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Report 33/94

STONEHENGE: 20TH CENTURY EXCAVATIONS PROJECT REPORT ON GEOPHYSICAL SURVEYS 1993-4

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Report on Geophysical Surveys 1993-4

SUMMARY

Despite the publication of two major survey projects in the Stonehenge Environs, Stonehenge in its immediate landscape setting has never been subject to any detailed non-invasive investigation. This report describes geophysical exploration of Stonehenge and the triangle of land that encloses it (the 'Stonehenge Triangle') undertaken in 1993-4 by the Ancient Monuments Laboratory. The surveys were carried out on behalf of English Heritage and Wessex Archaeology for the Twentieth Century Excavations at Stonehenge Project and consisted of a magnetometer survey of the whole triangle and a detailed resistivity survey of the famous henge monument. The magnetometer results provide new information on monuments and features in the triangle, some already documented but not previously subject to detailed study or survey. The resistivity data enhances the existing body of excavation and survey evidence for the arrangement and structure of the henge monument in its various phases. Both surveys therefore make a significant contribution to further understanding the history of an area at the heart of a landscape of outstanding archaeological importance.

INTRODUCTION

"Geophysical examination of an area outside the Stonehenge earthwork in order to identify the presence of any buried structures" was recommended in a survey of Stonehenge and its Environs published by the Royal Commission on Historical Monuments for England (RCHME) in 1979. Since then, with the exception of that over the Avenue, immediately north of the monument (Bartlett and David 1982) no published geophysical survey has taken place adjacent to or within the henge[1] - a remarkable situation given the wide use of geophysical techniques on archaeological sites in this country for over 30 years. The 20th Century Excavations Project with its aim of producing a definitive account of archaeological intervention at the monument (Lawson 1992), presented an obvious opportunity to rectify this omission which had resulted in a gap being left unresearched between Stonehenge and its wider more studied environs (Richards 1990).

Professor Atkinson's excavations in the 1950s and 60s were intended to answer specific outstanding questions that earlier excavation records were unable to provide. However, although his work was clearly aimed to be definitive, it was nevertheless a sample. Consequently, his reconstruction of the development of the monument was based on extrapolation of patterns of features (such as the Q and R holes) backed up by probing. That new discoveries were still possible was subsequently proved by Pitts in 1980 (Pitts 1982). As well as recording the evidence for former excavations at the site, a pre-requisite of further research therefore was to assess the reliability of judgements based on the previously excavated sample without resort to further destructive intervention. The Ancient Monuments Laboratory was thus commissioned to undertake the first full geophysical exploration of Stonehenge and its immediate landscape setting. The survey was carried out during 1993-4 with the following objectives:

i) To supplement the excavation record from the henge by attempting to map the full distribution of features partly known from excavation, and locating any possible previously unrecognised elements of the monument.

ii) To help set the excavations in the wider context of the immediate surroundings of the monument - an area not previously the subject of detailed study.

iii) To provide information on the recent history of landuse in the area and show the impact of modern activities on the site, thus assisting the description of the development of the monument up to the present day.

The surveys were carried out within the triangle of land enclosing Stonehenge defined by National Grid coordinates SU 11804186, 12014235 and 12674208 and bounded on the north by the A344 and to the south by the A303 (T) roads. This area, termed the "Stonehenge Triangle" for the purposes of this report (Figure 1), forms the core of the World Heritage Site and encompasses land owned and managed on behalf of the government by English Heritage with a strip of National Trust property along the western boundary. Apart from Stonehenge the only archaeological features visible on the ground in the triangle are barrows. With the exception of a large well preserved bell barrow (Amesbury 11[2], County Monument Number WI 64h) adjacent to the A344 and just to the east of Stonehenge, the barrows are all in a very degraded state and form a scattered group (Amesbury 4-10[2], County Monument Number WI 64a-g) west of Stonehenge on Stonehenge Down. The majority are recorded by Grinsell (VCH Wiltshire Vol. 1 1957) as being of simple bowl form.

Geology and Soils

The solid geology consists of periglacially weathered Upper Cretaceous Middle Chalk (Richards 1990, Pitts 1982) overlain by shallow humic rendzina soils of the Icknield Series (Soil Survey of England and Wales 1983).

Previous Geophysical Survey Work near Stonehenge :

Parts of the landscape surrounding Stonehenge were surveyed in the 1980s in support of the Stonehenge Environs Project (Richards 1990). This work included a survey of part of the Cursus (Gater 1987), Coneybury Hill, the Lesser Cursus and flint scatters identified during fieldwalking at Wilsford Down, Fargo Wood and King Barrow Ridge (Bartlett 1988a, 1988b). More recently, magnetic surveys of very large tracts of land have been carried out by contract organisations in advance of proposed road-construction options and the development of new visitor facilities. Additionally, a full survey of the Lesser Cursus has been completed (Bartlett 1993). Also, the Ancient Monuments Laboratory has carried out surveys of the interior of the nearby henge enclosure at Durrington Walls (AML Archive), the eastern end of the Cursus, Amesbury 42 long barrow (Payne and White 1988), and over the first turn of the Avenue. Results from the latter have been integrated within the following account.

METHOD

The first phase of the geophysical survey programme consisted of a fluxgate gradiometer survey[3] of the entire Stonehenge triangle. The speed of ground coverage of this survey method combined with the ability of magnetic survey to detect a wide range of buried archaeological features dictated that it was the only practical method to employ for the whole triangle. The main target of this work was to assess the area around Stonehenge for traces of associated settlement, and funerary or other activity - in the absence of fieldwalking and excavation evidence - and to define and confirm previously documented features (such as barrows). The henge monument itself was also included in the survey in spite of the anticipated modern disturbance. The magnetometer survey was followed up in May 1994 by a detailed resistivity survey[4] of the henge enclosure. The aim of this work was to supplement existing excavation and survey of the monument. Resistivity survey is potentially capable of locating the presence of further unidentified stone-holes or stumps (eg at Avebury: Ucko et al 1991). In addition it was hoped that the resistivity data would corroborate the location and extent of some of the past excavations. In addition to the survey of the henge, resistivity survey was also carried out over two barrows to the south-west, on Stonehenge Down (see below).

i) Magnetometry

The survey area was divided up into a grid of 30m squares, set out and measured into the henge and field boundaries using a total station theodolite (see Figure 2). Each square was surveyed using Geoscan FM36 fluxgate gradiometers with traverses 1m apart. The gradient of the Earth's magnetic field was measured at 0.1 nanotesla (nT) sensitivity at 0.25m intervals along each traverse. Traverses were orientated north-south. The data was recorded in the internal memory of the FM36 and periodically transferred in the field to diskette on a portable micro-computer for storage and verification. The resulting data-set was subsequently recombined in the laboratory using in-house software mounted on a graphics workstation facility and is presented as a series of interpolated greyscale or half-tone plots[5] and X-Y traceplots[6] (see below).

The total survey is presented in Figure 3 in the form of a greyscale plot of the raw data at 1:2500 scale in locational context. Owing to the detailed sampling interval and the considerable size of the survey coverage, the resulting data-set is very substantial. To enable display at an acceptable scale for adequate feature recognition, the data has been presented (after enhancement by a 1m Gaussian low-pass filter (Scollar 1990)) in two halves at 1:1250 scale as greyscale plots (Figures 4-6) and also as a set of four X-Y traceplots of the raw data (Figures 7-11).

ii) Resistivity

The grid used previously for the magnetometer survey was reinstated over the henge (Figures 15 & 16) and surveyed using a Geoscan RM15 resistance meter connected in the Twin Electrode configuration with a mobile probe separation of 0.5m. The survey was carried out with a reading interval of 0.5m along successive parallel traverses 30m long and 0.5m apart to increase the ability to detect features less than 1m across. The data was recorded in the internal memory of the RM15 and was perodically transferred during fieldwork to a portable Toshiba T2000 computer for storage and verification. The raw data from each grid square was subsequently reconstructed as for the magnetic data (see above). The resulting plots illustrate the lateral variation in resistance of the near-surface up to a depth approaching 1m. The plot of the raw data used in Figure 17 has also been combined with a plan of the henge (Figure 18) and a plan of the excavations at Stonehenge (Figure 19) to aid interpretation. In order to improve the recognition of archaeologically significant anomalies, the initial data was enhanced using a 3m Gaussian high pass filter to remove broad trends and highlight features less than 3m in width (Figure 20). This process proved extremely helpful in identifying small features such as the Y and Z holes in areas of lower than average background resistance. In addition the data was processed with a Wallis algorithm to enhance the generally high resistance area around the stone-settings (Figure 21). Directional edge-emphasising filters were also applied to produce a shadow or relief effect, which can provide similar detail to aerial photographs taken in snow or low light (Figure 22). An X-Y traceplot of the raw data is also supplied (Figure 23) for comparison with the greyscale plots.

RESULTS

1. Magnetometer Survey

Numerals in bold text refer to the interpretation diagram in Figure 13.

The Henge

The area within the henge is characterised by massive magnetic disturbance, due to the presence of near surface iron. The possibility that a thermal remanent magnetic effect from the igneous bluestones could have contributed to the magnetic disturbance around the henge should also be considered. Modern disturbance can be attributed to at least the following factors.

i) Metal underpinning around the stones from 1920s and 1950s restoration (**1**) (Chippindale 1983, 179).

ii) Clinker used to backfill Atkinson's excavations in 1963 (**1**) (Chippindale 1983, 179).

iii) The cables of an underground security listening system installed *c.* 1967 (Chippindale 1983, 255).

iv) Buried cables and inspection covers for a former floodlighting system (**2**).

v) Disturbance associated with the modern visitor access paths and footpath erosion control (**3**).

Despite such modern disruption, the survey shows that, as expected, the fill of the henge ditch remains intact on the north and west sides of the earthwork, as indicated by a stronger and more uniform magnetic response there (**4**). A contrasting weaker magnetic signal over the remaining parts of the ditch circuit indicates where the ditch was emptied and refilled during Colonel Hawley's excavations in the 1920s. Despite suggestions arising from previous excavations (Atkinson 1979, 23 and 104) the magnetometer data does not support the existence of numerous causeways across the henge ditch (although this is not conclusive, as responses to iron often interrupt the signal derived from the buried ditch-fill).

The Aubrey Holes

Because of the extent of modern disturbance, the only other features of the henge detected are the Aubrey Holes, two excavated stone-holes (E in the entrance causeway and 92 on the South Barrow) and the parallel ditches of the Avenue (**5**). The majority of the circle of 56 Aubrey Holes have been detected (see Figure 14). Large-scale disturbance and burial below the modern path has prevented detection of some of the Aubrey Holes (12, 19, 27, 31-32, 34-35, 40, 43-47, 51 and 54: a total of 15 out of 56). The response to the Aubrey Holes varies: in the case of those which have been excavated, the response is to ferrous material in the back-fill - either incidental or deliberate contamination. The anomalies from the unexcavated arc of the circuit are generally weaker as would be expected from undisturbed prehistoric fills and agree well with the positions identified by probing.

It is possible that parts of the circuit of Y holes have been detected on the south-west and north-east sides of the stone-settings, but these features are resolved more clearly in the resistivity data.

Linear Feature

Outside the henge a long straight linear anomaly was detected running across the north-west corner of the triangle on a SW-NE alignment (**6**). This feature, which generated a magnetic anomaly in the range of 6-10 nT, is interpreted as a continuation of the 'stockaded' ditch excavated at SU 1217 4228 in 1967 in advance of construction of the pedestrian subway (Vatcher and Vatcher 1968). The latter was of v-profile, 1.2m wide and 1.3m deep and filled with contiguous post-holes. It was interpreted as a Late Bronze Age boundary earthwork on account of the Deverel Rimbury ware in its lower fill. The linear is apparently linked to "celtic" field systems visible on aerial photographs to the west on Stonehenge Down which have also produced surface finds of Late Bronze Age date (Richards 1990, 279).

A combination of aerial photographic (RCHME 1979) and geophysical survey evidence (obtained in a previous survey in 1990) suggests that the linear does not terminate near the subway (cf Vatcher and Vatcher 1968). Instead, the ditch is broken by a gap and continues to the NE, nearly converging with the Avenue before curving away to the NW to be lost in ploughed and disturbed ground in Stonehenge Bottom (see Figure 12 and RCHME 1979, fig. 5). Further magnetometer survey may be worth attempting to follow its course northwards from the Avenue bend. A section cut across the ditch in 1953 (Atkinson 1979, 198) at its closest point to the Avenue showed it to be a very small feature at this point, no more than 0.5m deep (RCHM 1979, 25). The existence of this feature may account for the belief of Stukeley (1740, 35) and Colt Hoare (1810, 157-8) that the Avenue bifurcated in Stonehenge Bottom. (They were also evidently confused by the presence of a track, recorded in the 18th-century, from Stonehenge to Durrington on the line of the Avenue).

Ring Ditches and Barrows

The survey has detected the ditches defining the round barrows of group Amesbury 4-10 (Grinsell 1957; SAM Numbers WI64a-g) on Stonehenge Down, mostly documented as having been excavated by Sir Richard Colt Hoare in the early 19th-century. The reference number of each barrow is provided on the interpretation diagram (Figure 13). The barrow ditches show considerable diversity of shape, size and structure. The ditches of barrows 4 and 5 appear to be circles 29.5m and 39m in diameter respectively; barrow 6 - the best preserved in the group - has a double ring-ditch. Barrow 10 is slightly oval in form and may be a twin-disk barrow; the remaining barrows 7-9 are smaller and more irregular with segmented ditches and may represent a later or different burial tradition or even mini-henge structures (cf Fargo Wood: Stone 1938; Richards 1991). Modern ferrous contamination has interfered considerably with the response to the ring-ditches and it is therefore difficult to identify with any confidence anomalies compatible with burials within or around the barrows. Magnetic disturbance at the centre of barrow 6 may represent a central primary burial pit, but may equally well have resulted from later digging. The existance of a central feature in this barrow was confirmed by subsequent resistivity survey, however.

Long Barrow - Amesbury 10a

Although all the round barrows identified on OS maps have been confirmed, the survey does bring into question the existence of a slight elongated mound at SU 1194/4217 described by Hoare (1810, 128) as a long barrow and excavated by him without a result. This feature is scarcely visible on the ground today and numerous aerial photographs have failed to reveal evidence of side-ditches, even when the adjacent round barrows have produced conspicuous crop-marks (RCHM 1979). The magnetometer survey also failed to locate any such features, and therefore the presence of a barrow is now extremely doubtful. It is a distinct possibility, given Colt Hoare's lack of finds, and his enthusiasm for barrow excavation that he mistook a natural mound already very low in his day, for a barrow - an error perpetuated on modern maps. Two areas of magnetic disturbance coincide with the position of the long barrow as marked on OS maps (7), and may represent Colt Hoare's trenches.

Miscellaneous anomalies

In addition to the main anomalies discussed above, occasional isolated and dispersed examples can be interpreted cautiously as representing evidence of features such as pits and hearths. As (Mesolithic) pits have been located in the vicinity of the monument in the past (Lawson 1992 fig 4) the possibility that others, of any period, may exist elsewhere has to be considered. Although some isolated anomalies may be genuine archaeological features, they do not form clusters suggestive of occupation areas. Other anomalies could be muted responses to iron objects, or responses to naturally in-filled depressions in the chalk subsoil (Bartlett 1988b; Richards 1990). Examples are indicated on Figures 8-11. Perhaps of more significance is a faint curvi-linear anomaly (**8**) west of barrow 11 which may represent a silted ditch or gully.

Hawley's 'Graves'

Several substantial regions of very strong magnetic disturbance coincide with the general area where Colonel Hawley's site huts were situated, as shown on contemporary photographs (RCHME 1979 plate 1). It is documented that Hawley reburied unwanted finds, adjacent to his site huts (Chippindale 1983, 193) and it is therefore possible that the disturbances **(9)** are the response either to these 'Graves', or the hut foundations.

Modern Activity (excluding that within the Henge)

As in the area north of the Cursus (RCHM 1979), the influence of modern activity is widespread throughout the area surveyed. Much of this can be attributed to the period of the 1914-18 war, when a new fenced road **(10)** and an airfield **(11)** were constructed west of Stonehenge (Chippindale 1983, 175, 193, illustration 154 and RCHME 1979, plate 1). Although long-since removed or covered over, these former structures have left behind quantities of magnetic metal and building materials which have affected the magnetometer response over large parts of the survey. Magnetic disturbance also occurs over the site of custodians' cottages **(12)** that formerly stood near the eastern point of the Stonehenge triangle between the First World War and the 1930s (Chippindale 1983, 192, 194). In addition to the sites of former buildings, several ferrous pipelines, recognisable by a fluctuating positive and negative signal, intrude into the survey area **(13)**. The pipe to the south and east of the henge is associated with livestock watering troughs. Scarring of the ground surface by former tracks which once crossed through the western half of the henge has been detected north of the A303 **(14)**, as has the influence of former ploughing to the west of the former road at **(15)**. Although the sources of some of the modern disturbance can be identified from photographic records, much of the remaining more general disturbance is apparently random, and of cumulative and unknown origin.

2) Resistivity Survey of the henge

The henge has altered much since it came into public ownership due to the need to manage visitor access. Excavation has been carried out in tandem with restoration and consolidation to render the stones safe, and various approach paths have come and gone. It is clear that in addition to providing information of a purely archaeological nature, the results of the resistivity survey also reflect much of the recent history of the monument.

The results are described using the scheme that Atkinson adopted, working from the outside of the henge inwards. Letters in bold text refer to features indicated on the plot in Figure 24.

The henge earthworks

The circular earthworks of the Period I henge enclosure have been detected as a series of high and low resistance anomalies which show that they consist of a ditch **(A)** up to 3.0m in width bounded by a bank about 7m wide within the ditch **(B)**, and a counterscarp bank on the outside **(C)**. Although the outer bank now only survives as a slight earthwork and has therefore often been overlooked, it is shown by the survey to be almost as wide as the inner bank. Many previously published surveys of the monument omit this feature or show it only in part. The resistivity survey shows that it extends all the way around (apart from where it is broken by the NE entrance). The response to the outer bank has been affected in the south-west part of the survey by artificial grass matting laid down on the visitor route around the perimeter of the earthwork to prevent erosion **(D)**. This material, which retains water, is characterised by very low resistance readings. Two previous trial plots of artificial turf show up in this area as anomalous resistance (**E**). Hawley's diaries (Atkinson 1979, 28 & Wessex Archaeology archive) mention that a number of cremated burials were found deposited in the bank and at one point in the counterscarp bank the otherwise uniformly high resistance is interrupted by a localised low resistance anomaly (**F**). It is possible that this may represent a further burial deposit or, alternatively, a pit or hole of unknown purpose and date. Two areas of the south-east arc of the inner bank also appear to be disturbed, as shown by a fall-off in the resistance, and are likely to mark the positions of sections cut by Atkinson and Hawley (**G** & **H**).

The lengths of the ditch excavated by Hawley on the north-east, east and south sides of the monument appear as narrower and slighter low resistance anomalies compared to the undisturbed sections to the north and west. The response to the unexcavated parts of the ditch is compatible with observations of the uneven structure of the ditch elsewhere. Possible discontinuities in the ditch are visible at **I**, **J** and **K** and irregularities of its sides at **L** and **M**.

The response to the ditch and bank is interrupted on the NE side of the henge by the entrance causeway. This was enlarged in Atkinson's Stonehenge Period II (by filling in part of the ditch on the east side of the gap) when the axis of the monument was subtly realigned 5° to the east (Atkinson 1979, 70, 72-73, Burl 1991). The locations of the two stone-holes (D & E) (Atkinson 1979, 22, 26, 71) excavated by Hawley in the entrance next to the Slaughter Stone have not clearly been recovered by the survey. However, there is a discernible lowering of resistance (**N**) in the centre of the entrance causeway, displaced slightly to the north-east from the position of the relevant holes as marked on plans. It is possible that the stone-holes were back-filled with chalk, thus explaining the poor response. Stone-hole E was marked by an area of ferrous disturbance in the magnetometer data.

The causeway crossing the ditch on the south side of the henge has not been clearly detected, again due to the influence of Hawley's excavation. However, the survey has detected the corresponding breach in the bank (**O**) confirming the presence of a second entrance here.

The Avenue

The ditches of the Avenue have both been detected as low resistance anomalies (**P**). The bank inside the ditch on the eastern side of the Avenue is apparent as a slight linear anomaly (**Q**), but a similar response is lacking over the bank on the opposite side. This is because the latter has been eroded away by a cart-track in use until the early part of the 20th-century as seen on contemporary photographs (eg Chippindale 1983, 177). The survey has also detected, in the form of a low resistance anomaly (**R**), what is probably an excavation trench (possibly dug in 1953 by Atkinson) perpendicular to the Avenue, adjacent to the small excavated ring ditch around the Heel Stone. Within this area, a further oval low resistance anomaly (**S**), 2m wide, can be discerned with the aid of filtering (see Figure 20). This probably represents the position of a stone-socket (B) for one of the two stones (B and C: Atkinson 1979, 66) aligned on the central axis of the Avenue south of the Heel Stone. Stone-hole C has apparently not been detected.

The henge interior

The background resistance in the area enclosed by the bank and ditch is generally higher than that outside the henge. This is probably due to the accumulation of introduced stoney deposits within the henge termed the "Stonehenge Layer" by Atkinson[7]. Despite this effect, there is an enigmatic sharp drop in the level of background resistance across the middle of the henge from SW to NE roughly in line with the Avenue. The explanation for this change is uncertain. It may relate to the 'Stonehenge Layer' itself - the extent of which has not been fully defined by excavation (Atkinson 1979, 129, 213). Alternatively, soil erosion processes around the stones, compaction, or differential evapo-transpiration rates caused by vegetation changes may be responsible. Former trackways seen crossing the monument on aerial photographs taken in the early 20th-century from balloons (1904 RCHME) coincide remarkably well with the edges of this low resistance area, and it is conceivable that the Stonehenge Layer has been eroded away in these areas due to the proximity of the stone-circles and the Heel and Slaughter stones, past tourists keeping within the bounds of the two tracks, particularly if they were once fenced. An aerial photograph taken in 1921 (Chippindale p.185 ill. 154 - Salisbury Museum) shows less vegetation growth here and that the ground surface has been smoothed away. It is noteworthy that other former paths and cart-tracks that have eroded the earthworks have also been detected as low resistance anomalies at **T**, **U** and **V**.

The route of the present tarmac path overlies the course of a previous track in use until the 1920s. The course of this track can be seen (**W**) continuing northwards across the bank and ditch of the earthwork. The point at which it crosses the ditch is marked by a reversal from a low resistance to a high resistance anomaly which probably indicates the presence of an artificial surface or causeway to carry the track across the earlier ditch.

The eastern half of the henge between the stone-settings and the bank was trenched by Hawley using 20ft by 5ft cuttings. No plan of these excavations survives (if made), and as the survey has not detected any trace of these former interventions, their location still remains uncertain.

Perhaps the most significant and controversial find of the survey are three isolated high resistance anomalies (**X**, **Y**, and **Z**) that are of the right size, shape and magnitude to represent former positions or buried remnants of previously unrecorded outlying stones. Enigmatically, all these anomalies lie within areas assumed to have been stripped by Hawley. However, it is not clear how systematically he conducted his excavations, and it may be possible that they were missed. Anomaly **X** in fact probably lies just to the north and east of two areas investigated by Hawley at the South Barrow. The interpretation of these anomalies is necessarily very speculative and will require confirmation by follow-up non-destructive tests, and/or probing or augering (see below). Anomaly **X** lies on a line between the South and North Barrow and anomalies **Y** and **Z** form a pair roughly in line with a projection of the Avenue into the henge. The latter may be significant in the light of speculation[8] (ie. Castleden 1993, 131) on the possible former existence of parallel stone rows (cf West Kennet) along the line of the Avenue (see Pitts 1982, 90-91 for a discussion of this question).

The Aubrey Holes

Only a minority of the circle of assumed total of 56 Aubrey Holes has been detected, the clearest response coming from the previously excavated examples set inside the south-east arc of the bank between the South Barrow and the Slaughter Stone. Six unexcavated Aubrey Holes were detected as low resistance anomalies (49, 42, 38, 37, 34 and 33) and eight previously excavated holes were detected (26, 16, 15, 12, 11, 9 and 8), leaving the majority undetected. The generally poor and changeable response to these features is probably due to the fact that according to excavation evidence their fills were extremely mixed (some filled with chalk rubble) and their size very variable (Atkinson 1979, 27). It may be possible that some of the unexcavated ones which have been detected are those reused for cremation burial, but this is difficult to assess (see results of magnetometer survey, above).

The Barrows

The ditch and bank of the North Barrow has been detected where it is not obliterated by the track that formerly passed over it. A slight rectangular low resistance anomaly inside the ditch may indicate the hole of former Station Stone 94 recorded on John Aubrey's 1666 sketch plan of the henge (Fowles and Legg 1980, 80; plate 18, Chippindale 1983, 69). In the case of the excavated South barrow only the ditch has been detected as a slight low resistance anomaly.

The Y and Z holes

The Y holes have been detected quite clearly on the north-east and south-west sides of the Sarsen circle. As well as excavated examples, some unexcavated ones previously located by probing (17-19, 26-28: Atkinson 1979, 34) have been detected. Two more (23-24) on the NW side of the circles are visible with the aid of filtering in a region of generally low resistance (see Figure 16), and three others (20-22) are sealed by the modern visitor path. The survey confirms the irregular spacing of these features. Only on the SE side of the monument where the holes have been excavated is their circuit not very clear. Unlike the Aubrey Holes, the fills of the Y and Z holes are known to consist of a fairly uniform fine brown soil, presumably presenting a more detectable moisture contrast.

A similar response was obtained from the Z holes but because they are closer together and nearer the remains of the Sarsen circle their anomalies appear to join up into continuous arcs of low resistance (ie. east of sarsen circle - 8 holes) or become lost in the general disturbance from the stone-settings and excavations. Two unexcavated examples (17 & 18) on the west are particularly clear. Three more are visible in the filtered data north of stone 19. The total Z-holes detected are: 20-22, 18-17, 15-14, 12, 11-9, 7-1, 30-29, 27-25.

Stone-settings

Letters in bold text refer to Figure 25

"Stonehenge is a composite monument with a long history of construction... during which old work has been torn down to make way for new" (Atkinson 1979). Such is the complexity of the archaeological remains at the centre of Stonehenge - the cumulative result of this constant remodelling, it would be unrealistic to expect the survey to resolve detail of discrete features within the stone-settings. In particular the complex succession of bluestone circles, elipses and horseshoes - possibly five phases in all, has resulted in a honeycomb of intercutting pits and stone-sockets below ground. This, combined with the influence of past excavation backfill, concrete underpinning of the stones, and the presence of former gravel surfaces, seriously compromises the interpretation of the resistivity results. There is the added complication of the standing stones themselves influencing the data and introducing gaps in the survey coverage. Despite this rather pessimistic picture some information may be gathered from the results.

Sarsen Circle: two high resistance anomalies (**AA** and **BB**) near stones 16 and 19 coincide with the expected locations of the missing stones 15 and 20 of the sarsen circle. The anomaly observed near stone 16 may alternatively be linked to one of two test pits excavated near it by Gowland in 1901. The remaining four sarsen uprights that have disappeared, and the positions of known empty stone-sockets 8 and 13, have not been detected. High resistance readings were recorded around the majority of the standing stones in the sarsen ring, but notable reversals in resistance occur around stones 4, 5, 21-23, and 27, corresponding with excavation trenches opened by Atkinson.

Sarsen Horseshoe: similar trends in the resistance are visible in the areas of the sarsen horseshoe documented as excavated by Atkinson. An interesting area of low resistance has been found near stone 52, in an area which has apparently never been excavated.

Bluestone Circle: the majority of the bluestones that once formed a circle of an estimated 60 stones are now missing. Only 19 survive intact above ground, leaning or fallen. Previous excavation has shown that traces of missing bluestones survive beneath the surface in the form of stumps or sockets. It is therefore disappointing, but not unsurprising, that even in unexcavated areas the survey has apparently not been able to discriminate further remains of these settings. Robbed stones would probably not leave sufficiently well-defined holes and fragments of stone in the ground would probably be too small to produce appreciable resistivity anomalies. In areas where stone fragments and sockets are known to survive (eg in the area between BS 32 and BS 34), resistance values are uniformly high and no individual features can be discerned. The tightly rammed chalk packing of the underlying Q and R holes (Atkinson 1979, 58), if still in-situ, could have contributed to these high readings as could the modern surfaces laid down in the 1960s. Notably, a contrasting low resistance response was obtained over an unexcavated part of the bluestone circle between stones 41 and 45. However, except for around the extant stones, no individual anomalies compatible with traces of further buried stones are visible.

Bluestone Horseshoe: this horseshoe is originally believed to have consisted of 19 pillars of which 8 survive above ground. No traces of the missing ones were detected. Hole L north of BS 61 (Atkinson 1979, 82, & fig.3) may have been detected and also the grave excavated by Hawley east of 160b (Atkinson 1979, 62, & fig. 3).

With the exception of Atkinson's trenches around the sarsen settings, the survey was not very informative concerning the location and plan of former excavations within the stone monument.

CONCLUSIONS

Stonehenge has never previously been singled out as a target for geophysical survey. Perhaps this is because of a perception that there would be little else of new archaeological significance for the available technologies to discover. Also, and more understandibly, such a reluctance acknowledges the deleterious effects of modern disturbances concentrated within and around the monument.

Even less complicated stone circles present problems for archaeological geophysics and it was easy to be pessimistic about the potential of Stonehenge itself for such treatment. However, some optimism arose from results of an earlier programme of survey at Avebury which had shown the value of geophysics for re-assessing the archaeological record of megalithic sites (Ucko et al 1991). Here, however, the stones were more widely distributed, the targetted features larger and the development of the monument apparently less complex. Despite much more constrained conditions at Stonehenge, and notwithstanding the above reservations, the recent surveys there have nevertheless managed to obtain valuable information.

The magnetometer survey of the 'triangle' has mapped a range of archaeological features in the vicinity of Stonehenge including funerary monuments, linear ditches and a number of outlying miscellaneous and unclassified anomalies, perhaps pits or hearths. The survey also contains valuable information on the recent history of the area and the considerable impact of early 20th-century activity on and near the site. By focusing on the land immediately surrounding Stonehenge, the magnetometer survey also complements previous survey records of the wider environs of the monument (RCHME 1979; Richards 1990). The magnetometer data from the henge itself initially appeared to be too disturbed by modern ferrous material to be of any value; however, on closer inspection most of the Aubrey Holes and the henge ditch have been detected at least.

The resistivity survey has clarified the plan of the henge earthworks and has accurately mapped for the first time the fuller extent of previously recognised features such as the counterscarp bank, and the unexcavated Y holes. The survey also contains information relating to the ditch morphology, the position of the North Barrow, the course of former cart-tracks, previously excavated stone-holes and Atkinson's excavations around the Sarsen uprights. As many as three previously unknown stone-holes, pits or buried stones may be represented by localised high resistance anomalies between the henge ditch and the Sarsen circle.

Thus, whilst these results do not radically affect existing archaeological evidence about this unique monument, neither do they completely vindicate earlier inhibitions about applying geophysical survey there. As summarised above, significant findings have indeed been documented, and can be expected to usefully augment the work of the 20th-century Excavations Project. However, the significance of all the geophysical data cannot be fully assessed in the absence of actual ground intervention to validate the interpretation of many of the anomalies detected: this could be partly achieved, perhaps, with a limited programme of probing and/or augering and appropriate soil testing. There is scope, too, for the further application of geophysical techniques, once these become yet more refined.

* * * * *

Postscript

As this report was going to press, augering tests were carried out by Wessex Archaeology on some of the anomalies identified in the resistivity survey (Gardiner and Allen 1994). According to the limited techniques employed, anomalies X and Y in the henge were of indeterminate origin. The source of the low resistivity "shadow" in the henge was also ambiguous. The absence of an obvious reason for the anomalies does not however explain away their presence and their full significance will remain uncertain without more detailed investigation.

Andrew Payne,
ARCHAEOMETRY BRANCH, Ancient Monuments Laboratory *August 1994*

NOTES

1. Atkinson speculated that the Station Stones and holes 92 and 94 when taken together with other holes (F,G and H: Atkinson 1979, fig.1) discovered by Hawley just outside the line of the Aubrey circle may once have formed part of a circle of widely spaced sarsens immediately inside the bank and ditch. A search was therefore made for further holes that could be identified with this hypothetical early sarsen circle and an electrical resistivity survey (Atkinson 1979, 79) was used to test for an additional stone-hole between Aubrey Holes 4 and 5, but with negative results. In addition to this first documented use of geophysical techniques at Stonehenge, an unsuccessful trial fluxgate magnetometer survey was carried out around the henge in 1988 by D. Jordan of the Ancient Monuments Laboratory (AML archive).

2. The barrows of Wiltshire are listed by number and parish by L. V. Grinsell in VCH Wilts I (i) 1957. This classification has been adhered to in later publications such as RCHME 1979.

3. The field team that carried out the magnetometer survey during December 1993 and January 1994 consisted of Mark Cole, Peter Cottrell and Andrew Payne of the AMLab, assisted by Tom Williams of Bradford University.

4. The resistivity survey was carried out in May 1994 by Mark Cole, Neil Linford and Andrew Payne.

5. In this type of display each reading is represented by a block, which is alloted a shade of grey (using arrangements of dots or half-tones) between black and white, depending on the value. High readings are represented by lighter tones and low values by darker tones. A function called interpolation is used to simulate a more closely spaced interval between each reading block in the input data (by averaging between neighbouring values) to produce a smoother finish in the output data before final printing (Scollar et al 1986). The greyscales allocated to the data range are of two types: linear for the magnetometer data and non-linear for the resistivity data. The latter is used to increase contrast in the plot.

6. This method of display consists of a series of stacked graphs (each representing the line of a traverse of readings) of the instrument reading (Y) plottted against distance (X) along the ground.

7. Stonehenge layer : (Atkinson 1979, 63-5, 129, 213) - "a rubbly layer composed of fragments of natural flint, chips of bluestone and sarsen, and miscellaneous rubbish", which lies directly on the natural chalk but seals holes cut into it. It has been interpreted most recently by Atkinson (p.213) on the basis of

sample excavation and stratified artefactual dating evidence as a deliberate layer of flint metalling collected from nearby ploughed fields, laid down not later than AD 1700 combined with fragments of the stones chipped off as keepsakes.

8. The presence of stone rows along the Avenue was suggested by John Aubrey in 1666 (Long 1876, 33) and William Stukeley and Stukeley's friend Roger Gale writing to him in 1740 both mention holes that they had observed upon the Avenue banks. The relevant quotes according to Castleden (1993) are:

"It may be reckoned bold to assert an Avenue at Stonehenge when there is not one stone left, but I did not invent it, having been able to measure the very intervals of almost every stone, from the manifest hollows left in their stations and probably they were taken away when Christianity first prevailed here".
Stukeley 1722-4 The History of the Temples of the Ancient Celts. Source: Bodleian Library MS Eng. Misc. c. 323.

"I think you have omitted a remarkable particular which is that the Avenue up to the chief entrance was formerly planted with great stones, opposite to each other on the side banks of it".
Letter from Gale to Stukeley 1740. Source: Proceedings of the Society of Antiquaries of London 7, 1877, pp. 268-71.

LISTING OF FIGURES INCLUDED

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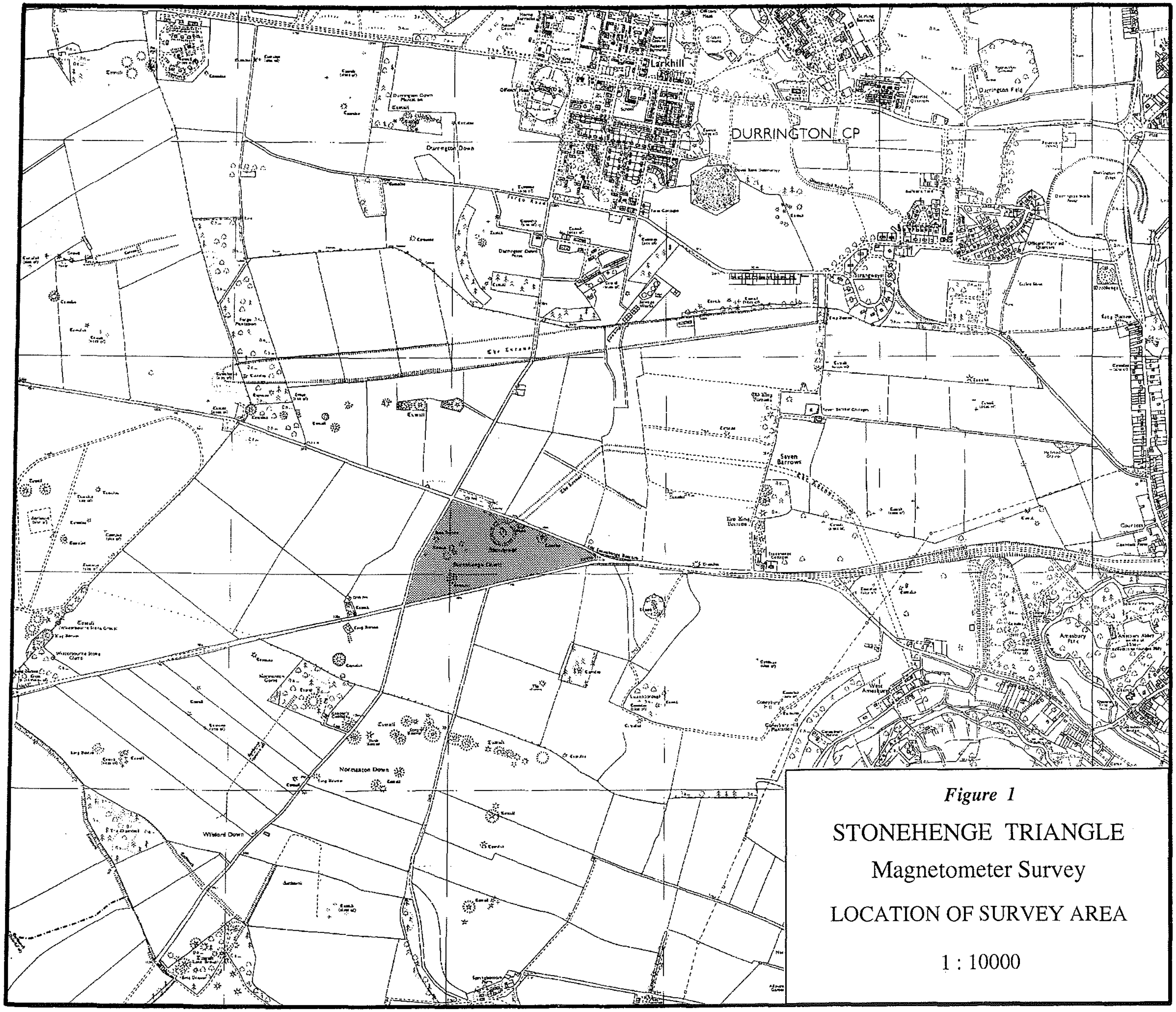


Figure 1

STONEHENGE TRIANGLE

Magnetometer Survey

LOCATION OF SURVEY AREA

1 : 10000

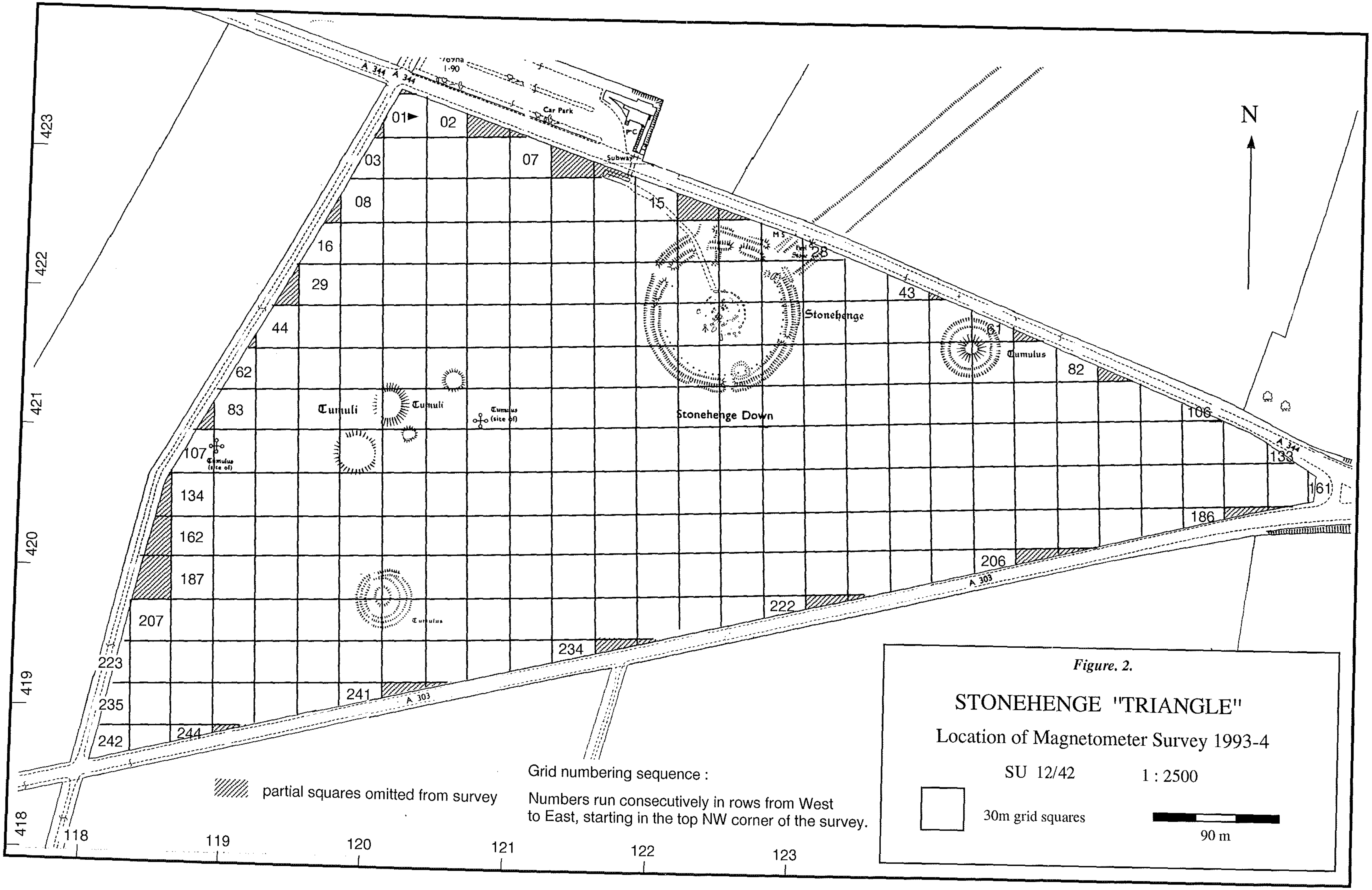


Figure. 2.

STONEHENGE "TRIANGLE"

Location of Magnetometer Survey 1993-4

SU 12/42 1 : 2500

STONEHENGE "TRIANGLE" Magnetometer Survey , 1993-4

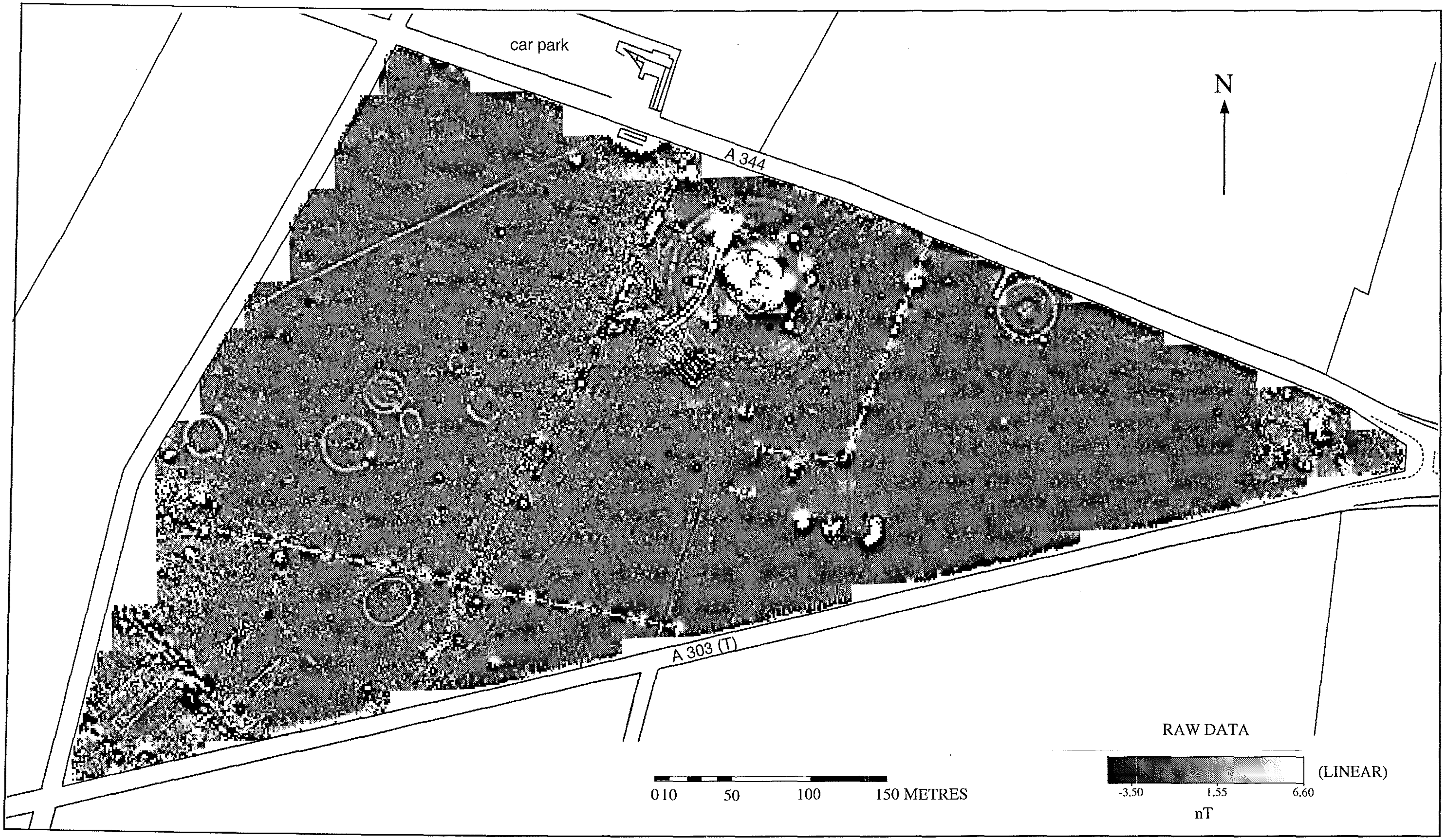


Figure 3 *Greyscale plot of total magnetometer survey coverage*

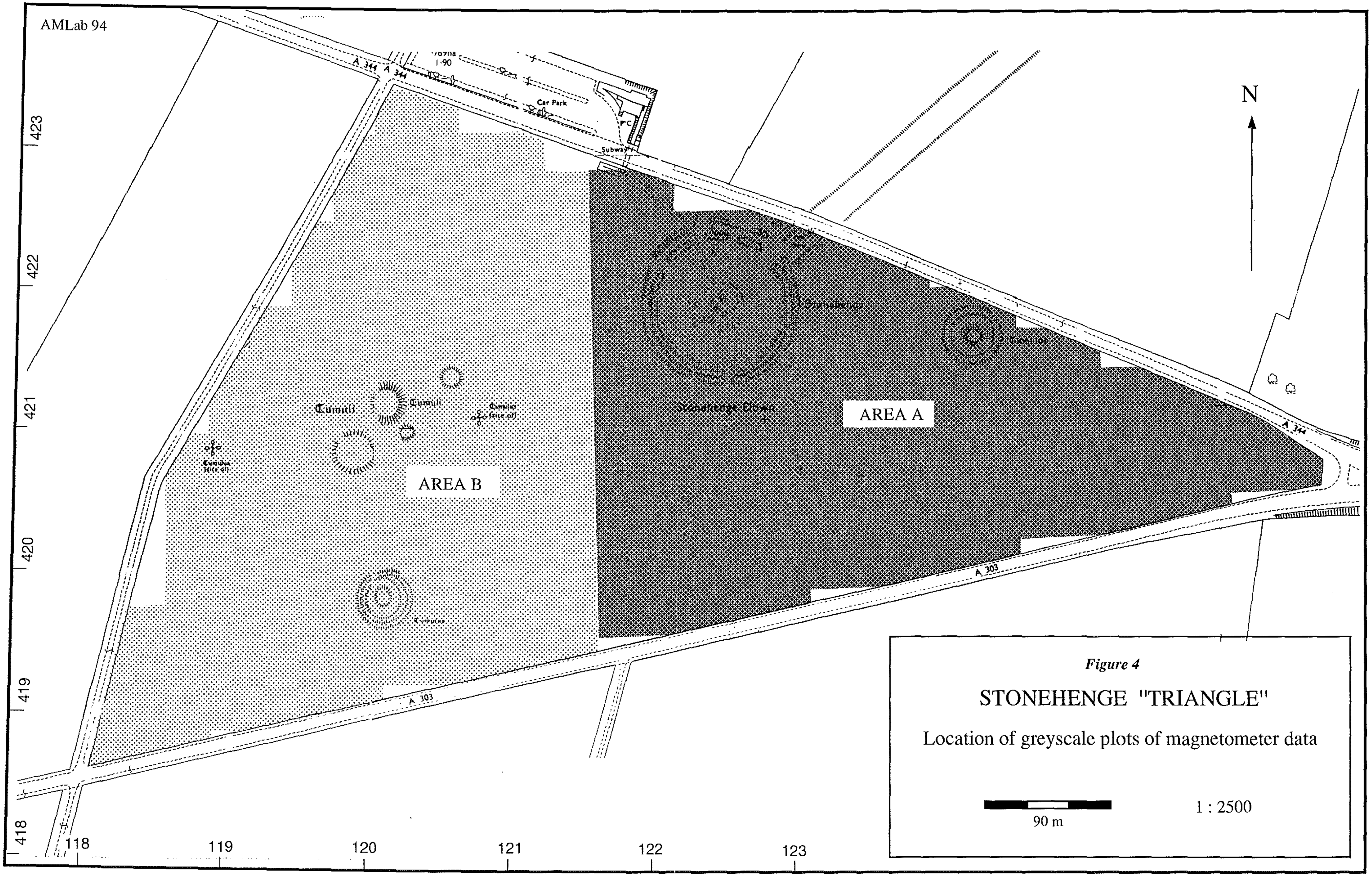


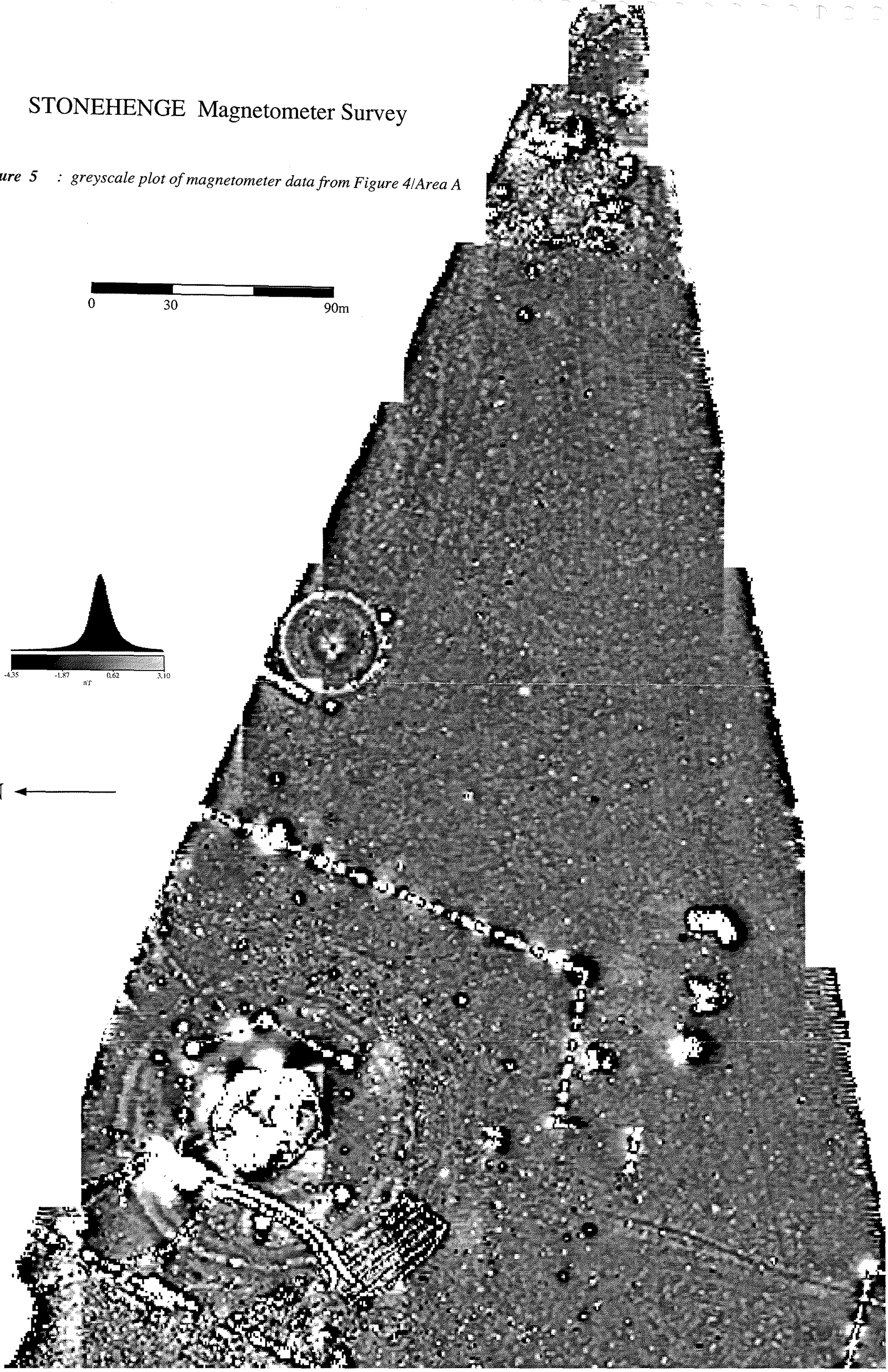
Figure 4

STONEHENGE "TRIANGLE"

Location of greyscale plots of magnetometer data

STONEHENGE Magnetometer Survey

Figure 5 *: greyscale plot of magnetometer data from Figure 4/Area A*



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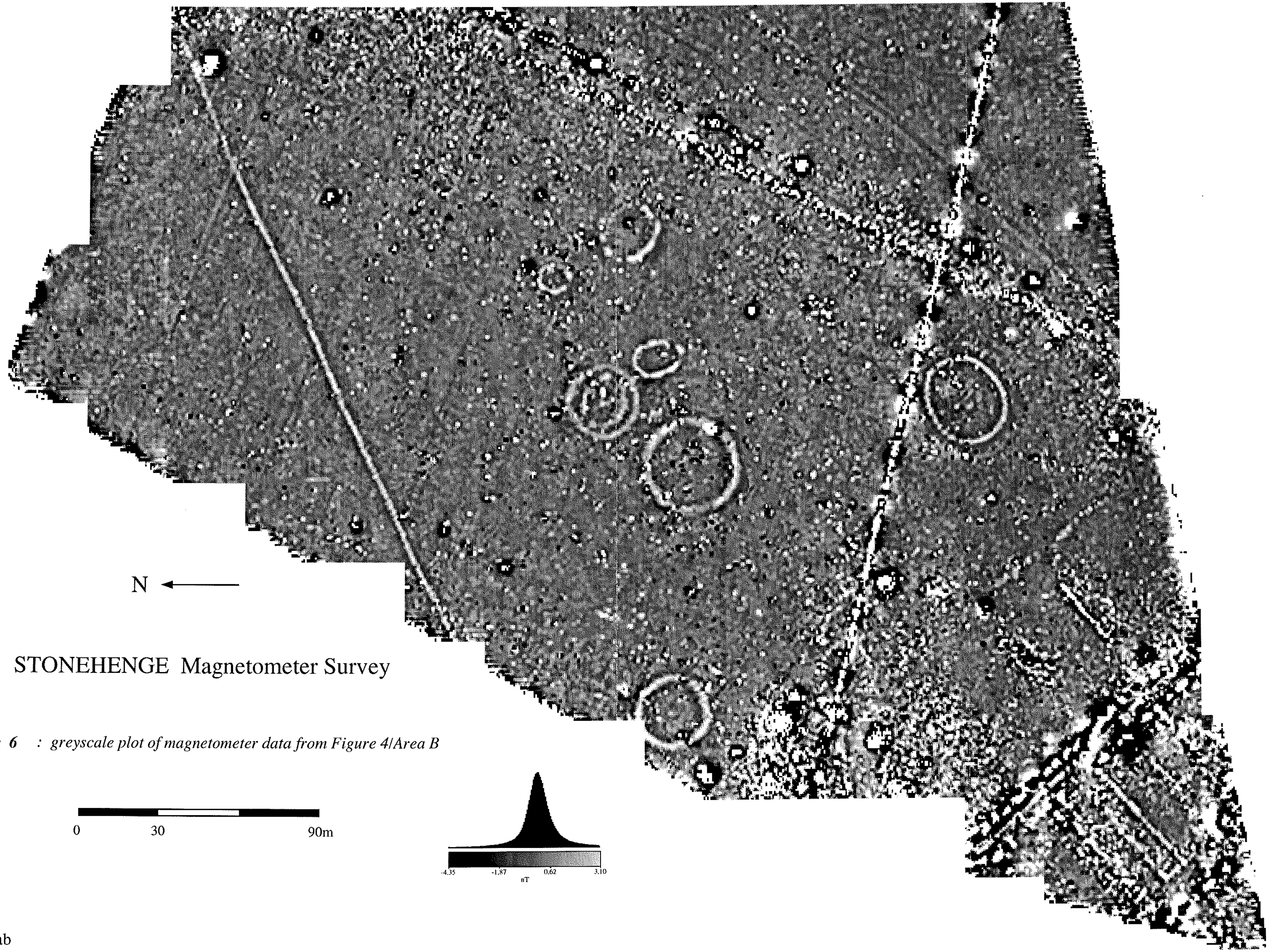


STONEHENGE Magnetometer Survey

Figure 6 *: greyscale plot of magnetometer data from Figure 4/Area B*

AMLab

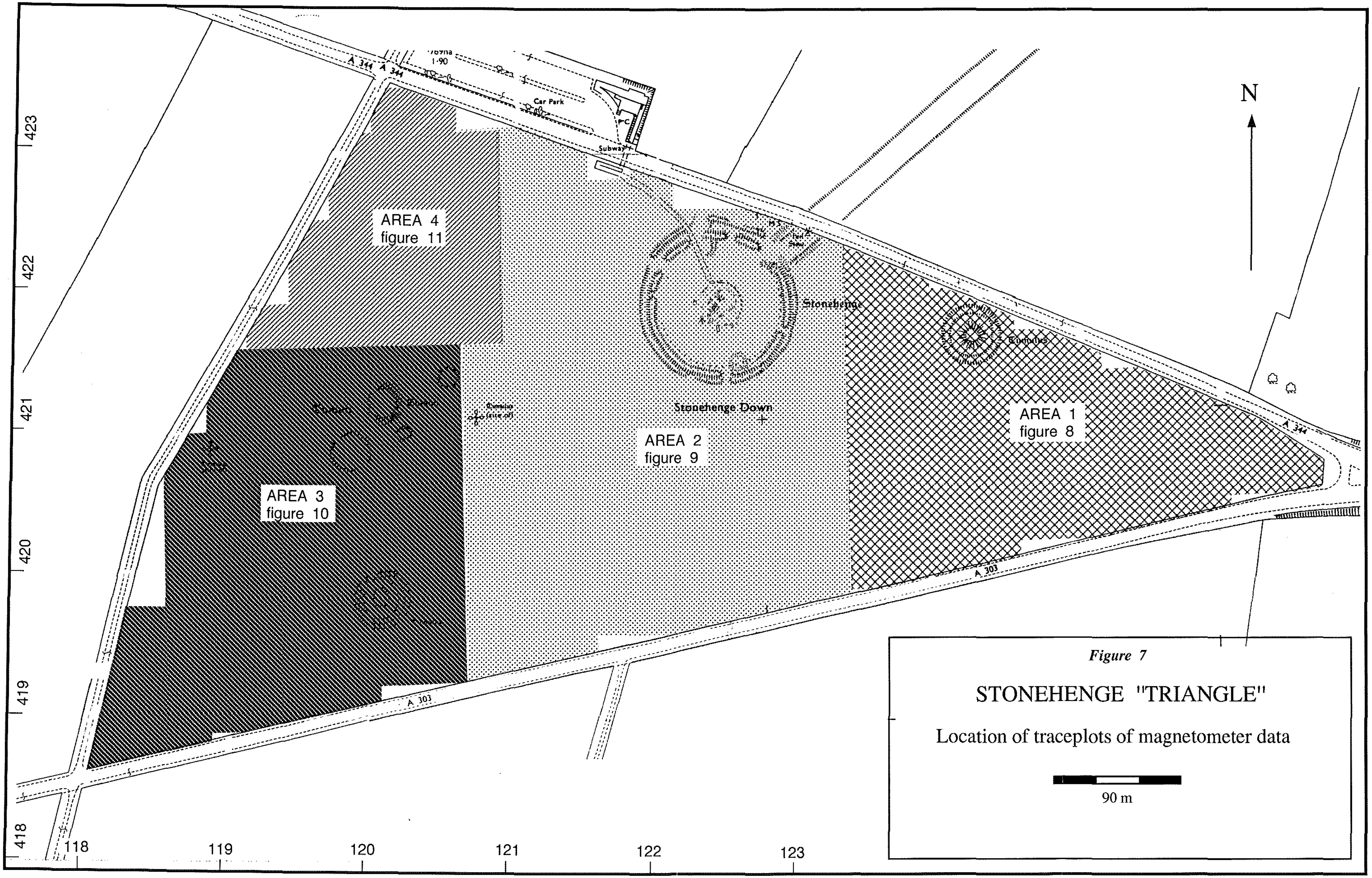


Figure 7

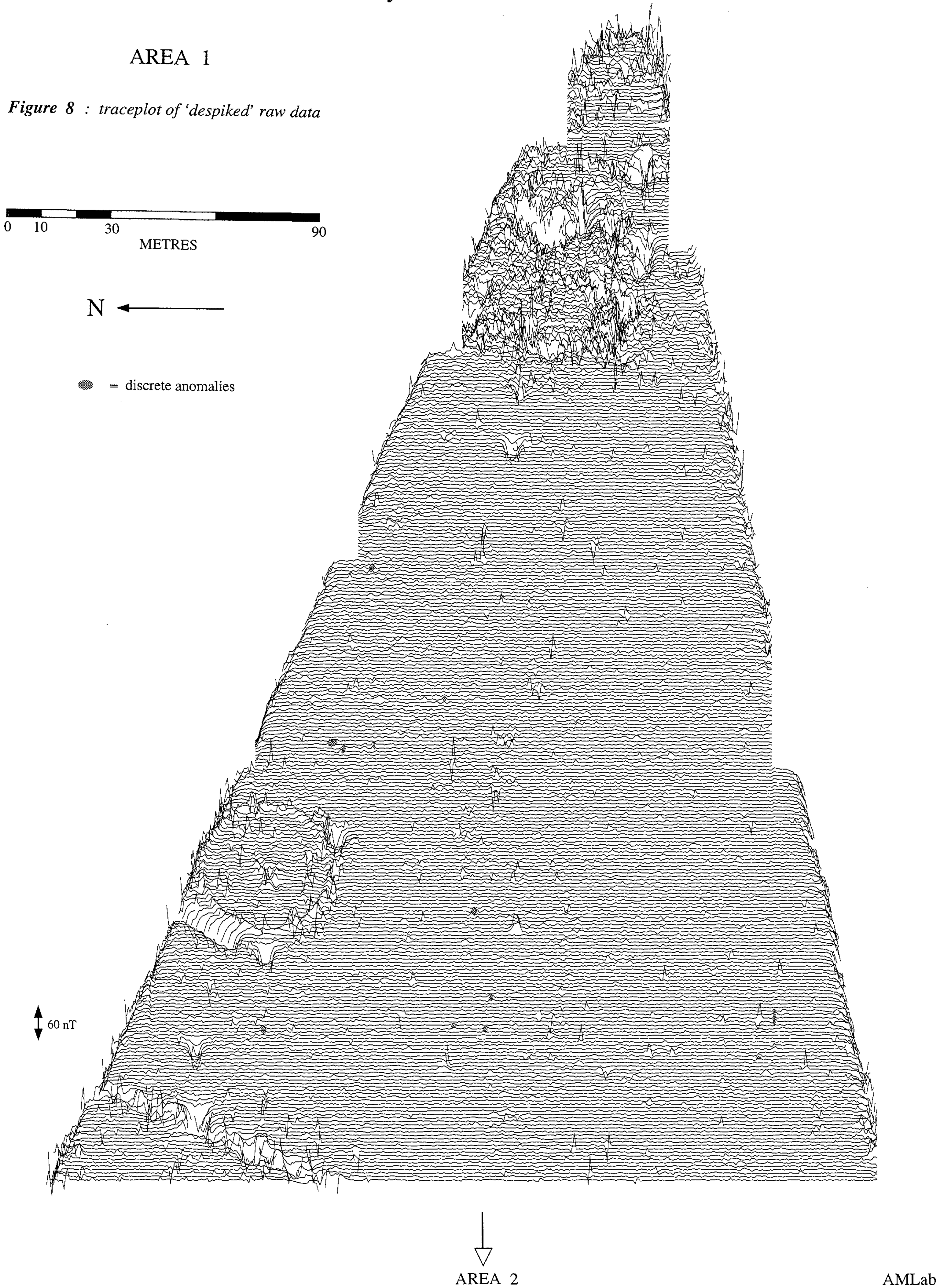
STONEHENGE "TRIANGLE"

Location of traceplots of magnetometer data

STONEHENGE Magnetometer Survey

AREA 1

Figure 8 *: traceplot of 'despiked' raw data*



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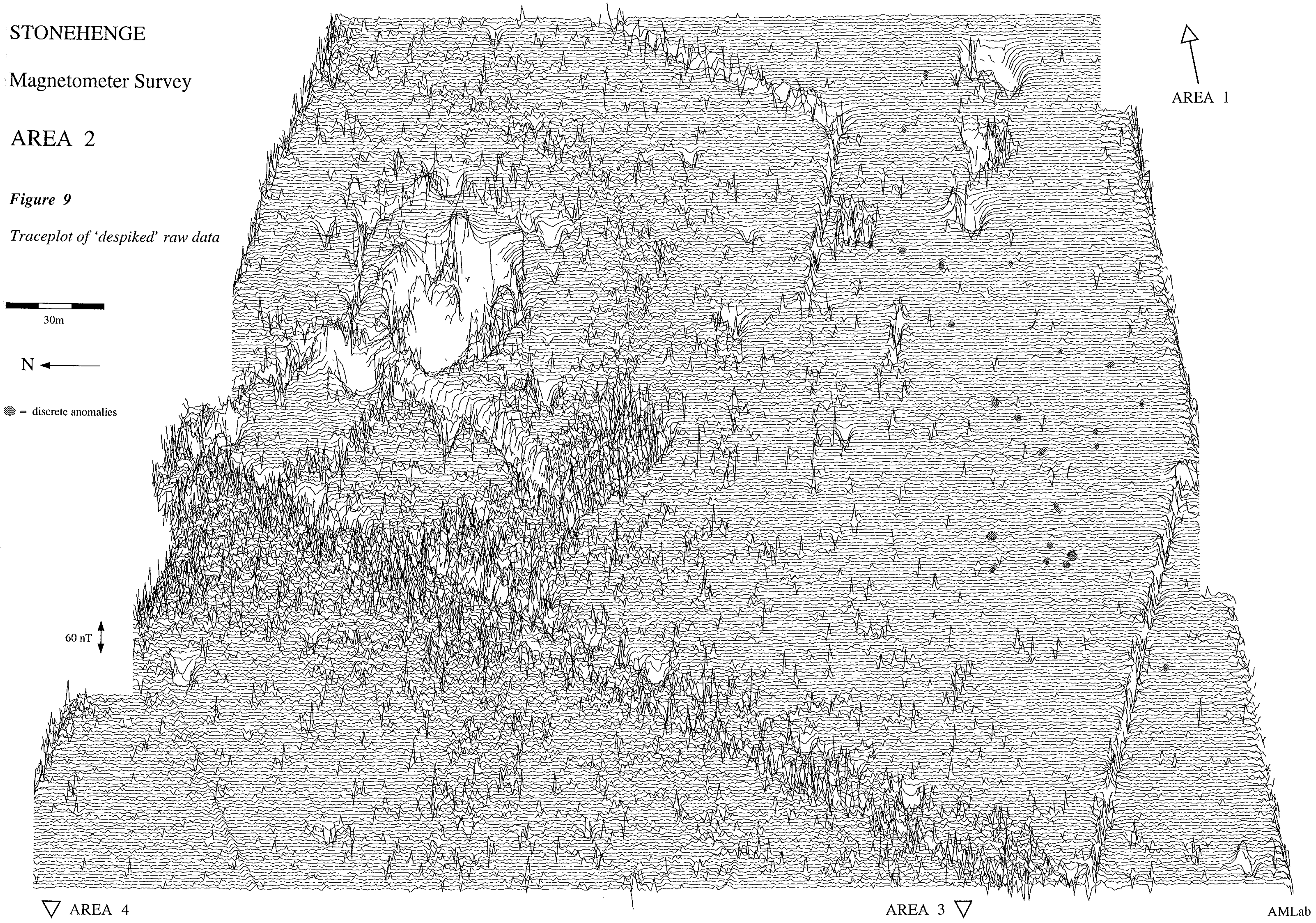
STONEHENGE

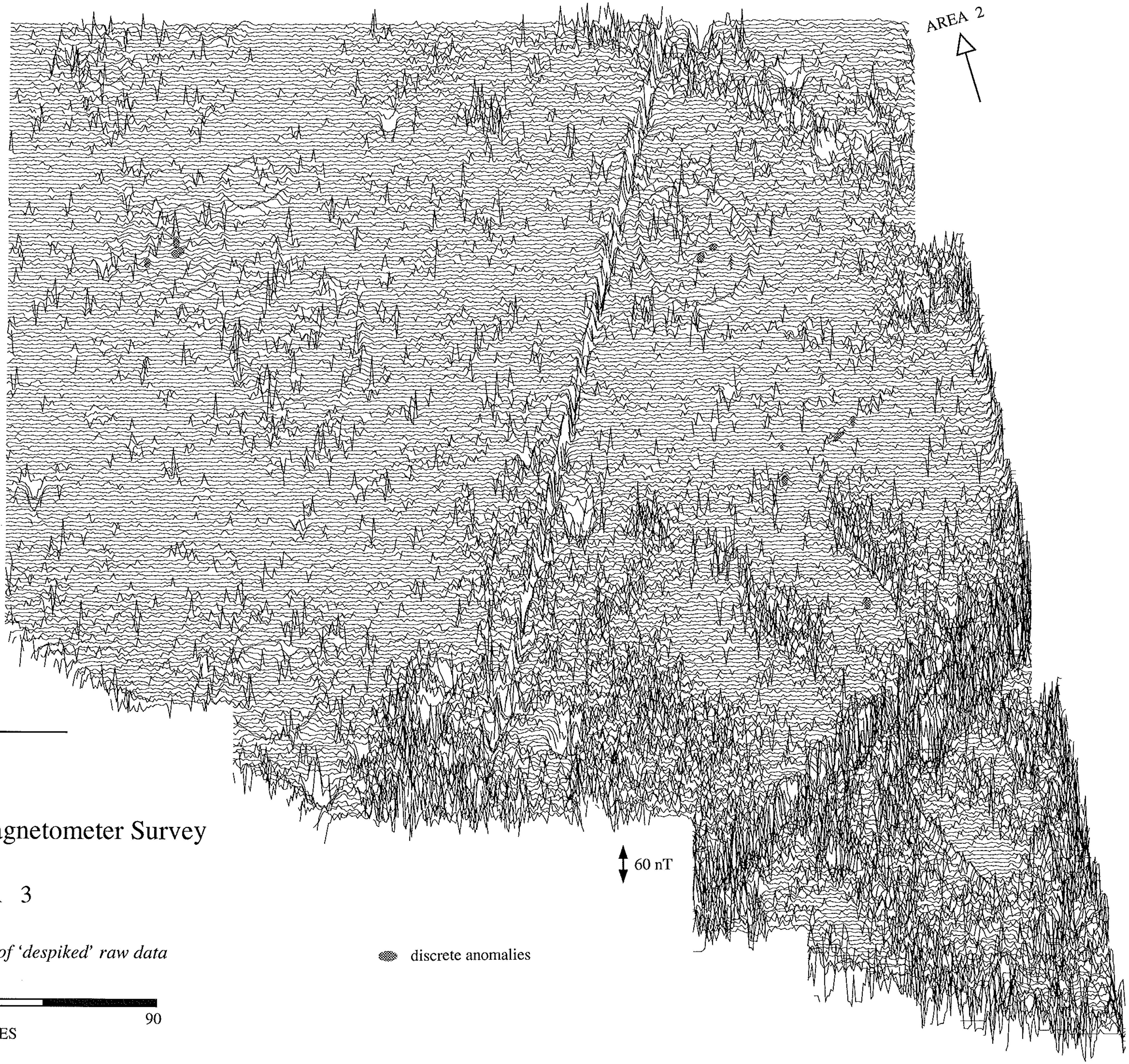
Magnetometer Survey

AREA 2

Figure 9

Traceplot of 'despiked' raw data





STONEHENGE Magnetometer Survey

AREA 3

Figure 10 : *traceplot of 'despiked' raw data*

STONEHENGE Magnetometer Survey

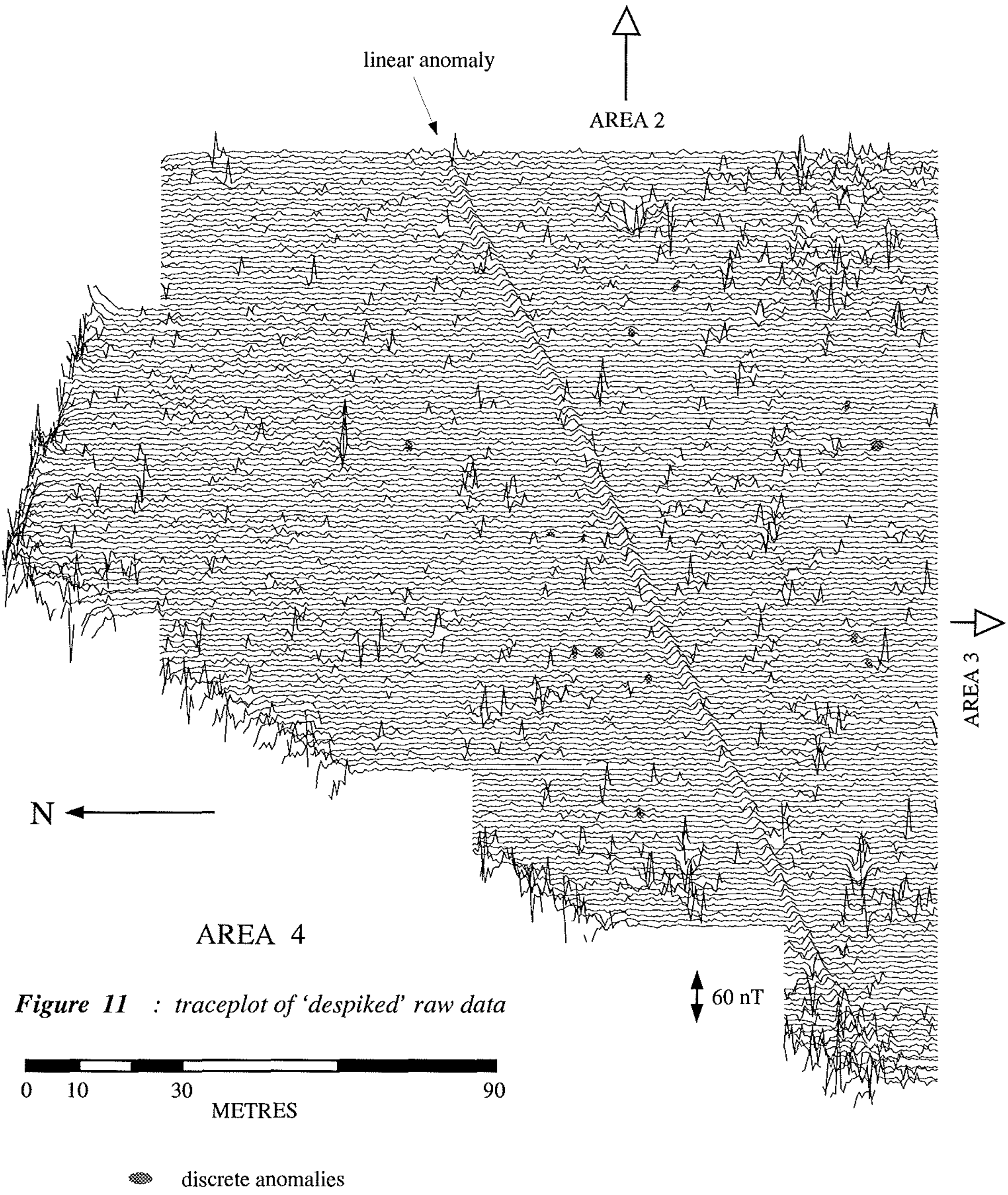


Figure 11 : *traceplot of 'despiked' raw data*

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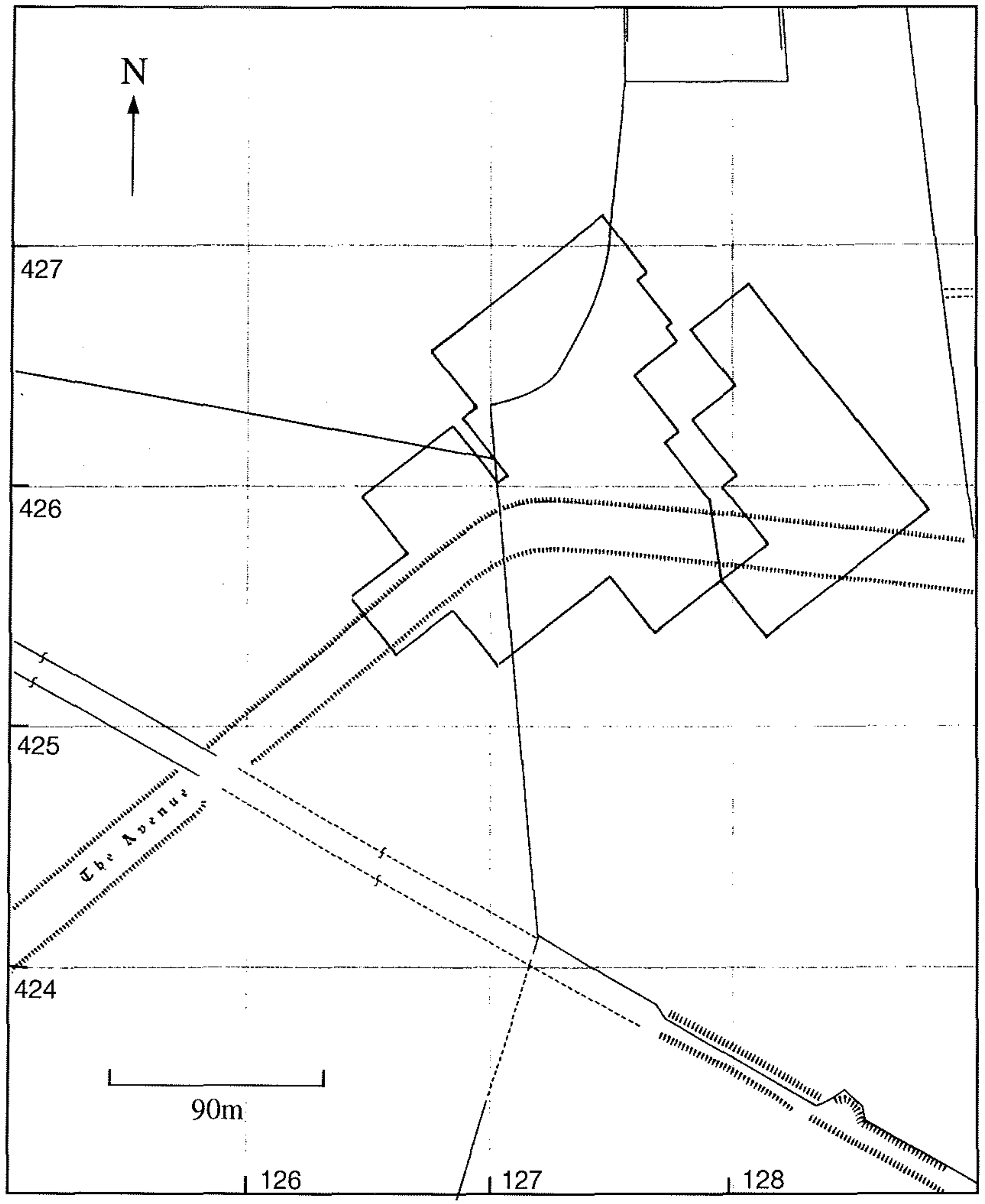
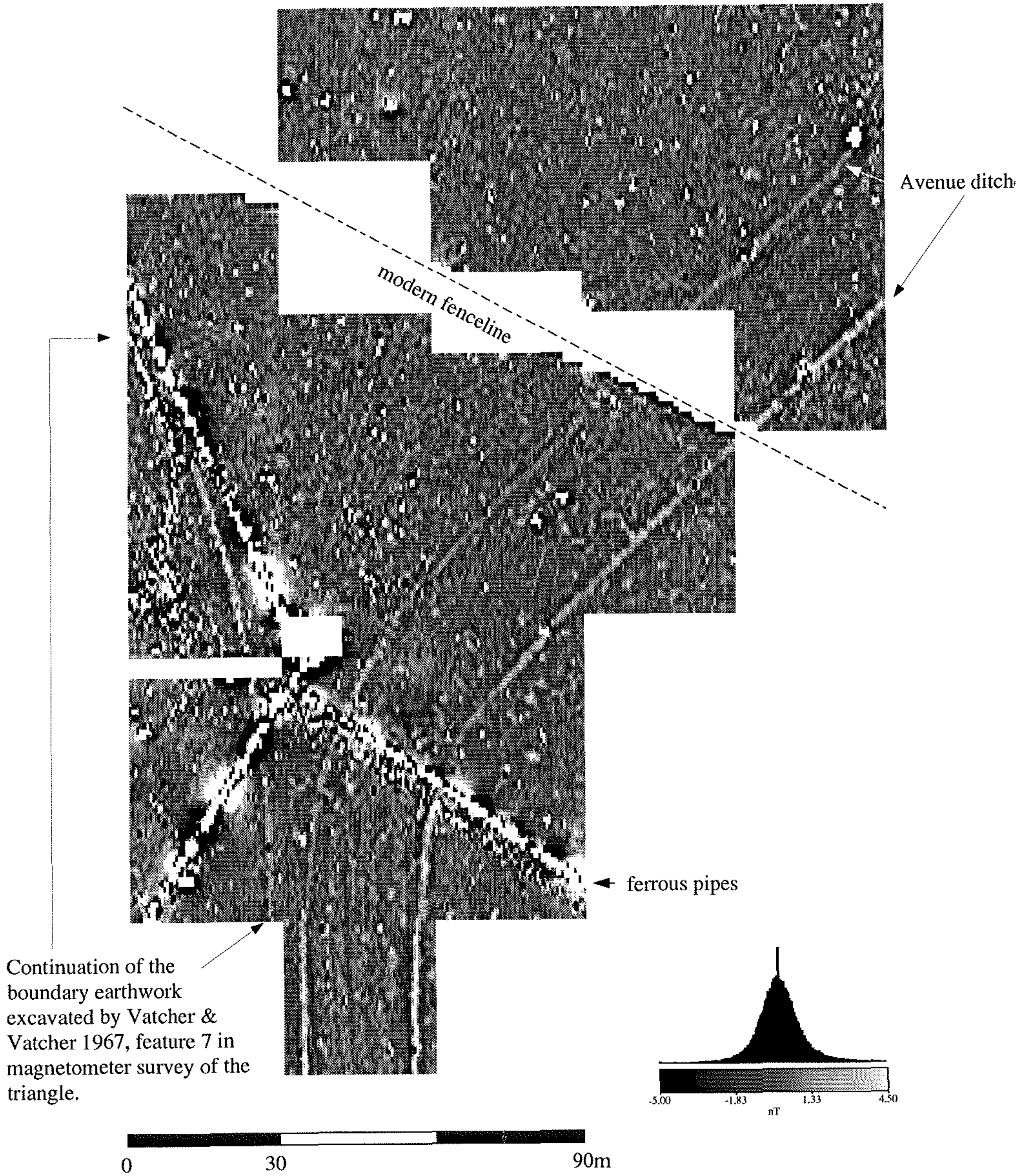
STONEHENGE - THE FIRST AVENUE TURN Magnetometer Survey 1990

Figure 12



Location of survey



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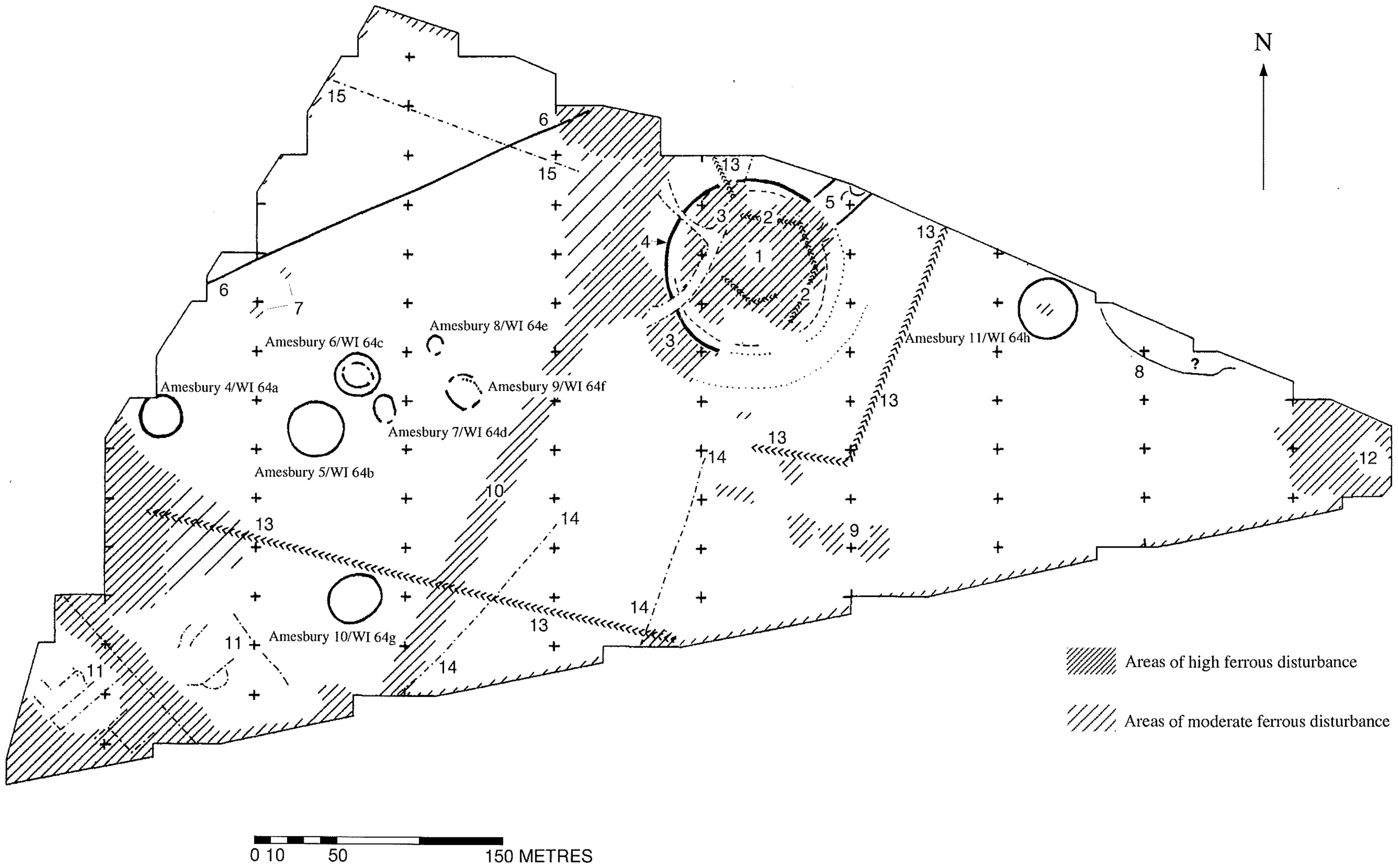
STONEHENGE "TRIANGLE" Magnetometer Survey

***Figure 13** : Interpretation*



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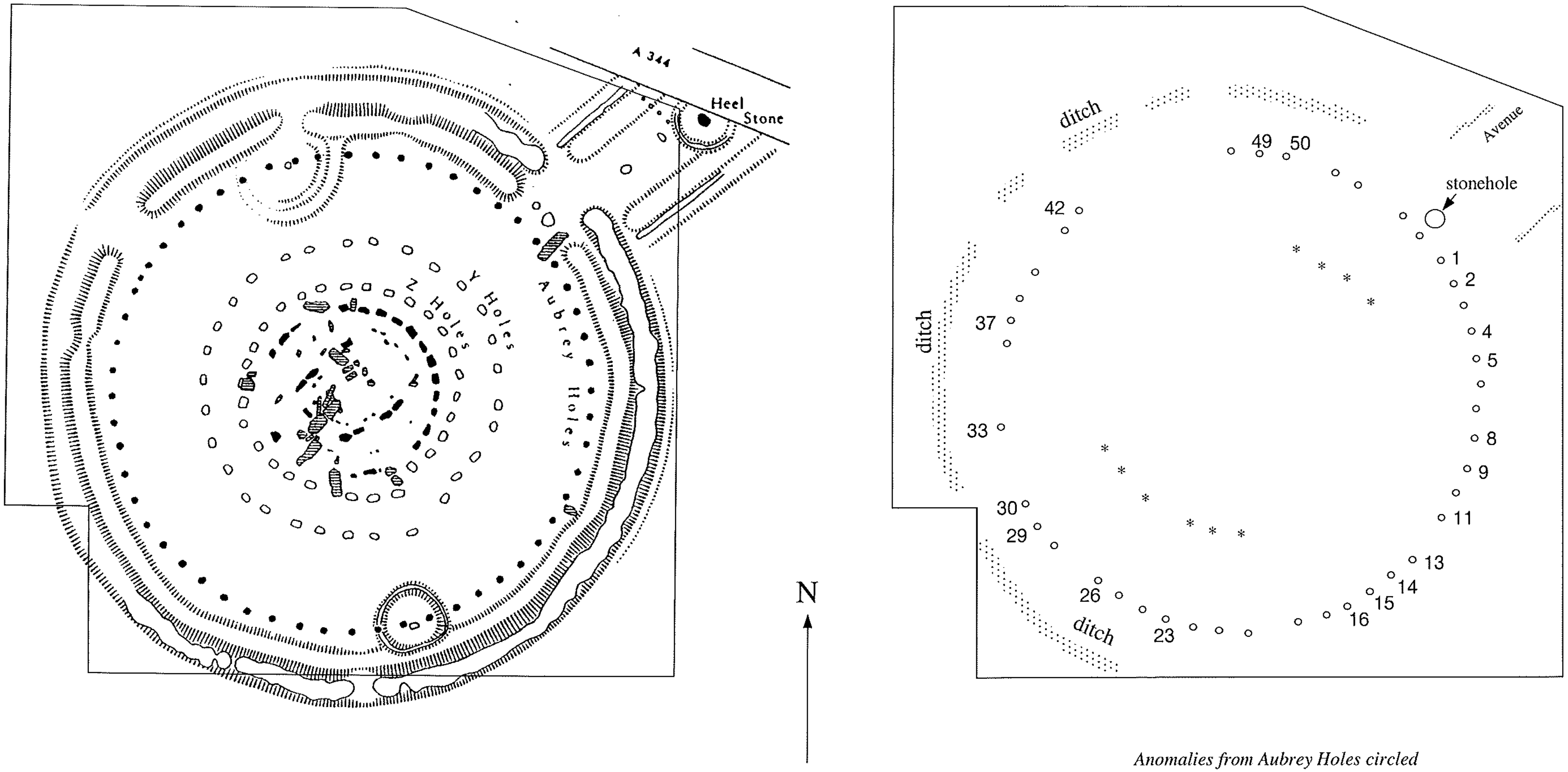
STONEHENGE Magnetometer Survey, Dec 1993

Figure 14

Interpretation of magnetometer data from henge, showing anomalies from Aubrey Holes



Anomalies from Aubrey Holes circled

** = possible response to Y holes*

(numbered anomalies confirmed by resistivity survey)

0 30 90m

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LOCATION OF RESISTIVITY SURVEY

Figure 15

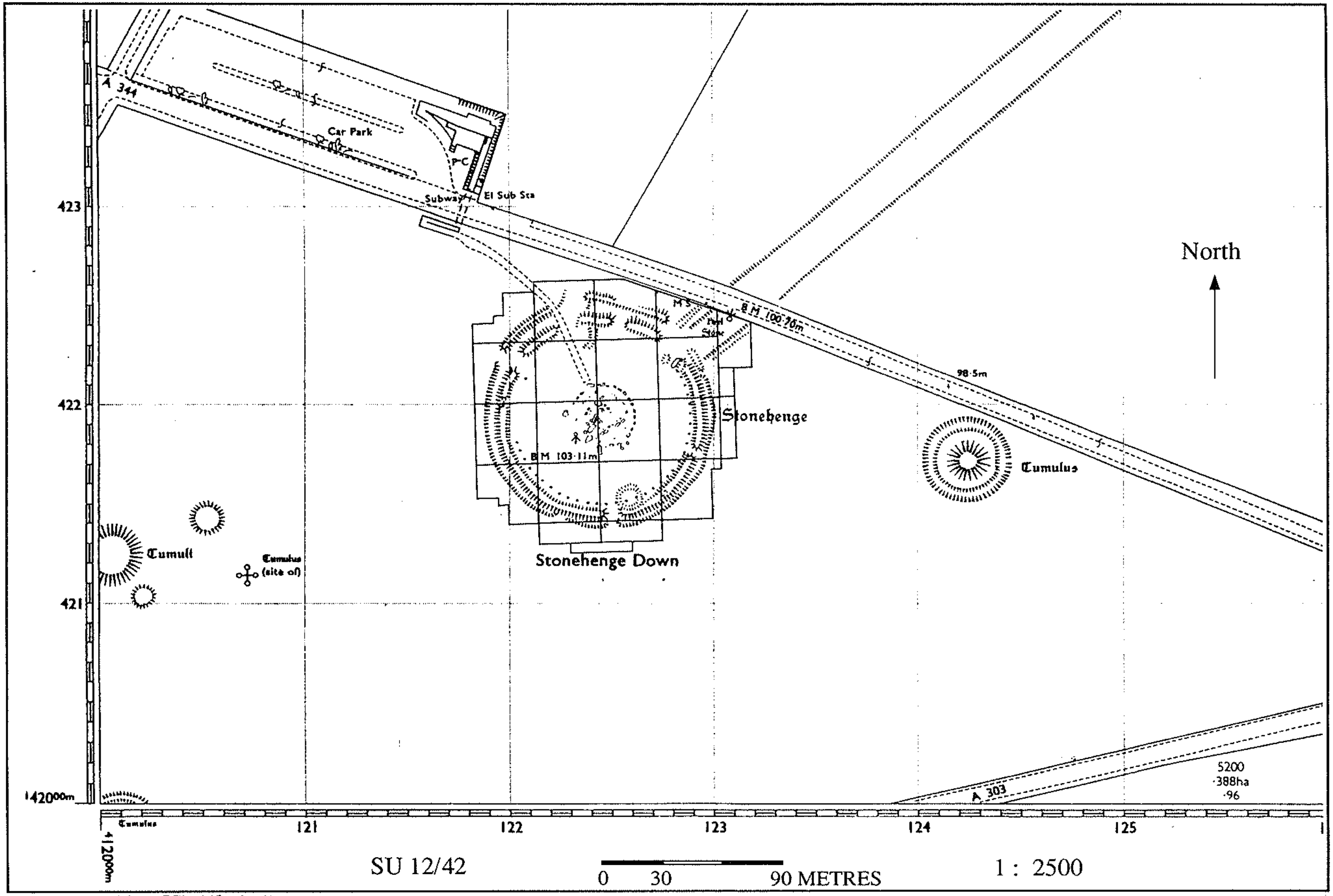
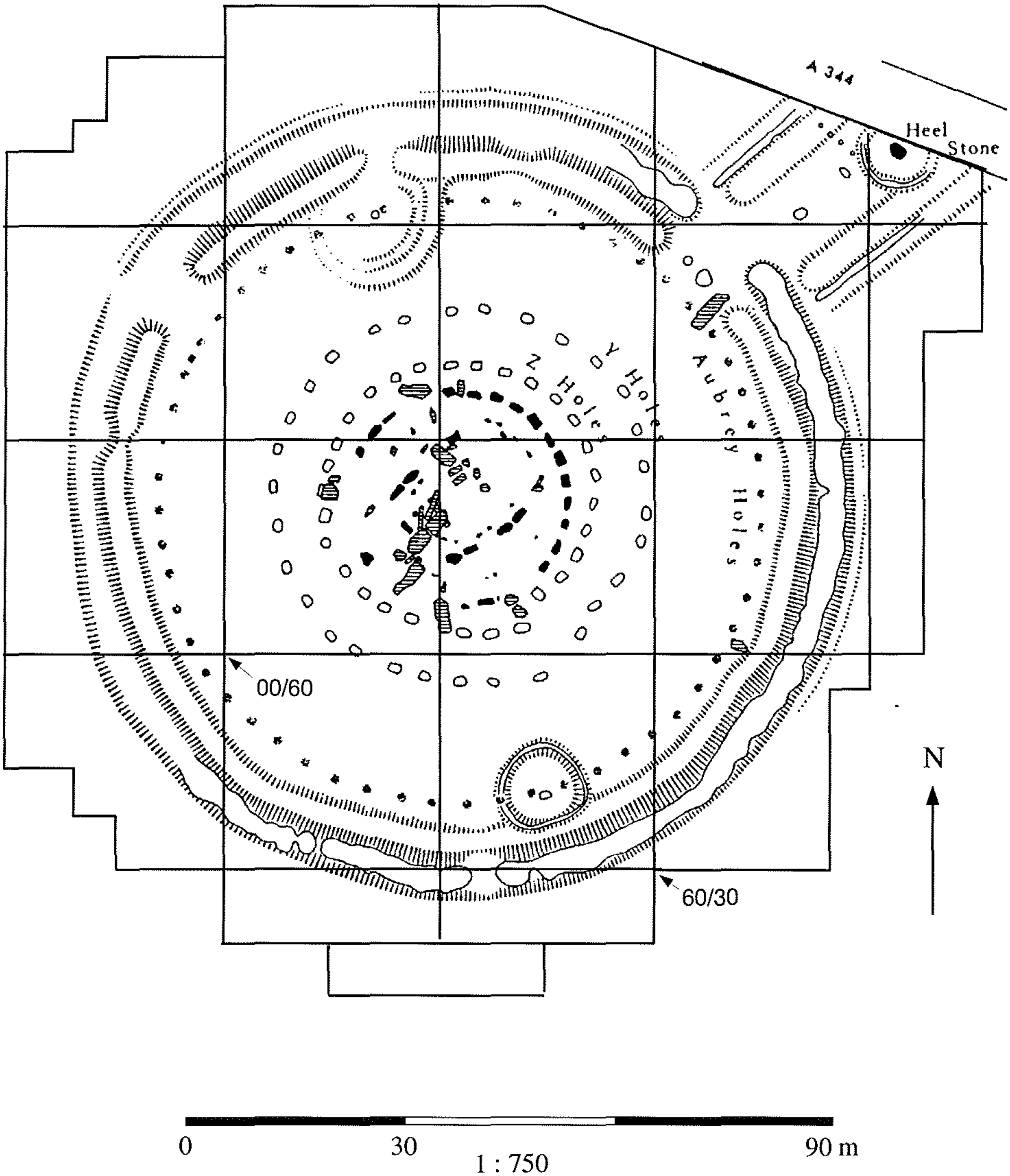


Figure 16

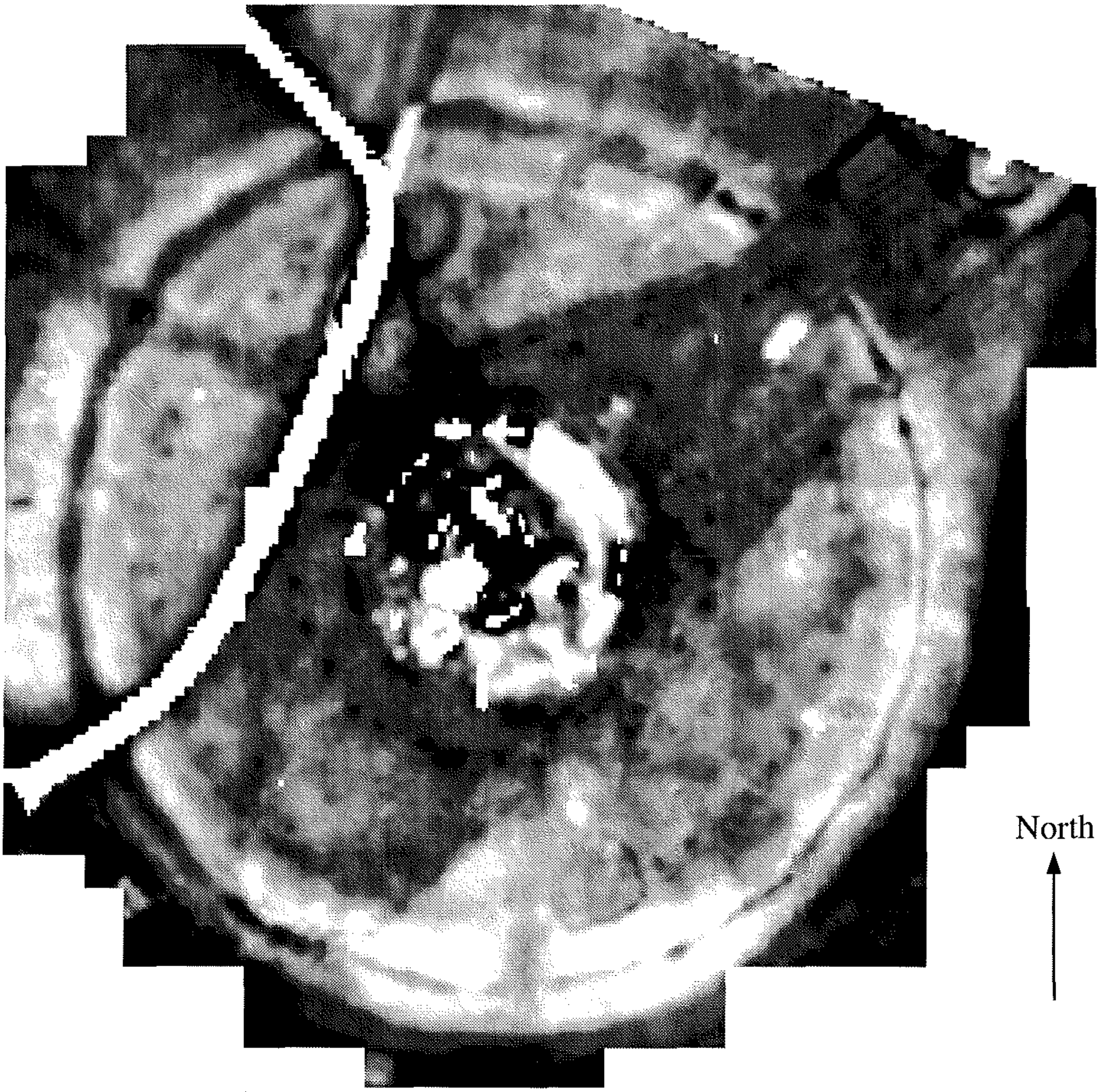
STONEHENGE Resistivity Survey

Location of Survey Grid

(based on RCHME plan 1979)



STONEHENGE Resistivity Survey, May 1994



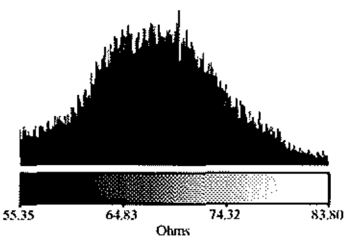


Figure 17

Greyscale plot of enhanced data

0 30 90 METRES

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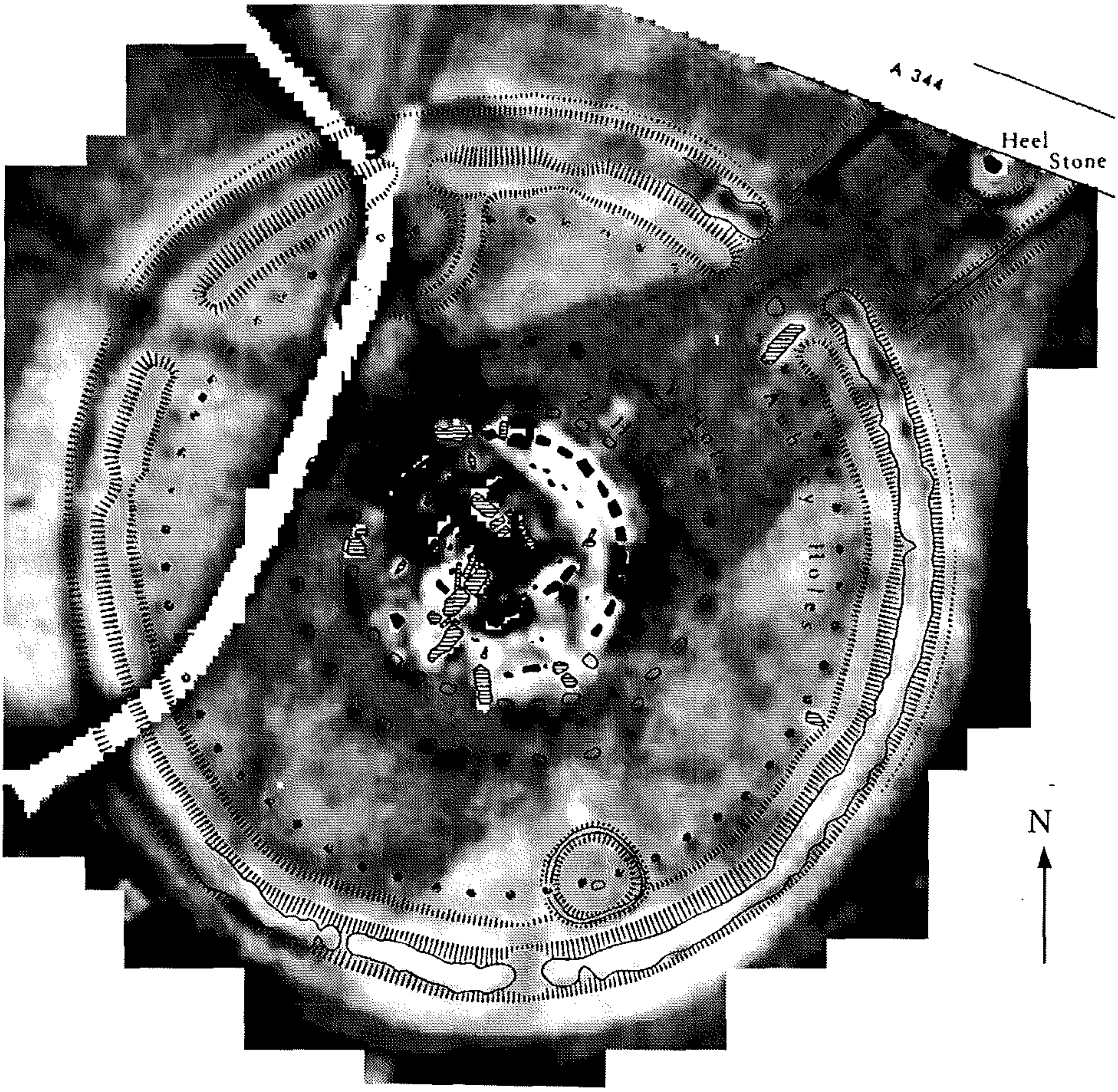
Figure 18

STONEHENGE Resistivity Survey



0 30 90 m

1 : 750

Resistivity survey in relation to general plan of Stonehenge (RCHME 1979)

KEY :
- Pit
- Standing stone
- Fallen stone
- Stone hole

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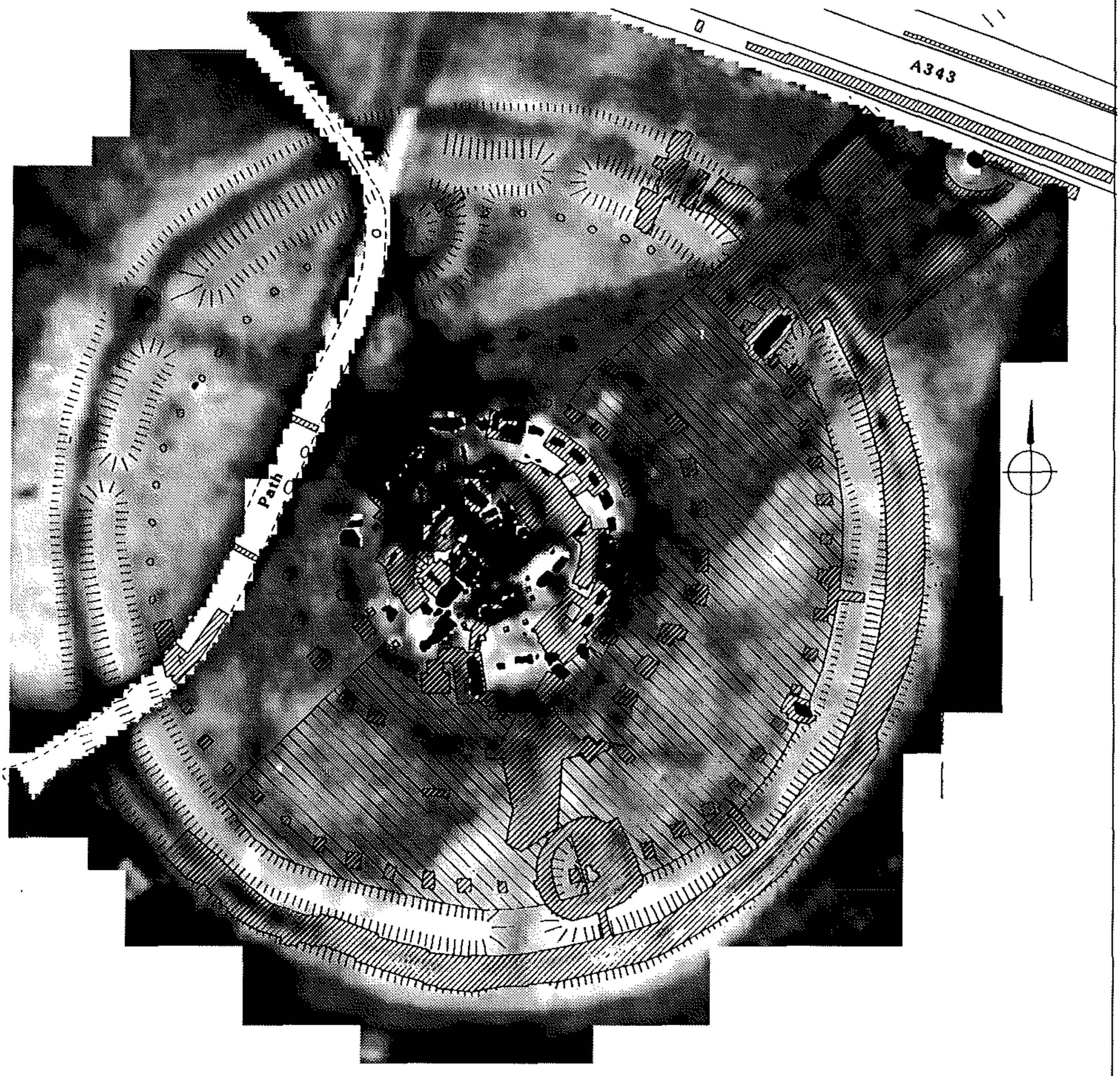
Figure 19

STONEHENGE Resistivity Survey



Best fit relationship of resistivity plot to plan of archaeological excavations

(plan derived from Lawson A J 1992)

0 30 90 m

1 : 750

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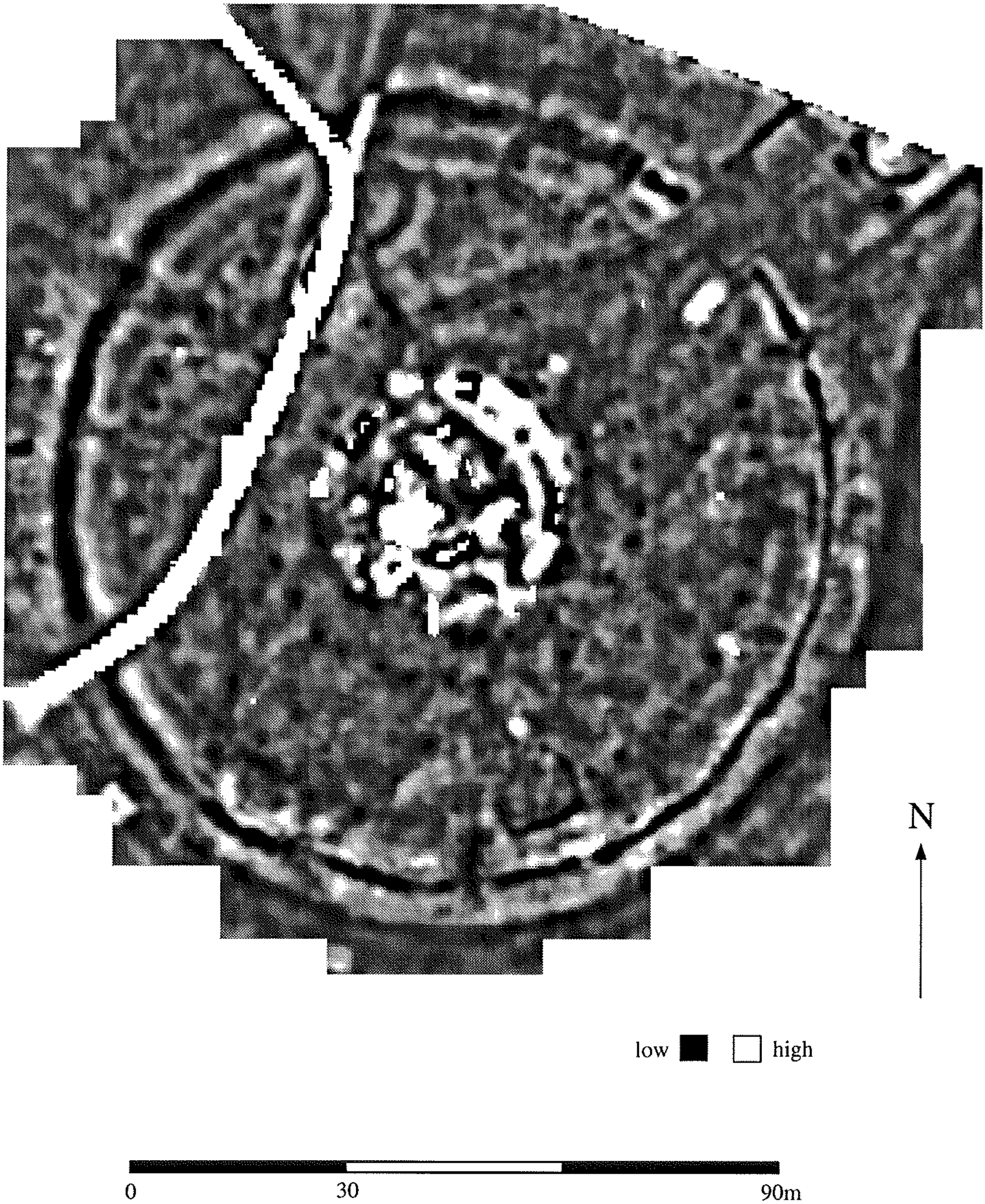
STONEHENGE Resistivity Survey , May 1994

Figure 20 *: 3m Gaussian high-pass filter*



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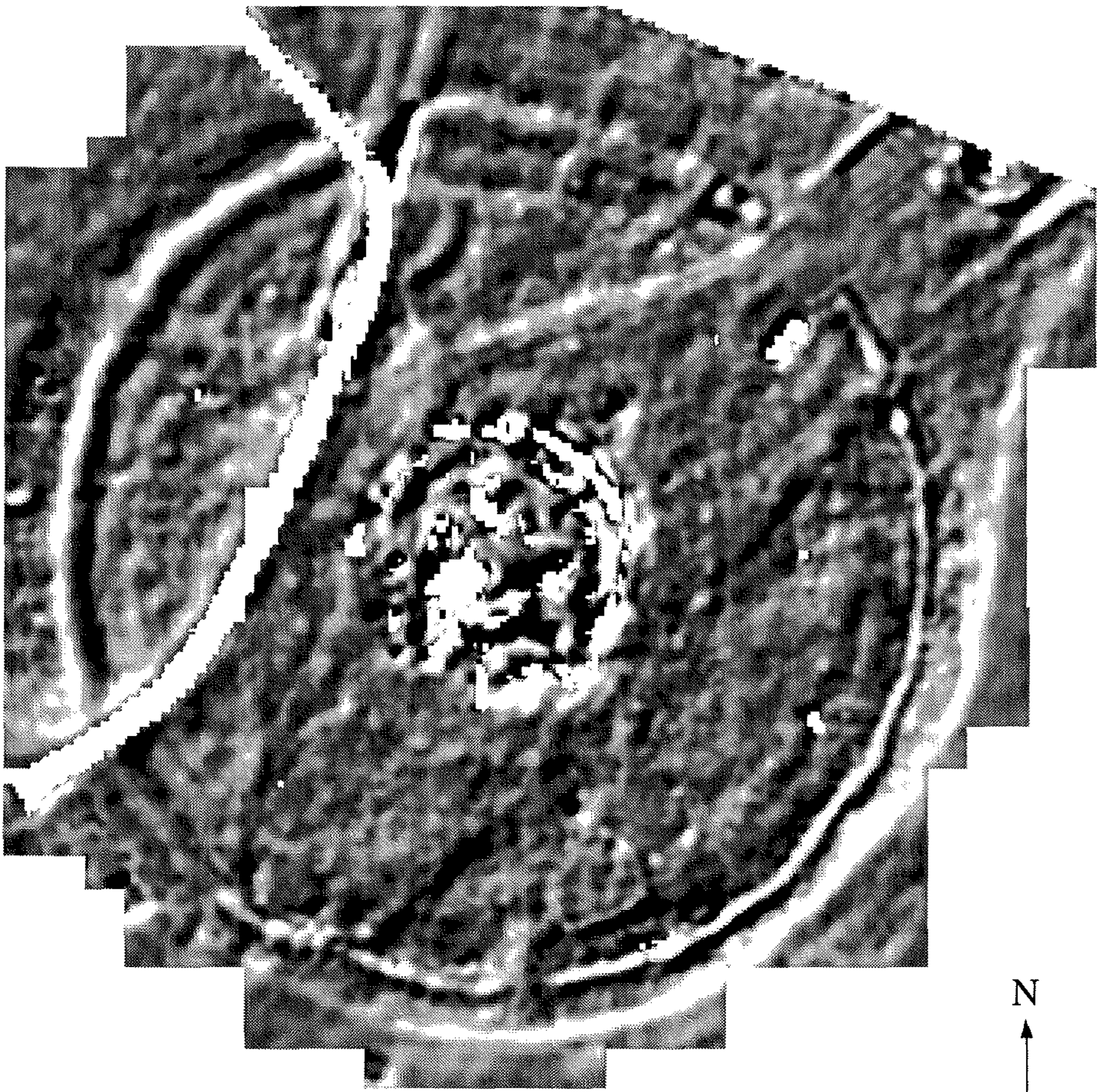
STONEHENGE Resistivity Survey 1994

Figure 22 *: directionally filtered resistivity data (from SE -> NW)*



N

0 30 90m

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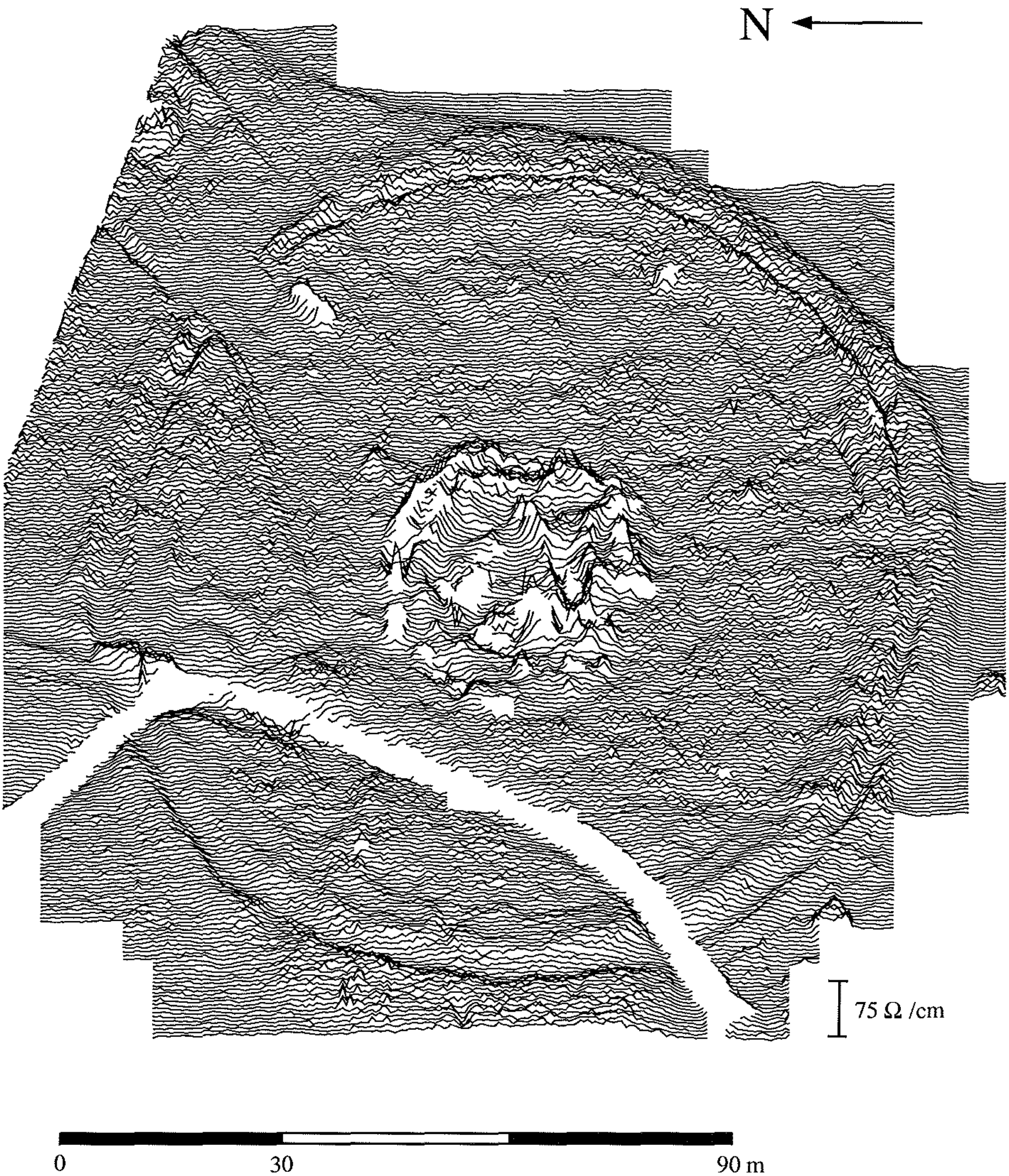
STONEHENGE Resistivity Survey 1994

***Figure 23** : X-Y traceplot of raw data*



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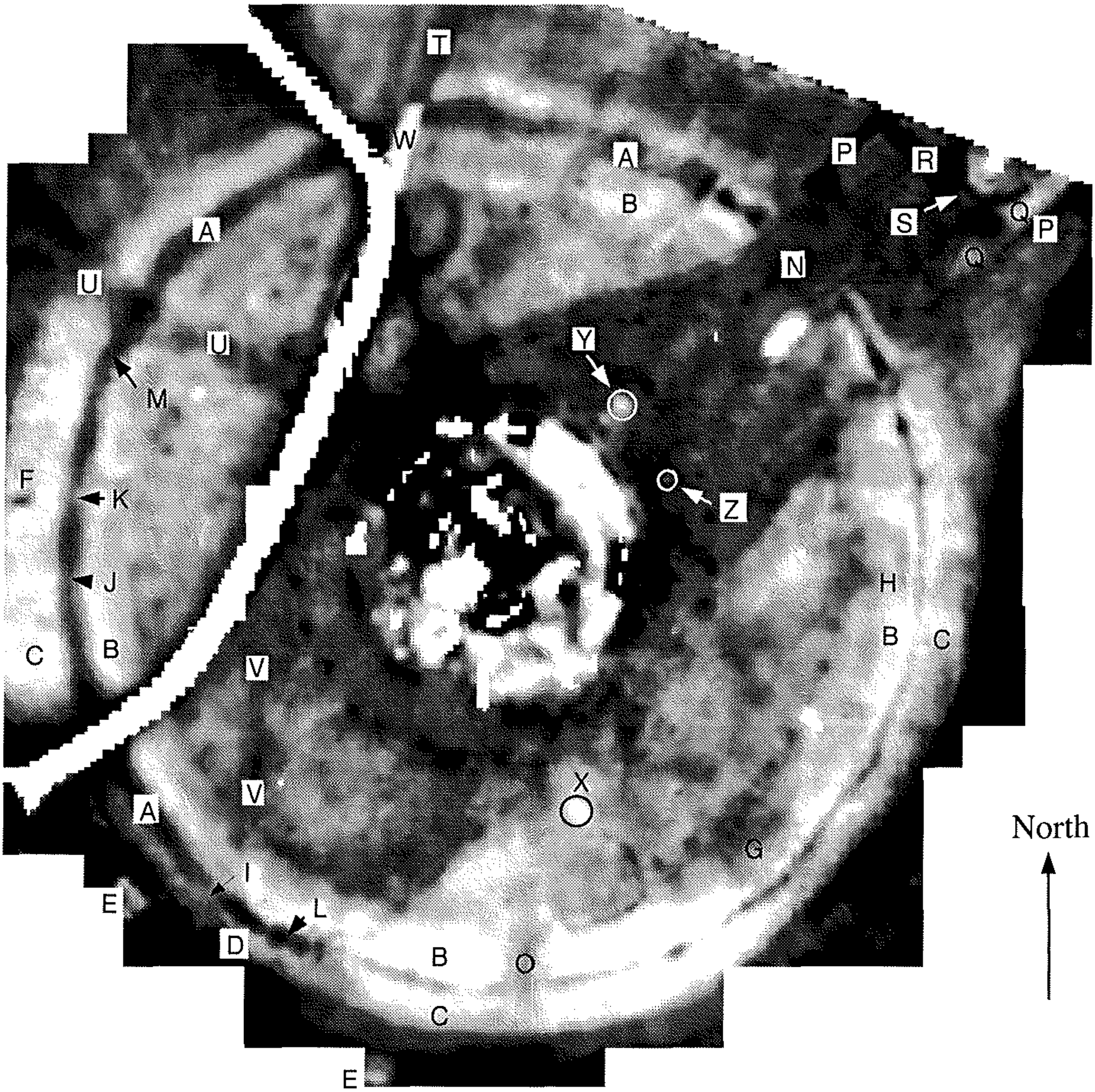
STONEHENGE Resistivity Survey, May 1994



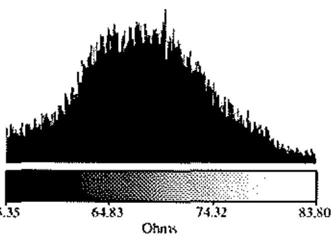


Figure 24

Greyscale plot of enhanced data

(A - Z = anomalies refered to in text)

0 30 90 METRES

AMLab 94

STONEHENGE

Resistivity Survey

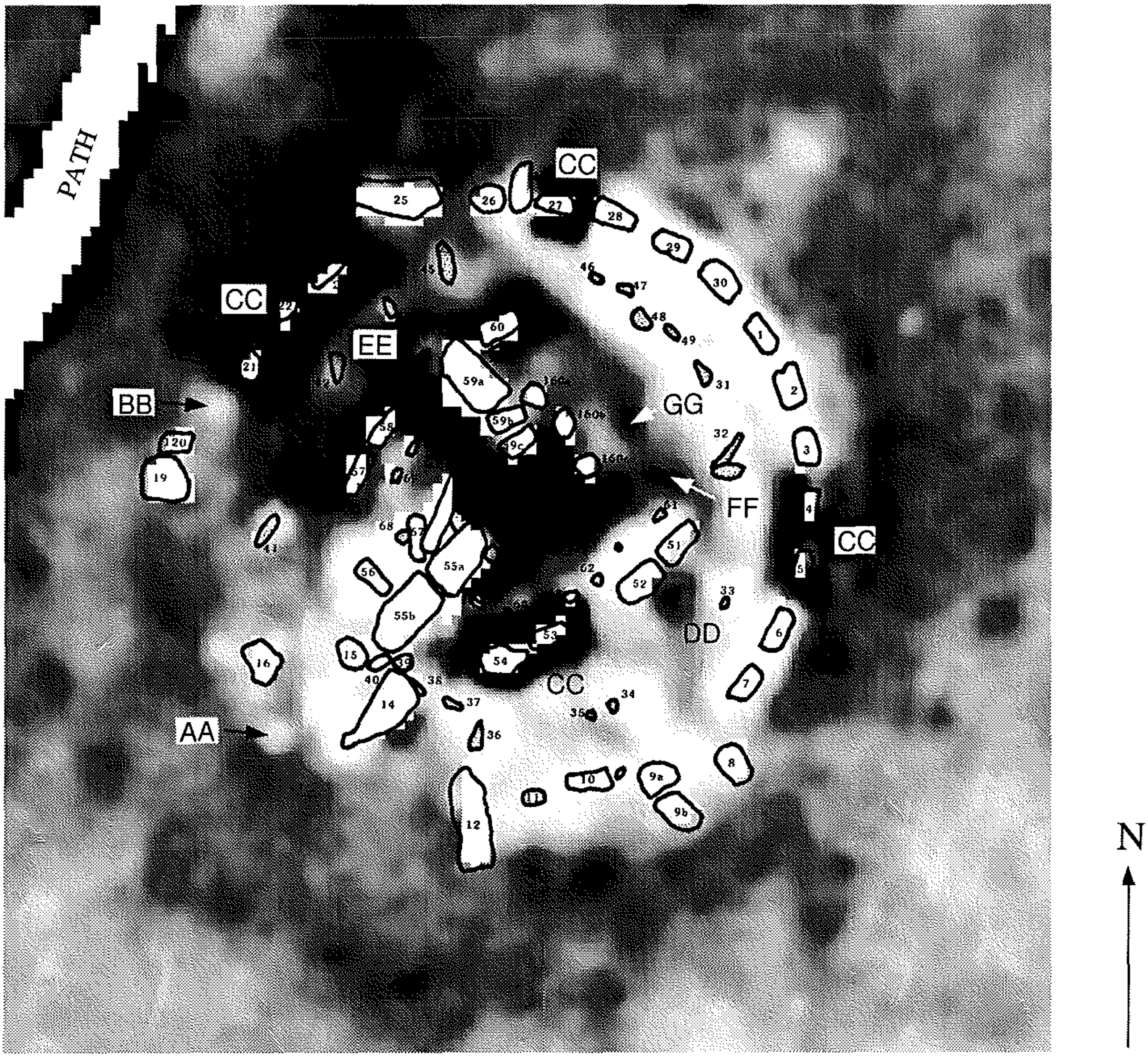


Figure 25

Plan of stone-settings overlain on extract from resistivity survey

0 10 30 m