CHAPTER 16

Geophysical Survey

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Introduction

The traditional application of shallow geophysical survey techniques has been largely restricted to identifying feature-dominated archaeology from the Neolithic onwards, although extinct landforms are frequently identified and there is no reason to exclude the Early Holocene from the scope of application. Due to the suspected extensive nature of occupation at Star Carr, the identification of a Mesolithic structure in 2008 and the (increasingly) shallow depths of peat and plough soil overlying archaeological deposits, the opportunity was taken to investigate the viability of geophysical survey at the site. This chapter reports on the geomagnetic and resistance surveys conducted in 2009 and 2010 (Figure 16.1).

The survey areas are mapped by the British Geological Survey (2016) as mudstones of the Speeton Clay Formation, overlain by either sands and gravels (uncertain age and origin) in 'dryland' areas or lacustrine deposits (clay, silt and sand) in the lake proper. However, archaeological investigations have better refined local mapping of the superficial deposits in the immediate area of the former Lake Flixton (Chapters 3 and 4) and the complex variations in these can significantly influence geophysical readings.

Historic mapping shows minimal changes in the local area. A field boundary dividing the southern field at Star Carr intermittently disappears and is reinstated between the 1850s and 1990s. 'Star Carr Bridge' is mapped c. 110 m to the west of the modern metal bridge until the 1970s, from which a bridleway leads southwest in the southern field in the 1950s, and north to Ling Lane until the 1910s. The northern field remains otherwise unchanged.

Background to Mesolithic Geophysics and work in the Vale of Pickering

The Mesolithic is situated at a crossroads in archaeological prospection methods. Although the dynamic reworking of deposits common in the Pleistocene is far more prevalent than in Holocene contexts, landscape processes in the Early Holocene have led to sites becoming deeply buried or truncated. For these reasons, a geomorphological approach to geophysical survey might be deemed most appropriate. Nevertheless, detection of archaeological features at an early stage of investigation at Mesolithic sites, conventionally considered to be

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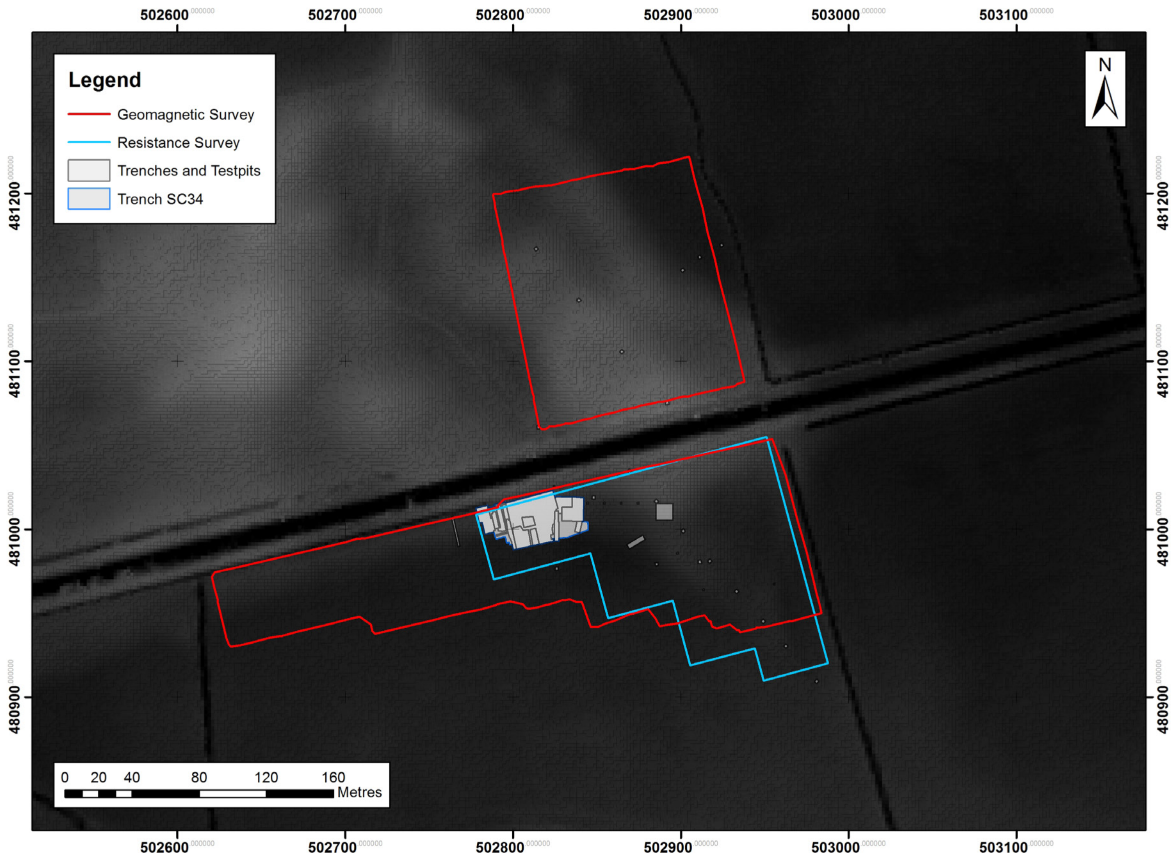

Figure 16.1: Plot of the survey locations and LiDAR topography (Copyright Edward Blinkhorn, CC BY-NC 4.0).

impoverished of such elements, is of equivalent importance in discerning foci of activity and scientific opportunities. However, identifying Mesolithic sites is difficult where excavation is not already underway, sediments are not exposed through erosion or the landscape context is locally unmatched. Indeed, a great majority of the best-known sites are discovered serendipitously rather than through concerted prospection.

Therefore, there is little comparative evidence for how Mesolithic archaeology might be manifested in geophysical survey output. The nature of Mesolithic features is poorly understood and it is the contrast deriving from archaeological features which make surveys such as those in the western Vale of Pickering (e.g. Powlesland et al. 2006) so rich. Additionally, the feature-based archaeology of later prehistory and the historic periods, its durability and detectability through remote prospection techniques such as aerial photography and topographic survey, amongst others, has facilitated the creation of large corpuses of data on form. Ground-truthing of these forms means that some degree of confidence can be ascribed to the interpretation of (Iron Age) square barrows, for instance, and thus a sense of antiquity can be discerned. However, hunter-gatherer archaeology tends to be more ephemeral. Moreover, Mesolithic archaeology is frequently found within multi-period landscapes yet has been buried for considerably longer, therefore increasing the potential for deformation of the target deposits.

Attempts have been made at a number of sites to incorporate more widely used geophysical survey techniques to detect Mesolithic archaeology. In the British Isles, structures discovered at Howick (Biggins 2007) and East Barns (Gooder 2007), and the pit identified on the Kingsdale Head project (Melton et al. 2014), all yielded strong, if diagnostically unremarkable, subround positive magnetic signals which are inherently undateable without further evidence.

Results from the Scottish Mesolithic Geophysical Survey Project (Finlay 2007) have yet to be widely published excepting Sand (Finlay and McAllen 2008), which unfortunately yielded negative results. Short reports reveal that at Port Lobh 1 on Colonsay a shell midden was identified and ground-truthed and at Newtown on

Islay (Finlay 2004) significant anomalies were identified close to a known Mesolithic site. In the Iberian Peninsula, magnetometry has successfully located both shell middens (Arias et al. 2017) and structures (Arias et al. 2015). At the Mesolithic hazelnut-roasting site at Duvensee, Germany (Hausmann et al. 2012), several survey techniques were trialled and while geomorphological modelling seems to have been the intention, significant geomagnetic anomalies were identified.

Unpublished work at Flixton School House to the east of Star Carr is probably the best analogue for the surveys presented below. Aside from modern ferrous anomalies, magnetometry responded most strongly to the probable plough disturbance on sub-surface topographical slopes, and magnetic enhancement was identified along the northern periphery of the island/dryland. Scattered discrete positive anomalies elsewhere across dryland areas may represent buried features—potential counterparts to those already excavated (Taylor and Gray Jones 2009).

Successes across Europe prove that magnetometry and resistance survey can be considered a valuable tool in Mesolithic prospection. However, in all of the above cases, the results are difficult to interpret, require close reading of the local geology, and beyond elevated magnetic responses in sizeable or strongly heat-affected features, Mesolithic features are near impossible to categorise through geophysical survey where similar features have not been identified locally.

Technique selection

Resistance and geomagnetic survey were selected to rapidly assess the Star Carr landscape prior to excavation, in the case of the former prioritising coverage over resolution. In addition to contributing to the growing number of surveys targeting Mesolithic deposits, these techniques are used widely in developer-funded contexts where a large proportion of Mesolithic archaeology is now identified (Blinkhorn 2012). Their selection addresses Strategic Theme S2.1 of the Mesolithic Research and Conservation Framework (Blinkhorn and Milner 2013): to explore the extent and ways in which geophysical survey and aerial remote sensing techniques can be used to understand the presence and nature of Mesolithic archaeology.

As electrical and magnetic techniques are reliant on different phenomena, it is often the case that one technique will respond to subsurface remains where the other does not, though differences can be changeable dependent on depth of target archaeology, their make-up (differentially porous or magnetic sediments), ground conditions, weather conditions, proximity of highly magnetic materials, and local bedrock and superficial geology.

Aims and objectives

Both archaeological features and a detailed reading of the local superficial geology and soils were considered the main targets of the surveys. The aims of the surveys were to determine the presence or absence, nature and extent of potential archaeological features within the survey area to inform both fieldwork and site management.

Methods

Resistance

The 1.56 ha resistance survey was undertaken in 2010 by one of the authors (EB) assisted by students from the Universities of York and Manchester. Land use had recently changed from crop to improved pasture and at the time of the survey was used for cattle grazing. Whilst the survey was underway an electrified fence was erected to restrict livestock access to the area marked for excavation. The survey area was situated over gently undulating ground at a mean O.D. of 26 m. Whilst the summer was generally dry, a day of rain had fallen in the area a week prior to the onset of the survey.

A 20 m grid was established across the survey area using a Leica total station theodolite (TST) along the baselines and corners, supplemented by tape-measured triangulated points, and were arranged to cover as much of the dryland peninsula as possible in the north-eastern portion of the Star Carr field. Measurements of earth resistance were determined using a Geoscan RM15 resistance meter with a mobile twin probe separation of 0.5 m, giving a maximum depth of readings of 0.75 m (Gaffney and Gater 2003, 32). A zig-zag traverse scheme was employed and data were logged in 20 m grid units. The instrument sensitivity was set to 0.1 ohm, the sample interval to 1 m and the traverse interval to 1.0 m, thus providing 400 sample measurements per 20 m grid unit.

Data were downloaded on site and Geoplot v.3.00t software was used to process the geophysical data as greyscale images. *EdgeMatch* was the sole processing function used. This function is used to remove grid edge discontinuities which may be present in twin electrode resistance surveys as a result of improper placement of the remote probes, here used to eliminate discontinuities in data acquisition. Although position of both remote and mobile probes was kept consistent when moving the former, exact placement cannot be guaranteed. However, it is possible that the discontinuities are instead a result of moisture loss from the peat.

Magnetometry

The Landscape Research Centre (LRC) assisted the POSTGLACIAL project by loaning equipment and processing the data from two surveys; that over the Star Carr site itself (LRC Site 498) and part of the field to the north of the Hertford Cut (LRC Site 497). The surveys at sites 497 (c. 1.68 ha) and 498 (c. 2.45 ha) were carried out by Hayley Saul (University of York) in February 2009 in cool overcast conditions, following heavy snowfall at the beginning of the month.

The north field was put down to grass though coverage was patchy across the area surveyed, and the ground surface was locally undulating with <150 mm sods and molehills. The survey area was bounded to the east by a drainage channel banked by reeds and incorporating some ferrous litter, to the southwest by a track, and to the south by the Hertford Cut banked by trees and hedges incorporating a barbed wire fence between 1.2 m and 2.1 m high. A drop in topography along a SE-NW axis in the northeast of the survey was noted, the land surface differing by c. 1.0 m.

The south field was laid to pasture with extensive disturbance at the site of trench SC23 and to the southeast, where a large puddle had survived since the 2008 excavation season. The ground surface was wet, locally muddy and undulating with molehills. The survey area was bounded to the north by a hedge c. 1.8 m high and, beyond, the Hertford Cut. A large metal trough was positioned at the northern limit of the survey, to the northwest of SC24. Significant variations in topography were noted across the survey area.

The LRC primarily uses a *Foerster Ferex 4.032 DLG* 4-probe fluxgate gradiometer array, mounted upon a wheeled cart for geomagnetic surveys. The cart is designed to support survey covering large areas, and rather than rely upon hand surveyed and laid out survey grids collecting data on an estimated grid, relying upon the walking speed of the surveyor, the Foerster instrument employs a real time Kinematic GPS to record spatial data, which allows precise positioning of each data point with a nominal 20 mm precision. The instrument, which collects data within a 0.2 nT (nanoTesla) sensitivity range, is set to log data at 0.10 m intervals along the survey traverse axis, recording the magnetic values of each of the four probes spaced at 0.50 m intervals covering a 2 m span, and provides a maximum depth of readings of 1–2 m. The data density at 20 readings per square gives better definition to any magnetic anomalies recorded than we see in conventional surveys based on data collected at 0.25 × 1 m intervals. The resulting data, whilst spatially very precisely located, requires more extensive processing than conventional gridded data. The processing generates a triangulated surface model of the magnetic response which is then intersected at regular intervals to create the resulting geo-referenced magnetic survey image. The processing, generation and spatial integration of the survey images is undertaken using G-Sys (a proprietary Geographic Database Management program used by the LRC which can also display, process and present digitised plans and images). The fully processed files are archived in TIFF and PNG formats with supporting location information held in linked text files. The resulting data files are also saved in kml or kmz files for use within Google Earth.

During the processing, the geomagnetic data is re-scaled through simple multiplication by a factor of 10 to minimise any potential problems resulting from mapping the nanoTesla values to 8-bit greyscale images. The surveys covered in this report are based upon magnetic values of +12.8 nT and -12.8 nT whilst out of range values are clipped prior to full processing. The use of the Kinematic GPS, employing real-time corrections, generates spatial referencing data on the ordnance survey OSGB36 national grid.

Survey results

Interpretations made below should be read in combination with Figures 16.2–16.5. Not all anomalies are referred to in the text, nor are all anomalies marked in the Figures. Dipolar anomalies are presumed to come from recent agricultural land-use.

North field

Data in the field to the north of the Hertford Cut is dominated by a series of E-W (Figure 16.3, M1) and NE-SW (Figure 16.3, M2) linear anomalies, almost certainly with modern agricultural origins. Aerial imagery (Google Earth imagery date 29th October 2008) shows a close spaced but intermittent NE-SW linear scheme of linear features and a wider spaced E-W series of crop marks. The former regime dominates across the survey although the E-W trends become more prominent to the south. Considering the recent potato crop in this field it is highly likely that both subsoiling and potato harvesting are responsible for the anomalies discussed.

To the northeast the linear trends are lost and an enhanced NW-SE signal coincides with a drop in topography. Agricultural activity can therefore be thought to create disturbed linear signals on dryland areas and become almost invisible in the peat of the lake. The discontinuity of these may be a result of deeper geomorphological features on the dryland where agricultural machinery does not disturb the solid substrate. One such feature is highlighted by an irregular trend of enhanced readings (Figure 16.3, M3), partnered by a NNE-SSW example to the west (Figure 16.3, M4).

Whilst noise created by modern activity precludes a closer reading of the survey, a small group of weak positive magnetic anomalies may relate to archaeological features. A faint semi-circular anomaly to the south (Figure 16.3, M5), measuring a maximum of 10 m across may be associated with other magnetically enhanced features. To the north of these, two rough circular anomalies (Figure 16.3, M6) each measuring approximately 3 m across may equally represent archaeological soil-filled features.

South field

Agricultural action is far less apparent in the southern field, although some presumed plough damage is evident in the magnetic survey (Figure 16.3, M7), perhaps corroborated by linear anomalies in the resistance data (Figure 16.5, R1) and concentrations of high resistance spikes close to the peninsula. The signal returned by the edge of the dryland peninsula is strong in both surveys. To the east a linear high-resistance anomaly (Figure 16.5, R2) matches a magnetic trend (Figure 16.3, M8), and to the west a sharp contrast between high and low resistance and magnetic disturbance denotes the edge of the dryland (Figure 16.3, M9).

Along the north of the field significant magnetic disturbance is evident (Figure 16.3, M10), contributed to by a number of possible factors, including ferrous material in the field boundary, material dumped from the Hertford Cut, desiccating peat, or agricultural land-use. To the northeast (Figure 16.3, M11) more discrete magnetic enhancements could relate to palaeoenvironmental sample processing conducted in this area. In places, arrangements of dipoles or weak positive anomalies (Figure 16.3, M12), one group associated with Clark's cutting IV, may indicate former fence lines. Crescentic low-resistance anomalies (Figure 16.5, R3), each c. 10 m in diameter, found on the peninsula have no corresponding magnetic signal; their nature is uncertain and was unresolved by excavations in Trench SC35.

A large zone of magnetic disturbance (Figure 16.3, M13) correlates with both a zone of very low resistance readings (Figure 16.5, R4) and the location of standing water. The resistance signal is simply explained though the magnetic response is more obscure, perhaps deriving from modern dumped material used to fill the puddle. A more complex explanation invokes bacterial action on the iron and sulphur compounds in the waterlogged zone leading to magnetically enhanced, though disturbed, signals.

Subtle variations in the magnetic signal across the plot may be an indication of the condition of the peat, its depth or the degree to which it is affected by geomorphological change; for instance, the marbling evident at the east of the magnetic plot in an area interpreted here as wetter (on the basis of the resistance results) yet still on the dryland of the peninsula. However, to the west, greater depth of peat has yielded a more consistent quiet signal. Equally, the highest resistance results along the peninsula correlate with a fairly quiet magnetic signal.

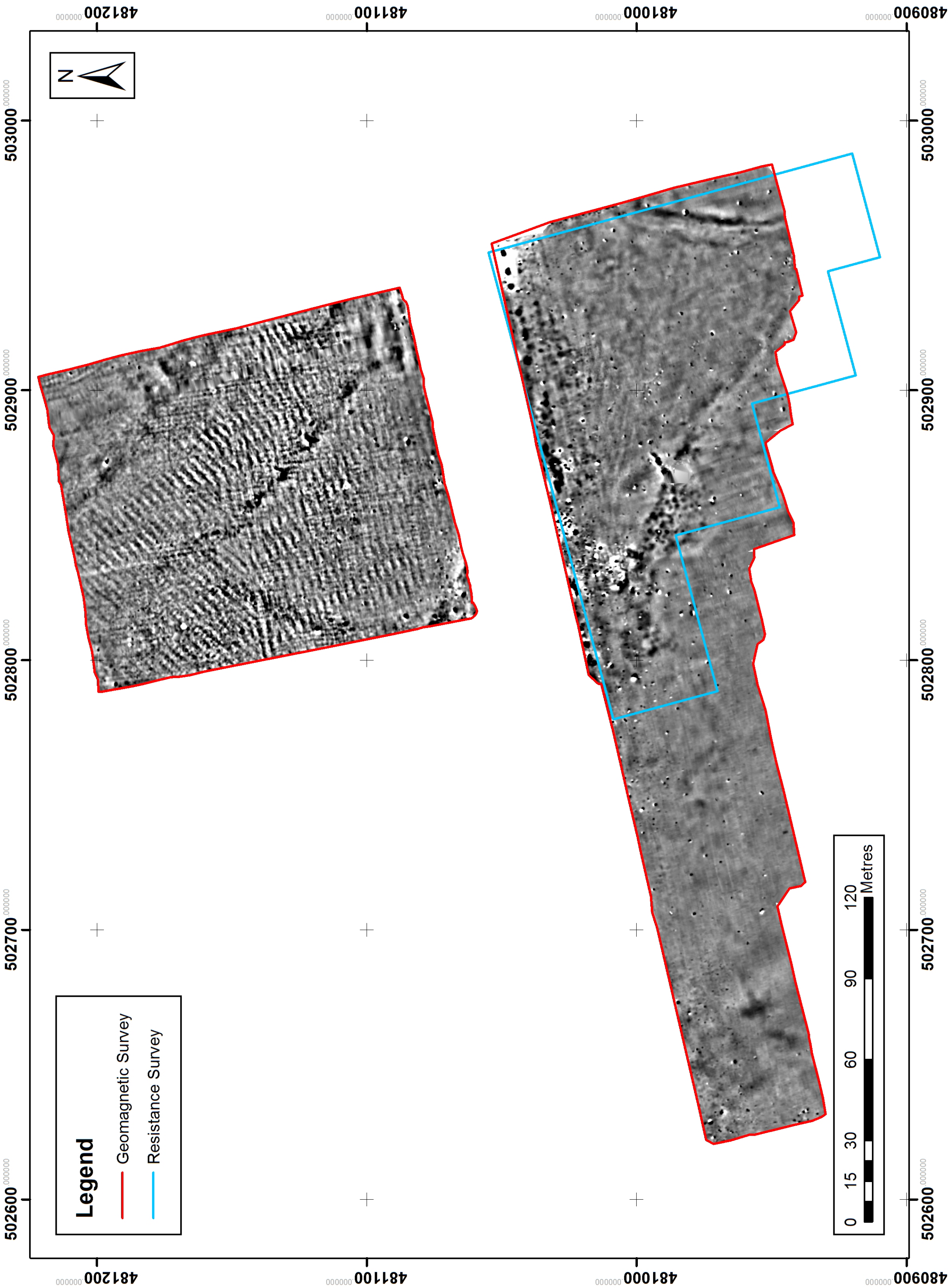

Figure 16.2: Magnetometry survey: data clipped to between +12.8 nT and -12.8 nT (Copyright Edward Blinkhorn, CC BY-NC 4.0).

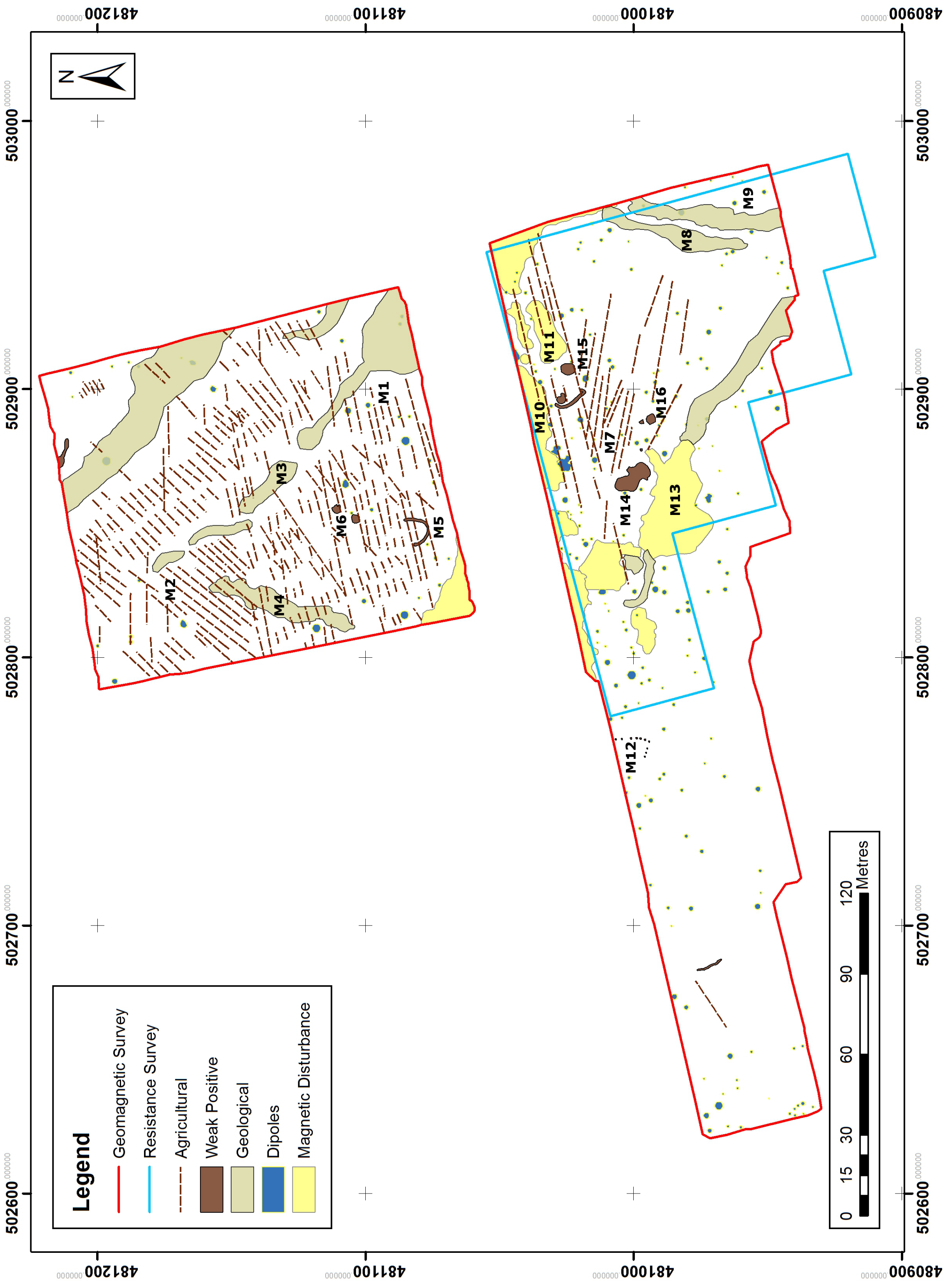

Figure 16.3: Magnetometry survey: interpretation (Copyright Edward Blinkhorn, CC BY-NC 4.0).

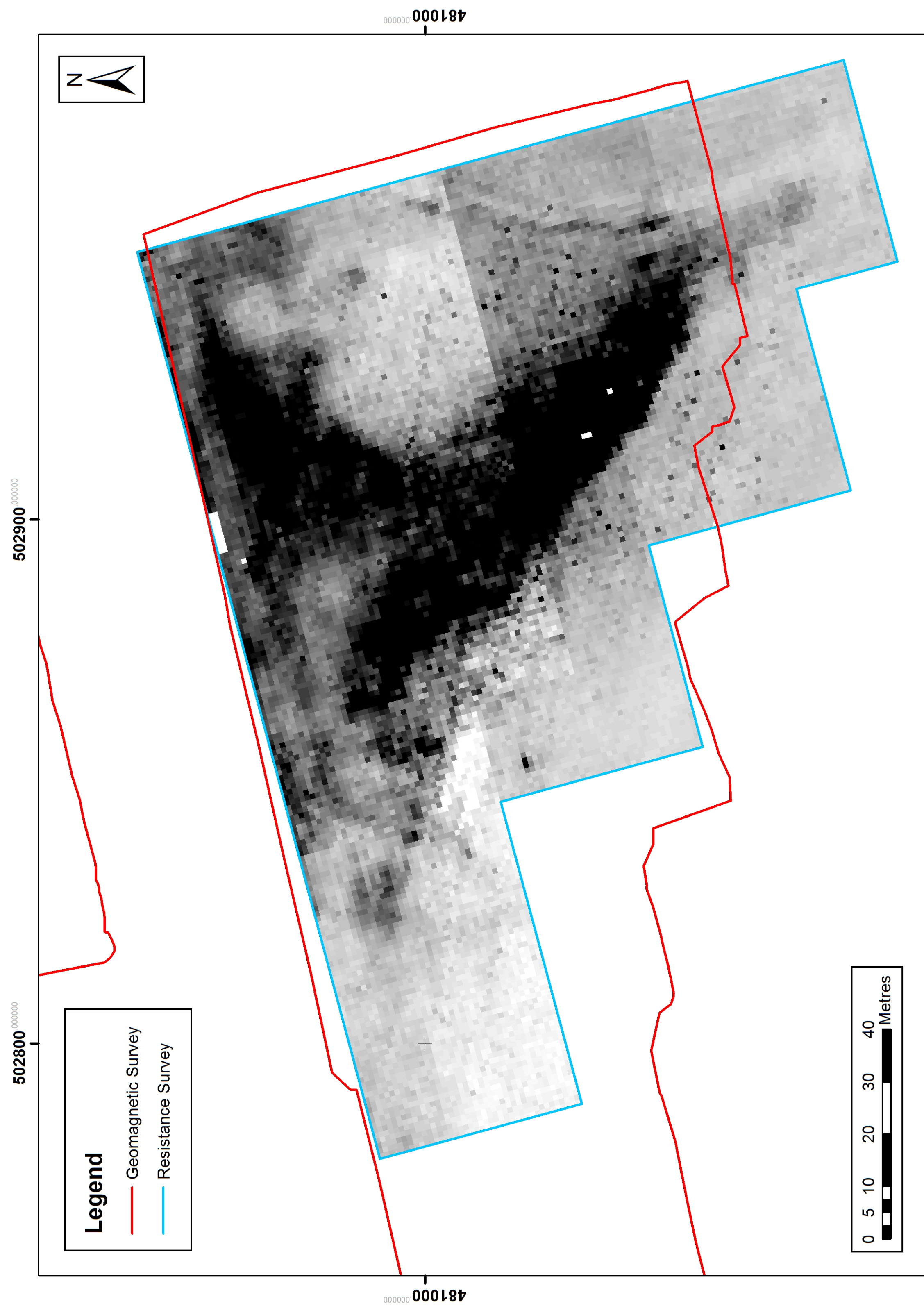

Figure 16.4: Resistance survey: data clipped to 25–85 Ohms (Copyright Edward Blinkhorn, CC BY-NC 4.0).

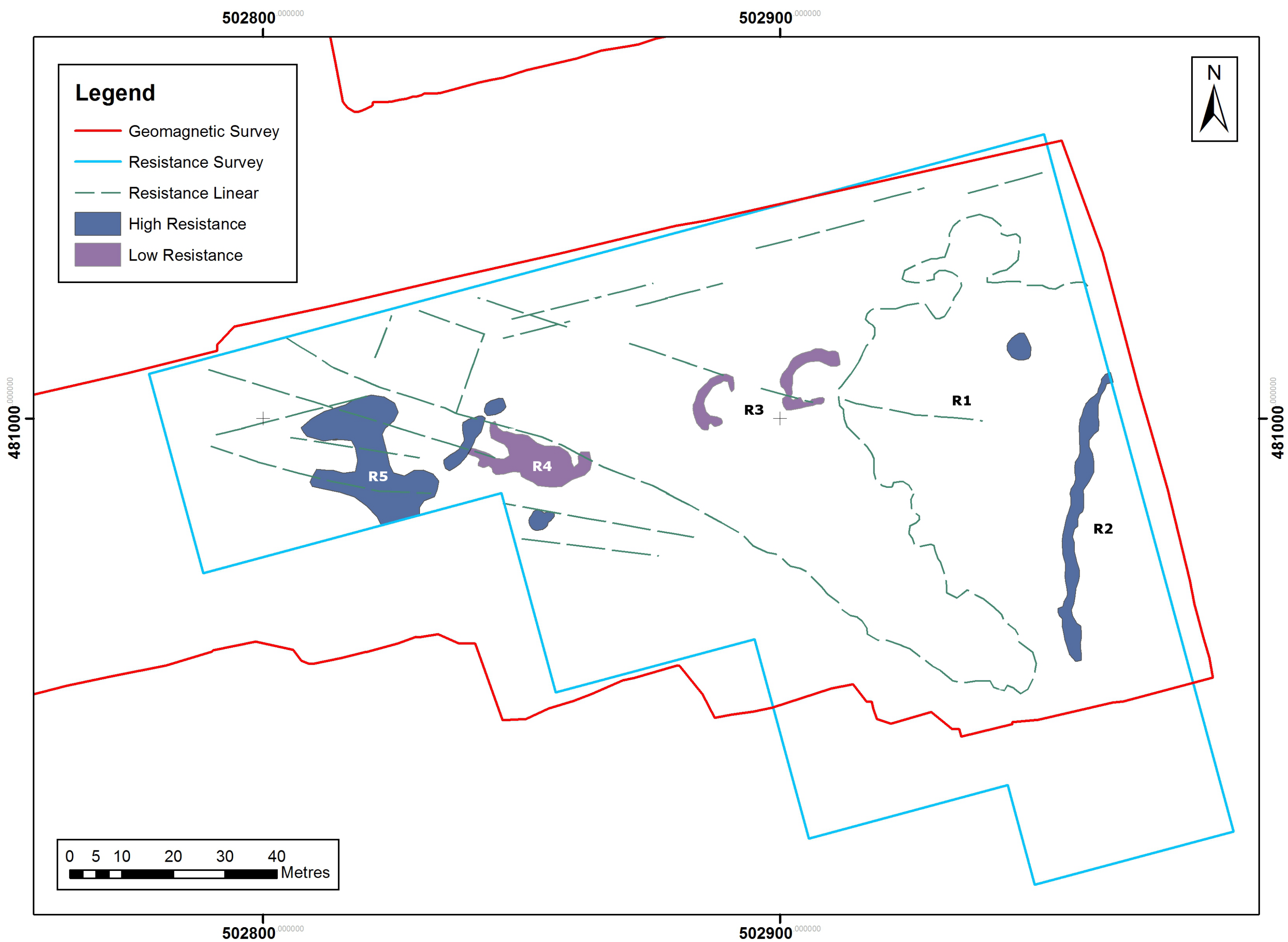

Figure 16.5: Resistance survey: interpretation (Copyright Edward Blinkhorn, CC BY-NC 4.0).

Patches of magnetic enhancement nearby (Figure 16.3, M14) broadly match variable resistance readings, perhaps showing the edge of significant localised peat development.

A small number of subround positive anomalies may be archaeological in origin (Figure 16.3, M15), although their distribution across the survey in areas of magnetic disturbance to the north urges a cautious interpretation. A single similar anomaly is located farther south (Figure 16.3, M16).

Little in the geophysical survey results correlates well with the archaeological discoveries, although trenches SC21 and SC24 are clearly visible. The western and central dryland structures have no discernible signal in either survey, despite associations with burnt flint, and the surveys were commissioned following the excavation of the SC08 structure in Trench SC24, leading to specious results. However, concentrations of wood are located in an area of subtle variations in the resistance results (Figure 16.5, R5), west of the waterlogging, which are most likely related to the complex hydrology and geology at the site which influences much of the resistance data.

Discussion

The greatest value in the plots presented here is the wider landscape approach whereby detail of the geomorphology can be extrapolated across the area surveyed and complement geochemical analyses and subsurface topographical modelling to understand the detailed geological architecture of Lake Flixton. Geomorphological responses dominate in the surveys, unsurprising considering the glacial derivation of landforms in the region. At the broader scale, significant anomalies can be correlated with ancient lake-edge topography, visible today due to peat shrinkage and demonstrated by auger survey (Chapters 3 and 4).

Perhaps more interestingly, subtler elements of geomorphology appear to be represented in the data. The resistance survey highlights the difficulty in making a clear distinction between 'dryland' and 'lake': the eastern portion of the peninsula yields readings similar to the lake peats, and significant areas of locally low resistance immediately to the east of trench SC34 suggest moisture retention, as does mottling south of trench SC35, associated with two semi-circular anomalies. The high resistance of the dryland is broken up to the north by a number of lower resistance readings, and discrete anomalies at both ends of the scale across the resistance survey illustrate the complexity of the subsurface ground structure.

The area southeast of trench SC34 is difficult to interpret and comprises complex variations in both resistance and magnetic data (Figure 16.6). Evidence from excavation implicates the influence of artesian springs in the Lake Flixton landscape and the possibility remains that such a spring is located nearby yielding modern waterlogging and expected low resistance, and minor variations in resistance readings in this area might represent a more complex depositional sequence than the contrast suggests. The effects of intrusive geology on the geomagnetic and resistance surveys are unknown, although they are likely to affect both, and differently. Magnetically enhanced deposits may be brought to the near surface in instances where there is significant vertical transport of deposits, though equally, target deposits might be eroded and replaced with magnetically unenhanced sediment. Dependent on the antiquity of springs, the resultant channels and modern soil moisture levels, resistance results may or may not accurately reflect ancient geomorphology. Peat cover may be reflected in both the survey results with magnetically quiet and widespread low resistance areas appearing to correlate with greater depths of peat, whereas shallow coverage leads to the inverse.

The geophysical surveys are ambiguous in the sense that clear-cut features are not easily interpreted. Nevertheless a small number of features are discernible which may relate to archaeological activity, although these have not been excavated and are difficult to truly justify without ground-truthing. These comprise equivocal anomalies all between c. 3–5 m in diameter in areas of relative magnetic enhancement or disturbance, and are the only examples suggestive of any excavated, albeit rather weakly. Needless to say the subround forms yield no information on date. Archaeological features revealed during excavations are not clearly represented in the data due to their proximity to magnetically noisy zones and presumed lack of local contrast in either magnetic or moisture. Considering the extent of plough damage in some areas, features cut into hard substrate may be the only evidence to survive.

Consideration must be given to the duration of deposition in the Lake Flixton landscape. The influence of many thousands of years of change is represented in the surveys: in the geological make-up of the landscape, regimes of hydrology, modern agricultural practice, recent archaeological interventions and possible archaeo-

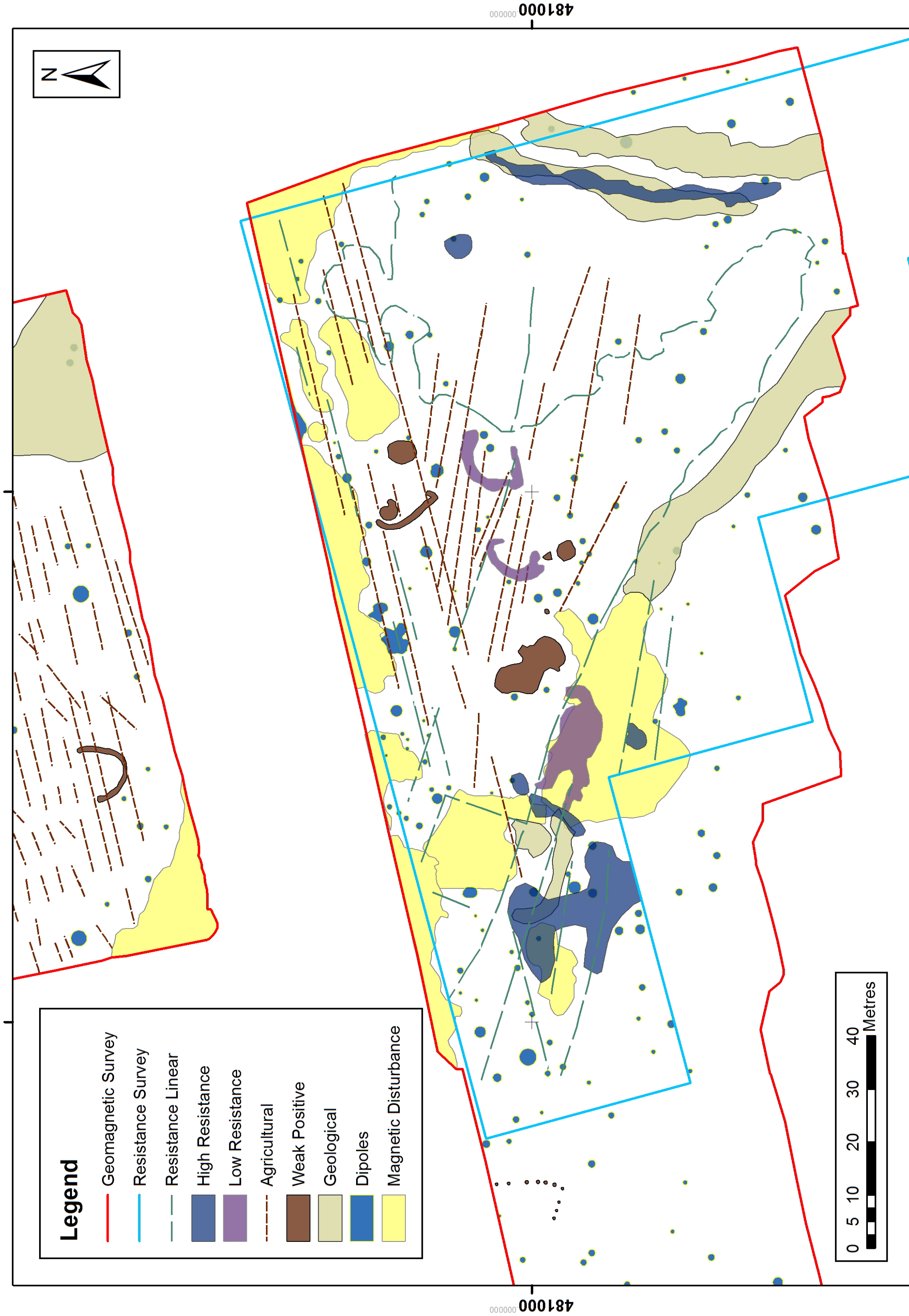

Figure 16.6: Detail of the south field, superimposed magnetometry and resistance interpretations (Copyright Edward Blinkhorn, CC BY-NC 4.0).

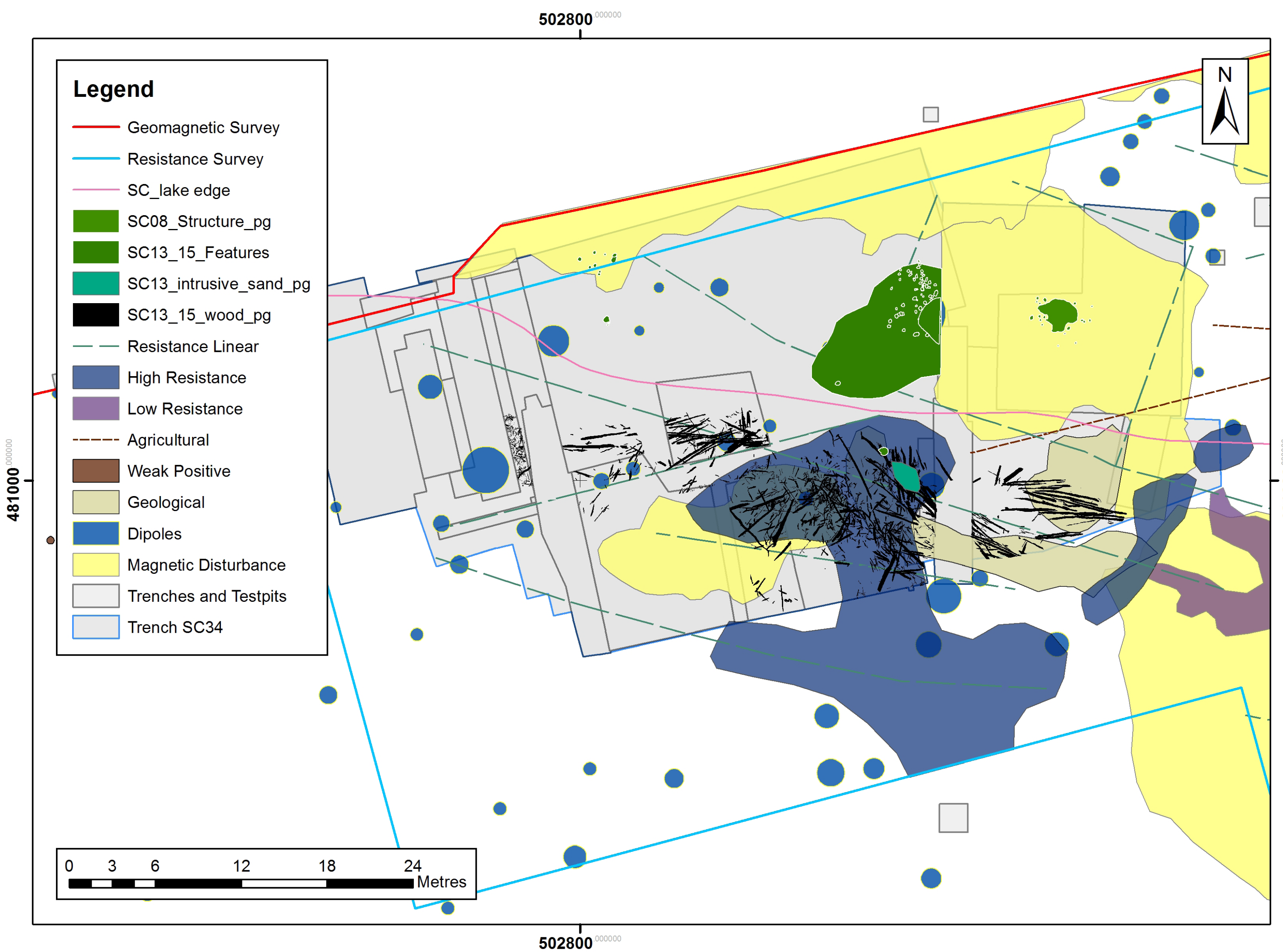

Figure 16.7: Correlation of geophysical survey interpretations with excavated findings (Copyright Edward Blinkhorn, CC BY-NC 4.0).

logical anomalies. Few indicators of date are inherent in the data beyond dipole responses and that which can be garnered from mapping. The data seems to support an argument that a more detailed geomorphological picture can gleaned from the techniques used here, though the antiquity of the deposits surveyed is in question. Natural electrical and geomagnetic phenomena measured in the surveys is a statement of modern condition rather than ancient configuration, and studies such as that on deterioration at the site (Chapter 22) highlight the influence of modern interference. Further interferences may derive from the Neolithic to post-Medieval periods.

Conclusions

This study has highlighted how traditional geophysical techniques can be of value in well-trodden parts of an archaeological landscape. However, it is not a final statement on the nature of deposits at Star Carr. Rather, the data should serve as the basis for an iterative model whereby schemes of interpretation could be extrapolated across horizontal space, drawing on other datasets which detail point-specific information, such as auger surveys and geochemical analyses, and alongside other remote datasets such as LiDAR or aerial photography. Considering the close spacing of the geophysical readings, appropriately sampled datasets would be of most value. In this way the geophysical surveys may function as a valuable proxy for the depth of Holocene deposits or even their condition.

Despite the absence of conventionally interpretable anomalies, and the uncertainty in those which have been identified as archaeological, geomagnetic and horizontal resistance survey may not be considered the most appropriate approaches with which to target the Mesolithic. At the time of the survey, other methods such as electrical resistance tomography or ground penetrating radar, whilst defining stratification would not have enabled such widespread coverage, nor were these widely deployed techniques. Considering the landscape processes at work and resolution of the data when interpreted geomorphologically, the results can be considered a useful resource in refining knowledge of the complex history of deposition at Star Carr.