Class	Comments
1	TMI	Texture	Area	Agricultural	Cultivation	Probably modern and demonstrating the presence of a magnetically susceptible topsoil
2	TMI	Texture	Linear - discontinuous	Natural		There is here a transition between two soil textures, the relatively smooth one to the NE and the more variable one, perhaps due to thinner or different soil, to the SW. There is a similar transition at [13] between the same two textures [14] and [15]
3	TMI	Reduced	Linear - continuous	Structure?	Bank?	Possible foot of a former field boundary bank, not known from old OS map editions and irregular which could suggest enclosure within primary clearance and therefore a medieval or earlier date. There may be an entrance through it at [4]. In the southern field a more tentative continuation of this feature is highlighted as [9]. The bank, if that is what it is, would be a few metres wide but a natural origin is also possible
4	TMI	Reduced	Linear - continuous	Structure		See [3]
5	TMI	Texture	Area	Agricultural	Cultivation	Cultivation, maybe modern, although differently aligned to [1] within the same field
6	TMI	Enhanced	Linear - continuous	Fill		This may be a narrow (< 1 m) wide ditch fill or alternatively a more magnetic furrow from the set [7]
7	TMI	Texture	Area	Agricultural	Cultivation	Cultivation, probably not modern and similar in character to ridge and furrow but slightly more closely spaced furrows, so 4-5 m rather than 6-7 m
8	TMI	Enhanced	Linear - continuous	Fill		Possible narrow (< 1 m) ditch fill but equally possible a crack type structure within the top of the limestone
9	TMI	Reduced	Linear - continuous	Structure		See [3]
10	TMI	Strong variable	Area	Debris		A scatter of debris, maybe infilling a hollow or former pond, although none is known at this location

11	TMI	Texture	Area	Agricultural	Cultivation	Probably former cultivation, similar to [7], like ridge and furrow
12	TMI	Enhanced	Linear - continuous	Fill?	?	Uncertain, has the appearance of a small ring ditch but this may be misleading due to the interaction of possible cultivation anomalies [11] and natural sources
13	TMI	Texture	Linear - discontinuous	Natural		See [2] for a similar likely natural transition between magnetic textures, probably between different depths of soil
14	TMI	Reduced	Linear - continuous (group)	Agricultural	Drain	An area of land drains that appear to meet a spine parallel to textural transition [13]. This might imply that [13] was once also a field boundary
15	TMI	Texture	Area	Natural		The highly variable magnetic field in this area might imply a thinner soil compared to [14] to the east
16	TMI	Enhanced	Linear - continuous	Fill?	?	Possible ditch fill, but uncertain

3.3 Conclusions

The site has been identified as within an area of low archaeological potential and hence little was expected, an expectation that appears to be borne out by the magnetic data. There is though evidence for possible former enclosure, e.g. a large example defined by stony banks and maybe also some other enclosure ditches. The latter may be associated with areas of ridge and furrow like former cultivation present in at least two locations across the site.

3.4 Caveats

Geophysical survey is reliant upon the detection of anomalous values and patterns in physical properties of the ground, e.g. magnetic, electromagnetic, electrical, elastic, density and others. It does not directly detect underground features and structures and therefore the presence or absence of these within a geophysical interpretation is not a direct indicator of presence or absence in the ground. Specific points to consider are:

- some physical properties are time variant or mutually interdependent with others;
- for a buried feature to be detectable it must produce anomalous values of the physical property being measured;
- any anomaly is only as good as its contrast against background textures and noise within the data.

TigerGeo will always attempt to verify the accuracy and integrity of data it uses within a project but at all times its liability is by necessity limited to its own work and does not extend to third party data and information. Where work is undertaken to another party's specification any perceived failure of that specification to attain its objective remains the responsibility of the originator, TigerGeo meanwhile ensuring any possible shortcomings are addressed within the normal constraints upon resources.

4 Methodology

4.1 Magnetic Principles

4.1.1 Physical concepts

Magnetic survey for any purpose relies upon the generation of a clear magnetic anomaly at the surface, i.e. strong enough to be detected by instrumentation and exhibiting sufficient contrast against background variation to permit diagnostic interpretation. The anomaly itself is dependent upon the chemical properties of a particular volume of ground, its magnetic susceptibility and hence induced magnetic field, the strength of any remanent magnetisation, the shape and orientation of the volume of interest and its depth of burial. Finally the choice and configuration of measurement instrumentation will affect anomaly size and shape.

Sites present a complex mixture of these factors and for some the causative affects are not known. However, depth of burial and size are usually fairly constrained and background susceptibility can be estimated (or measured). The degree of remanent magnetisation is harder to predict and depends on both the natural magnetic properties of the soil and any chemical processes to which it has been subjected. Fortunately heat will raise the susceptibility of most soils and topsoil tends to be more magnetic than subsoil, by volume.

It is hard to draw reliable conclusions about what sort of geology is supportive of magnetic survey as there are many factors involved and in any case magnetic response can vary across geological units as well as being dependent upon post-deposition and erosional processes. In general a relatively non-magnetic parent material contrasting with a magnetisable erosion product, i.e. one which contains iron in the form of oxides and hydroxides, will allow archaeological structures to exhibit strong magnetic contrast against their surroundings and especially if the soil has been heated or subjected to certain processes of fermentation. In the absence of either, magnetic enhancement becomes entirely reliant upon the geochemistry of the soil and enhancement will often be weaker and more variable.

Analysis of the British Geological Survey (BGS) Geochemical Atlas (G-Base) for total soil iron reveals that for England and Wales 50% of the samples (the interquartile range) lie between 1.9% and 3.6% percentage iron with the median at 2.7%.

The principal magnetic iron mineral is the oxide magnetite which sometimes occurs naturally but is more often formed during the heating of soil. Subsequent cooling yields a mixture of this, non-magnetic oxide haematite and another magnetic oxide, maghaemite. Away from sources of heat, other magnetic iron minerals include the sulphides pyrite and greigite while in damp soils complex chemistry involving the hydroxides goethite and lepidocrocite can create strong magnetic anomalies. There are thus a number of different geochemical reaction pathways that can both augment and reduce the magnetic susceptibility of a soil. In addition, this susceptibility may exhibit depositional patterns unrelated to visible stratigraphy.

Most structures of archaeological interest detected by magnetic survey are fills within negative or cut features. Not all fills are magnetic and they can be more magnetic or less magnetic than the surrounding ground. In addition, it is common for fills to exhibit variable magnetic properties through their volume, basal primary silt often being more magnetic than the material above it due to the increased proportion of topsoil within it. However, a fill containing burnt soil may be much more magnetic than this primary silt and sometimes a feature that has contained standing water can produce highly magnetic silts through mechanical depositional processes (depositional remanent magnetisation, DRM).

A third structural factor in the detection of buried structures is the depth of topsoil over the feature. As fills sink, the hollow above accumulates topsoil and hence a structure can be detected not through its own magnetisation but through the locally deeper topsoil above it. The volume of soil required depends upon the magnetic susceptibility of the soil but just a few centimetres are often sufficient. Such a thin deposit can, however, easily be lost through subsequent erosion by natural factors or ploughing.

4.1.2 Instrumentation

The use of the magnetic sensors in non-gradiometric (vertical) configuration avoids measurement sensitisation to the shallowest region of the soil, allowing deeper structures, whether natural or otherwise to be imaged within the sensitivity of the instrumentation. This also allows the detection of shallow broad variations in magnetic susceptibility that might have archaeological significance. Suppression of ambient noise and temporal trends is reduced and therefore need reduction during processing.

The theoretical slightly reduced lateral resolution inherent to using non-gradiometric sensor arrays is practically not an issue and especially if processing includes a vertical pseudo-gradient conversion. The non-gradiometric system is thus overall a more capable configuration than the short gradiometers often used for archaeological studies.

Caesium instrumentation has a greater sensitivity than fluxgate instruments, however, at the 10 Hz sampling rate used here this increase in sensitivity is limited to about one order of magnitude. Greater benefit is obtained from a better signal-to-noise ratio meaning that sub-nanoTesla measurement is more practically achieved.

The array system is designed to be non-magnetic and to contribute virtually nothing to the magnetic measurement, whether through direct interference or through motion noise.

4.2 Magnetic Survey

4.2.1 Technical equipment

Measured variable	Magnetic flux density / nT (Total Magnetic Intensity / nT after removal of regional trend)
Instrument	Array of Geometrics G858 Magmapper caesium magnetometers
Configuration	Non-gradiometric transverse array 4 sensors, ATV towed
Sensitivity	0.03 nT @ 10 Hz (manufacturer's specification)
QA Procedure	Continuous observation
Spatial resolution	1.0m between lines, 0.25m mean along line interval

4.2.2 Monitoring & quality assessment

The system continuously displays all incoming data as well as line speed and spatial data resolution per acquisition channel during survey. Rest mode system noise is therefore easy to inspect simply by pausing during survey, and the continuous display makes monitoring for quality intrinsic to the process of undertaking a survey. Rest mode test results (static test) are available from the system.

4.3 Magnetic Data Processing

4.3.1 Procedure

All data processing is minimised and limited to what is essential for the class of data being collected, e.g. reduction of orientation effects, suppression of single point defects (drop-outs or spikes) etc. The processing stream for this data is as follows:

Process	**Software**	**Parameters**
Measurement & GNSS receiver data alignment	Proprietary	
Temporal reduction, regional field suppression	Proprietary	Bandpassed 0.3 – 10.0s
Gridding	Surfer	Kriging, 0.25m x 0.25m
Smoothing	Surfer	Gaussian lowpass 3x3 data (0.75m)
Pseudo-gradient conversion	Proprietary	1m vertical

Potential field processing procedures are used where possible on gridded data from the above processing, allowing simulation of vertical gradient data, separation of deep and shallow magnetic sources, etc. The initial processing uses proprietary software developed in conjunction with the multisensor acquisition system. Gridded data is ported as data surfaces (not images) into Manifold GIS for final imaging, contouring and detailed analysis. Specialist analysis is undertaken using proprietary software.

4.4 Magnetic Interpretation

4.4.1 Introduction

Numerous sources are used in the interpretive process, which takes into account shallow geological conditions, past and present land use, drainage, weather before and during survey, topography and any previous knowledge about the site and the surrounding area. Old Ordnance Survey mapping is consulted and also older sources if available. Geological information (for the UK) is sourced only from British Geological Survey resources and aerial imagery from online sources. LiDAR data is usually sourced from the Environment Agency or other national equivalents, SAR from NASA and other topographic data from original survey.

Information from nearby surveys is consulted to inform upon local data character, variations across soils and near-surface geological contexts. Published data from other surveys may also be used if accompanied by adequate metadata.

Interpretation of magnetic data is undertaken using total intensity data, vertical pseudo-gradient and where relevant, shallow field, component models in parallel although for clarity only a subset of these may be presented in the report.

4.4.2 The contribution from geology and soils

On some sites, e.g. some gravels and alluvial contexts, there will be anomalies that can obscure those potentially of archaeological interest. They may have a strength equal to or greater than that associated with more relevant sources, e.g. ditch fills, but can normally be differentiated on the basis of anomaly form coupled with geological understanding. Where there is ambiguity, or relevance to the study, these anomalies will be included in this category.

Not all changes in geological context can be detected at the surface, directly or indirectly, but sometimes there will be a difference evident in the geophysical data that can be attributed to a change, e.g. from alluvium to tidal flat deposits, or bedrock to alluvium. In some cases the geophysical difference will not exactly coincide with the geological contact and this is especially the case across transitions in soil type.

Geophysical data varies in character across areas, due to a range of factors including soil chemistry, near surface geology, hydrology and land use past and present. These all contribute to the texture of the data, i.e. a background character against which all other anomalies are measured.

4.4.3 Agricultural inputs

Coherent linear dipolar enhancement of magnetic field strength marking ditch fills, narrow bands of more variable magnetic field or changes in apparent magnetic susceptibility, are all included within the category of former field boundaries if they correlate with those depicted on the Tithe Map or early Ordnance Survey maps. If there is no correlation then these anomaly types are not categorised as a field boundaries.

Banded variations in apparent magnetic susceptibility caused by a variable thickness of topsoil, depositional remanent magnetisation of sediments in furrows or susceptibility enhancement through heating (a by product of burning organic matter like seaweed) tend to indicate past cultivation, whether ridge-based techniques, medieval ridge and furrow or post medieval 'lazy beds'. Modern cultivation, e.g. recent ploughing, is not included.

In some cases it is possible to identify drainage networks either as ditch-fill type anomalies (typically 'Roman' drains), noisy or repeating dipolar anomalies from terracotta pipes or reduced magnetic field strength anomalies from culverts, plastic or non-reinforced concrete pipes. In all cases identification of a herring bone pattern to these is sufficient for inclusion within this category.

4.4.4 Features of archaeological interest

Any linear or discrete enhancement of magnetic field strength, usually with a dipolar character of variable strength, that cannot be categorised as a field boundary, cultivation or as having a geological origin, is classified as a fill potentially being of archaeological interest. Fills are normally earthen and include an often invisible proportion of heated soil or topsoil that augments local magnetic field strength. Inverted anomalies are possible over non-earthen fills, e.g. those that comprise peat, sand or gravel within soil. This category is subject to the 'habitation effect' where, in the absence of other sources of magnetic material, anomaly strength will decrease away from sources of heated soil and sometimes to the extent of non-detectability.

Former enclosure ditches that contained standing water can promote enhanced volumetric magnetic susceptibility through depositional remanence and remain detectable regardless of the absence of other sources of magnetic enhancement.

Anything that cannot be interpreted as a fill tends to be a structure, or in archaeological terms, a feature. This category is secondary to fills and includes anomalies that by virtue of their character are likely to be of archaeological interest but cannot be adequately described as fills. Examples include strongly magnetic bodies lacking ferrous character that might indicate hearths or kilns. In some cases anomalies of ferrous character may be included.

On some sites the combination of plan form and anomaly character, e.g. rectilinear reduced magnetic field strength anomalies, might indicate the likely presence of masonry, robber trenches or rubble foundations. Other types of structure are only included if the evidence is unequivocal, e.g. small ring ditches with doorways and hearths. In some circumstances a less definite category may be assigned to the individual anomalies instead.

It is sometimes possible to define different areas of activity on the basis of magnetic character, e.g. texture and anomaly strength. These might indicate the presence of middens or foci within larger complexes. This category does not indicate a presence or absence of discrete anomalies of archaeological interest.

4.5 Glossary

Acronym	Type	Definition
A	Physical quantity	SI unit Amp of electric current
BGS	Organisation	British Geological Survey
CIfA	Organisation	Chartered Institute for Archaeologists
dB	Physical quantity	Decibel, unit of amplification / attenuation
DRM	Process	Depositional Remanent Magnetisation
EAGE	Organisation	European Association of Geoscientists and Engineers
EGNOS	Technology	European Geostationary Navigation Overlay Service
ERT	Technology	Electrical resistivity tomography
ETRS89	Technology	European Terrestrial Reference System (defined 1989)
ETSI	Organisation	European Telecommunications Standards Institute
EuroGPR	Organisation	European Ground Penetrating Radar Association, the trade body for GPR professionals
G-BASE	Data	British Geological Survey Geochemical Atlas
GeolSoc	Organisation	Geological Society of London, the chartered body for the geological profession
GNSS	Technology	Global Navigation Satellite System
GPR	Technology	Ground penetrating radar
GPS	Technology	Global Positioning System (US)
inversion	process	A combination of forward and backward modelling intended to construct a 2D or 3D model of the physical distribution of a variable from data measured on a 1D or 2D surface. It is fundamental to ERT survey
IP	Physical quantity	Induced polarisation (or chargeability) units mV/V or ms
m	Physical quantity	SI unit metres of distance
mbgl	Physical quantity	Metres below ground level
MHz	Physical quantity	SI unit mega-Hertz of frequency
MS	Physical quantity	Magnetic susceptibility, unitless
mS	Physical quantity	SI unit milli-Siemens of electrical conductivity
nT	Physical quantity	SI unit nano-Tesla of magnetic flux density

Acronym	Type	Definition
OFCOM	Organisation	The Office of Communications, the UK radio spectrum regulator
Ohm	Physical quantity	SI unit Ohm of electrical resistance
OS	Organisation	Ordnance Survey of Great Britain
OSGB36	Data	The OS national grid (Great Britain)
OSTN15	Technology	Current coordinate transformation from ETRS89 to OSGB36 co-ordinates
RDP	Physical quantity	Relative Dielectric Permittivity, unitless
RTK	Technology	Real Time Kinematic (correction of GNSS position from a base station)
s	Physical quantity	SI unit seconds of time
TMI	Physical quantity	Total magnetic intensity (measured flux density minus regional flux density)
TRM	Process	Thermo-Remanent Magnetisation
V	Physical quantity	SI unit Volt of electric potential
WGS84	Data	World Geodetic System (defined 1984)

4.6 Selected reference

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4.7 Archiving and dissemination

An archive is maintained for all projects, access to which is permitted for research purposes. Copyright and intellectual property rights are retained by TigerGeo on all material it has produced, the client having full licence to use such material as benefits their project. Where required, digital data and a copy of the report can be archived in a suitable repository, e.g. the Archaeology Data Service, in addition to our own archive.

The archive contains all survey and project data, communications, field notes, reports and other related material including copies of third party data (e.g. CAD mapping, etc.) in digital form. Many are in proprietary formats while report components are available in PDF format.

The client will determine the distribution path for reporting, including to the end client, other contractors, local authority etc., and will determine the timetable for upload of the project report to the OASIS Grey Literature library or supply of report or data to other archiving services, taking into account end client confidentiality.

TigerGeo reserves the right to display data rendered anonymous and un-locatable on its website and in other marketing or research publications.

5 Supporting information

5.1 Standards and quality (archaeology)

TigerGeo is developing an Integrated Management System (IMS) towards ISO certification for ISO9001, ISO14001 and OHSAS18001/ISO45001. For work within the archaeological sector TigerGeo has been awarded CIfA (Chartered Institute for Archaeologists) Registered Organisation status.

A high standard of client-centred professionalism is maintained in accordance with the requirements of relevant professional bodies including the Geological Society of London (GeolSoc) and the Chartered Institute for Archaeologists (CIfA). Senior members of TigerGeo are professional members of the GeolSoc (FGS), CIfA (MCIfA & ACIfA grades) and other appropriate bodies, including the European Association of Geoscientists and Engineers (EAGE) Near Surface Division (MEAGE) and the Institute of Professional Soil Scientists (MISoilSci).

In addition TigerGeo is a member of EuroGPR and all ground penetrating and other radar work is in accordance with ETSI EG 202 730.

The management team at TigerGeo have almost 50 years of combined experience of near surface geophysical project design, survey, interpretation and reporting, based across a wide range of shallow geological contexts. Added to this is the considerable experience of our lead geophysicists in a variety of commercial and academic roles. All geophysical staff have graduate and in many cases also post-graduate relevant qualifications pertaining to environmental geophysics from recognised centres of academic excellence.

During fieldwork there is always a fully qualified (to graduate or post-graduate level) supervisory geophysicist leading a team of other geophysicists and geophysical technicians, all of whom are trained and competent with the equipment they are working with. Data processing and interpretation is carried out by a suitably qualified and experienced geophysicist under the direct supervision and guidance of the Senior Geophysicist. All work is monitored and reviewed throughout by the Senior Geophysicist who will appraise all stages of a project as it progresses.

Data processing and interpretation adheres to the scientific principles of objectiveness and logical consistency. A standard set of approved external sources of information, e.g. from the British Geological Survey, the Ordnance Survey and similar sources of data, in addition to previous TigerGeo projects, guide the interpretive process. Due attention is paid to the technical constraints of method, resolution, contrast and other geophysical factors.

There is a strong culture of internal peer-review within TigerGeo, for example, all reports pass through a process of authorship, technical review and finally proof-reading before release to the client. Technical queries resulting from TigerGeo's work are reviewed by the Senior Geophysicist to ensure uniformity of response prior to implementing any edits, etc.

Work is undertaken in accordance with the high professional standards and technical competence expected by the Geological Society of London and the European Association of Geoscientists and Engineers.

All work for archaeological projects is also conducted in accordance with the following standards and guidance:

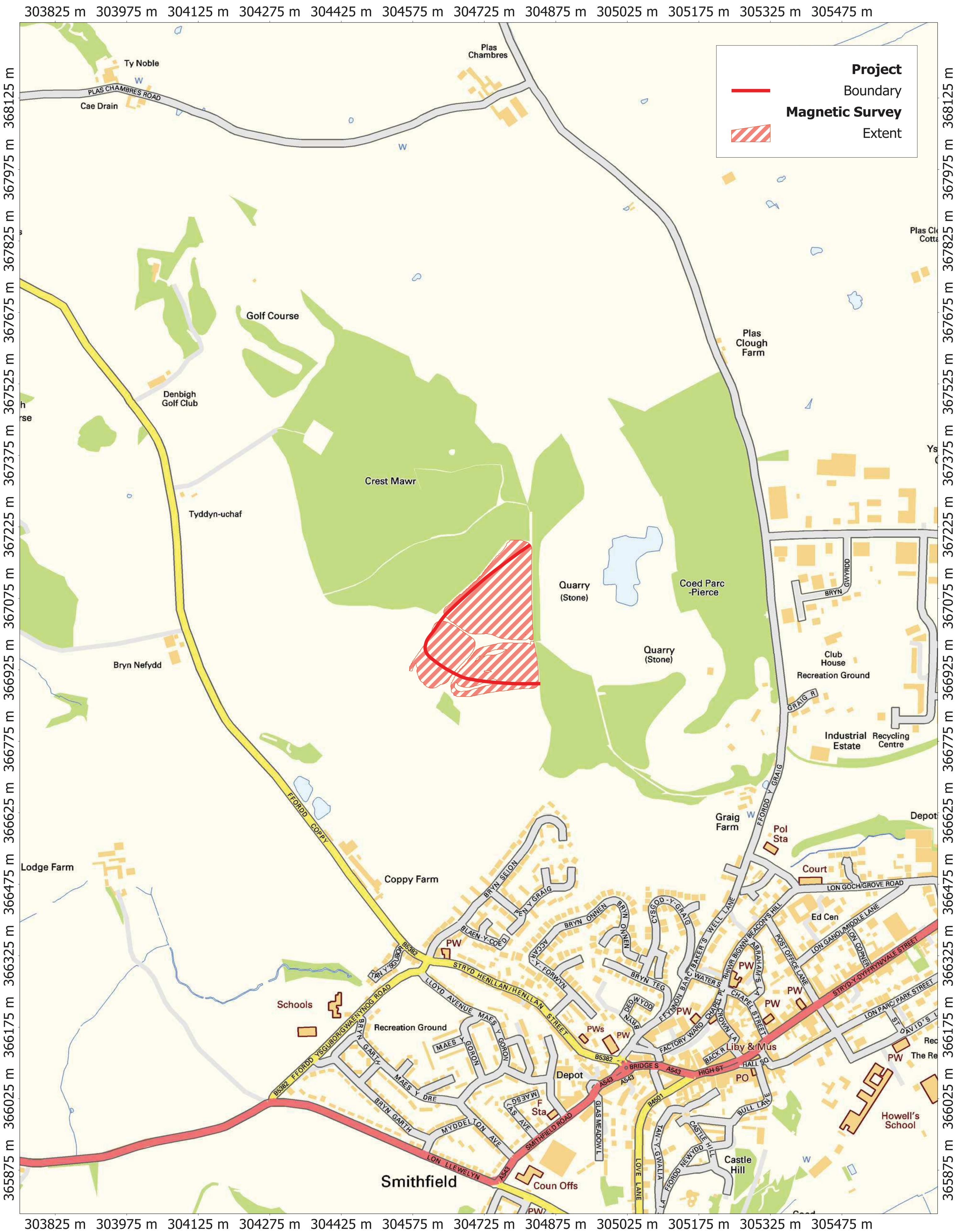
- David et al, "Geophysical Survey in Archaeological Field Evaluation", English Heritage, 2008;
- "Standard and guidance for Archaeological Geophysical survey", Chartered Institute for Archaeologists, 2014 (Updated 2016);

and TigerGeo meets with ease the requirements of English Heritage in their 2008 Guidance "Geophysical Survey in Archaeological Field Evaluation" section 2.8 entitled "Competence of survey personnel".

5.2 Key personnel

Martin Roseveare, MSc BSc(Hons) MEAGE FGS MCIfA	**Senior Geophysicist, Director**
Martin specialised (MSc) in geophysical prospection for shallow applications and since 1997 has worked in commercial geophysics. Elected a GeolSoc Fellow in 2009 he is now working towards achieving CSci. A member of the European Association of Geoscientists & Engineers, he has served on the EuroGPR and CIfA GeoSIG committees and on the scientific committees of the 10th and 11th Archaeological Prospection conferences. He has reviewed papers for the EAGE Near Surface conference, was a technical reviewer of the Irish NRA geophysical guidance and is a founding member of the ISSGAP soils group. Professional interests include the application of geophysics to agriculture and the environment, e.g. groundwater and geohazards. He is also a software writer and equipment integrator with significant experience of embedded systems.	
Anne Roseveare, BEng(Hons) DIS MISoilSci	**Operations Manager, Environmental Geophysicist - Data Analyst**
On looking beyond engineering, Anne turned her attention to environmental monitoring and geophysics. She is a Member of the British Society of Soil Science (BSSS) and has specific areas of interest in soil physics & hydrology, agricultural applications and industrial sites. Amongst other contributions to the archaeological geophysics sector over the last 18 years, Anne was the founding Editor of the International Society for Archaeological Prospection (ISAP) and is a founding member of the ISSGAP soils group. Specifications, logistics, safety, data handling & analysis are integral parts of her work, though she is happily distracted by the possibilities of discovering lost cities, hillwalking and good food.	
Jennifer Smith, MSc	**Fieldwork Manager, Environmental Geophysicist**
Jen developed an interest in all aspects of topographical and geophysical survey whilst studying for a MSc in Archaeological Science at the University of Bristol. During her studies she obtained valuable experience in the use of and data analysis for various terrestrial geophysical techniques as well as develop her interest further by adding marine geophysical techniques to her working theoretical knowledge. She has worked as a near-surface geophysicist within archaeology for several years and has developed a good knowledge of UK geology. Outside of work, Jen is currently learning Java code but is easily distracted by keeping fit, exploring the world or some other hobby.	
Daniel Lewis, MA BA(Hons) ACIfA	**Consultant Archaeologist**
Daniel studied archaeology at the University of Nottingham and worked in field archaeology for many years, managing urban and rural fieldwork projects in and around Herefordshire. When the desk became more appealing he jumped into the world of consulting, working on small and large multi-discipline projects throughout England and Wales. At the same time, he returned to University, gaining an MA in Historic Environment Conservation. With over 15 years' experience in the heritage sector, Daniel has a diverse portfolio of skills. Here he ensures that geophysical work within the heritage sector is well grounded in the archaeology. His spare time includes much running up mountains	
Luigi Benente, MSc	**Consultant Environmental Geophysicist**
Luigi is an experienced geologist specialized in geophysics, who gained a blend of practical and technical experience within explorations carried out in Italy, Peru, Colombia, Ecuador, Mexico, Uzbekistan, Thailand and Nigeria. Resourceful and hardworking with a positive attitude in problem solving, he has the ability to lead a team through challenging tasks, organizing people and equipment in order to hit the goal in safety and with time conscious professionalism. He is attracted to discover hidden things within the earth and after celebrating with friends, good wine, good beer and lots of food he is able to repair most broken things...	

Alexandra Gerea, MSc, BSc, PhD Candidate	**Geophysical Processor & Analyst**
Alexandra has a BSc in Geophysics and an MSc in Applied Geo-biology and started a PhD in the UK after living in Portugal for six months working on her master's degree. Since 2008 she has used most mainstream processing applications across electrical, magnetic and radar methods. She combines a love of nature and science and is currently studying plant roots in agricultural environments using geophysical methods. When not doing that she enjoys travelling, hiking, nature, yoga, books, foreign languages and cats. Two years ago she found a passion for electronics and started building different devices including intelligent gardening systems and coding in Python.	



DQD191 Denbigh Quarry, Denbighshire

DWG 01 Site Location

Orthographic Scale: 1:10000 @ A4 Spatial Units: Meter. Do not scale off this drawing

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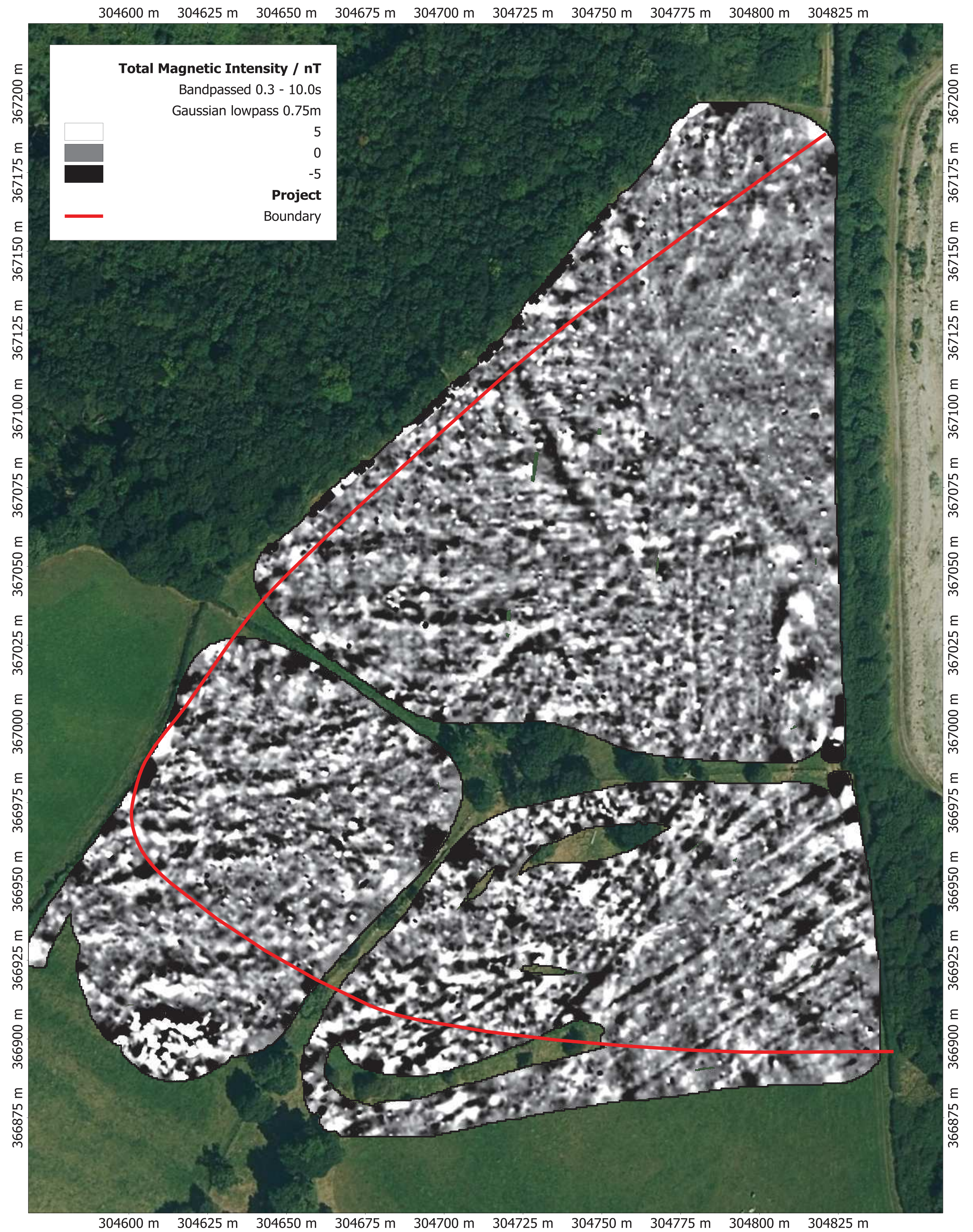

DQD191 Denbigh Quarry, Denbighshire
DWG 02a Total Magnetic Intensity Data

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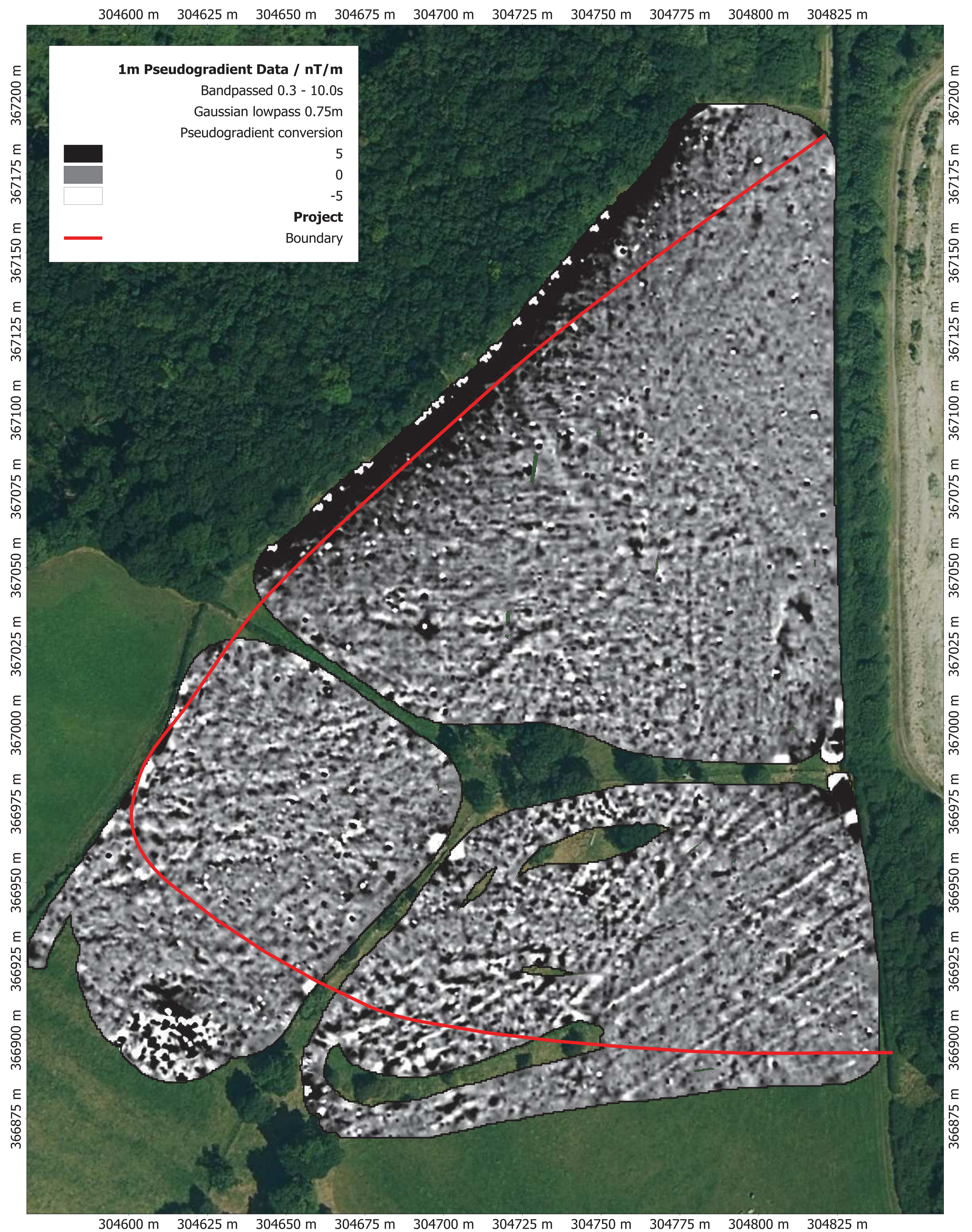

DQD191 Denbigh Quarry, Denbighshire
DWG 02b Vertical 1m Pseudogradient Data

Orthographic Scale: 1:1500 @ A4 Spatial Units: Meter. Do not scale off this drawing

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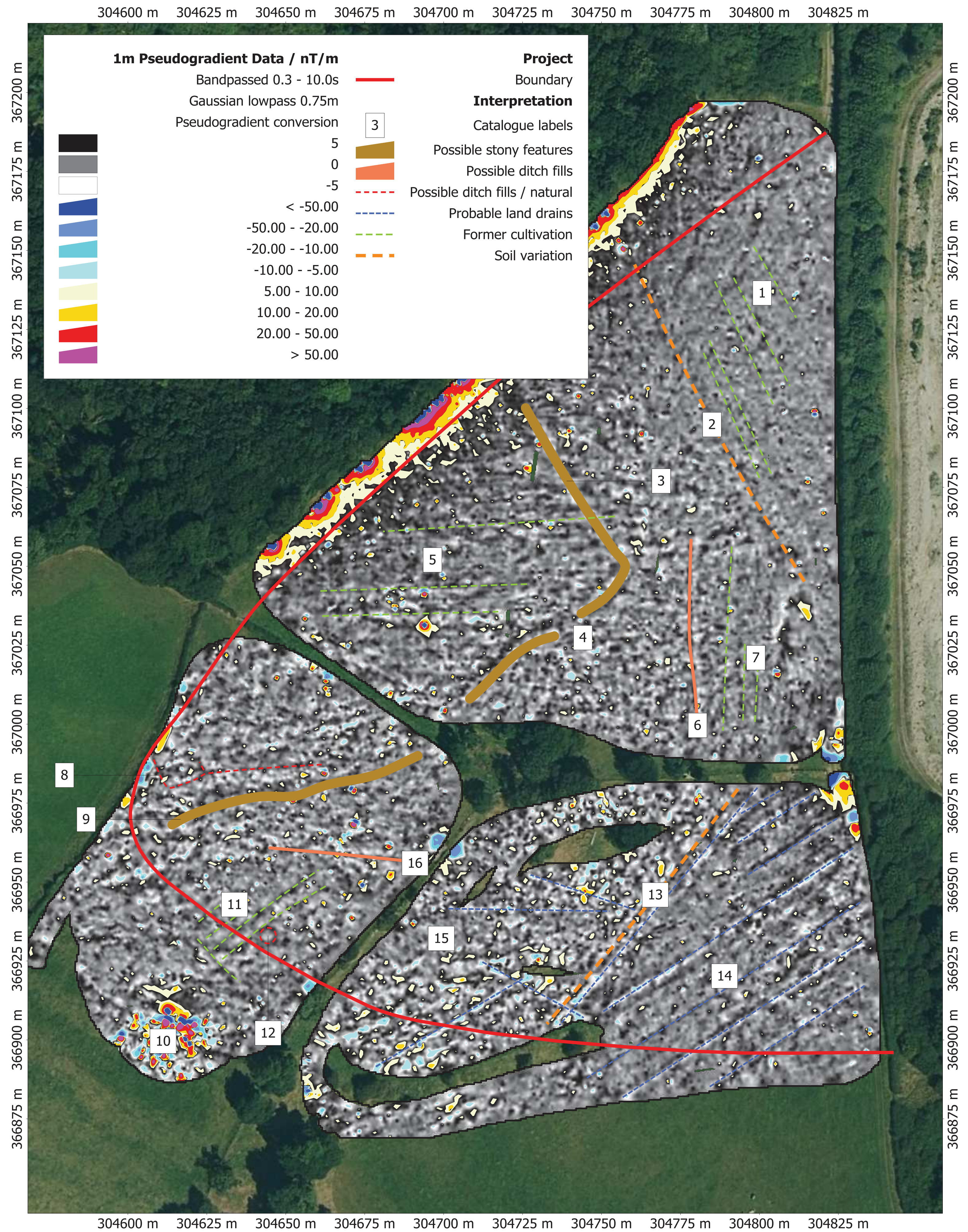

DQD191 Denbigh Quarry, Denbighshire
DWG 03 Interpretation

Orthographic Scale: 1:1500 @ A4 Spatial Units: Meter. Do not scale off this drawing
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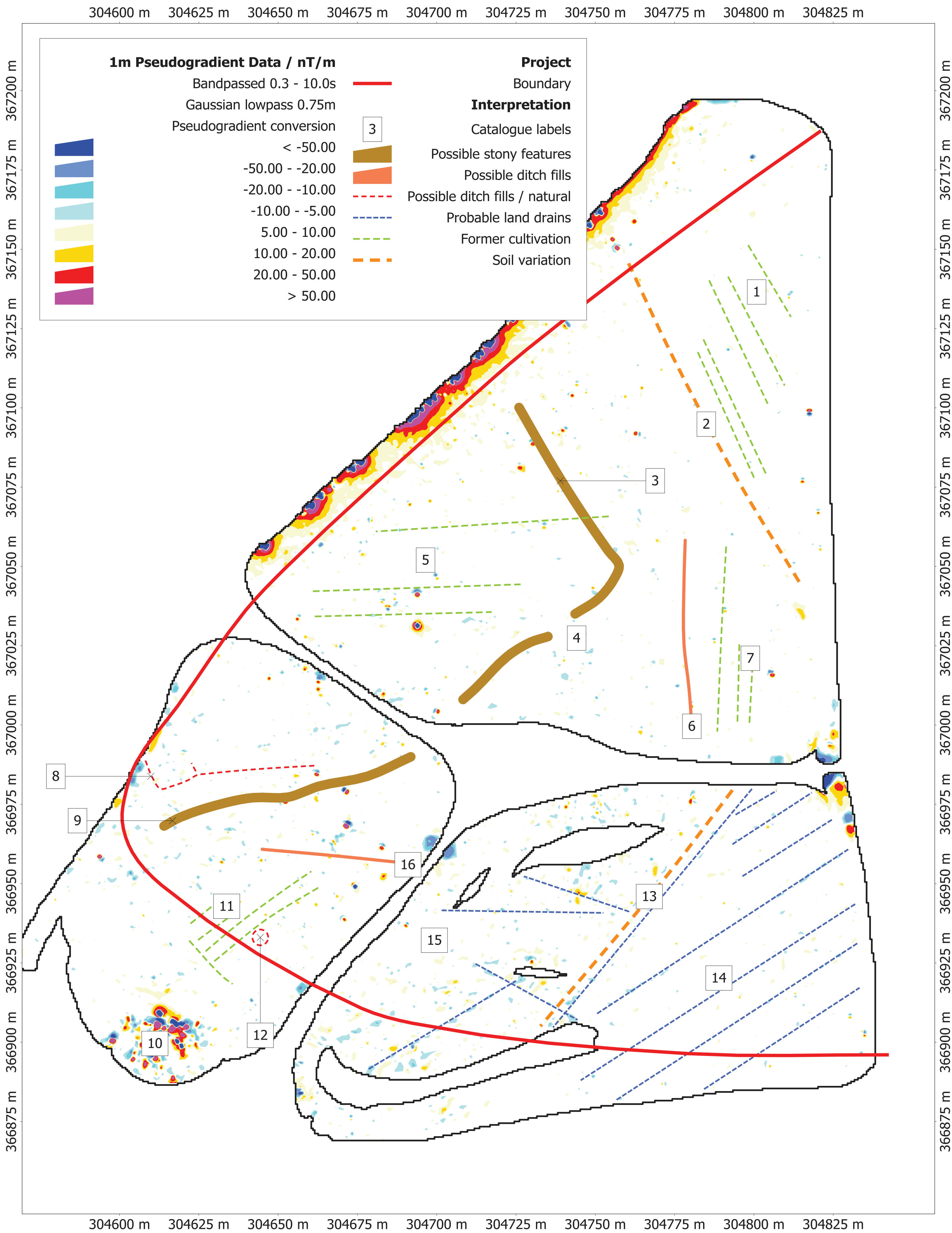

DQD191 Denbigh Quarry, Denbighshire
DWG 04 Interpretation - Vector

Orthographic Scale: 1:1500 @ A4 Spatial Units: Meter. Do not scale off this drawing
File: DQD191.map

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