UNIVERSITY OF BRADFORD
DEPARTMENT OF ARCHAEOLOGICAL SCIENCES

GEOPHYSICAL SURVEY OF LEAD SMELTING FEATURES IDENTIFIED ON TOTLEY BOLE HILL, BLACKA MOOR NATURE RESERVE, SHEFFIELD

A.J. Powell

Department of Archaeological Sciences
University of Bradford
Bradford BD7 1DP

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A.J. Powell
Department of Archaeological Sciences
University of Bradford
Bradford BD7 1DP
Tel. (01274) 233531 Email: a.j.powell3@bradford.ac.uk

ABSTRACT

A magnetometer (fluxgate gradiometer) and earth resistance survey was conducted over part of Totley Bole Hill near Sheffield. The purpose of the survey was to determine the feasibility of using these geophysical prospection techniques over archaeological lead smelting activities and to ascertain the extent of the remains of these activities. The magnetometer results successfully identified several lead smelting features whilst the earth resistance survey produced disappointing results, due to a combination of site geology and potentially high ground water content caused by adverse weather conditions. Recommendations are made for further investigations to be undertaken on this site.

INTRODUCTION

Totley Bole Hill is part of the Blacka Moor Nature Reserve, which is administered by the Sheffield Wildlife Trust, and has been designated a scheduled ancient monument by English Heritage (monument number 24985) due to the numerous medieval and post-medieval lead smelting activities known to have taken place. Much research has been undertaken into the history of the early lead mining and smelting industries, an example of which is Kiernan (1989). The Totley Bole Hill area has been surveyed by fieldwalking and several lead smelting sites noted, in particular a “bole” feature towards the southern end of the hill which was reported on by Kiernan and van de Noort (1992). Ed Dennison Archaeological Services Ltd. carried out a topographical survey (Dennison & Richardson 2003) which identified in greater detail the bole and some other sites believed to be blackwork ovens. Subsequently, an opportunity arose to carry out a geophysical survey on Totley Bole Hill as part of a PhD research project being conducted at the Department of Archaeological Sciences, University of Bradford; as far as is known, no geophysical surveys have ever been undertaken on Totley Bole Hill.

The objectives of this survey were to determine:

- the feasibility of using geophysical prospection techniques over archaeological lead smelting activities, and
- to what extent the traces of these activities still exist.

The work was carried out with the assistance of Rob and Margaret Vernon and Irene Zananiri, and with the permission of the Sheffield Wildlife Trust (Annabelle Kennedy). A Section 42 Licence was obtained from English Heritage (Keith Miller, Inspector of Ancient Monuments, Yorkshire Region) and the Peak District National Park Authority archaeologist (Sarah Whiteley) informed.

LOCATION

Totley Bole Hill lies approximately 10km (6¼ miles) south-west of Sheffield city centre, at NGR SK 290 798 (Figure 1). The overall plan of the southern end of Totley Bole Hill where the survey was carried out is shown in Figure 2 and indicates the general topographic features, the lead smelting sites and the survey locations. This report uses the same site numbers designated by the Dennison and Richardson (2003) survey. The main complex of sites are at the southern end of the Bole Hill (Sites 8 to 15), with Sites 10 and 15 being of primary interest, whilst a second area (Site 22) is approximately 110m north of Site 10.

THE GEOPHYSICAL SURVEY

The survey was undertaken on several dates during the summer of 2005: 2nd June, 28th July, 1st August and 11th August. The weather was extremely varied from high winds and rain (2/6 & 28/7), hill fog and rain (1/8) to dry and sunny (11/8). Two survey techniques were employed: magnetometer, using a Geoscan FM256 fluxgate gradiometer, and earth resistance, using a Geoscan RM15 instrument (twin probe array, 0.5m mobile electrode spacing). Due to the weather conditions the latter was utilised over Site 10 only. Magnetic susceptibility measurements using a Bartington MS2D field coil were considered but not carried out as the ground surface over the survey areas varied between open soil and stone, through rough grass to heather cover, all of which were not conducive to giving good and consistent field coil contact and reliable readings.

The survey was divided into two parts, one over the main complex (Sites 8 to 15) and the other over Site 22. The survey base line was established with reference to the large stone identified on Figure 3 at the interface of grids 7 and 11, starting at point X 5.35m from the stone's centre and running northwards parallel with its eastern face. The base line was extended northwards for 110m from point X to point Z shown on Figure 5 to link together the Site 22 and main complex survey grids. An intermediate point was set up at Y (not shown) which was at 37.5m north of X and 4.85m perpendicular to the cairn (Site 16, Figure 2). The error associated with the setting-up of the grids was no more than 10cm in both north-south and east-west directions.

At the main complex, a total of sixteen 10m x 10m grids were laid out as shown in Figure 3. Magnetometer readings were taken over this area at a resolution of 0.5m (0.5m intervals at 0.5m traverses) with the instrument sensitivity set to 0.1nT. Six 5m x 5m grids were laid out specifically over Site 10, the bole reported by Kiernan and van de Noort (1992), in order to identify better any anomalies associated with the bole. Both magnetometer and earth resistance readings were taken over these six grids at 0.25m resolution (0.25m intervals and 0.25m traverses). Figure 4 shows the relationship between the 5m and 10m grid layouts. At Site 22, six 10m x 10m grids were laid out as shown in Figure 5, and magnetometer readings also taken at 0.5m resolution and instrument sensitivity of 0.1nT. In addition, a separate set of magnetometer readings were taken in Site 22 grid 2 at 0.5m resolution but at an instrument sensitivity of 1nT, due to a very high positive anomaly being identified in this grid causing the instrument to overrange on the 0.1nT sensitivity setting.

The data were processed using Geoplot V3; magnetometer raw data were corrected for zero mean grid where appropriate and interpolated, no filtering being used, whilst the earth resistance raw data were despiked, median filtered and interpolated. The data are presented as clipped plots only; relief graphics were examined but did not provide any extra detail compared to the clipped plots.

THE GEOPHYSICAL DATA – MAIN COMPLEX (SITES 8 TO 15)

Figure 6 shows the 10m grid magnetometer survey data superimposed on the detailed plan of the main complex. The mean value of the raw data from these 16 grids is 0.2nT; the standard deviation is 10.3nT. Although the data are generally of low positive and negative values, maximum values of 205nT and -119nT were recorded. These two readings are not directly related as they are about 23m apart, and consequently could be generated by *inter alia* individual stray iron-based objects lying below ground surface. Figure 7 shows the raw magnetometer data clipped to various ranges. As the clipping level reduces various archaeological features emerge. Distinct areas of activity are identifiable as well as other weak anomalies; these will be discussed in detail below. There is an apparent inconsistency between the position of the magnetometer survey plot relative to the detailed plan. This has been examined and the magnetometer grid location confirmed as correct, a result which has a significant outcome on the interpretation of the magnetometer data.

THE GEOPHYSICAL DATA – SITE 10

Figure 8 shows the 5m grid magnetometer and earth resistance survey raw data clipped to various ranges. The mean value of the raw magnetometer data is 0.6nT; the standard deviation is 23.8nT. The maximum values recorded were 252nT and -126nT. A distinct area of activity is noted.

The mean value of the raw earth resistance data is 160 ohms and the standard deviation is 52.8 ohms. The maximum and minimum values recorded were 616 and 96 ohms. Due to its isolated position, the maximum value is considered to have been caused by poor contact. For the clipped resistance ranges a graphics area was selected specifically over the presumed location of the bole (grids A, B and C in Figure 4), thereby making the interpretation of the plots easier by removing the influence of the data derived from the adjacent path. Two very weak anomalies are identifiable.

THE GEOPHYSICAL DATA – SITE 22

Figure 9 shows the 10m grid magnetometer survey data superimposed on the detailed plan of Site 22. The mean value of the raw data from these 6 grids is -0.9nT; the standard deviation is 22.8nT. The maximum values recorded were 194nT and -150nT. Excluding the data from grids 1 and 2, the raw data values become -1.6nT (mean), 7.2nT (standard deviation) and 55nT/-58nT (maxima). The raw data for the single survey over grid 2 produced a mean value of 33nT, a standard deviation of 245nT and maxima of 1757nT and -158nT. Figure 10 shows the raw magnetometer data clipped to various ranges. Distinct areas of activity are identifiable; these will be discussed below. The plot of the single set of data from grid 2 is dominated by the very large positive anomaly (greater than 2000nT) which overwhelms any weaker anomalies as the clipping level increases. A similar effect can be seen in grid 1 caused by another relatively high positive anomaly. The white area in the north-west corner of grid 2 is caused by overrange values in the data recording.

INTERPRETATIONS - MAIN COMPLEX (SITES 8 TO 15)

Several identifiable anomalies from analysis of the survey data are shown in Figure 11. These anomalies, marked by lower-case letters and where appropriate referenced by grid locations in Figure 3, are listed below:

Anomalies (a) and (b): Two sub-circular areas of activity, located on the flat area of the site. Both anomalies are apparent over a wide range of clipped data from ±100nT to ±10nT (Figure 7). [Note that superimposing the 5m grid magnetometer survey plot onto the detailed plan of the main complex (Figures 3 & 4) results in an interpretation which corresponds to anomaly (a).]

Anomaly (c): A weak rectangular anomaly lying between (a) and (b) and is less distinct than either over the same ranges of clipped data.

Anomaly (d): An area of activity weaker than (a) and (b) on the western downslope of Totley Bole Hill below these anomalies. The anomaly appears to be associated with the activities occurring at (a) and (b).

Anomaly (e): An apparently oval or sub-rectangular anomaly at the lowest point of anomaly (d), with a maximum positive value of 76nT. It is possibly a small group of burnt stones buried under rough grass cover.

Anomaly (f): An apparently oval or sub-rectangular anomaly, with a maximum positive value of 107nT. Possibly a small group of burnt stones, similar to (e).

Anomaly (g): An area of weaker activity than (d), this anomaly coincides with Site 13 and extends south-westwards across the path. The area, described as mounds by Dennison and Richardson (2003), is associated with bare soil and stones.

Anomaly (h): This is an area of weak activity to the east of Site 15, which is described as a possible blackwork oven or slag hearth by Dennison and Richardson (2003). The anomaly coincides with the spur of land seen in grid 15 and there is no visible presence here of any slag or burnt material.

Anomaly (i): A weak circular anomaly coinciding with the area of charcoal and bare soil shown in grid 12.

Anomaly (j): Ten apparently sub-circular anomalies, with a range of maximum positive values from 22nT to 132nT (mean 52nT); like anomaly (g) they are possibly small groups of burnt stones, but buried instead under a thin layer of grass-covered top soil.

Anomaly (k): Four weak linear anomalies which do not correspond to site topography and could be the response to geological features.

The above anomalies are determined from the magnetometry surveys. The following is the only interpretation which could be made from the limited earth resistance survey over Site 10:

Anomaly (l): Two weak anomalies, shown dashed in grids 7 and 8. The smaller, apparently oval anomaly (grid 7) is marginally stronger than and overlaps the other larger, circular anomaly (grid 8), and also coincides with anomaly (a). It is possible that the smaller anomaly is part of a structure but this is unlikely to be proved without intrusive investigation. It is also feasible that both anomalies are the response to geological features.

INTERPRETATIONS - SITE 22

Identifiable anomalies from analysis of the survey data are shown in Figure 12. These anomalies, marked by upper-case letters and where appropriate referenced by grid locations in Figure 5, are listed below:

Anomaly (A): This is a very large positive anomaly, shown in grid 2. Further investigation is required to determine the nature of this anomaly, but it is most unlikely that it is associated with lead smelting.

Anomaly (B): A sub-rectangular area (grids 1 & 2) of relatively high positive values, which could be connected with anomaly (A) or possibly be geological in nature.

Anomalies (C) and (D): Two areas of weak activity spread over grids 1 and 3. Anomaly (C) corresponds with the topographic features west of the path whilst anomaly (D) coincides with the areas of slag and bare soil identified by Dennison and Richardson (2003).

Anomaly (E): An area of significant activity spread over the survey area as shown. The anomaly is not obvious as it is buried under a combination of heather, rough grass or a thin layer of grass-covered top soil, but it is feasible that it may be a spread of slag and stone.

Anomaly (F): Seven weak linear anomalies which do not correspond to site topography and could be the response to geological features.

CONCLUSIONS

The survey objectives have been achieved by demonstrating that it is feasible to conduct geophysical prospection techniques over archaeological lead smelting activities, and that the traces of these activities do exist to an extent which can be determined.

For ease of use and maximisation of data recording, a magnetometer survey employing a fluxgate gradiometer has been shown to be the most appropriate survey method at Totley Bole Hill and may also be suitable at other similar locations. Alternative magnetic survey techniques may be unsuitable.

As noted above, magnetic susceptibility surveys were not undertaken due to the variable nature of the ground surface over the different parts of Totley Bole Hill that were surveyed. However, this survey technique should be considered for use at other lead smelting sites as a norm to complement magnetometer surveys, but subject to ground surface considerations at each site.

The magnetometer survey revealed considerable activity, a greater amount than that identified by the topographical survey, both over the main complex (Sites 8 to 15) and Site 22. At the main complex, two areas of more concentrated activity have been identified, as well as a large area below them on the western downslope of Totley Bole Hill. Anomaly (a) in Figure 11 does not coincide with the bole identified by Kiernan and van de Noort (1992), or surveyed by Dennison and Richardson (2003), i.e. Site 10/1 in grid 8 of Figure 3, instead corresponding more with Site 10/2 in grid 11. There is no evidence from the magnetometer data of any anomalies which coincide or are associated with the Site 10/1 bole channels shown in Figure 3. This does not mean that these channels do not exist; there may not be a sufficiently high magnetic signal from them which stands out against the surrounding background data. Anomaly (b) is similar in shape and size to (a), but is not visible on the ground, being buried under grass-covered topsoil. Anomaly (c) could be associated with a structure of some kind but there is no obvious supporting topographical evidence. There is a sufficient quantity of lead slag remaining in the bare patches of ground on the flat area of the main complex site to conclude that there was a significant amount of lead smelting taking place here; the anomalous areas (a) and (b) have a high probability of being directly related to the smelting process whilst anomaly (d) could be an extensive slag dump.

At Site 22, two areas of activity, (C) and (D) in Figure 12, have been identified. Due to the large amount of lead slag material which is visible close to both anomalies, either in the patches of bare soil or along the path, it is possible that these two areas are associated with slag heaps. It is feasible that anomaly (D) could be the site of another lead smelting bole, although there is no supporting topographical evidence such as a sizeable quantity of stones and patches of bare soil as seen at Site 10. The extent of anomaly (E) running in a south-east/north-west direction along the downslope contours to the north of anomaly (D) and the similarity of its magnetometer data values to the Main Complex anomaly (d), suggests that this area could also be a slag dump. There is sufficient survey and visual evidence to conclude that lead smelting was also taking place in this part of Totley Bole Hill. Further investigation to determine the nature of the anomalies (A) and (B) in Figure 12 is recommended. It is possible that the effects of (A) are masking further low level activity similar to anomalies (d) and (E).

The earth resistance survey over Site 10 was not as successful as originally anticipated. Although the results showed that a tentative interpretation was possible, the survey appears to have been affected by two factors: (a) site geology – soil erosion along the path (Figure 3) has revealed many pieces of naturally occurring stones just below ground surface which suggests that there is only a thin layer of top soil on this part of Totley Bole Hill, and (b) ground water content – it is extremely likely that the data were influenced by the heavy rainfall that occurred immediately before and during the survey. These factors do not suggest that earth resistance surveys should not be attempted at other similar lead smelting locations.

RECOMMENDATIONS

The survey has revealed the remains of much lead smelting activity, but as a consequence there are some matters which require investigation in order to further the understanding of lead smelting on Totley Bole Hill and elsewhere. The following recommendations are made for consideration in any future research on the Totley Bole Hill site:

- Selective sampling of the areas presumed to be slag dumps, for example (d) in Figure 11 and (C) in Figure 12, so that analysis can be undertaken to determine the magnetic properties of the slag;
- Minimal excavation of the anomalies (j) in Figure 11 to determine whether these are burnt stones as interpreted;
- Undertake a full contour survey of the Totley Bole Hill site to determine the relationship (if any) between the presumed slag dumps and the anomalous areas (a) and (b) in Figure 11 and (D) in Figure 12 (this has the potential for "reverse location" of smelting sites where these have not be identified by topographical or geophysical survey);
- Establish a permanent benchmark on Totley Bole Hill, for example on the flat area at the southern end of the site, so that all surveys, current and future, can be aligned.

ACKNOWLEDGMENTS

I should like to thank Annabelle Kennedy at Sheffield Wildlife Trust for permitting access to the Totley Bole Hill site and to Keith Miller at English Heritage for issuing a prospection licence for the survey to proceed. Special thanks to Rob and Margaret Vernon and Irene Zananiri for assisting with the survey for the most part in very wet and windy conditions. Thanks are also due to David Kiernan for bringing the site to my attention and for showing me its potential for geophysical survey, and to Ed Dennison for granting permission for me to use the figures from his topographical survey report. Armin Schmidt's comments on the draft report are greatly appreciated.

Alan J. Powell
Postgraduate Researcher
Department of Archaeological Sciences
University of Bradford

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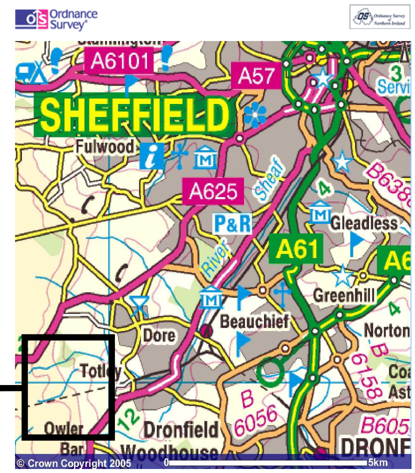
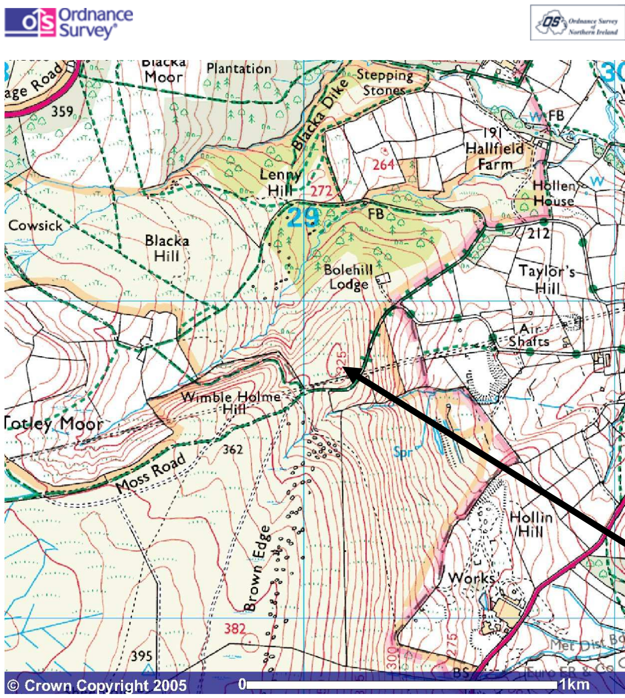
REFERENCES

Dennison, E. & Richardson, S. 2003. *Blacka Moor Nature Reserve, Sheffield, South Yorkshire: archaeological survey of Bole Hill.* Beverley, E. Yorkshire: Ed Dennison Archaeological Services Ltd. (unpublished EDAS report 2003/193.R01 for Sheffield Wildlife Trust)

Kiernan, D. 1989. *The Derbyshire lead industry in the sixteenth century*. Chesterfield: Derbyshire Record Society.

Kiernan, D. & van de Noort, R. 1992. *Bole Smelting in Derbyshire*. In Willies, L. & Cranstone, D. (eds.) *Boles and Smeltmills*, 19-22.





Survey location:
Totley Bole Hill – SK 290 798

Figure 1: Location of Totley Bole Hill, Blacka Moor Nature Reserve, Sheffield

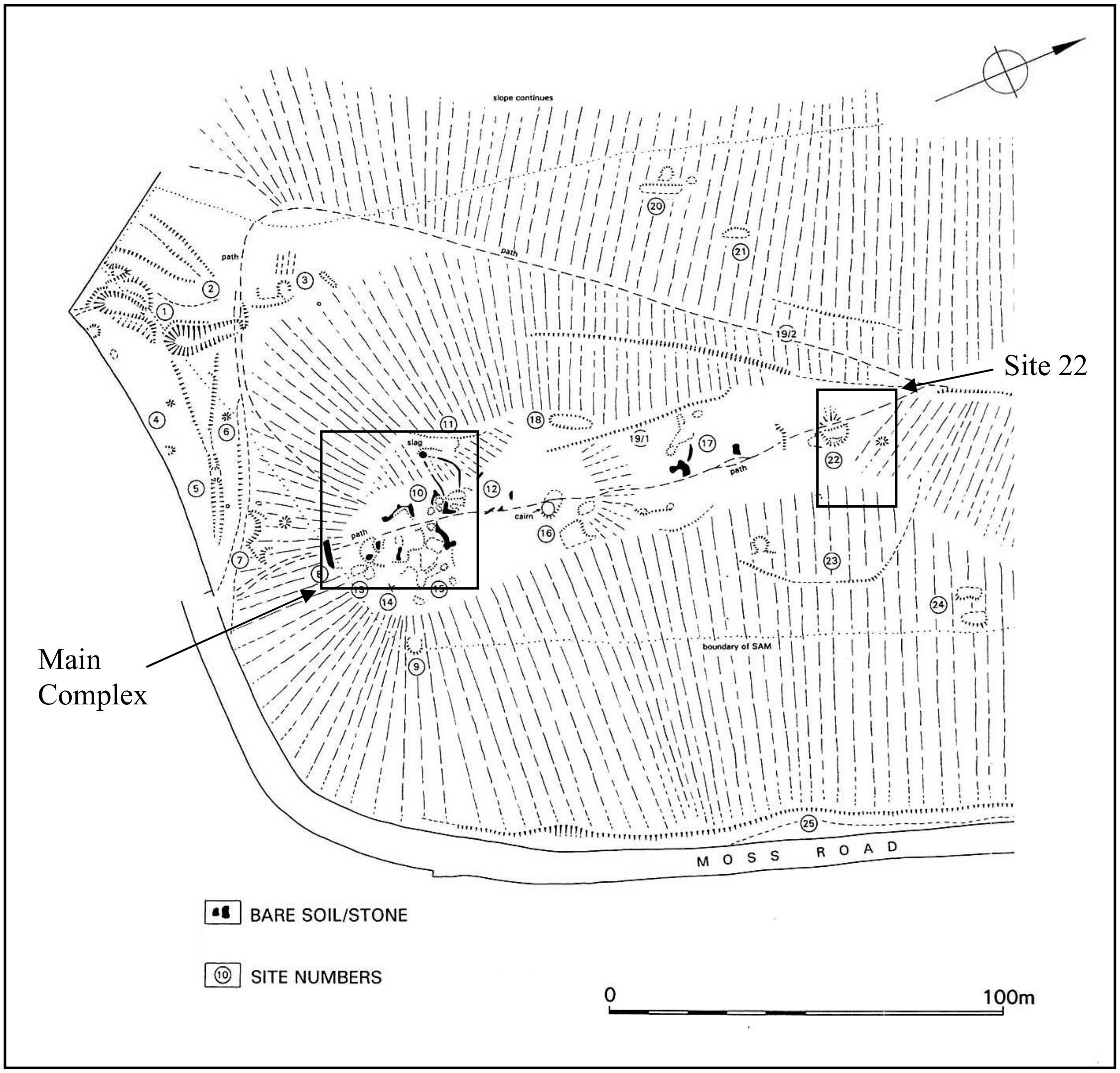


Figure 2: Overall plan of Totley Bole Hill southern end, showing the locations of the Main Complex and Site 22 survey areas (adapted from Dennison & Richardson 2003, Fig. 5)

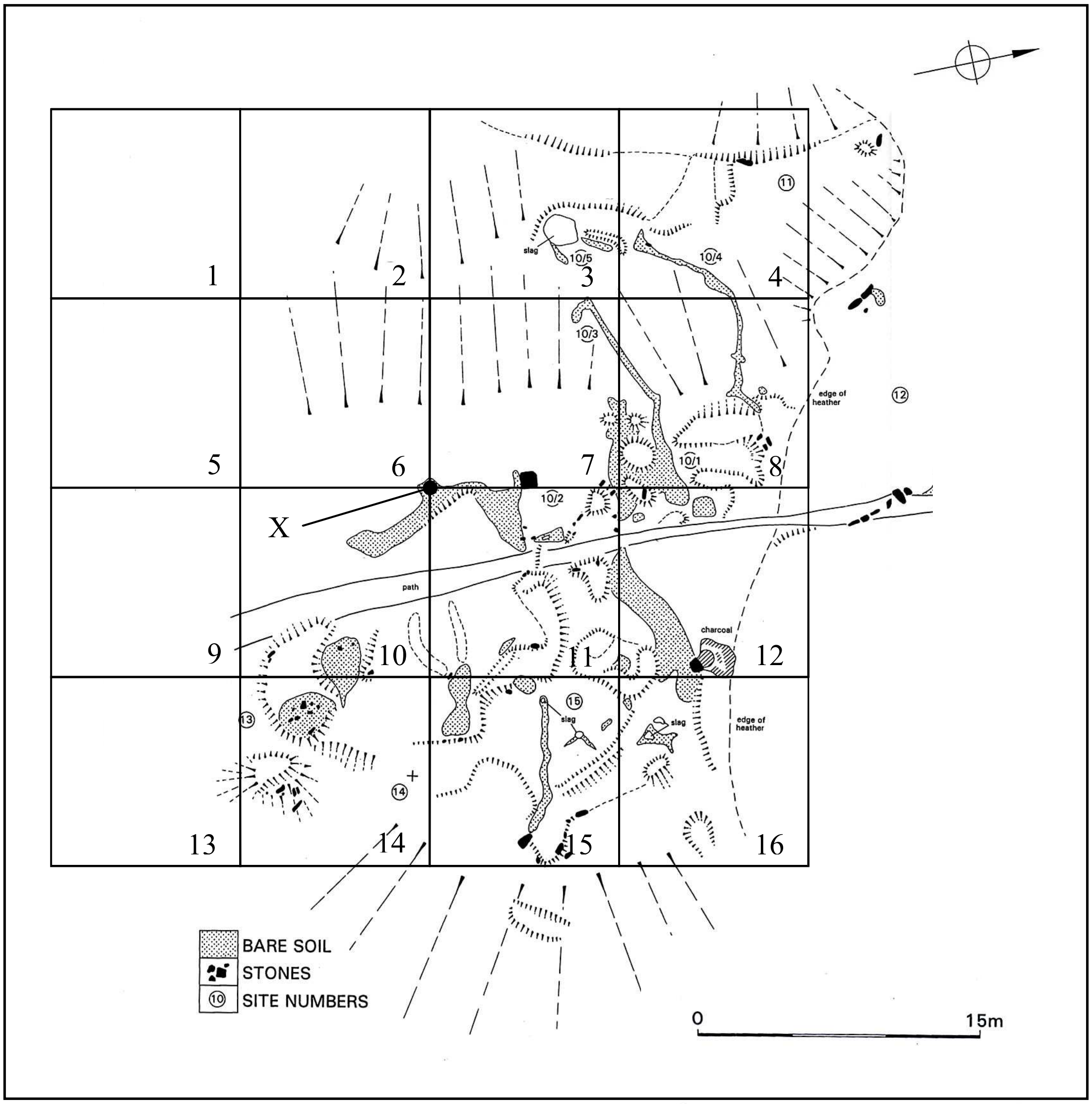


Figure 3: Detailed plan of Totley Bole Hill main complex (Sites 10 to 15), with survey grids superimposed

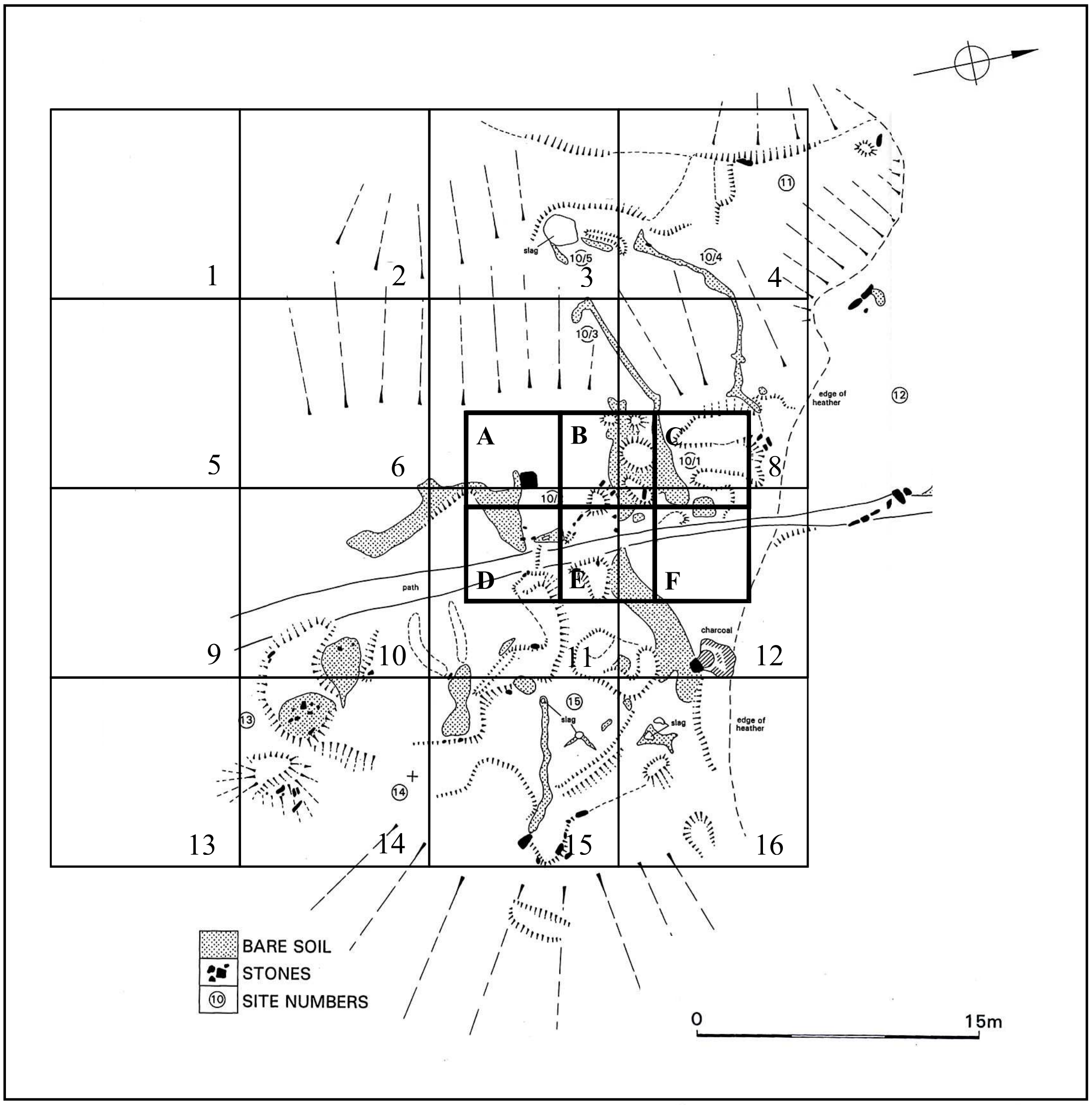


Figure 4: Detailed plan of Totley Bole Hill main complex, showing the relative positions of the 5m and 10m survey grids

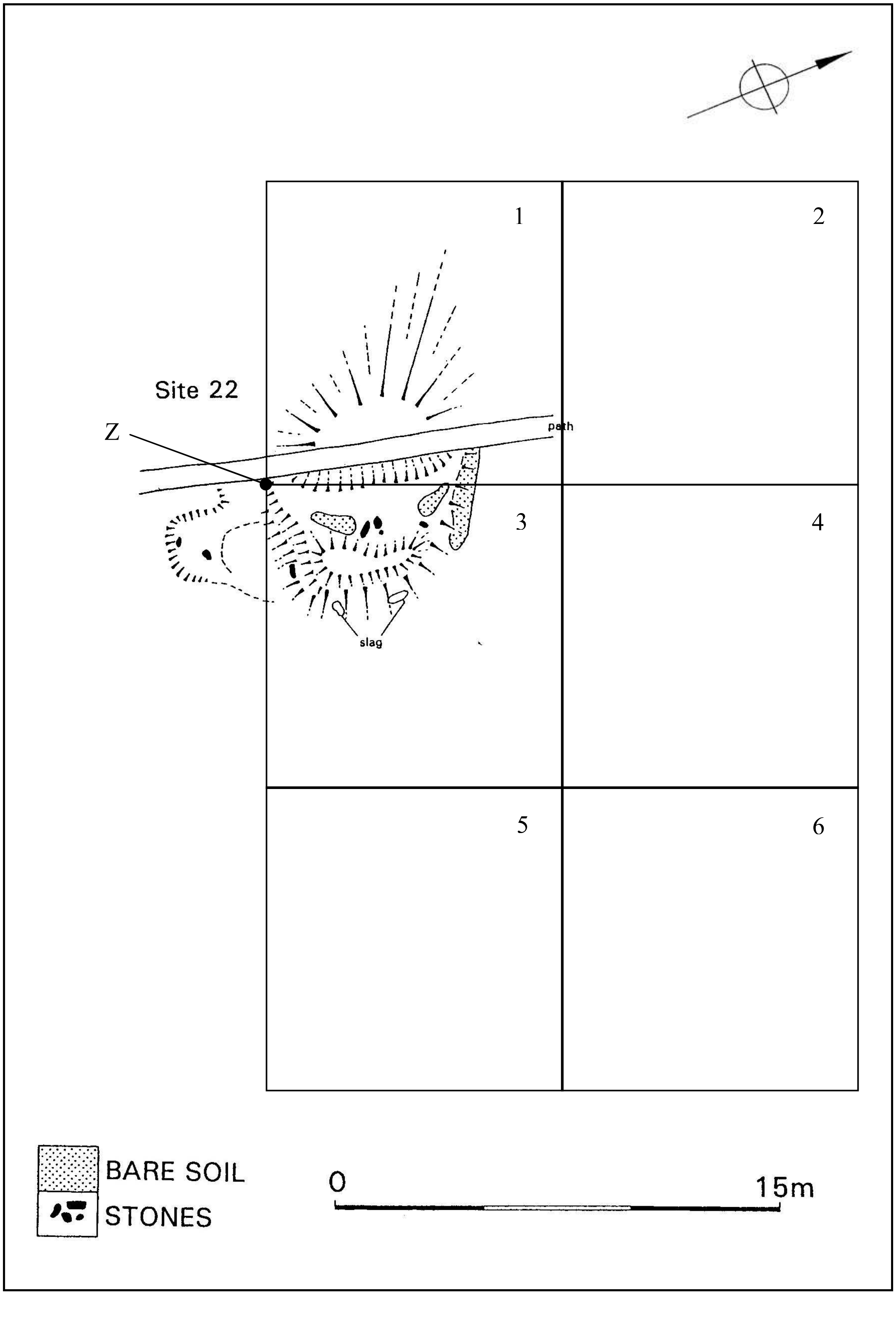


Figure 5: Detailed plan of Totley Bole Hill Site 22, with survey grids superimposed

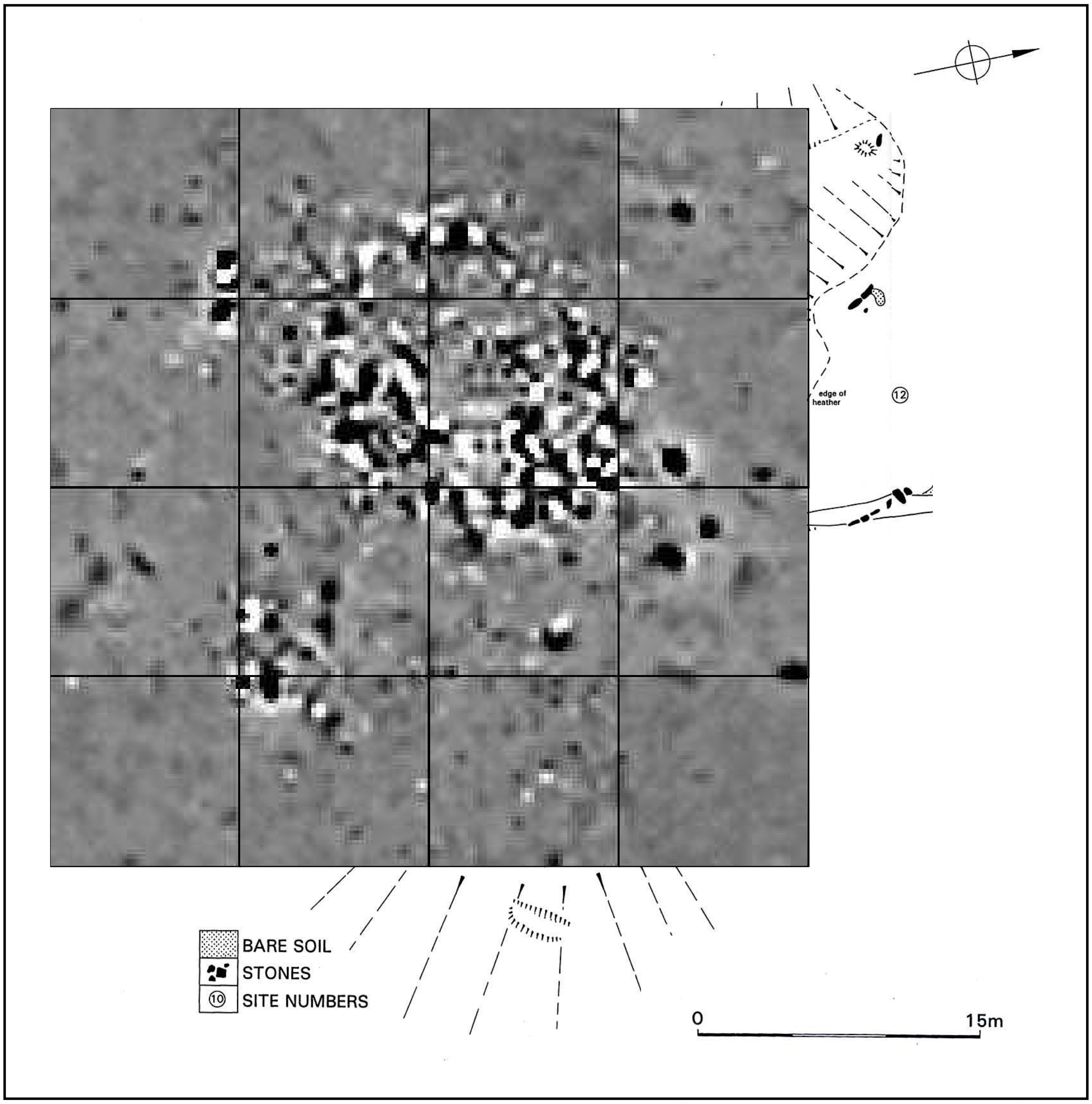


Figure 6: Detailed plan of Totley Bole Hill main complex (Sites 10 to 15), with survey plot superimposed – clipped range: -20nT (white) to 20 nT (black)

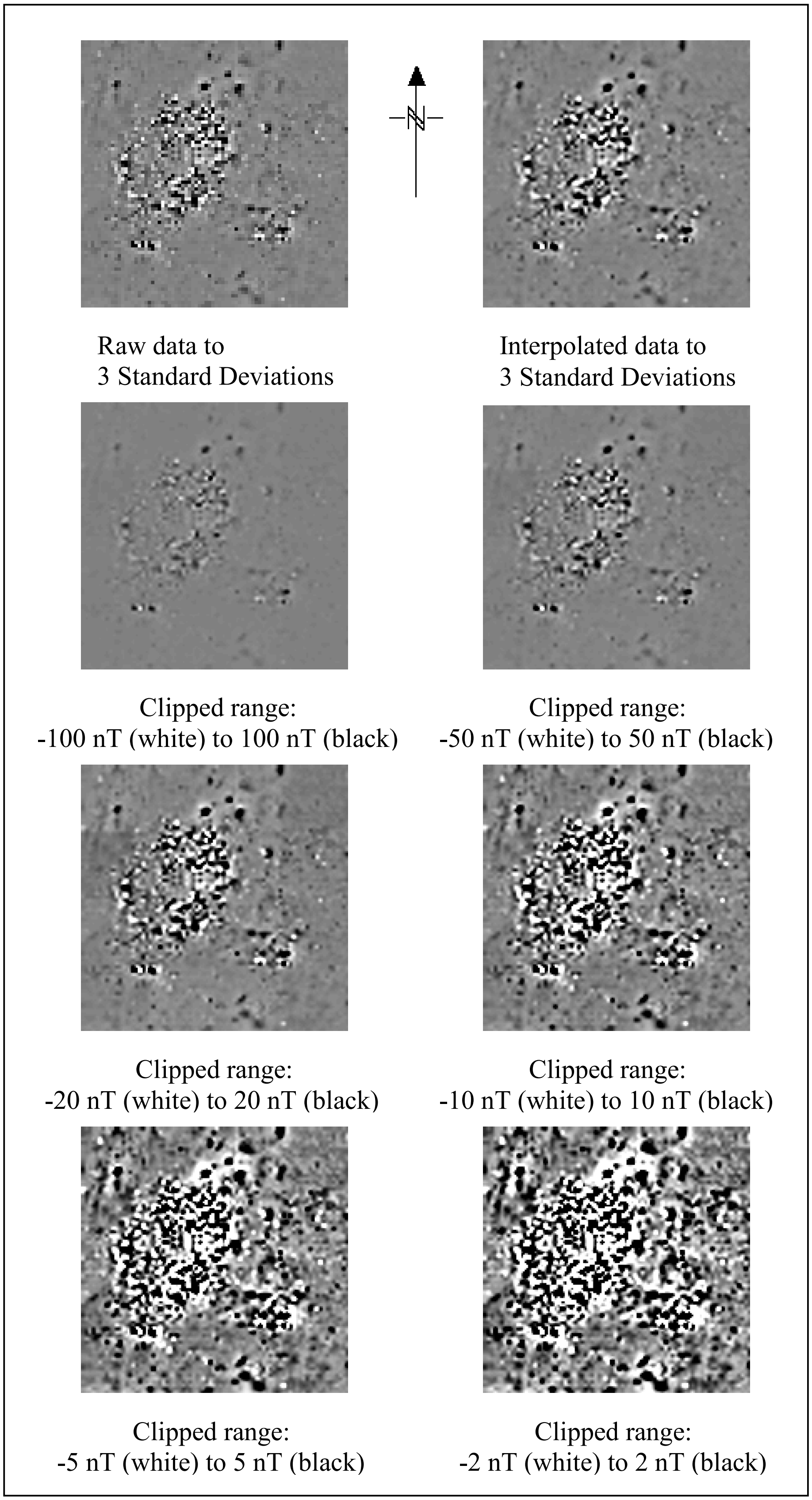


Figure 7: Totley Bole Hill main complex survey plots – raw and clipped data

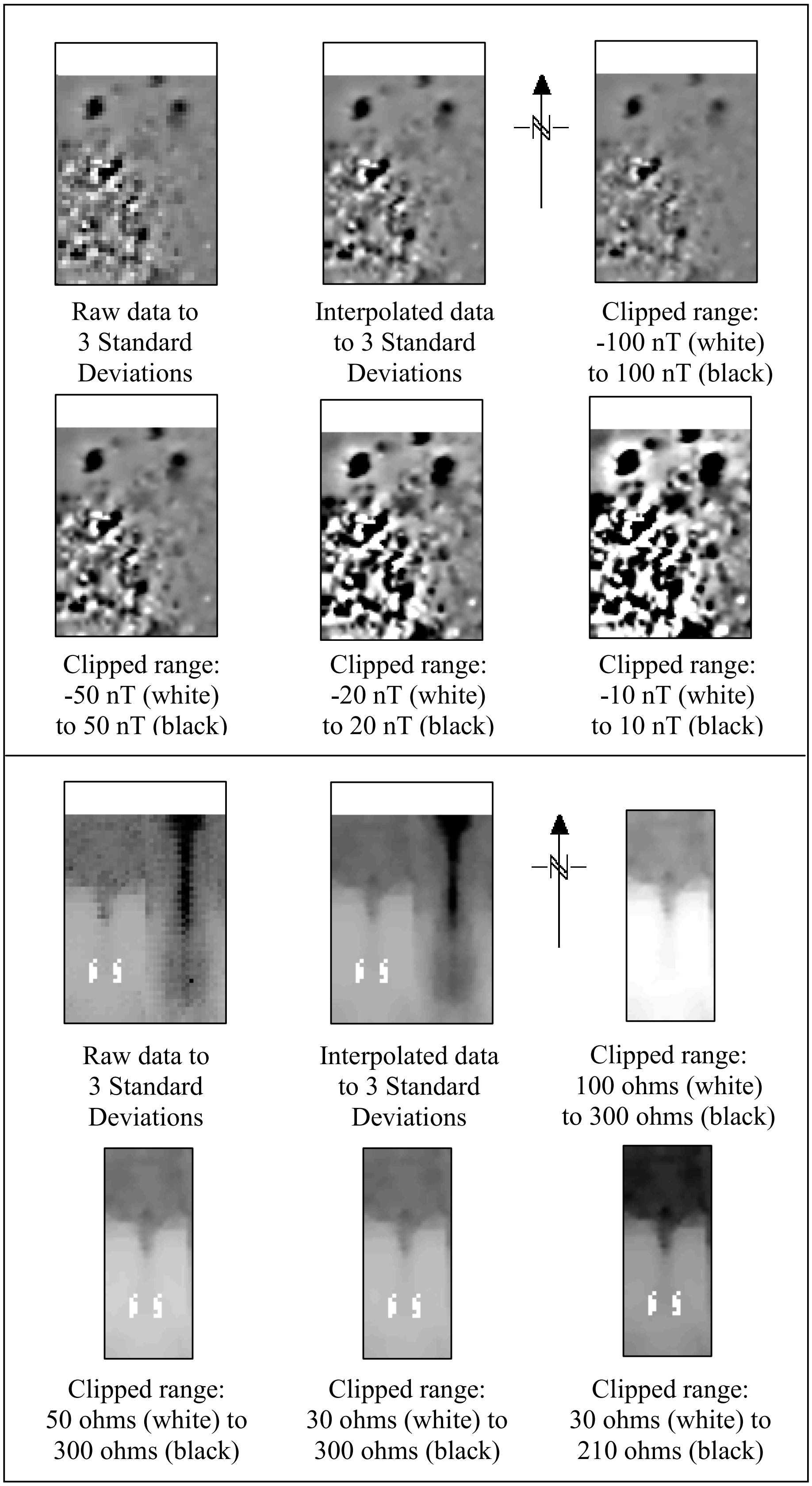


Figure 8: Totley Bole Hill Site 10 magnetometer (upper) and earth resistance (lower) survey plots – raw and clipped data

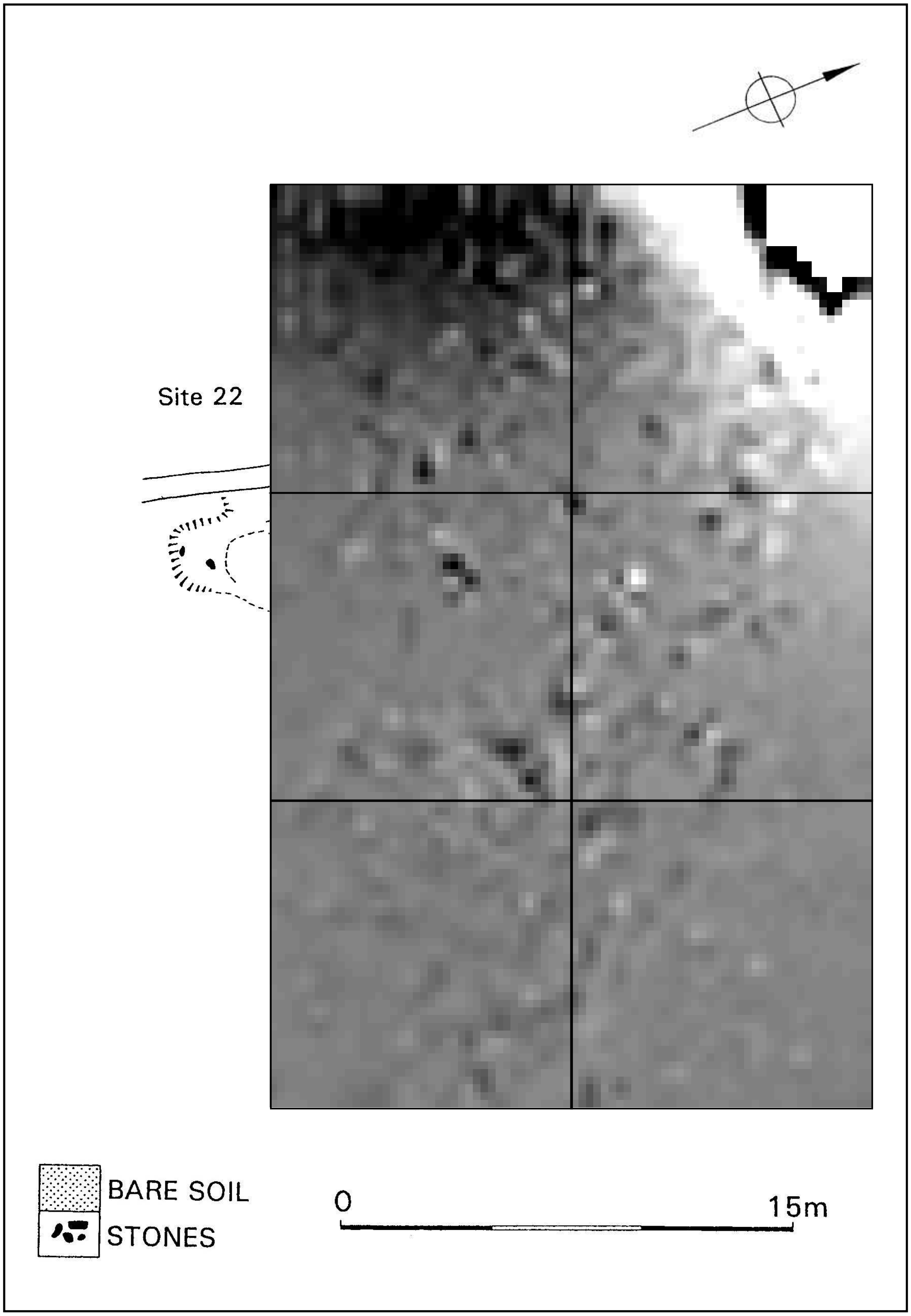


Figure 9: Detailed plan of Totley Bole Hill Site 22, with survey plot superimposed – clipped range: -50nT (white) to 50 nT (black)

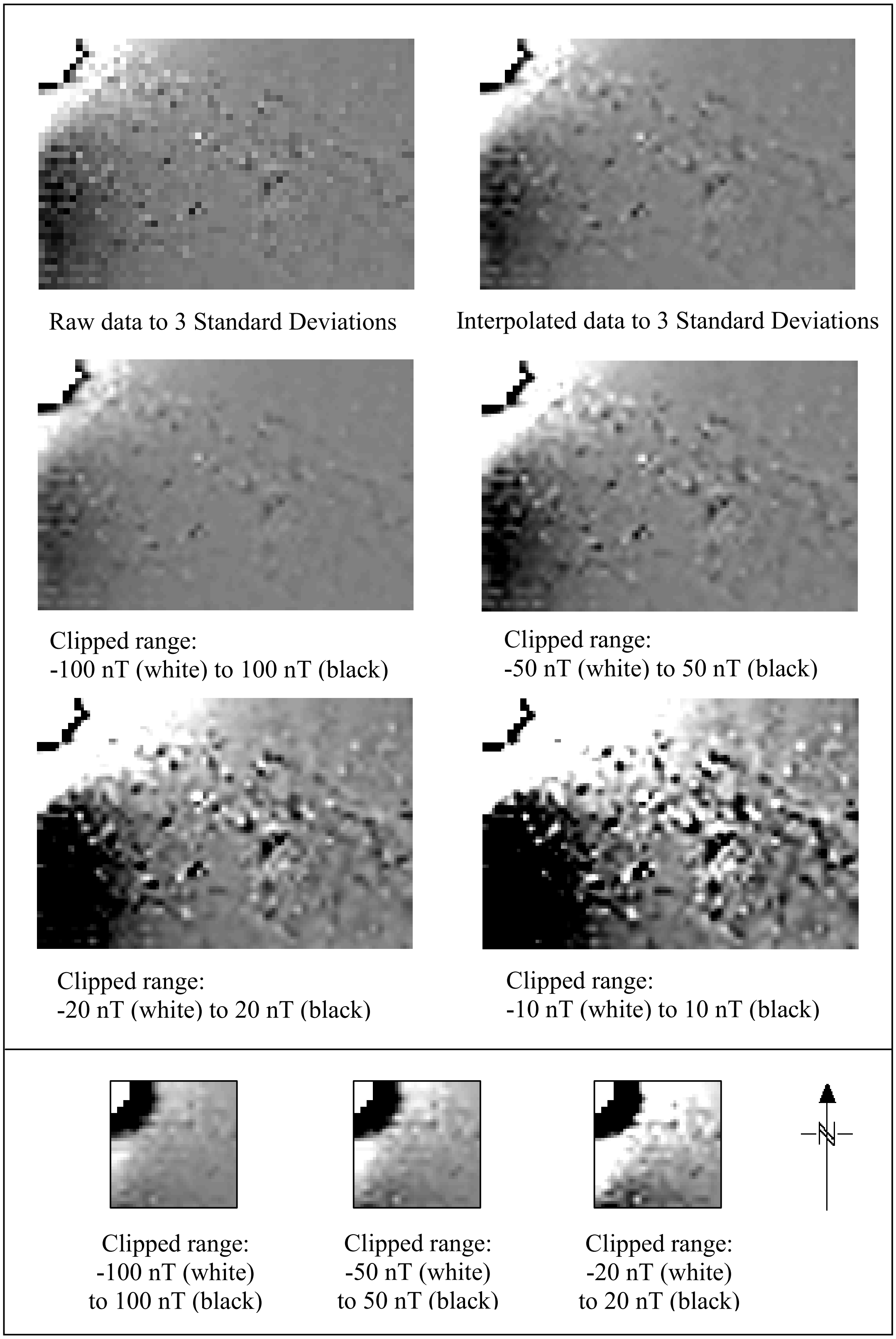


Figure 10: Totley Bole Hill Site 22 survey plots – raw and clipped data for the whole site (upper) and grid 2 (lower)

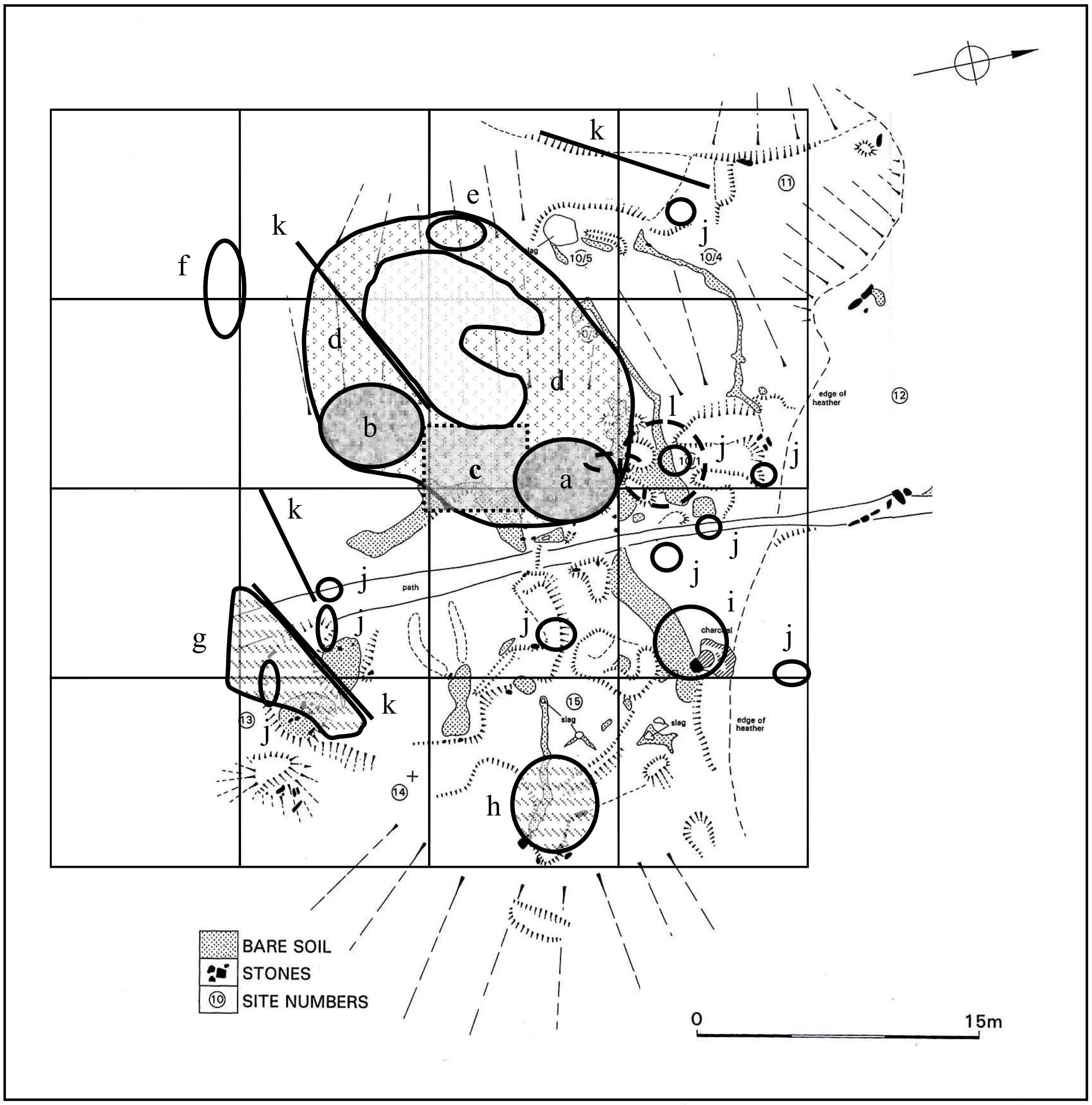


Figure 11: Totley Bole Hill main complex (Sites 10 to 15): interpretation

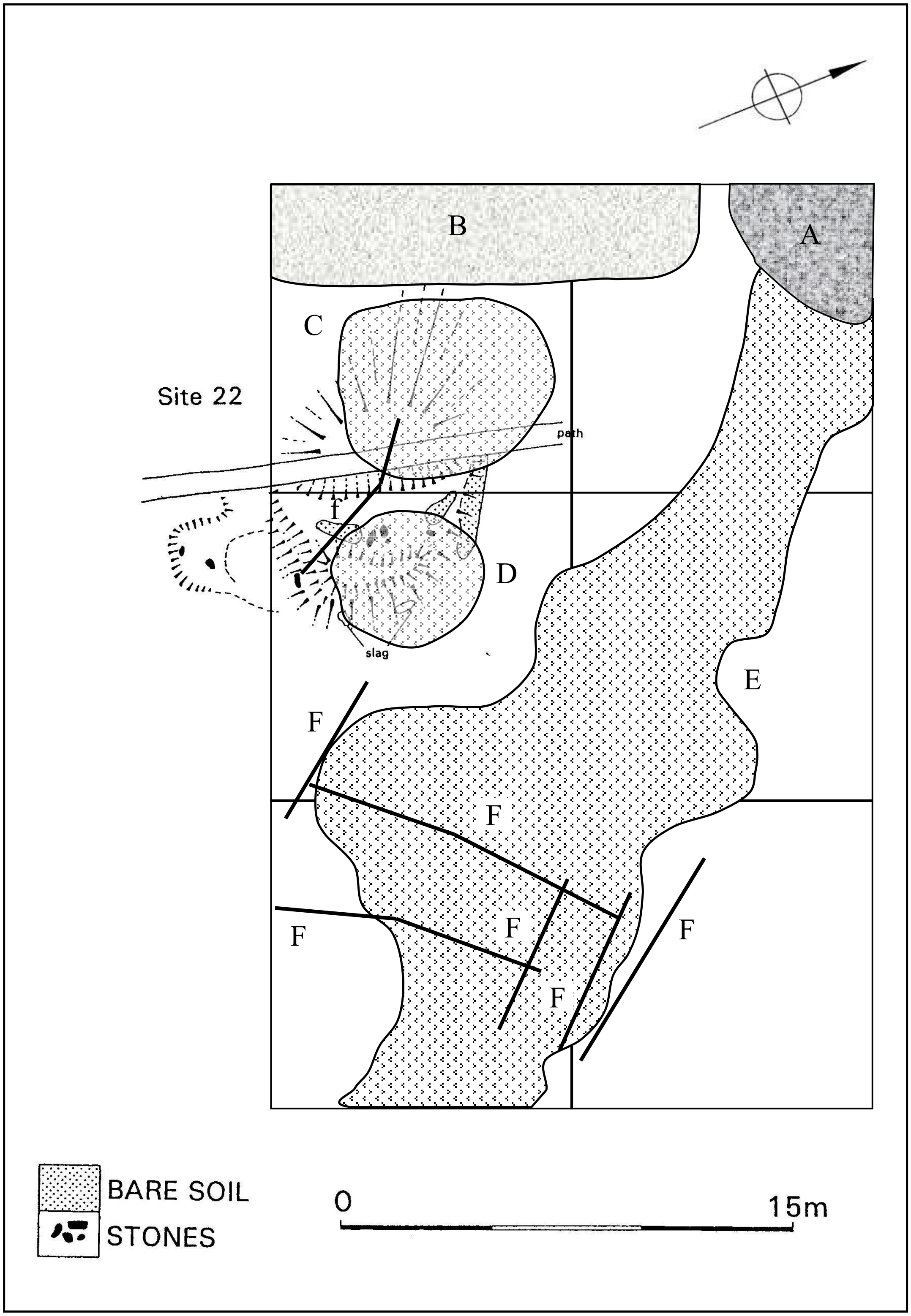


Figure 12: Totley Bole Hill Site 22: interpretation