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Castell Dinas Bran, Llangollen, Denbighshire

Geophysical Survey Report
(Caesium Vapour Magnetic and Electrical Resistance - Archaeology)

Project code: DBL161

Produced for:

Denbighshire Archaeological Service

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Environmental Geophysics – Survey, Research and Consultancy

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Castell Dinas Bran, Llangollen, Denbighshire

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Non-Technical Summary

A magnetic and electrical resistance survey was commissioned by the Denbighshire Archaeological Service to prospect land at Castell Dinas Bran, Llangollen for buried structures of archaeological interest.

Cultivation was found throughout the fort's interior which has obvious implications for the survival of prehistoric features and especially within a shallow soil. The overall impression is that significant soil, possibly with cultural debris within it, has moved downslope to form a colluvial fill behind the fort's rampart.

Nothing was seen in the data that would suggest the presence of masonry remains within the keep of the castle, however, they may not be detectable with electrical techniques within a shallow soil over bedrock.

The possibility that the rampart has been burnt is interesting and although clearest at [26] it might also account for the strong magnetic anomalies observed through much of the fill behind the rampart.

Table of Contents

1 Introduction

Land within the Iron Age hillfort and medieval Castle at Dinas Bran, Llangollen, Denbighshire was surveyed with multiple geophysical survey techniques to prospect for features of potential archaeological interest.

Work was to a brief supplied by Fiona Gale of Denbighshire Archaeological Service (Gale, 2016), that specified the use of magnetic and electrical techniques at the site. A little over one hectare of ground was surveyed with both methods, limited by slope and by the presence of scree or rubble for the electrical resistance technique.

Country	Wales
County	Denbighshire
Nearest Settlement	Llangollen
Central Co-ordinates	322250, 343060

2 Context

2.1 Background information

Castell Dinas Bran (Historic Environment Record PRN SM 1101174) is designated as a scheduled monument (De 021) and comprises an Iron Age hillfort and a medieval stonework castle. The following paragraphs are extracted from "*A short guide to Castell Dinas Bran*", produced by the Clwyd Powys Archaeological Trust (www.cpat.org.uk) that describes both elements of the monument.

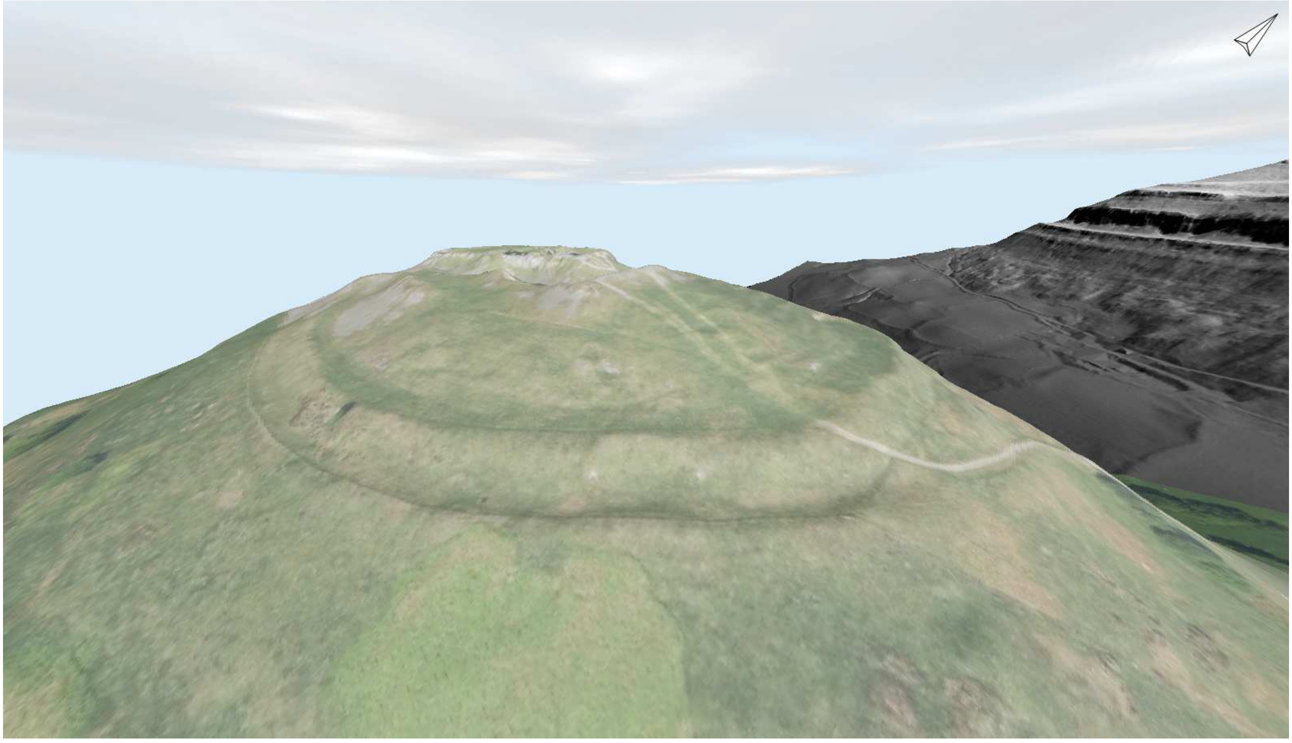
The guide describes the Iron Age hillfort site as, *"......... a single bank and ditch enclosing an area of about 1.5 hectares. To the south and west the defences are most considerable being up to 8 metres high in places. The entrance lies in the south-west corner of the fort and is defended by an inward curving bank. To the north the fort is defended by the natural steepness of the land and no earthwork defences were required".*

It continues with the stonework castle, stating that, "*...... it was built towards the later part of the 13th century by the princes of Powys Fadog and was the site of a meeting between the sons of Gryffydd Maelor in 1270 when they granted the lands of Maelor Saesneg for the upkeep of their mother, Emma Audley. During the wars between Llywelyn ap Gruffydd, Prince of Wales and Edward I of England the castle was burnt by the Welsh before it was captured in 1277 by Henry de Lacy, earl of Lincoln. It was not repaired and ceased to be used after the 1280s.*

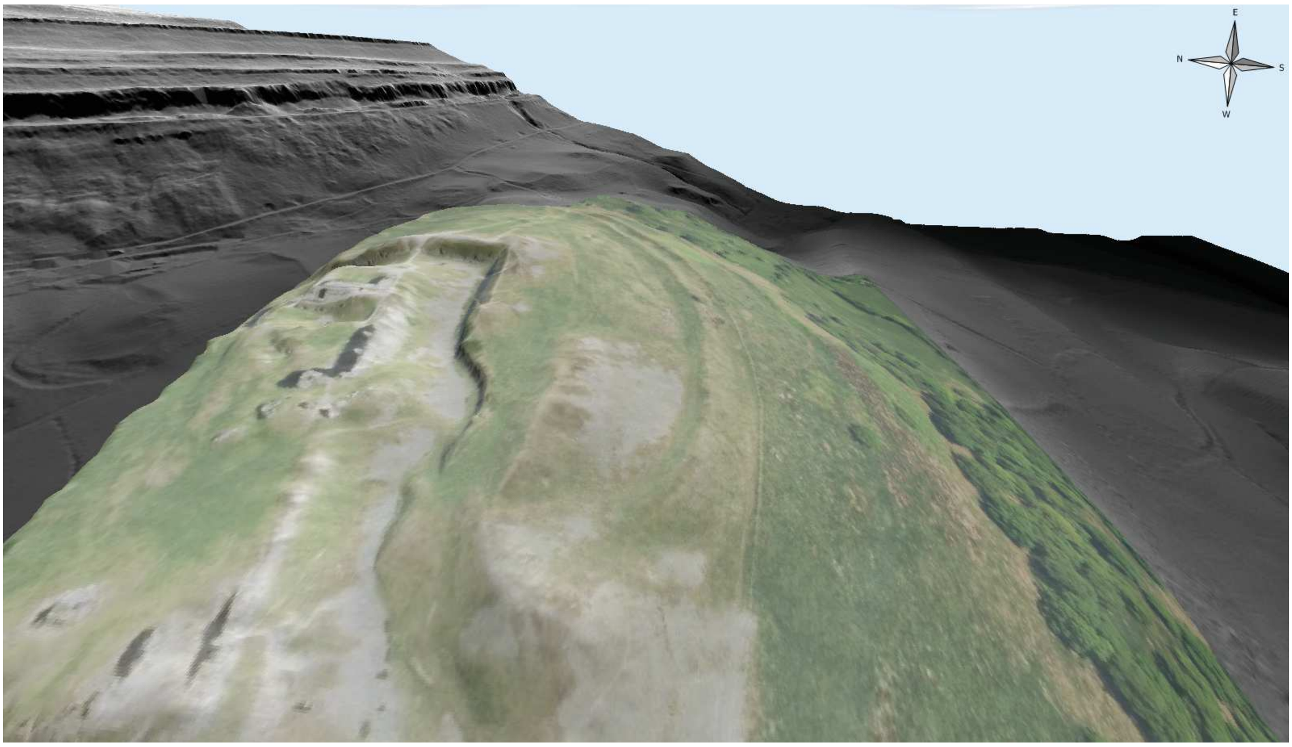
The castle consists of a courtyard with the main buildings being ranged along the east end and with a tower built partway along the south curtain wall. The tower is the most impressive part of the standing remains, originally it protruded south of the curtain wall. A large rectangular building with windows looking southwards lay to the east of the tower. This may have been a hall or chapel. The keep is a large square building set in the south-east part of the castle, only the west wall and part of the south survive to any height. On the outside of the south wall is a wide buttress housing the chutes of a pair of latrines. The original entrance to the keep lies on the west side where the remains of stairs can be seen. The gatehouse is in the north-east corner and is flanked by round towers. The castle is defended by a deep rock-cut ditch on the east and south sides".

The image below, generated by draping an aerial photograph onto a LiDAR DTM, showed the site from the east, with the hillfort prominent in the foreground and the castle occupying the summit of the hill behind.

TIGERGEO



Below is the same model viewed from the west and shows the amount of hill top that has been modified by the addition of the medieval castle.



2.2 Environment

Soilscapes Classification	Freely draining acid loamy soils over rock (13)
Superficial 1:50000 BGS	None recorded – Glaciofluvial Sheet Deposits, Devensian – Sand and Gravel (GFSDD) in immediate area
Bedrock 1:50000 BGS	Dinas Bran Formation – Mudstone and Sandstone, Interbedded (DBG)
Topography	Undulating hilltop above steep slopes
Hydrology	Natural
Vegetation Cover	Grass

3 Discussion

3.1 Introduction

The sections below first discuss the geophysical context within which the results need to be considered and then specific features or anomalies of particular interest. Not all will be discussed here and the reader is advised to consult the graphical elements of this report.

3.2 Principles - magnetic survey

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.

Archaeological 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.

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.

3.2.1 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. However, this does remove suppression of ambient noise and temporal trends which have to be suppressed later during processing. When compared to vertical gradiometers in archaeological use, there is no significant reduction in lateral resolution when using non-gradiometric sensor arrays and the inability of gradiometers to detect laminar structures is completely avoided.

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.

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.

3.3 Principles – electrical resistance survey

Electrical resistance is the measured consequence of electrical resistivity, the degree to which a material restricts the flow of electric current. Within soil this is generally due to a combination of factors, including the chemistry due to the mineral and humic components, these to some extent working in opposition, plus the size of pore spaces, their degree of interconnection, to what extent they are water filled and whether the surface of the pore spaces are electro-chemically active. The latter reason is why clay tends to be less resistive than silt while pore dynamics govern the soil's response to hydraulic cycling.

For any given soil, the hydraulic context directly impacts upon the 3D distribution of electrical resistivity variation. Given the temporal character of the former, the latter also varies in time. Electrical resistance data collected in dry conditions after rainfall will be different from that collected in wet conditions after a period of dry weather. Data collected after a short period of rain will be different from that collected after prolonged rain. However, there is one constant: after a period of no rainfall electrical resistivity contrast within soil will always be at a minimum and therefore survey is unlikely to useful. The hydraulic output from a soil is as important as input from rainfall; drainage from a surface soil is influenced by deeper deposits, the degree of saturation of the ground, slope and whether it can physically trap water within its pore spaces, e.g. clays.

Considerable temporal and spatial variation across a variety of scales is therefore normal and the detection and mapping of structures of archaeological interest is dependent upon these. However, certain principles can be applied:

- an open-textured soil will always hydrate and drain faster than a heavier one;
- clay soils will retain moisture longer than sands and silts;
- soils will normally be less resistive than mortared masonry structures, however an un-mortared structure can behave more like an open-textured soil;
- unconsolidated fills tend to be more open-textured than undisturbed ground;
- wet soils are less resistive than dry ones.

With these in mind and given appropriate conditions it is evident that electrical resistance survey can detect things like buried pit and ditch fills, walls and similar structures. Floors may be indirectly detected if they modify drainage of the soil. However, their chances of detection are entirely dependent upon the local soil hydrology and hence the weather conditions prior to and during survey, the soil type and surface treatments (e.g. ploughed, not ploughed, grass or bare soil, etc.). Variation of any of these within a survey will likely change the relationship between measured electrical resistance and the archaeological interpretation.

Finally, no physical variation exists in isolation and the patterns of electrical resistance observed at the surface relate not to individual structural variations but to the combination of all variations within the 3D electrical current path. Those variations with the greatest influence upon the current vector will be most manifest within the resistance measurement. As a consequence, closely spaced structures may not be separately resolved, their depth of burial will affect the result and likewise their penetration into the ground. Given adjacent pairs of structures or fills with opposing resistivity characteristics, only one may be resolved. As an extension of this, paradoxes may be evident, e.g. the effect upon drainage (potentially low resistance) of a masonry structure may be more evident than the structure (high resistance) itself. A high resistivity structure close to the surface may force the majority of current to flow over it, producing a low resistance anomaly.

3.3.1 Instrumentation

The pole-pole, or as commonly called in archaeological applications, the twin-probe array, is one of many that can be used, each with its own benefits and drawbacks across the spectra of resolution, sensitivity, signal to noise ratio and anomaly form. The pole-pole is especially sensitive to lateral variation beneath the array but relatively insensitive to laminar structure. This sensitivity is marked at shallow depths, thus for a 0.5m AM (mobile current and potential) probe separation a depth of investigation of approximately 0.75mbgl applies, though with some variation.

Because the exact geometry of the array is rarely known (due to the constant variation of relative orientation and separation of the two sets of probes) the measurement is expressed as electrical resistance, in Ohm, not the volume specific quantity of resistivity. Measurements are thus not directly comparable across sites and nor is their size indicative of particular materials etc., unlike the resistivity measure available from electrical resistivity tomography or from variations of the Wenner array, both of which shares the same fundamental principles.

Within the pole-pole array configuration, the primary variable is the AM probe spacing. Increasing this from 0.5m increases the sensitivity of the array to deeper variations, however, measurements remain significantly affected by shallower variations due to current paths. Conversely, decreasing the spacing sensitises the measurement to regions closer to the surface.

For discrete buried structural entities (e.g., walls and pit or ditch fills) the volume of ground affected by the resistivity contrast is larger than the physical extent of the structure and thus variations smaller than the survey resolution can be detected not mapped, a behaviour critical to interpretation of the data. As for all planar survey methods the higher the spatial resolution of the survey the better the result will be, although with diminishing returns beyond some resolution dependent upon local resistivity contrast and structure size (and hence weather conditions prior to survey).

3.4 Character & principal results

The following paragraphs represent an interpretive summary of the survey. The numbers in square brackets refer to individual anomalies described in detail below and shown on DWG 03 onwards.

3.4.1 Geolocation

Data was collected by both methods in regular grids, their location established using Network RTK GNSS to within 0.02m. In addition, the magnetometer cart was GNSS-tracked during operation to support variable along-line speed dictated by the terrain.

3.4.2 Data

Data quality for both data sets is overall high and for the magnetic data (total magnetic intensity – TMI) the high data resolution of 0.5m x 0.1m (mean) has allowed good definition of anomaly shapes. This in turn has supported the use of the vertical pseudo-gradient (PSG) to delineate and reveal small scale magnetic structure. Within the magnetic data there are small variations inherent to use of the sensors on a handcart on rough terrain, however, nothing of sufficient size to compromise interpretation.

Magnetic contrast is high and comparison of the TMI and PSG data suggests that most of the anomalies have fairly shallow sources, most likely within the soil and the top of the rock. It is also implied that a significant amount of variation probably relates to changes in soil depth across the site.

The electrical resistance data is smoothly variable and non-uniform throughout except within the keep of castle. Strong natural variations of 100Ohm and more exist and at spatial sizes similar to anomalies expected to be of archaeological interest. Contrast and quality are high but it is not a particularly easy data set to interpret. This is partly why LiDAR imaging and contour generation was incorporated into the project, to better understand the relationships between the two geophysical properties and the topography.

3.4.3 Geology and soils

The total magnetic intensity data (TMI) is strongly variable across the site. The British Geological Survey (BGS) G-Base iron value (5km resolution) is 2.6% which is reasonable, slightly below average but arguably close to the median level. Anomalies > 20nT and apparently from natural sources are therefore unexpected and a strong indicator that soils at this site are unusually magnetic. Why is uncertain but may be due to agricultural processes and / or the combination of these with the bedrock. Extensive burning (e.g. of scrub) is itself unlikely to cause such a strong enhancement, unless prolonged and repeated. Accumulated soils, e.g. at [13] and [21], where logically greater depth exists, create anomalies stronger than other variations at the site, although in these locations maybe there is also cultural material and heated soil.

There appear to be two contexts beneath the castle's keep, with solid rock [3] evident along the spine of the hilltop and buried within a levelled area formed upon fill material [1] to each side. The fill on the southern side is perhaps within part of a larger quarry excavated for the castle, traces of which may survive as the wider area of rock-cut ditch south of the keep.

To the east there is evidence for two possible dykes intrusive within the rock below the hillfort. Both are apparent through being strongly magnetic with one, [10], outcropping at [6] and the second to the south at [33] where a strongly reduced magnetic intensity anomaly is aligned parallel to [10].

Thin soils seem typical of the hillfort's interior, e.g. [11] and is shown hatched on DWG 05. At [31] there is scree, partly from the natural slope but also perhaps from the castle defences.

3.4.4 Land use

An unexpected discovery was that the whole of the interior of the hillfort has been cultivated in the past with relict furrows [20] and [29] (of ridge and furrow type cultivation) extending round the contours. This will have disturbed, potentially seriously, any features of prehistoric data within the interior. This cultivation may also be the origin of a series of terraces, e.g. at [7] and [8], rather than these being the sites of structures contemporary with the fort.

Several paths cross the site, e.g. [16], [17] and [30], the first apparently having multiple ways snaking up the slope. All the paths exhibit low magnetic intensity typical of thin soil or stone and slightly reduced electrical resistance and seem to have been deeply eroded at times.

3.4.5 The castle

Of the castle itself, not much can be said, the magnetic and electrical surveys providing more an impression than detail. Outside the keep, at [14] and [32] there are signs of accumulated scree and debris eroded off the outer bank. At [14] this appears to slightly overlap the relict cultivation although the latter appears to have respected the original bank and to therefore post-date it.

Within the keep the levelled rock forming the floor is evident at [3], surrounded by fill material [1]. The latter contains magnetic anomalies [2] typical of ferrous debris but whether this is original to the fill or due to later intrusions is not clear.

The northern edge [4] of the rock [3] is strongly magnetic for reasons that are not clear, however, this could also be debris or simply a natural anomaly caused by the rock being more magnetic than the material of the fill (although again why this should be the case is not clear). Likewise, close to the southern edge are more string magnetic anomalies [5] and these are parallel to the possible dykes [10] and [33]. This might be just coincidence.

3.4.6 The hillfort

The terraces apparent east of the castle are associated with magnetic anomalies of variable form. Within [7] there is a non-magnetic fill, or perhaps bedrock, at its base whereas at [8] the base seems to contain, at one end, magnetic material. Whether this is due simply to deeper soil or to a deposit containing heated soil or cultural debris is uncertain but the electrical resistance data doesn't suggest deeper soil.

The relict cultivation furrows run around the contours and align with this terraces but it is not certain whether the terraces were created for cultivation or were conveniently reused by it. There appear to be furrows within the floors of the terraces.

Within the southern part of the fort two possible but platforms [27] and [28] have been observed. The former lacks obvious geophysical associations but [28] is associated with reduced magnetic intensity, perhaps indicate of shallower soil at it's base, assuming this is not simply a topographic effect related to data collection.

Elsewhere other small topographic features have a less obvious association with geophysical anomalies. e.g. at [18] where there is a loose association with low magnetic intensity (so perhaps thinner soil) but less obviously so than at [7]. Nearby magnetic debris might relate to the adjacent footpath. At [19], slightly lower down the slope there is again reduced magnetic intensity below the hood of the earthwork.

At [9] there is ferrous-type debris within a discrete hollow adjacent to an earthwork projecting south from the northern rampart. The origin of this debris is unknown.

Both magnetic and resistance data sets imply a fill behind the eastern and southern arcs of the rampart and the low resistance anomaly is perhaps 2m narrower than the associated spread of magnetic debris in some parts. This could imply a difference between chemical and physical structure or that the magnetic (cultural?) debris extends slightly further into the interior of the fort than the fill.

For much of its length the fill is associated with strongly magnetic materials but not always, e.g. at [12] and [25] where the resistance is low but without significant magnetic anomalies; there may also be a structure and a slight platform at [25]. Elsewhere, e.g. at [13] and [21] the low resistance band contains strongly magnetic materials with anomaly strengths exceeding 30nT which is high, even for this site.

The gap between [13] and [21] was perhaps an entrance although the earthwork is low continuous, albeit with a slight change of shape at this location.

At [26] the rampart itself is hugely magnetic which might suggest it has been burnt and if so this might also account for the magnetic materials within the fill behind it, e.g. at [21].

Within the hillfort there are a number of discrete rectangular areas of low resistance, e.g. at [15] where a small (2-3m) patch of strongly reduced resistance lacks obvious explanation. At [22], [23] and [24] there are a series of low resistance rectangular anomalies extending into the slope, the first two being about 8m long and 2.5m wide. The third, [24], is less clear and might have a natural origin.

3.5 Conclusions

Overall there is not a lot of evidence for features of archaeological interest although what is visible is quite significant. The presence of cultivation throughout the fort's interior has obvious implications for the survival of prehistoric features and especially within a shallow soil. The furrows follow the contours and have a slightly irregular spacing 3-4m apart. The overall impression is that significant soil, possibly with cultural debris within it, has moved downslope to form a colluvial fill behind the fort's rampart.

Nothing was seen in the data that would suggest the presence of masonry remains within the keep of the castle, however, they may not be detectable with electrical techniques within a shallow soil over bedrock.

The possibility that the rampart has been burnt is interesting and although clearest at [26] it might also account for the strong magnetic anomalies observed through much of the fill behind the rampart.

It has not been possible to determine whether the terraces east of the castle are contemporary with the hillfort or the product of later cultivation.

3.6 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 Survey

4.1.1 Technical equipment – magnetic survey

Measured variable	Magnetic flux density / nT
Instrument	Array of Geometrics G858 Magmapper caesium magnetometers
Configuration	Non-gradiometric transverse array (2 sensors, handcart])
Sensitivity	0.03 nT @ 10 Hz (manufacturer's specification)
QA Procedure	Continuous observation
Spatial resolution	0.5m between lines, 0.1m mean along line interval (at 10 Hz)

4.1.2 Technical equipment – electrical resistance survey

Measured variable	Apparent electrical resistance (array configuration dependent)
Instrument	Geoscan RM15 Advanced
Configuration	0.5m Pole-pole (twin probe) array, current 1mA
Sensitivity	Nominally 1 Ohm (least significant digit)
QA Procedure	Continuous observation
Spatial resolution	1.0m between lines, 0.5m along line interval

4.2 Data processing

4.2.1 LiDAR

1m resolution digital terrain model (DTM) data was sourced from LLE Geoportal for Wales and processed using version 1.1 of the Relief Visualisation Toolbox (RVT), Slovenian Academy of Sciences and Arts, 2014.

4.2.2 Magnetic 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 0.0 – 40.0s (hillfort) Bandpassed 0.0 – 10.0s (castle)
Gridding	Surfer	Kriging, 0.25m x 0.25m
Smoothing	Surfer	Gaussian lowpass 3x3 data
Vertical pseudogradient conversion	Proprietary	1m
Imaging and presentation	Manifold GIS	

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 and detailed analysis. Specialist analysis is undertaken using proprietary software.

4.2.3 Electrical resistance procedure

Process	Software	Parameters
Spike reduction	Proprietary	Manual replacement using median of 3x3 window
Imaging and presentation	Manifold GIS	

4.3 Interpretation

4.3.1 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 contractors may also be used if accompanied by adequate metadata.

4.3.2 Geological sources

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.

4.3.3 Agricultural sources

Linear anomalies 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 magnetic or electrical properties caused by a variable thickness of topsoil, variable drainage conditions, 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 as repeating dipolar anomalies from terracotta pipes or reduced magnetic field strength or increased electrical resistance 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.

4.3.4 Archaeological sources

Interpretation of anomalies as of archaeological interest depends upon their recognition as not being within the previous two categories and not typically of natural origin. Layout and spatial character therefore influence this decision. Recognition of fills and lateral changes of material is normally critical, most archaeological features being characterisable in this manner. Likewise, voids or earth fast stony materials are good indicators.

On some sites the combination of plan form and anomaly character, e.g. rectilinear reduced magnetic field strength or increase resistance 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 geophysical 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.

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4.5 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 and has appointed Alan Ward of Bigfoot Services Limited as our ISO/HSE Technical Advisor. 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.

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". The management team at TigerGeo have over 30 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.

All work is 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 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.

5.2 Key personnel

Senior Geophysicist (Quality manager)	Martin Roseveare MSc BSc(Hons) MEAGE FGS MCIfA
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.	
Operations Manager (Safety manager)	Anne Roseveare BEng(Hons) DIS MISoilSci
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.	
Archaeological Consultant	Daniel Lewis MA BA(Hons) ACIfA
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.	
Geophysicist	Kathryn Cunningham BSc(Hons) FGS
Kathryn has been with TigerGeo for more than 18 months and has undertaken over 100 surveys comprising total field magnetometry, twin probe resistivity, electrical resistance tomography, ground penetrating radar and laser-scanning. Her particular role is to ensure all aspects of fieldwork run smoothly, including site-specific paperwork, liaison, internal auditing and risk assessment. In addition she has increasing responsibilities in data processing and interpretation. She graduated with a BSc (Hons) in Applied Geology in 2015 from the University of Plymouth, is a Fellow of the Geological Society and enjoys acrobatics and sunny days.	
Geophysicist	Jack Wild BSc(Hons) FGS
Down to earth and a recent Plymouth University graduate in geology (GeolSoc accredited degree) Jack entered the world of shallow geophysics with an Atkinson Leapfrog. Happiest when in the field he has undertaken geological projects Europe wide including in Sicily and the Spanish Pyrenees and closer to home has studied much of the Cornish and Devon coast. The mystery of what lies below drives his interest in the collection and interpretation of high quality data - be it from magnetometry or GPR he just cannot resist(ivity)!	

DBL161 Castell Dinas Bran, Llangollen, Denbighshire

DWG 01 Site Location

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

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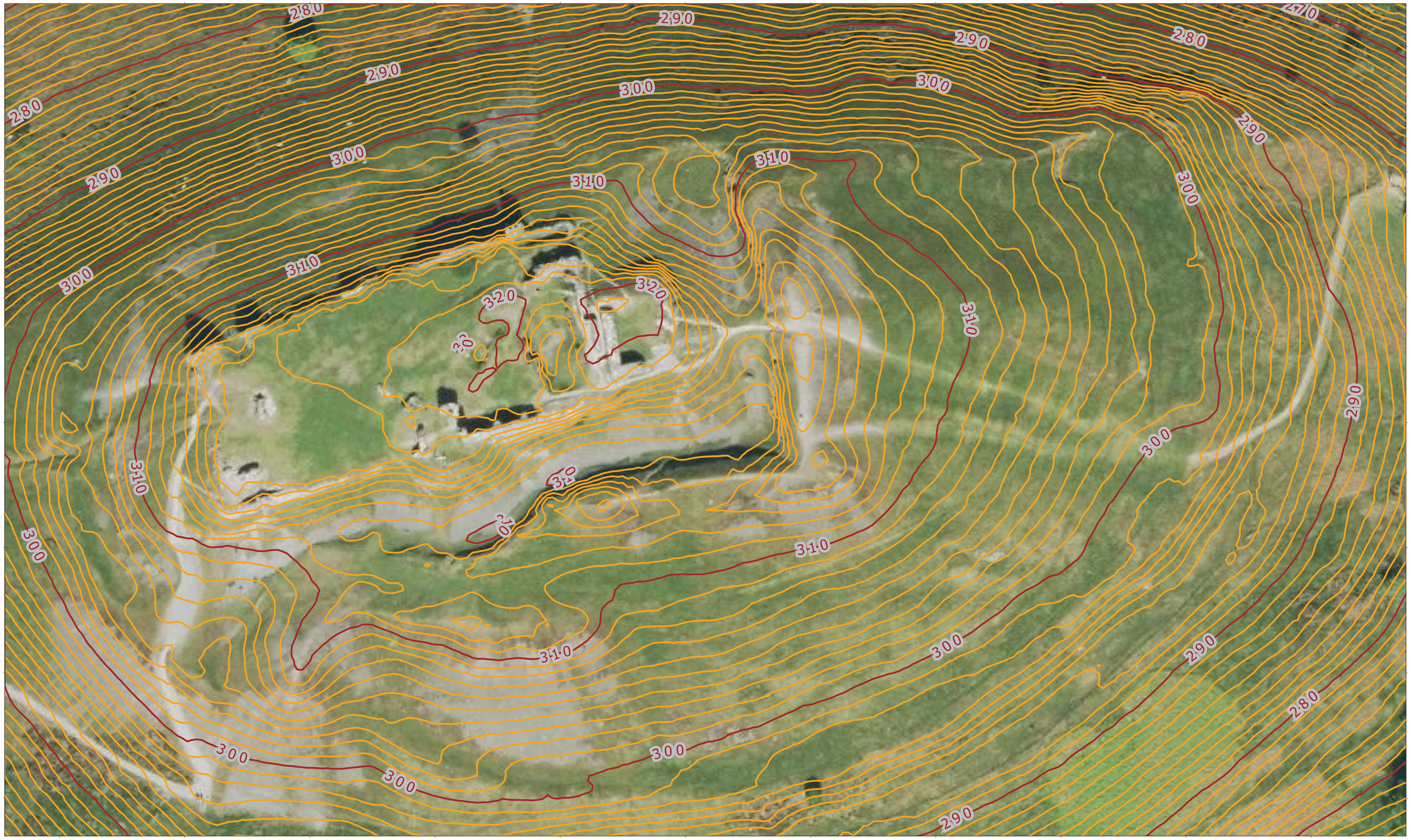

DBL161 Castell Dinas Bran, Llangollen, Denbighshire
DWG 02a Topography - LiDAR Contours (10m and 1m)

Orthographic Scale: 1:1000 @ A4 Spatial Units: Meter. Do not scale off this drawing
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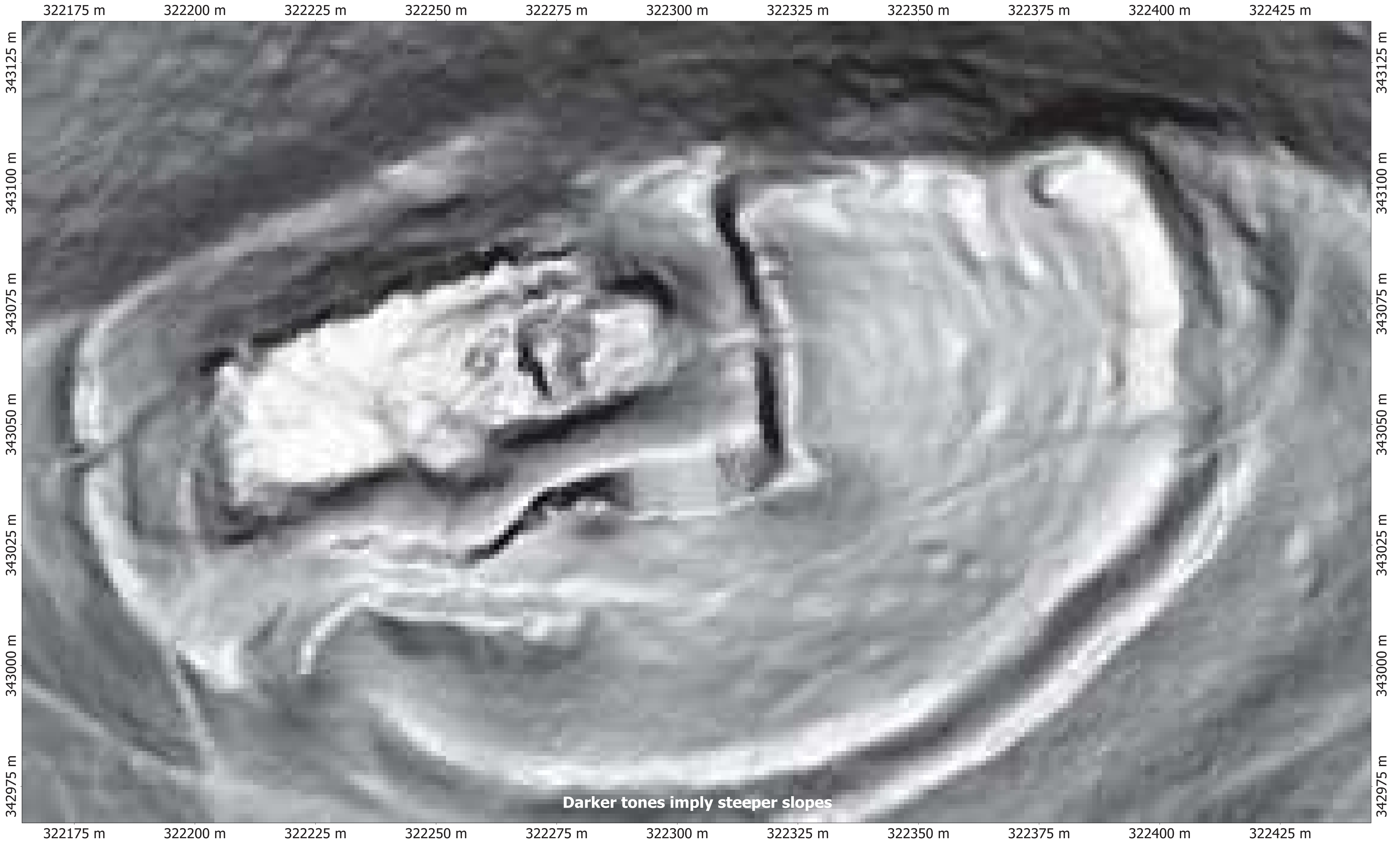

DBL161 Castell Dinas Bran, Llangollen, Denbighshire
DWG 02b Topography - LiDAR Slope Gradient

Orthographic Scale: 1:1000 @ A4 Spatial Units: Meter. Do not scale off this drawing
File: DBL161.map

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DBL161 Castell Dinas Bran, Llangollen, Denbighshire
DWG02c Topography - LiDAR Analytical Hill-shaded

Orthographic Scale: 1:1000 @ A4 Spatial Units: Meter. Do not scale off this drawing
File: DBL161.map

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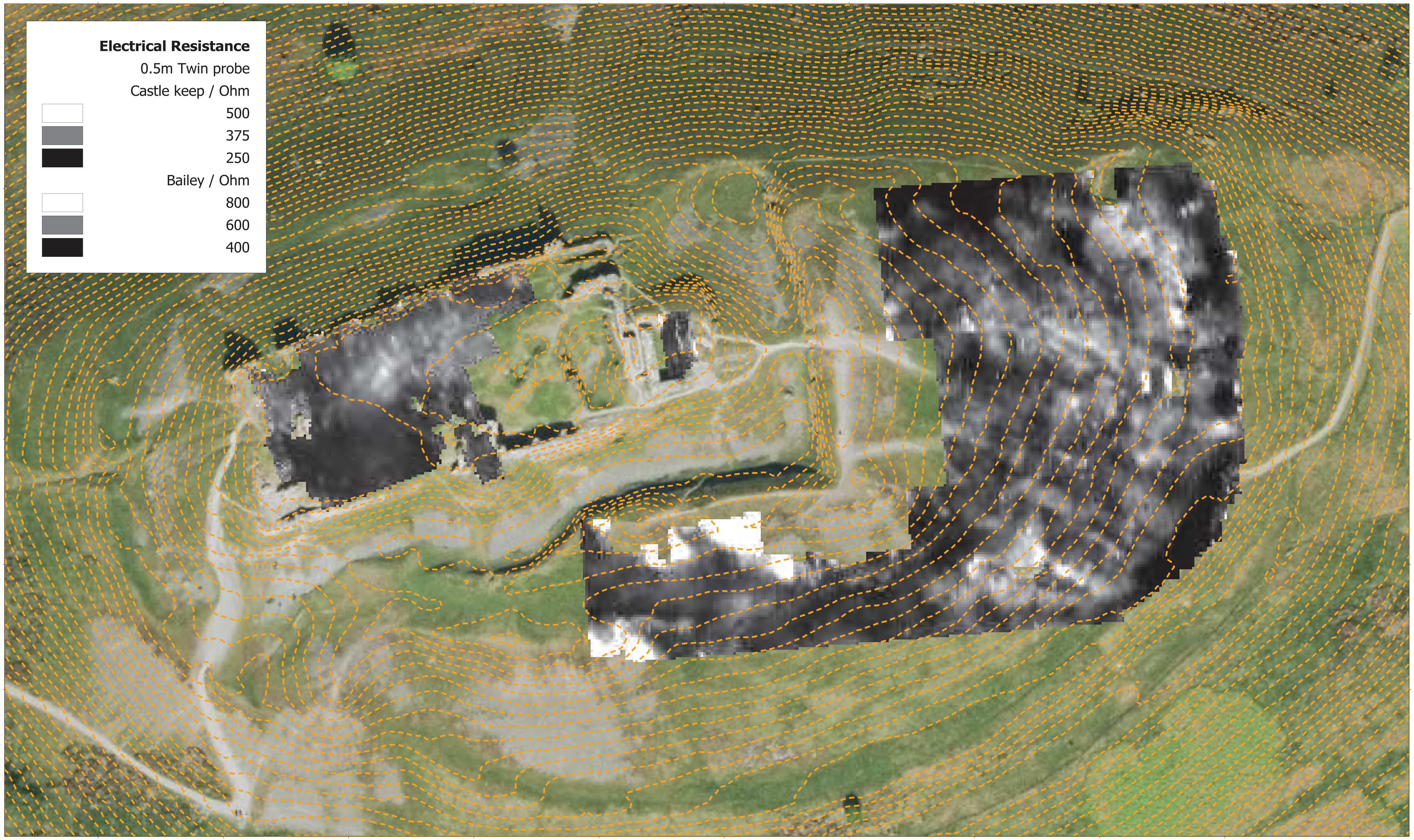

DBL161 Castell Dinas Bran, Llangollen, Denbighshire
DWG 03a 50cm Twin-probe Electrical Resistance

Orthographic Scale: 1:1000 @ A4 Spatial Units: Meter. Do not scale off this drawing
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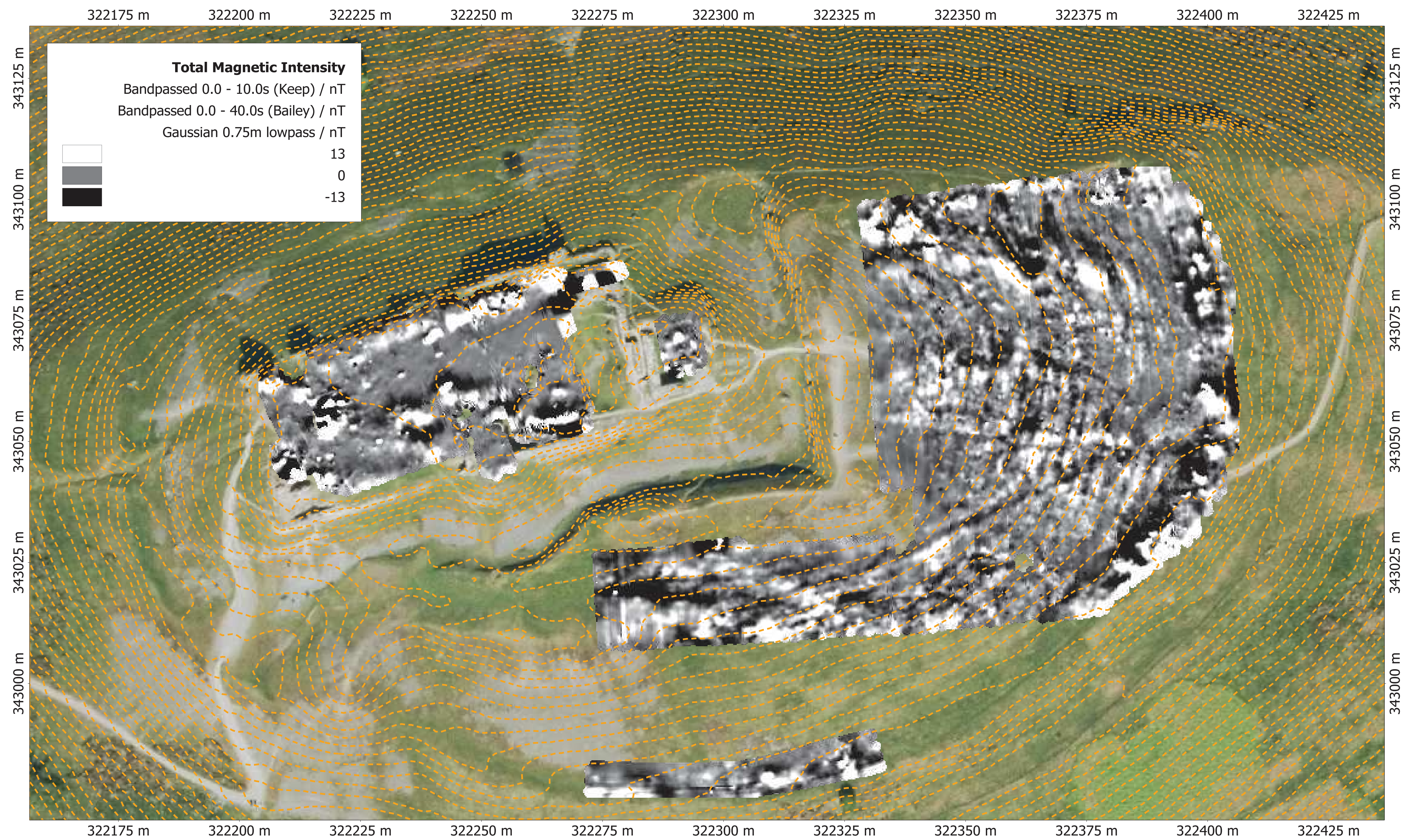

DBL161 Castell Dinas Bran, Llangollen, Denbighshire

DWG 04a Magnetic (TMI - Total Magnetic Intensity) Data

Orthographic Scale: 1:1000 @ A4 Spatial Units: Meter. Do not scale off this drawing

File: DBL161.map

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DBL161 Castell Dinas Bran, Llangollen, Denbighshire
DWG 04b 1m Pseudogradient of Magnetic (TMI - Total Magnetic Intensity) Data

Orthographic Scale: 1:1000 @ A4 Spatial Units: Meter. Do not scale off this drawing
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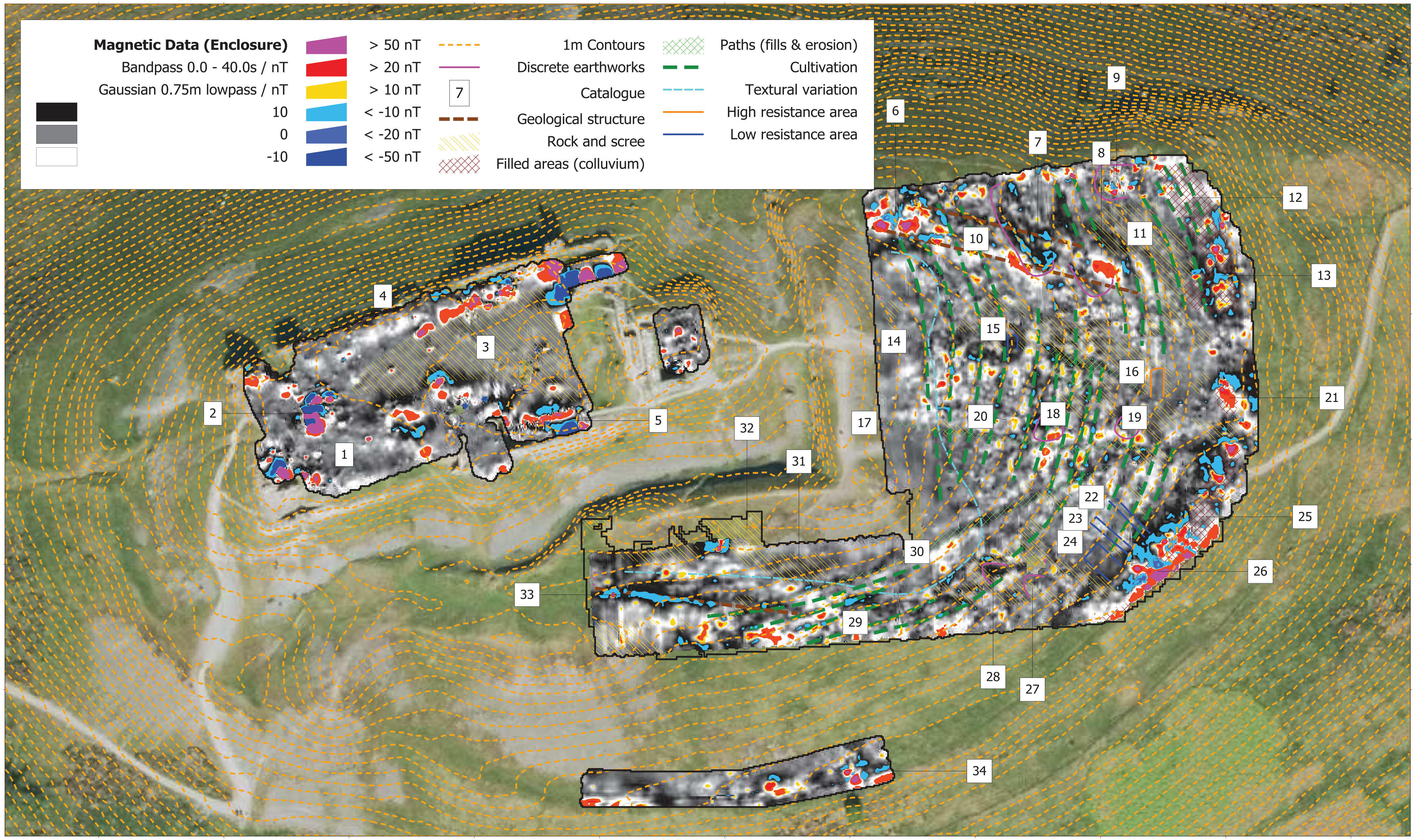

DBL161 Castell Dinas Bran, Llangollen, Denbighshire
DWG 05a Interpretation

Orthographic Scale: 1:1000 @ A4 Spatial Units: Meter. Do not scale off this drawing
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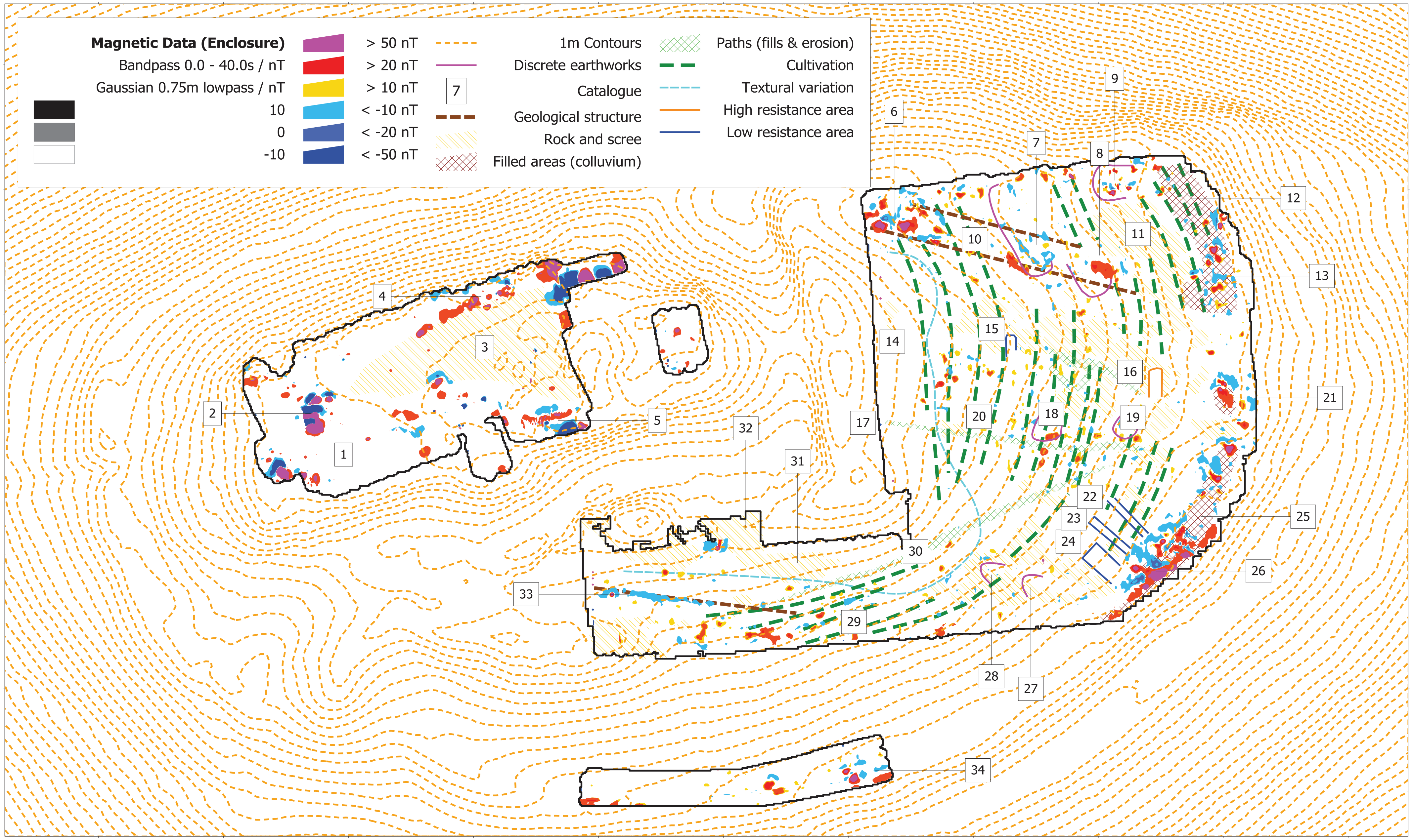

DBL161 Castell Dinas Bran, Llangollen, Denbighshire
DWG 05b Interpretation - Vector Only

Orthographic Scale: 1:1000 @ A4 Spatial Units: Meter. Do not scale off this drawing
File: DBL161.map

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