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Ancient Monuments Laboratory
Report 16/99

AN EVALUATION OF THE IRONWORKING SITE OF SHERRACOMBE, DEVON

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Summary

An ironworking complex on Exmoor, subsequently dated to the late Iron Age or early Roman period, was investigated using a fluxgate gradiometer to scan the visible remains. A range of samples of metalworking debris, including slag collected from the site, was analysed using X-ray diffraction spectrometry. The effectiveness of the rapid scanning technique is discussed with reference to the composition of ironworking debris.

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An Evaluation of the Ironworking Site of Sherracombe, Devon.

David Starley

Introduction

A visit to this ironsmelting site was made on 30 July 1996 in the company of Veryan Heal, the Exmoor National Park Archaeologist, and Gill Juleff who was undertaking an assessment of the remains of mining and metal extraction activities in the park on behalf on the Park Department and the National Trust. Although the date of the site was unknown at the time, a radiocarbon date from a single charcoal sample subsequently indicated a late Iron Age/early Roman date for the smelting activity (Juleff 1997).

The site was visible as a number of features along the north-west bank of a small stream, mostly up-stream of Sherracombe Ford. Generally, the ground rose steeply to this side and was largely grass pasture with occasional trees and one strip of marshy ground with reeds and bracken. A topographical survey, prepared by the Royal Commission on the Historical Monuments of England, shows the these features (Figure 1).

Although small quantities of slag were distributed widely over the site, most was concentrated in three slag heaps: The first (labelled I) lay approximately 10m north of the ford, whilst another large heap (II) was sited approximately 150m upstream. A smaller mound (III) lay approximately 30m downstream. The second two heaps had both been partly eroded by the water flow. Further from the stream at a higher elevation a number of small platforms had been cut into the hillside. Rabbit scrapes had uncovered a few very small fragments of slag in some of these, but no other indication of function was evident.

Debris from the slag heaps included large (>5kg) pieces of tap slag from the smelting of iron and some furnace lining. However, no definite pieces of ore were identified and no slag diagnostic of iron forging, such as the characteristic "smithing hearth bottoms", were noted. The uneven topography and low packing density of the heaps makes any estimation of the quantities of slag very inaccurate, however approximately 500 tonnes is suggested. Without an opportunity to study the purity of the ore by analysis it is not possible to estimate the output of iron from the site. The site certainly operated on a reasonably large scale, and has significant regional importance.

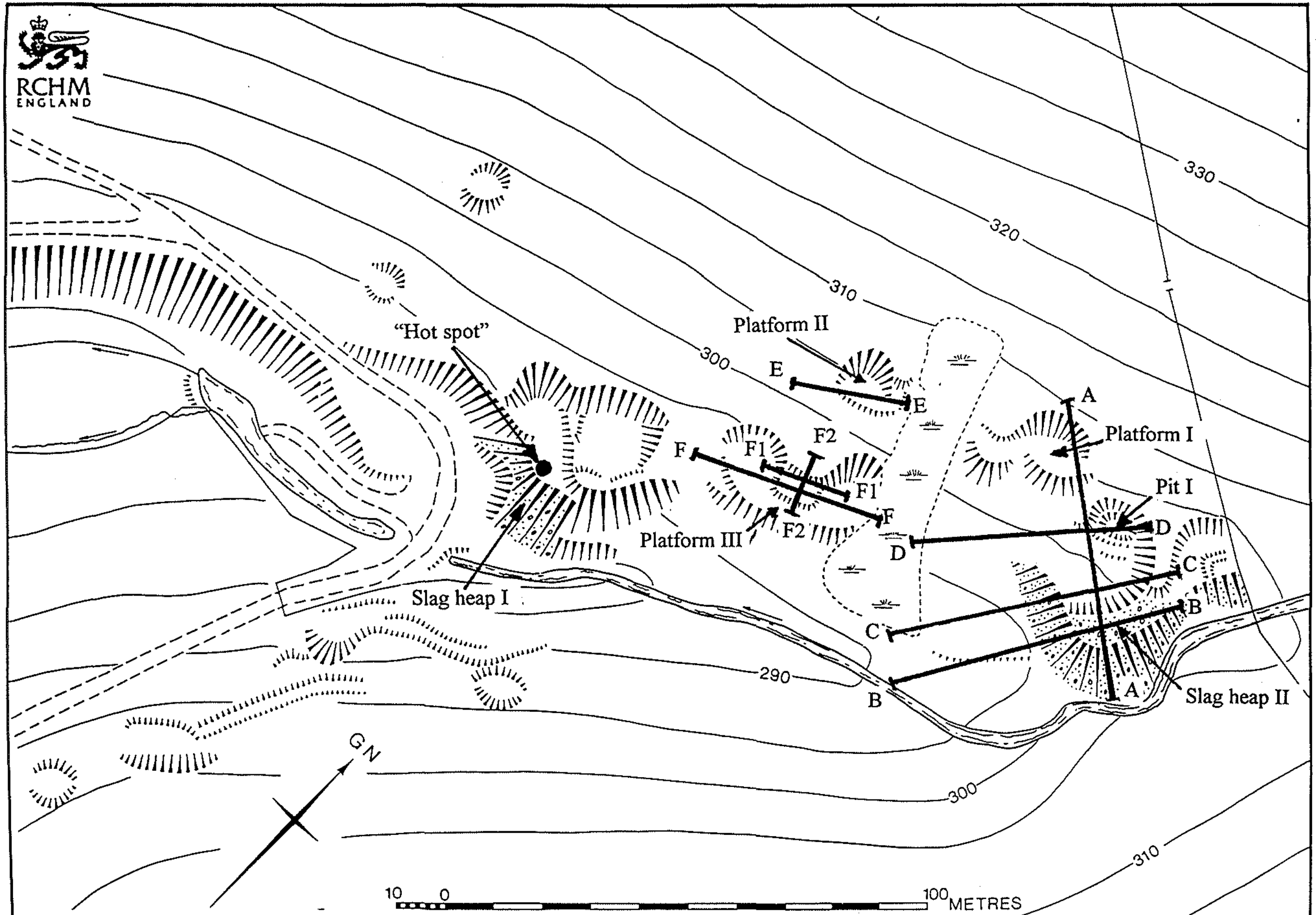

Figure 1 Sherracombe. Position of magnetometer transects **Courtesy of RCHME**

Dating any site typologically is very imprecise. Smelting technology in which slag is tapped from the furnace is most usually associated with high output requirements of the Roman and medieval periods, but this hypothesis is based on the excavation and dating of relatively few sites, with regional data biases. Despite the proximity of the stream, there was no evidence of the utilisation of water power for bellows or hammer working, which would have indicated a later medieval date. At the time of the visit, it was thought that the size of the slag flows was probably more typical of a site of medieval rather than Roman date. Subsequently however, a single radiocarbon date was obtained from slag heap I (Juleff 1997). The date (Beta 98972) was 2000±50BP (cal. BC160-AD90 at 95% probability), thus making Sherracombe the earliest known ironworking site on Exmoor. This difference between expected date and the scientifically determined date highlights our lack of understanding of iron production remains, itself the result of a paucity of thoroughly investigated and dated sites.

Magnetometer Scanning

The site visit provided an opportunity to carry out preliminary investigations of the magnetic response of an iron smelting site. It was hoped that in the brief time available this would give some indication of the function of some of the discrete topographical features visible on the site, as well as providing an assessment of the potential effectiveness of a detailed magnetometer survey. The instrument used was a Geoscan Research FM 36 fluxgate gradiometer. This was used to scan transects across areas of particular interest, including slag mounds, hollows and platforms cut into the hillside (for location of transects see Figure 1). Due to the terrain these were not carried out strictly on north-south and east-west alignments, but on transects either running along the contours approximately parallel to the stream or perpendicular to this direction. Because of "drift" in the magnetometer, after the first transect all further scanning was carried out with the magnetometer held in the same orientation.

Table 1 Transect Details

Transect	Direction from	Direction to	Reading interval (m)	Features scanned
A	south-east	north-west	1	slag heap II, platform I
B	north-east	south-west	1	slag heap II,
C	north-east	south-west	1	slag heap II,
D	north-east	south-west	1	pit I
E	north-east	south-west	1	platform II
F	north-east	south-west	1	platform III
F1	north-east	south-west	0.5	platform III
F2	south-west	north-east	1	platform III

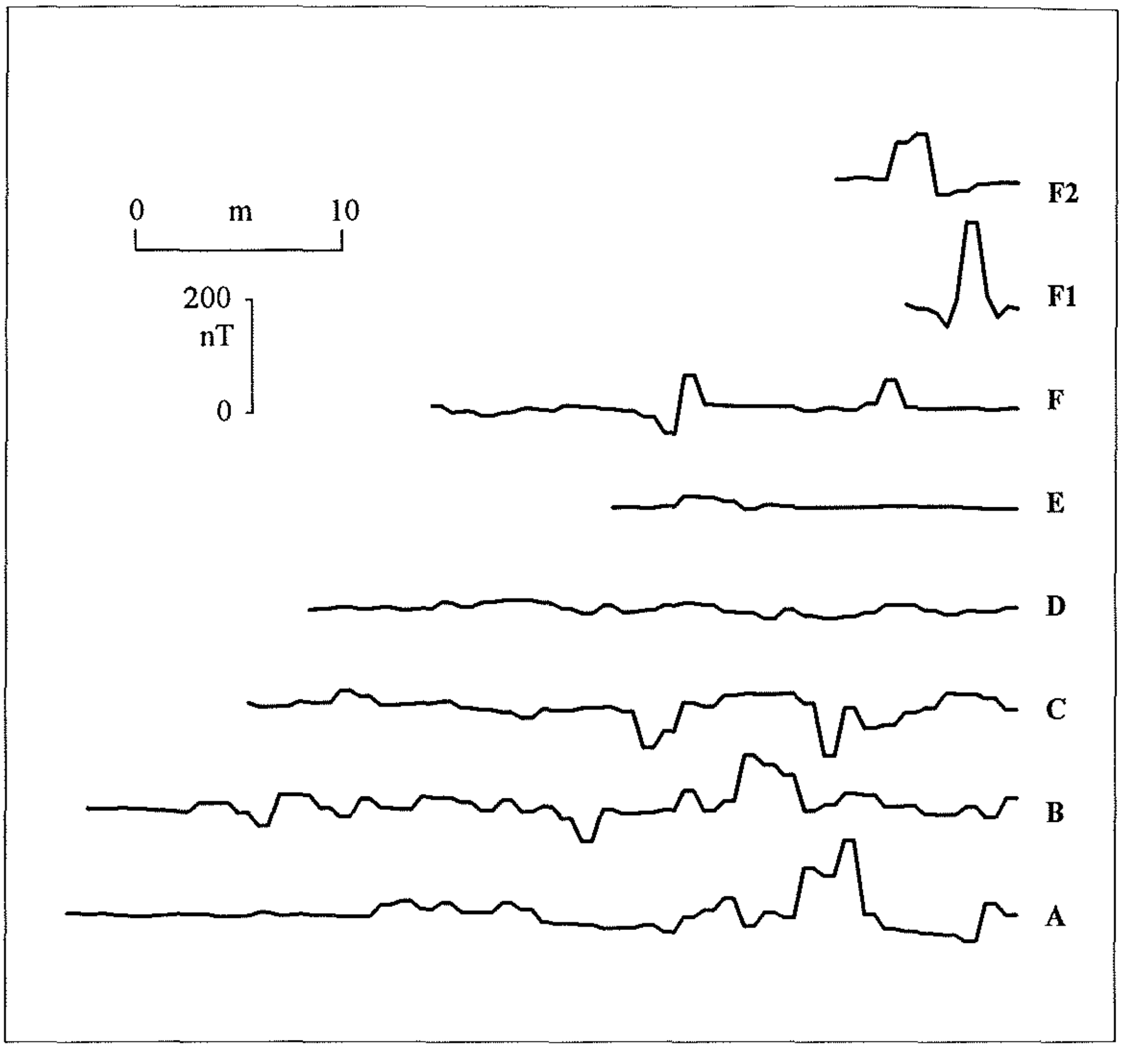

Chart 1 Magnetometer transects
A; right to left corresponds to south-east to north-west
B, C, D, E, F, F1; north-east to south-west
F2: south-west to north-east

As shown in Chart 1, very high readings, often above 100nT, were frequently obtained. Whilst these figures demonstrate the very strong signals that are obtained when surveying metalworking debris, it is important to bear in mind the tendency for these to dominate the results. Even the relatively "quiet" areas of the transects may contain archaeological features. However, the low resolution setting of the magnetometer and coarse scale used in Chart 1 prevent these being recognised.

The first two transects, A and B, together with further non-linear scanning showed Slag Heap II to be magnetically very noisy. Consistently high positive readings (100-170 nT) extended along its crest and a negative (shadow) extended around the slope to the south-east and south-west. Remanent magnetism from an *in situ* fired feature typically gives a dipole effect with high positive values towards the northern extremity of the feature and negative readings to the south. In this case the negative shadows to the south of the slag heap on transects A and B most probably result from the topography - a steep bank of highly magnetic material to one side may unduly influence the field as detected by the uppermost sensor of the fluxgate.

Where transect A continued to the north-west over Platform 1 consistent background readings were obtained but a small area below this platform provided slightly elevated values. The south-west end of transect B also produced some high values as it approached the stream. Transect D failed to find any strong magnetic features associated with Pit I, although the slight variability of the readings may indicate the presence of scattered slag in this area.

Like the north-west end of transect A, most of transect E gave uniform, low readings suggesting that little if any metalworking debris extends this far from the stream. However, a series of raised values over a length of 3m at the south west end of transect E may have an archaeological origin, possibly due to some form of heating.

Transects F, F1 and F2 focused on the unusual kidney-shaped Platform III which had a further raised rectangular platform in its center. On each transect a sharp, strong response was detected. These could be due either to a small but intensely fired hearth or a buried ferrous object.

In addition to the linear transects, scanning with the magnetometer around Slag Heap I found that a small raised mound on the top with a diameter of approximately 1 metre gave higher readings (200nT) than the surrounding slag (30-40nT).

Laboratory study of debris from Sherracombe and other sites

The magnetic properties of archaeological deposits depend on a number of factors including the iron content, the way in which this is combined with other elements, past heating histories and the magnetic domain size - which is dependent on particle size and mineral type.

To help understand the responses of the magnetometer at Sherracombe, a sample of tap slag (obtained from an eroding slag heap on the site), together with other debris typical of this smelting technology, was analysed in the laboratory. The other samples were two bog ore samples from an experimental reconstruction, one of which had been roasted on an open pyre, and a piece of vitrified hearth/furnace lining from the excavations of the extra mural settlement associated with Ribchester Roman fort.

Table 2 Identification of minerals in debris by X-ray diffraction analysis					
XRD	Sample	Crystalline components			
Ref.		Main	Secondary	Small	Trace
N 103	Bog ore unroasted	Quartz, SiO_2	-	-	A suggestion of a semi-crystalline component perhaps, Lepidocrocite, FeO(OH)
N 104	Bog ore roasted	Haematite, Fe_2O_3	Quartz, SiO_2	-	-
N 106	Vitrified hearth / furnace lining, (Ribchester)	Quartz, SiO_2	Haematite, Fe_2O_3	Maghemite, Fe_2O_3 Goethite, FeO(OH)	Anorthite $(Ca,Na)(Al,Si)_2\ Si_2O_8$
N 110	Tap slag (Sherracombe)	Fayalite, $2FeO.SiO_2$	Wüstite, FeO	-	Possibly Galaxite $MnAl_2O_4$

X-ray diffraction (XRD) analysis showed that all four materials contain iron. Although N103 shows only traces of an iron mineral, a high iron content is known to have been present from earlier X-ray fluorescence analysis. Thus it would appear that the iron is present, but in an amorphous form not detectable by XRD. Significantly a different combination of iron -containing minerals are present in each of the materials investigated; N 103 contained lepidocrocite and the amorphous compound. N104 haematite, N106 haematite, maghemite and goethite and N110 fayalite and wüstite.

These differences in composition help us to understand the response of the magnetometer. As had been observed on site, a piece of tap slag brought close to the lower sensor of the fluxgate magnetometer gave a relatively modest reading. This can be explained by the predominance of fayalite and wüstite in this type of slag; these compounds have a low magnetic susceptibility.

By contrast the maghemite content of the fired clay would give this material a high magnetic susceptibility, hence this material would be expected to show a strong induced magnetic field. Any areas of ore roasting should be detectable as a strong magnetic anomaly.

The response of ores is less clear cut. Although some rock ores such as magnetite, and to a lesser extent haematite, would give a strong magnetic signal, the results of this investigation suggest that for bog ores (in many regions, the most important source of iron in the past) it is only after roasting, with the formation of the haematite that the ore would give a reasonably strong magnetic signal.

Whilst the above results help to predict the magnetic behaviour of specific types of metallurgical debris, XRD analysis does have limitations. Firstly, it can only detect crystalline materials. The sample of bog ore came from a batch used successfully in smelting experiments, for which the quartz content must be less than half the iron content. However the analytical technique emphasised crystalline quartz rather than semi-crystalline lepidocrocite and any amorphous iron compounds would not have been detected at all. Furthermore the instrument used was not particularly sensitive to small quantities of material. The ferrimagnetic mineral magnetite Fe_3O_4 is often encountered in ironworking debris but was not detected by XRD and may have been present below the detection limits of the instrument. In practice even very small concentrations of this mineral are sufficient to create very strong magnetic responses.

Conclusions

Magnetometer scanning did provide a rapid and non-interventionist means of determining how far slag extended beyond the visible features of the site. This provided an aid to, though not a direct means of, determining the amount of slag on site - a vital factor in calculating the output of an iron production site.

Simple magnetometer scans were unable to detect clear magnetic dipoles which could confidently be identified as *in-situ* heated features, such as furnaces. This may be because:

1. No undisturbed furnaces / furnace bases survived *in-situ* at Sherracombe.
2. Surviving furnaces /furnace bases were obscured by collapsed superstructure and dumped slag.
3. The chosen methodology of scanning and data presentation, whilst rapid, is much less informative than conventional area surveys. The higher resolution and two dimensional plotting of these may allow *in-situ* furnaces to be more readily identified.

The highest magnetometer responses did coincide with the top of the slag heaps. Certain "hot spots" may correspond to the position of furnaces. However, it is thought probable that topographic effects - the relative proximity of an uneven ground surface to the two fluxgates of the magnetometer - would tend to exaggerate the magnetic response of high points and minimise the response in hollows and near the base of steep, highly magnetic features. Therefore these "hot spots" may not be significant archaeologically.

None of the smaller platforms produced strong magnetic anomalies. They therefore do not appear to have been used for processes such as the roasting of ore, which would also have been expected to produce a strong magnetic response.

Suggestions for further work

Laboratory-based magnetic investigation of the slag, lining and ore samples, currently being undertaken within the Ancient Monuments Laboratory needs to be completed and compared with the XRD analysis results. It may then be necessary to repeat XRD analysis after magnetic extraction and concentration of highly magnetic minerals, currently below the detection limits of the instrument.

For both understanding the layout of the site at Sherracombe and assessing the value of magnetic surveying and scanning of ironworking sites, a full geophysical survey of this site is strongly recommended. If possible, this should be followed with limited archaeological excavation of the site, to determine the form of furnace used and to recover samples of fuel, ore and slag for the study of magnetic properties, chemical analysis and dating.

The samples of debris from the excavation should be examined and analysed to identify the type of ore used, its iron content and the composition of the slag. Charcoal from the site should be examined to identify species and evidence for tree management, such as coppicing. The data from these could then be combined with excavation data to determine the likely output of iron from the site, its demands in terms of fuel and ore during its productive period and its importance to the economy of the region.

Reference

Juleff, G. (1997) Earlier Ironworking on Exmoor. Unpublished preliminary study. Exmoor National Park Authority and The National Trust (Holnicote Estate).

Appendix I Fluxgate magnetometer scans, Sherracombe, Exmoor (values in nT)

Transect distance \ from	A se→nw	B ne→sw	C ne→sw	D ne→sw	E ne→sw	F ne→sw	F1 ne→sw	F2 sw→nw
0	22 (1)	54 (4)	32 (8)	35 (11) (2)	33 (7)	34 (7)	33 (14)	34 (16) (2)
0.5							37	
1	45	18	55	28	33	32	16	34
1.5							59	
2	-30	38	63	29	36	36	204	32
2.5							205	
3	-17	22	65	21	38	34	51	18
3.5							-3	
4	-14	24	35	30	38	33	24	10
4.5							33	
5	-11	39	25	40	37	36	33 (15)	131 (17)
5.5							42	
6	-6	38	1	40	38	90		114
7	24	61	-5	25	36	43		39
8	171 (2)	64	35	17	36	31		45
9	102	42 (5)	-60	14 (12)	36	36		41
10	116	30	44	19	36	30		
11	17	100	64	31	37	37		
12	28	120	62	12	41	38		
13	-1	140 (6)	64	24	32	38		
14	56	49	60 (2)	26 (2)	48	39		
15	32	30	38	41	56	42		
16	19	70	45	44	59	100 (13)		
17	-12	31	-12	40	38	-15		
18	2	26	-45	29	34	16		
19	-5	24	28 (3)	25	37	30		
20	-4	33	36	40	36	33		
21	3	-30 (3)	35	24		38		
22	6	15	30	33		41		
23	7 (3)	38	31	44		31		
24	33	28	15	49		34		
25	46	50	26	49		27		
26	28	30	31	45		21		
27	29	47	35	37		30		
28	46	55	48	46		27		
29	34	57	44	33		40		
30	50	32	42	30				
31	43	35	40	36				
32	20	53	59	32				
33	20	19	70	37				
34	22	35	46	33				
35	24	60	47	31 (10)				
36	21	60	38					
37	27	-1 (7)	37 (7)					
38	20	25	44 (10)					
39	19	44						
40	23	44						
41	23	27						
42	21	30						
43	19	33						
44	21	35						
45	25	34						
46	24	35 (8)						
47	26							

(1) 1 m from stream
(2) top edge of slope
(3) base of slope
(4) from edge of steep slope on north end of bulge
(5) 3 m back from edge of slag slope over river
(6) top edge of slope on sw side
(7) edge of bog
(8) at the stream
(9) 4m nw of start of transect B
(10) in bog
(11) parallel with transect C
(12) bottom of hollow
(13) on square platform
(14) along platform only 0.5m intervals
(15) off platform
(16) at right angles to transect F1
(17) edge of platform