GEOPHYSICAL SURVEY AT TOMEN Y MUR ROMAN FORT, GWYNEDD, NORTH WALES

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Report prepared by Grace Corbett, Jozef Doran, Kim Jurecki, Robert Johnston[1] and Colin Merrony[2]

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[1] R.Johnston@shef.ac.uk [2] C.Merrony@shef.ac.uk
Department of Archaeology, University of Sheffield, West Street, Sheffield, S1 4ET.

1. SUMMARY

Gradiometer and resistance surveys were undertaken within the interior of Tomen y Mur Roman Fort as part of a postgraduate training course in archaeological survey. The aims of the survey were to confirm and improve understanding of the layout and function of structures previously identified in the fort and to evaluate the suitability of resistance survey as a technique for investigating Roman forts in North Wales. Approximately 40% of the interior of the fort was surveyed using a fluxgate gradiometer and a resistance meter. The results were better than expected, showing evidence for barrack blocks, granaries, the Principia, roads and possible industrial areas. The geophysical survey complemented and enhanced previous surveys, and demonstrated there is potential for future more detailed, higher resolution survey at the site.

2. INTRODUCTION

2.1. Project background

The surveys were undertaken as a component of a University of Sheffield postgraduate training course in archaeological survey and geophysics based in the Trawsfynydd area, North Wales, in Easter 2008. In addition to the fieldwork at Tomen y Mur, geophysical survey was completed at a hilltop enclosure at Rhoswen and a programme of upland survey was carried out within the former Bronaber artillery range. The results of this fieldwork will be the subject of separate reports (Baxter et al. In Prep.; Cowsill et al. In Prep.).

2.2. Site location and land use

The Roman fort at Tomen y Mur is situated in a commanding position on the brow of a low spur overlooking Afon Prysor – now Llyn Trawsfynydd, at the crossing point of the Roman roads from Caernarfon to Caer Gai and Brithdir to Canovium (SH 705386; 285m AOD) (Fig 1). The area is currently under pasture and grazed by sheep.

2.3. Site description and history

Four main periods of occupation are still visible on the site: post medieval farm buildings and stone boundaries, the substantial remains of a Norman motte, and two phases of Roman fort, represented by earthworks and walls. The Roman remains are part of a wider complex including a bath-house, small amphitheatre, parade ground, roads and practice camps.

The earliest phase of the fort was probably an earthen auxiliary fort, 1.7ha in area, built in 77-78 AD during Agricola's campaign in North Wales (Dudley & Webster 1965, Jarrett 1969, Frere 1978, Wacher 1978). In the Trajanic/Hadrianic period, it was rebuilt in stone and reduced to about two-thirds of its original size by contracting the north-west line of defences (Jarrett 1969, Arnold and Davies 2000). This action was commemorated in a series of 10 centurial stones discovered in the nineteenth-century. The fort does not seem to have been garrisoned for long after the rebuilding, and may have been abandoned as early as the middle of the second-century AD. A fifth-century gravestone found nearby indicates some form of continued settlement in the area (Arnold & Davies 2000, Crew forthcoming).

Based on stories from the *Mabinogion*, it is possible that the area may hold the remains of a Dark Age hall or *Llys*. (Jones & Jones 1949). There is little archaeological evidence to support this, although a timber-built construction overlying the Roman road just outside the southeast entrance may be a candidate (Crew forthcoming). The name Tomen y Mur derives from the Norman motte – the most prominent feature on the site (Davies, 1967) – for which the fort provided a ready made bailey. The Norman phase of occupation is associated with the campaigns of William Rufus in the late eleventh-century but there appears to be no historical evidence for the establishment of the motte. The motte is built over, and presumably reuses, the northwest gate of the later roman fort, leaving the possibility that substantial remains of the gatehouse are preserved beneath the motte (NMR 95478).

The fort was overlain by post-medieval field walls, probably at the end of the eighteenth-century, and a now dilapidated farm (NPRN 89465), comprising two building groups arranged around a yard, was built into the northeast rampart.

There is a long history of archaeological investigation at the site. Excavations were undertaken in 1850 and 1868 around the southeast gate and bath complex, and a more recent excavation in 1962 in the northwest defences investigated the sequence and chronology of the fort's reduction in size (Simpson 1962, Jarrett 1969). None of the excavations intrudes significantly into the interior of the reduced fort. Various programmes of survey have been undertaken at Tomen y Mur. The first detailed survey was undertaken by Colin Gresham in the 1930s (Gresham 1938). Aerial photograph mapping of the landscape around the fort was completed by the RCAHMW and published in *Snowdonia from the Air* (Crew and Musson 1996). Subsequent more detailed topographic and gradiometer surveys were undertaken by Engineering Archaeological Services. The geophysical survey covered the interior of the fort, and produced relatively good results, showing the location and layout of some of the buildings. The gradiometer survey did not, however, reproduce the clarity of the recent programme of fieldwork at forts on the alluvial gravels of northeast Wales (Hopewell 2005).

2.4. Survey objectives

The survey was undertaken following consultation with the archaeologist for Snowdonia National Park Authority. The objectives of the surveys were defined as follows:

- confirm and improve understanding of the layout and function of structures identified on earlier aerial photographic and geophysical surveys;
- evaluate the suitability of resistance survey as a technique for investigating Roman forts in North Wales.

2.5. Evaluation of survey methods

Resistance and gradiometer area surveys were carried out (see the appendix for an explanation of these techniques). The gradiometer identifies features that produce a different magnetic signal to their immediate surroundings, such as a large pit or ditch, particularly where this is filled with burnt material, stone walls where these comprise non-local materials, and features associated with burning at high temperatures, notably hearths, kilns and their associated residues. The resistance meter is sensitive to changes in the moisture content of the soil, and is consequently affected by concentrations of stone, as in wall lines or cobbled areas, which have a low moisture content and show up as high resistance anomalies, and ditches and pits, which can have a high moisture content and return a low resistance.

The structures within the fort interior are likely to return strong anomalies for both the gradiometer and resistance surveys. There are, nonetheless, a few factors that may mitigate against their effectiveness. The drift geology, a glacial clay, may contain stone from a variety of sources and so can offer a complex magnetic background that can disguise archaeological features. The clay is also poorly draining, and excess soil moisture can influence the effectiveness of the resistance survey. There is also a strong possibility that the Roman structures will have been disturbed, notably during the robbing of stone during the construction of the Norman motte and the post-medieval farm and field walls.

3. METHODS

3.1. Dates and conditions of fieldwork

Six days were spent undertaking the surveys during April 2008. The weather was changeable, with both wet and dry windy conditions, but the soil remained damp throughout the fieldwork. The survey was supervised by Colin Merrony (University of Sheffield).

3.2. Grid locations

Forty-two 20x20m full or partial grids were surveyed with the gradiometer, covering the majority of the interior of both phases of the fort, and 21 20x20m full or partial grids were surveyed with the resistance meter, covering approximately 40% of the interior of the later phase of the fort (Fig. 1). The grids were laid out north-south, offset from the northwest-southeast alignment of the fort to prevent the possibility of the edge of grids and traverses affecting the visibility of linear archaeological features. The positions of the grids were recorded using a total station (Leica 407) from permanent control points established and referenced to the Ordnance Survey grid using a Leica SR20 GPS.

3.3. Survey methods

The instruments used for the surveys were a Geoscan RM15 resistance meter with a twin array set at 0.5m and a Geoscan FM18 fluxgate gradiometer. The sampling was undertaken at 1m intervals along 1m traverses walked in a zigzag pattern during the resistance survey and 0.25m intervals along 1m traverses, again walked in a zig-zag pattern, for the gradiometer survey.

3.4. Data processing and presentation

The data was downloaded, processed and prepared for presentation using Geoscan's Geoplot version 3.0 for Windows. The final illustrations were produced using ArcGIS version 9.1, Adobe Photoshop CS3 and Adobe Illustrator CS3.

The raw resistance data was processed in the following ways:

- clipped at ± 3 standard deviations;
- despiked with x and y radii =1, and a threshold of 2.5-3 standard deviations;
- grid matching was achieved using the add function or edge match;
- a high pass filter was applied in most cases to filter out geology;
- interpolation was applied to increase the resolution from 1 x 1m to 0.5 x 0.5m;
- Standard deviation function was applied in some cases to enhance features that were statistically different to the background.

The raw gradiometer data was processed in the following ways:

- clipped at ± 5-6 nT to remove large noise spikes and to improve the visibility of features of potential archaeological interest;
- zero mean traverse function was applied to remove striping effects in the traverse direction and to improve edge match between the grid squares;
- despiked with x and y radii = 1, and a threshold of 3 standard deviations;
- low pass filter was used to smooth the appearance of the data and enhance the visibility of features – though this tends to exaggerate some features and disguise small anomalies;
- standard deviation function was applied in some cases to enhance features that are statistically different to the background.

Where additional processing and enhancement has taken place it is listed on the corresponding figure caption.

4. RESULTS

4.1. Gradiometer Survey (Figures 2-4)

The gradiometer survey covered the majority of the interior of both phases of the fort with the exception of the motte and modern stone boundary wall. The clearest archaeological features on the survey are a series of long rectangular structures, sharing an alignment with the long axis of the fort, inconsistently defined by linear negative readings and enclosing areas that are notably 'noisier' than their surroundings (1-7 on Fig. 4). Some sub-divisions, perpendicular to the long axis, are apparent in features 3 and 5. Bi-polar anomalies are visible within all the structures: at the north-west end of 2, 3, 4 and 5, along the southwest side of 1 and the northeast side of 4, and in a wide band between 6 and the northeast bank (12). Features 1-7 all lie southeast of a relatively quiet band of readings, defined on the northwest by a faint linear feature (14), and roughly bisecting the phase two fort. A similarly quiet band of readings runs perpendicular to the first, centrally placed between structures 3 and 4.

The reasonably clear and regular pattern in the southeast half of the survey area is not matched in the northwest. A number of rectangular areas of larger negative and positive readings are identifiable (7-11). Two of these, 7 and 8, are located in the remains of the phase 1 fort; the others are in the area defined by the phase 2 fort, northwest of 14. The strength of the bipolar readings within 7, 8 and 9 are particularly striking, as is the regularity of the two parallel, but slightly offset, lines of smaller bipolar anomalies in 10. Only a short section of the earthworks of the northwest bank of the phase 1 fort appear on the survey (13).

4.2. Resistance Survey (Figures 5-7)

The resistance survey was restricted to the later phase of the fort, in an area to the east of the modern boundary wall. The results are less complex than the gradiometer survey, though broadly complementary. One structure (a, Fig. 7) is identifiable as a rectangular area defined by a high resistance anomaly in the same location as feature 3 on the gradiometer survey. A perpendicular sub-division at the northwest end of the structure corresponds with a bipolar feature on the gradiometer survey. Additional high resistance linear features (b) lie to the northeast of and on the same alignment as a, but these do not form definite structures. There is a band of low resistance readings between a and b, corresponding with the 'quiet' zone between 3 and 4 on the gradiometer survey. One further identifiable structure seems to be located northwest of a and b. The full extent of this is not clear as the northwest side is truncated by the motte, but it is roughly 22x26m in size, with an entrance to the southeast and some sub-division within the interior.

A few less well-defined features were visible on the inside edge of the northeast bank of the fort: a band of low resistance (c), along with an sub-rectangular structure (h). In the northwestern half of the survey area, there are two rather broad linear, low resistance features (e), and two possible structures (f and g).

4.3. Interpretation

Both surveys show clear differences in the layout of the phase 2 fort either side of a line between the northeast and southwest entrances. To the southwest, there is a range of six, similarly sized, rectangular structures, arranged with three on either side of a probable roadway leading from the southwest entrance towards the centre of the fort (the Via Praetoria). At least some of the structures were probably built in stone, as two produced high resistance anomalies. The poorer definition of the buildings on the southeast side of the resistance survey may be because the stone walls had been dismantled. However, the lines of positive anomalies on the gradiometer survey could be post-holes, suggesting a timber construction or perhaps a veranda (as at Llanfor: Hopewell 2005, 251). Sub-divisions are visible in parts of the buildings, and four of the six have a bipolar magnetic anomaly in the northwest end. There is a possibility, based on the resistance survey, that the southwest end of the buildings was slightly enlarged, forming an L-shape. The location, size, layout and regularity of these buildings means that they are probably barracks.

The strong magnetic anomalies between the barrack blocks and the northeast rampart, and perhaps continuing a short distance along the southeast rampart, could result from burning, for instance associated with kilns, ovens or hearths, or they may result from a dump of ferrous material. The former interpretation is supported by parallels with excavated Roman forts where cooking ovens or workshops were situated against the inside of the rampart (Hopewell 2005, 200-201), as at Caerleon (Nash Williams 1956), though this is by no means proven in this case.

It is more difficult to interpret the features northwest of the Via Praetoria. A headquarters building, the Principia, was identified on the southeast side of the motte as a cropmark on an early aerial photograph of the site. This corresponds with high resistance features on the resistivity survey, and a few faint lines may be discerned on the gradiometer survey – although these are more likely to be cultivation ridges, as there are more parallel lines to the northeast. The high resistivity of the anomalies would suggest that the structure was stone built, while its relatively poor definition may be a consequence of the robbing of building materials during the construction of the motte.

A further five areas of magnetic disturbance were identified northwest of the Via Praetoria during the gradiometer survey. None of these are as clearly defined as the probable barracks, with the exception of two parallel lines of bipolar anomalies to the west of the Principia. It is possible that these are the burnt remains of a granary building – usually identified by stone or timber supports for a raised floor. The structures in the phase 1 fort, to the northeast, might also comprise a series of postholes associated with granaries, but this is very speculative, and there are a wide range of other buildings that might have been present.

There are a few features identified during the survey that may not be a consequence of the Roman occupation of the site. These include an area of cultivation, a small irregular shaped feature in the southeast corner, and possible oval of postholes in northeast corner.

5. CONCLUSIONS

The geophysical survey at Tomen y Mur has complemented and enhanced the previous gradiometer survey undertaken by Engineering Archaeological Services. There is potential for further geophysical survey at the site. This could include extending the survey areas within the fort's interior and investigating other locations within the immediate landscape. The quality of the results attained thus far suggests that more detailed, higher resolution survey within the interior would also be worthwhile, for instance using a caesium magnetometer.

6. ACKNOWLEDGEMENTS

We wish to acknowledge the help of the following: John G Roberts (Snowdonia National Park Authority) for instigating and supporting the fieldwork, Peter Crew for advice and help with unpublished sources, the land owner for allowing access to the site, and Cadw for consent to survey a Scheduled Ancient Monument.

7. REFERENCES

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8. Appendix – Technical details of the methodologies

8.1. Resistance meter

The Geoscan RM15 measures the electrical resistance of soils and sediments. Fours electrodes are employed: two current probes (that pass the electric current) and two potential probes (that measure the resistance to the passage of that current). These four electrodes may be arranged in various ways. Depending on the arrangement, measurements of similar volumes of sediments can be obtained and the amount measured may be used to calculate a value of resistivity of the sediments. In the twin-probe arrangement the electrodes are 'paired' (a current probe with a potential probe), with one of the pairs remaining in a fixed position whilst the other pair is moved thereby measuring the resistivity variations across a grid. The twin-probe array has a depth penetration of up to 1 metre, although the nature of the overburden, underlying geology and soil moisture levels will cause variations in this figure.

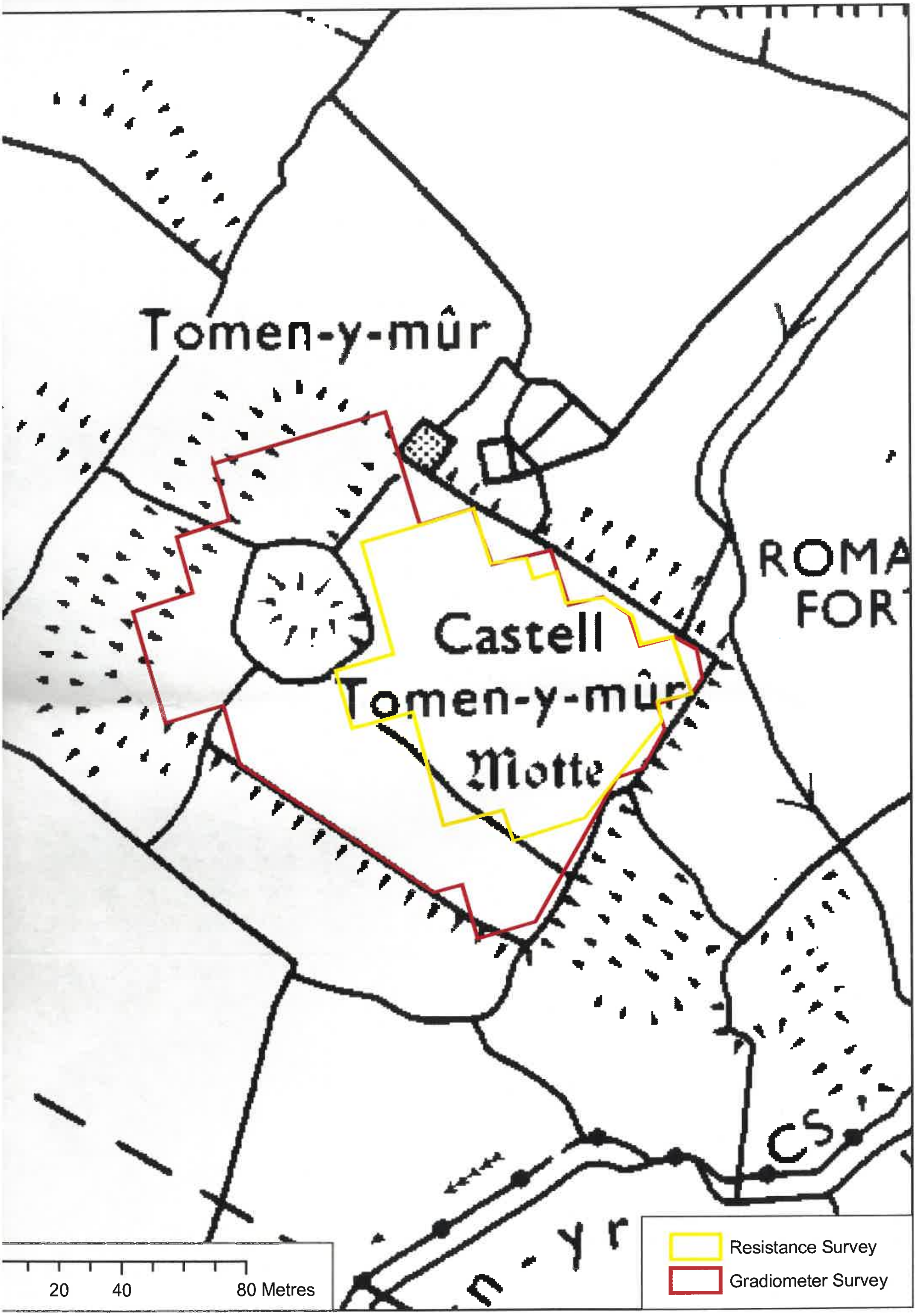
The resistance to the passage of an electric current through a soil or sediment is primarily related to moisture content. Electric current passes more easily through moist deposits than dry. Consequently resistance survey is particularly suited to the definition of buried archaeological remains that are the result of past human actions that have altered the ability of the deposits to hold moisture. The foundations of a stone wall hold considerably less moisture than the organic-rich fill of a ditch or pit. Consequently the resistance values of a pit or ditch may be expected to be significantly lower than those of a stone wall. Complete waterlogging or desiccation of soils and sediments can cause these differences to become (temporarily) undetectable and so weather conditions and general soil moisture levels must be noted.

8.2. Fluxgate gradiometer

The Geoscan FM18 is a Fluxgate Gradiometer that utilises two sensors to measure external magnetic fields. The upper sensor is positioned to detect the earth's magnetic field, while the lower sensor detects the earth's magnetic field plus any other magnetic field resulting from below ground features. The two measurements are compared so that the effect of the earth's magnetic field can be removed. The strength of any other magnetic field present is then recorded. The instrument is carried so that one sensor is positioned vertically above the other and measurements are taken at intervals across a fixed grid.

There are two main mechanisms by which archaeological deposits are able to possess a magnetic field and therefore become detectable by magnetometer survey. The first of these is *thermoremanent magnetisation*. This results when a material containing iron oxide particles (i.e. virtually any soil or subsoil) is heated up to above the Curie point of the iron oxide particles it contains (650 degrees Centigrade or more). On heating the iron oxide particles demagnetise. When the material cools, the iron oxide particles remagnetise as far as possible preferentially aligned with the earth's magnetic field for the material as a whole. This magnetic field can be detected by the gradiometer survey. The second mechanism is that of *magnetic susceptibility*. This is the ability of a material to become magnetised when placed in a magnetic field. Iron Oxides are highly magnetically susceptible, although the precise level of this depends on the form of the oxide. Consequently increasing the concentration of iron oxide or changing the form of the iron oxide particles will make a deposit more magnetically susceptible. If this deposit is placed within a magnet a greater magnetic field will result. Fortunately all archaeological deposits, along with everything else on the Earth, are within the Earth's magnetic field at all times and the resulting magnetic fields can be detected by a gradiometer survey.

9. FIGURES



1 Plan of Tomen y Mur Roman Fort showing the location of the survey areas.

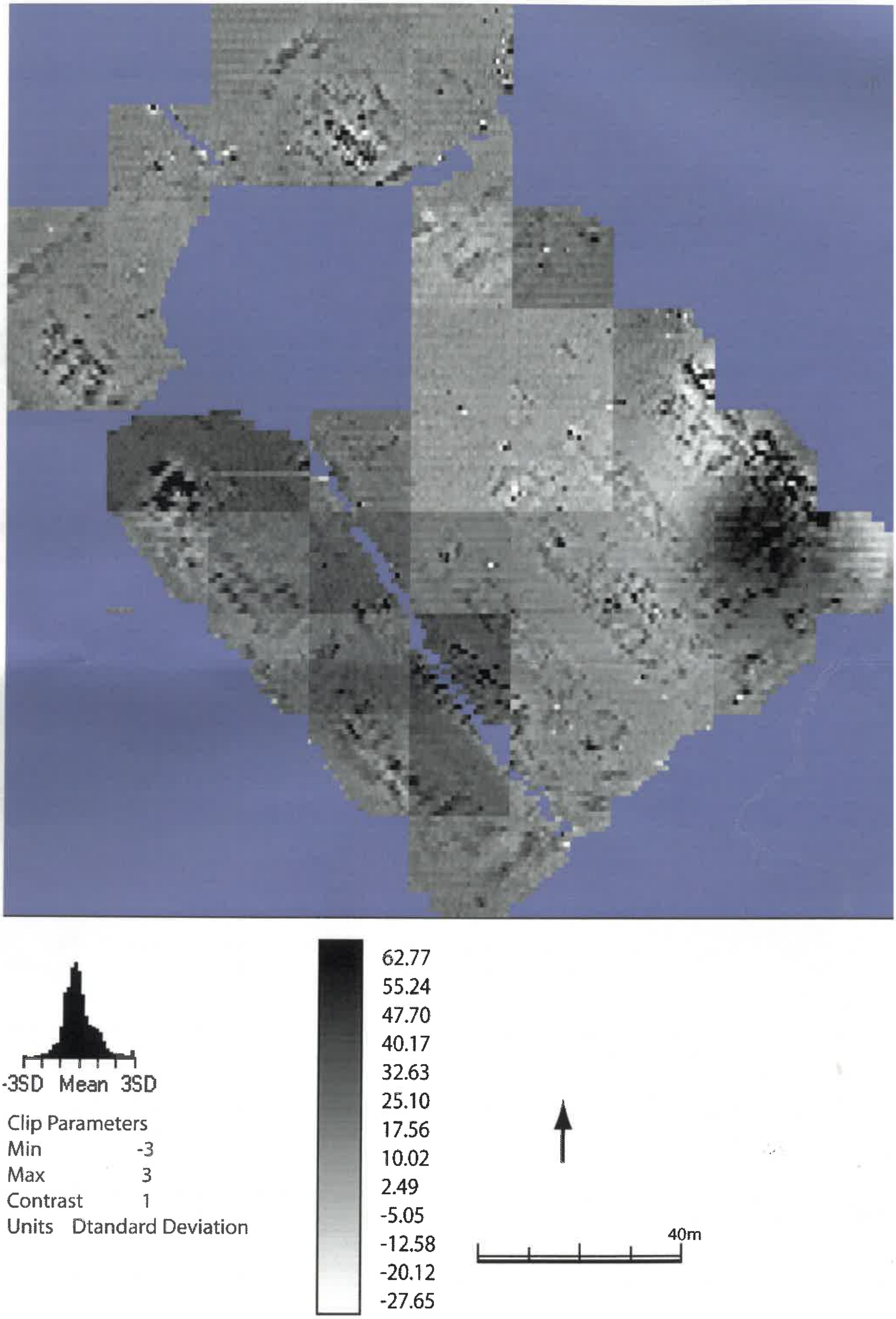


Fig. 2 Un-processed gradiometer survey data, Tomen y Mur Roman Fort

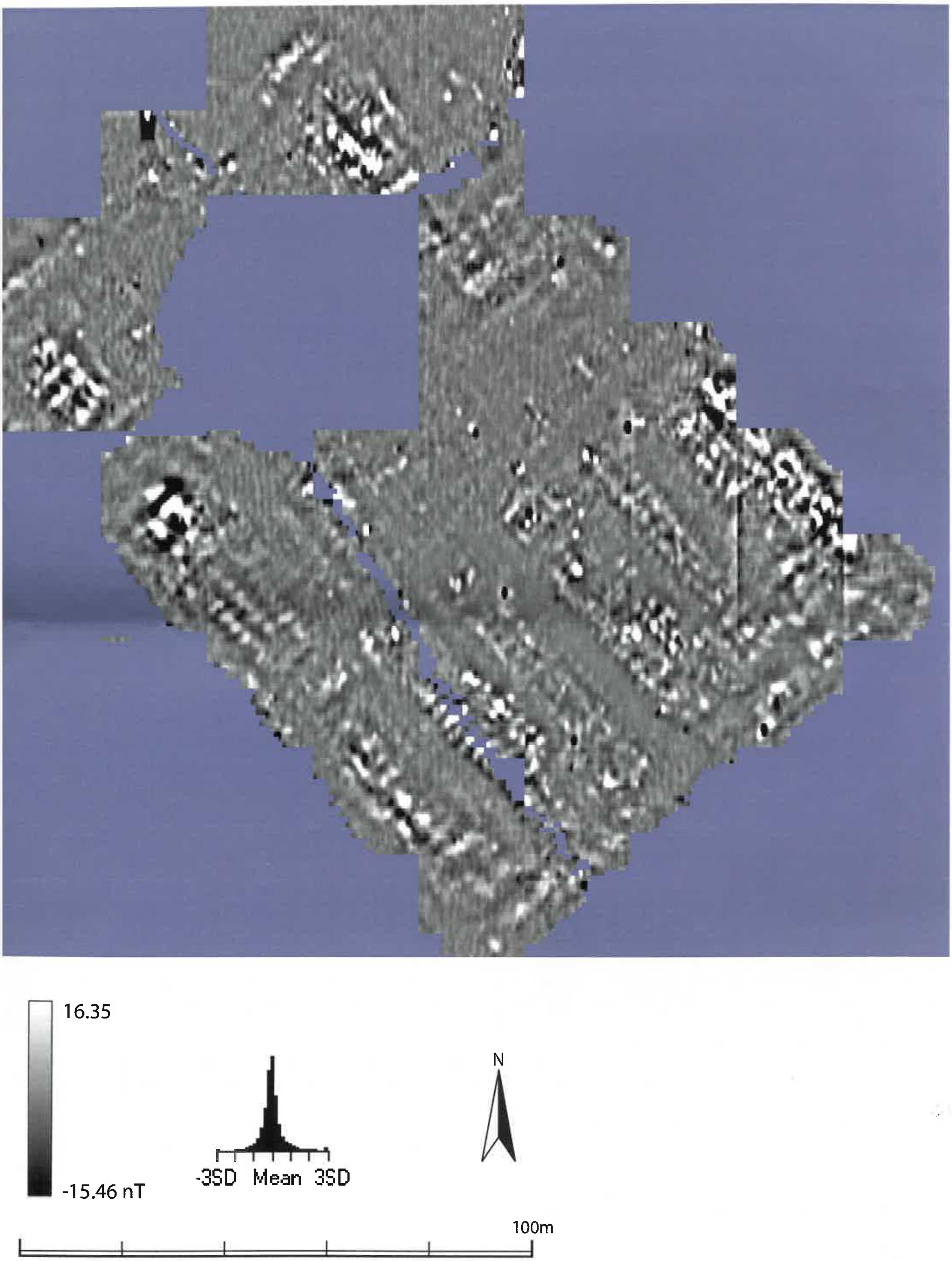


Fig. 3 Processed gradiometer survey of Tomen y Mur Roman Fort.

Fig. 4 Interpretation of the processed gradiometer survey of Tomen y Mur Roman Fort.

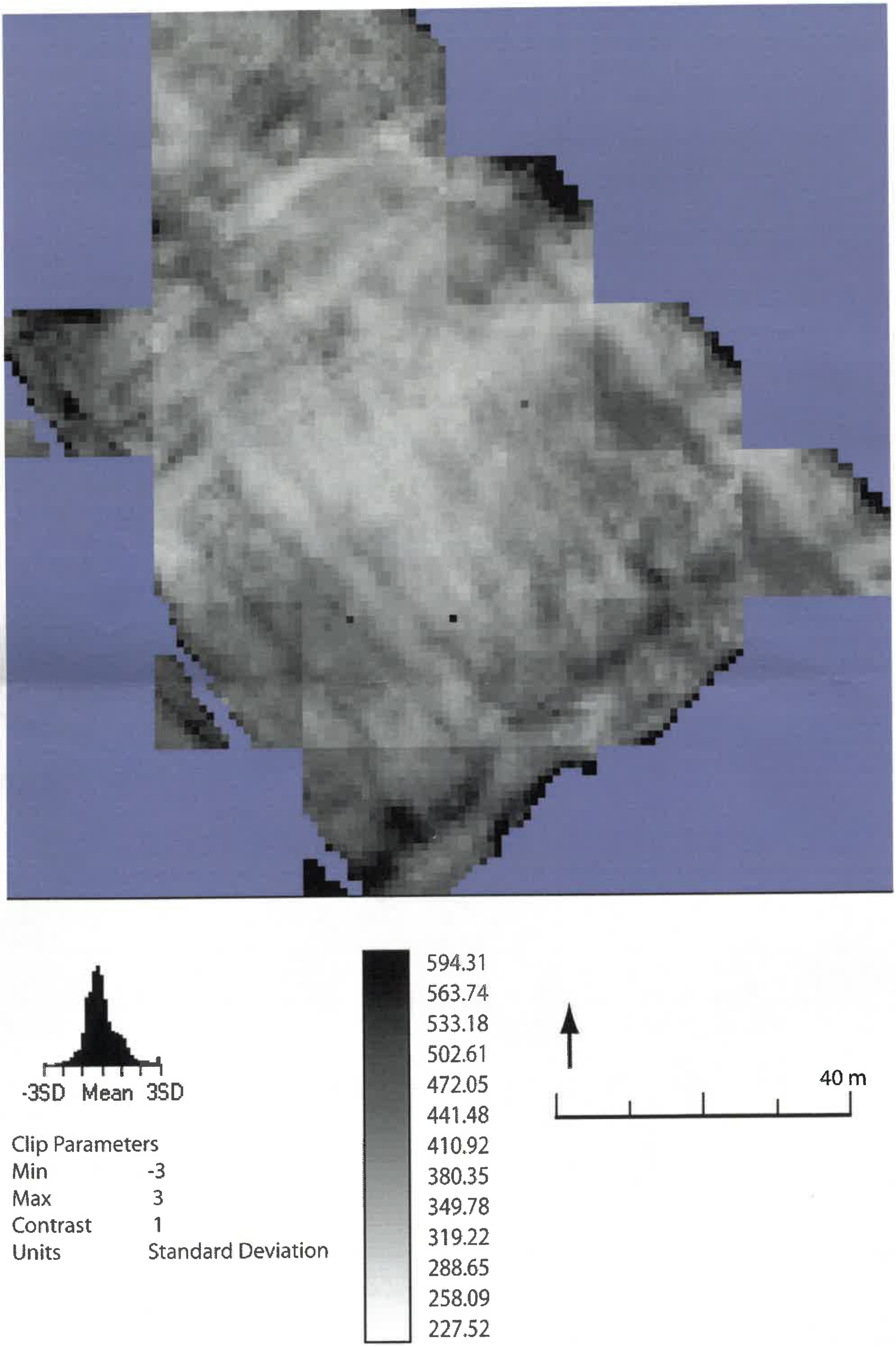


Fig. 5 Un-processed resistance survey data, Tomen y Mur Roman Fort

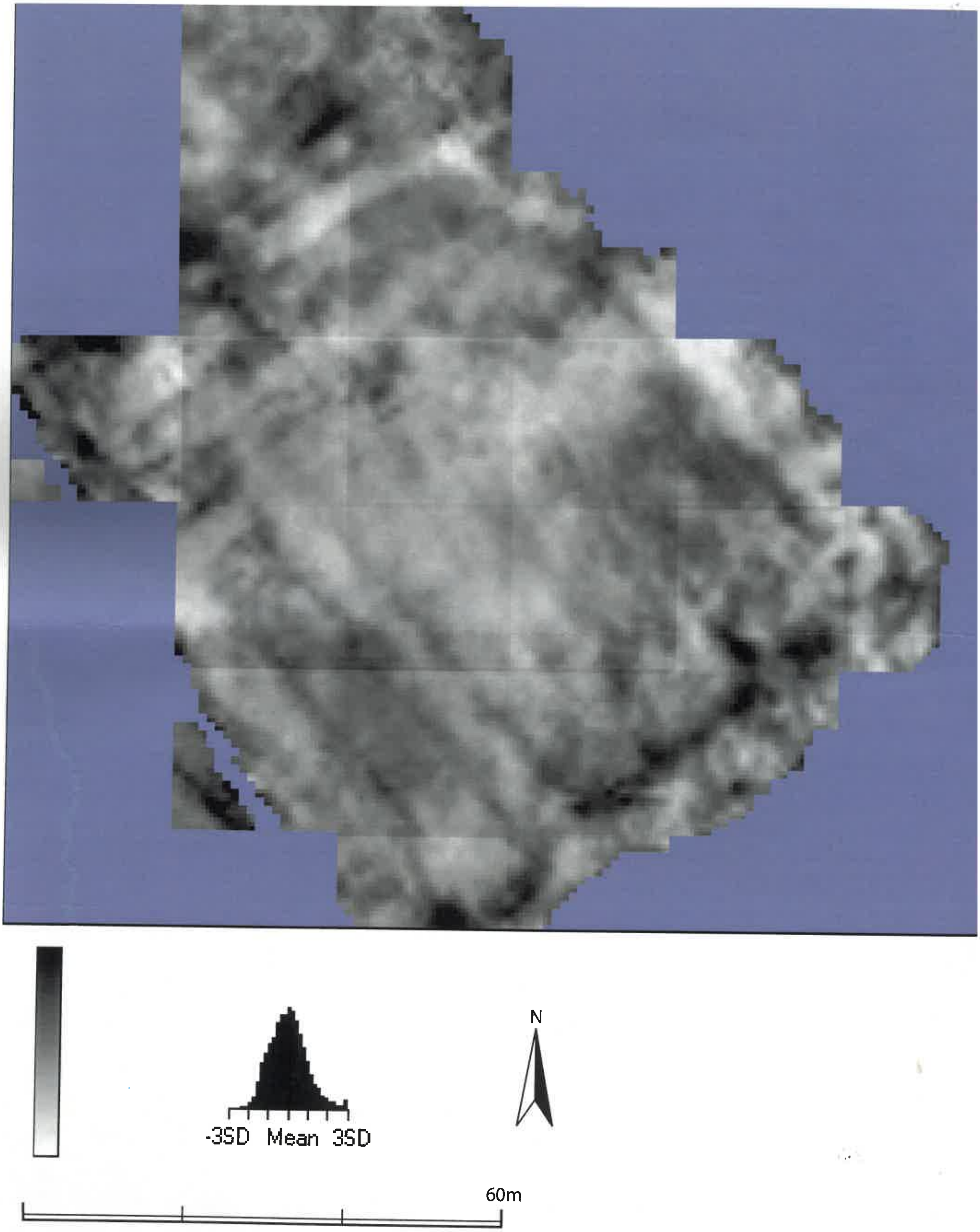


Fig. 6 Processed resistance survey of Tomen y Mur Roman Fort.

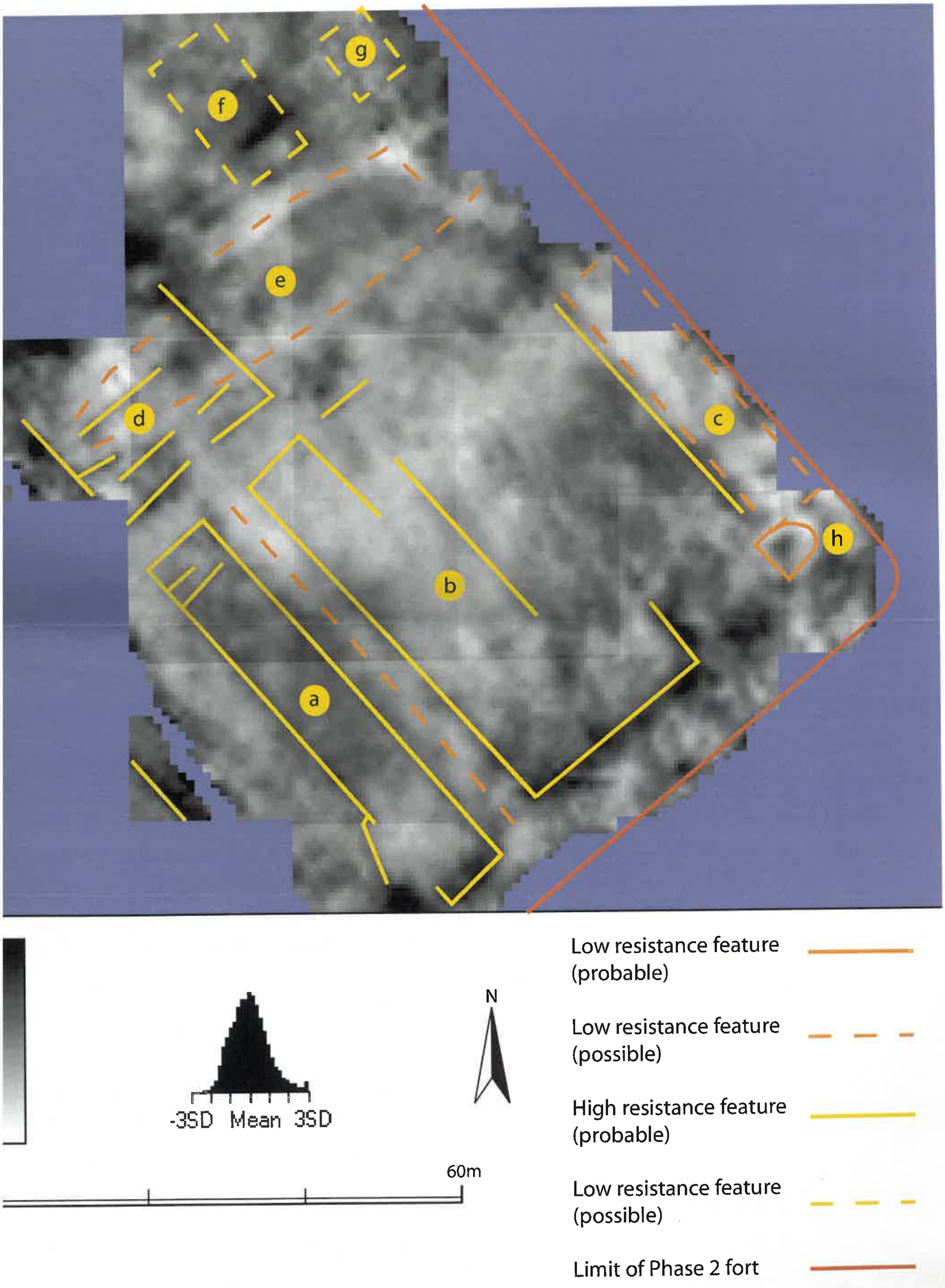


Fig. 7 Interpretation of the processed resistance survey of Tomen y Mur Roman Fort.