SPA CLOUGH, CASTLESHAW

Second Interim Excavation Report

The Greater Manchester Archaeological Unit

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1. Introduction

At the head of Castleshaw Valley in Saddleworth, Oldham, can be found traces of ancient iron smelting. The evidence for this industry has come from the discovery, in 1907, by Ammon Wrigley, of a furnace base and, more recently, through the identification of a substantial spoil heap of tap slag. Initial analysis showed that the iron smelters were using free standing shaft-type furnaces, a technology prevalent from the late Iron Age to late medieval period. Field survey and excavation in 1992 revealed the potential of the site and posed many interesting questions (Redhead, 1992).

This second interim report presents the results of field investigation and scientific study carried out during 1993. The excavation was kindly supported by North West Water plc and conducted under the auspices of the Greater Manchester Archaeological Unit. The British Academy generously funded the scientific analyses.

2. Results from the 1992 Excavations and a Research Brief for 1993

A two week programme of field study in 1992 concentrated on a linear slag spoil heap located next to Spa Clough, at grid reference SD 9987 1037, together with an adjacent area of grass covered depressions (Redhead, 1992).

Exploratory excavation revealed that much disturbance had taken place relatively recently in this area and the above depressions appeared to be the result of this. The close proximity of the reservoir and canalised stream channels suggested a late 19th century date for the "robbing" activity, for the Castleshaw Reservoirs were constructed in 1889. No furnace bases were encountered and only one feature, comprising a layer of fire reddened clay and charcoal pieces [090], gave the impression of being associated with any smelting industry.

A magnetometer survey of the slag spoil heap produced several sharp anomalies and suggested, along with surface analysis, that the slag was concentrated at the northern side of the spoil heap. It was not certain how much of the slag, if any, had been re-deposited from the late 19th century reservoir construction. In 1993, therefore, it was proposed that a trench be excavated across the north side of the slag spoil heap in order to record the stratigraphy and, it was hoped, locate slag and furnace deposits in situ.

Dating of the smelting industry in the valley had been problematic. Historical research shows that the valley was owned by Roche Abbey in the medieval period, but only a short distance from Spa Clough itself was Castleshaw Roman fort. Several sherds of medieval coarse-ware pottery had been found during the excavation but this material was unstratified and therefore unreliable. Neither did the intact furnace base revealed by Wrigley early this century provide any dating evidence. To establish a dated origin for iron smelting in this area was, therefore, a priority and in order to do this in situ furnace deposits had first to be located and then archaeomagnetic and radiocarbon dating analysis carried out.

A further subject of study identified in 1992 was the need to better define the actual area of smelting activity in this part of the Castleshaw valley (fig 1). Wrigley's furnace was further up the valley side on Cudworth Pasture, a considerable distance from Spa Clough. Were there a series of smelting furnaces which crept up the valley using up raw materials as they went or were we looking at separate sites? A large number of depressions occupied the valley side on Cudworth Pasture. Were these also related to furnace activity? It was therefore essential to examine the area around Wrigley's site through survey and excavation in order to establish its relationship with the Spa Clough site.

The research of 1992 also threw up other questions that needed to be addressed in the 1993 season:

What was the source of the raw material being used? It was suggested that the iron ore being smelted was bog iron; this theory needed to be proved or disproved.

Was there any evidence for structures around and enclosing the furnaces? Did the smelters employ wind breaks or more substantial structures in order to create a controlled firing environment?

Were other iron processing activities being carried out on site, for instance roasting or primary smithing?

With these questions in mind a further short season of excavation and field survey was undertaken in the Castleshaw Valley in the last two weeks of June.

3. Field Survey in 1993

An extensive survey was carried out using a Bartington MS2 Magnetic Susceptibility System. Detailed analysis of the results is still being carried out but a summary is presented here. Two approaches were adopted:

- a detailed survey of the slag spoil heap and the Wrigley furnace area

- broad traverses of the valley side between the two known smelting sites (plate 1).

A 20m x 20m area covering the northern half of the slag spoil heap was examined at 0.5m intervals (plate 2). Last year's Area 1 excavation formed the west edge and the canalised stream the east edge of this survey zone. As might be expected, the results mirrored that of the magnetometer survey previously carried out on this site in 1992. The highest anomaly occurred on the northern-most fringe of the slag spoil heap where there was clear physical evidence of a dense concentration of slag and furnace debris. Unfortunately excavation showed that this slag was re-deposited in more recent times. Further south, there were several smaller, more discrete anomalies most of which still await excavation, but one was investigated and proved to be the furnace base [F350].

The site of Wrigley's excavated furnace was evident as a small, grass-covered depression with some stones which appeared to line the edges. Lying loose in the base, there still remained a large lump of agglomerated slag, interpreted as the furnace base described by Wrigley and indicated in his sketch (Wrigley, 1912, p 171-2). About 8m to the south of this furnace site was a grassy mound which could have been the slag spoil heap from the original smelting or, alternately, the spoil from Wrigley's excavation itself.

Two 20m x 20m squares were examined, again at 0.5m intervals, over and around the site of Wrigley's furnace. Much of the area showed little magnetic susceptibility. However, the spoil mound and furnace site appeared as strong anomalies, as one would expect with so much buried slag. Two further anomalies showed to the west of the furnace: one was indicated by a depression c 10m away, and the other just to the east, showed as a low earthwork, perhaps indicating more slag spoil.

A contour survey was carried out on the area covered by these two 20m squares and the resulting contour map (fig 2) also revealed the four features indicated by magnetic susceptibility. It was decided to carry out a small, exploratory excavation (Area 4) on the depression c 10m to the west of the Wrigley furnace site.

The distance between the Wrigley furnace and the site beside Spa Clough was c 200m. Numerous pits and clusters of sandstones which were originally thought to be associated with the smelting industry were evident across the valley side. A series of traverses c 20m apart and running from Bank Clough to Spa Clough (fig 1) were, therefore, tested for magnetic susceptibility. The results were negative with no anomalies being encountered. This evidence suggests that the pits and stones relate to the construction of the reservoir in the late 19th century.

The magnetic susceptibility survey, the results of which were partly tested by excavation, have proved to be an effective method of locating smelting deposits. It showed that there are at least two separate iron smelting sites at the head of Castleshaw Valley at Spa Clough and Cudworth Pasture. Moreover, further survey is likely to reveal more potential furnace sites.

4. The 1993 Excavations

Based on last year's research and results from the magnetic surveys, two areas were investigated by excavation. One of these, Area 3, was located over the slag spoil heap beside Spa Clough whilst the other, Area 4, was placed adjacent to the site of Wrigley's furnace on Cudworth Pasture. This field work took place over a two week period at the end of June.

Area 3

The main focus of this season's work was the north half of the slag spoil heap beside Spa Clough. Initially, a trench 5m wide x 12m long was opened up along a west-east axis just to the east of last year's Area 1 excavation (fig 3). This new trench, Area 3, took in two semi-circular depressions and a concentration of exposed slag which had produced major anomalies from the magnetometer and magnetic susceptibility surveys. The trench terminated to the east where the slag spoil heap had been cut to create a track beside the canalised stream (Spa Clough) (plate 3).

Removal of turf and topsoil showed all but the north west corner of the area to be covered by a thick deposit of slag [301] up to 15cm deep. In some places the slag was found to have been re-deposited, as it overlay a black humic layer of decayed turf [339] (fig 5, section S-T). Once the slag was removed, the archaeology resolved itself into three parts (fig 6). In the north west corner was a deposit of silty clay [338] associated with a dense, random concentration of boulders. This was cut by an "L" shaped trench c 2m wide, which linked the two depressions originally identified in the rapid surface plan (fig 3). This trench also cut an area of slag and charcoal which occupied the eastern 6m of Area 3.

[338] was overlain by a deposit up to 15cm deep of mid to light brown loam [302], identical to [102] removed from most of Area 1 last year. Equally [338], which was a mottled spread of patches of light grey and brown silty clay with iron pan staining, was very similar to [107]. Both were associated with numerous boulders. [338] came off onto natural mid-yellow silty clay and it is likely that these deposits represent glacially deposited boulder clay and stone which has subsequently altered through weathering, hillwash and leaching.

The 1991 field survey of the slag spoil heap and its immediate environs identified a number of circular or semi-circular depressions as potential remains of furnaces (Redhead, 1991). Excavations in 1992 yielded extensive evidence of robbing activity around these depressions and Area 3 proved to be no exception. The hollow immediately to the north of the exposed concentration of slag was in fact the north terminus of a robber trench. This trench [F332] was c2m wide and its western edge curved round to create a depression in the south west corner of Area 3. The southern extent of the trench was unknown. The trench had been backfilled with loose dark humic soil, peat, large patches of yellow clay and numerous boulders of various sizes [333]. This backfill was partly overlain by a thick deposit of tap slag [301].

Previous interpretations of the origin of this robbing activity had centred on the re-use of tap slag and, perhaps, other furnace materials. It would now appear that the robbers were looking for suitable boulders to use in the construction of the reservoir walls and/or the revetting walls used to canalise the reservoir feeder streams. Amongst the stones thrown in as backfill into [F332] was a rectangular one which had clearly been semi-worked. Diagonal tooling marks were apparent on the upper surface which was half dressed whilst the other long faces of the stone had been worked flat (fig 6, plate 4). Although there was a sizeable quarry at Foxstones Brow (fig 1) (with a tramway leading down to the upper reservoir), it was evidently worthwhile for the reservoir navvies to extract loose stones from the hillside which in consequence is speckled with their robbing pits. Magnetic susceptibility surveying has also confirmed that these pits had no apparent connection with any sort of smelting industry.

Luckily, upcast from the late 19th century stone extraction activity had masked an area of earlier deposits which proved to have survived in situ. Beyond the cut of the robber trench on the eastern side of Area 3 was a shallow layer of tap slag in a mid to dark red-brown silty clay loam [303] which was sealed by a buried turf line (fig 5, section S-T) and which itself overlay spreads of charcoal and features associated with iron smelting. The charcoal died out towards the north edge of Area 3 but appeared to be concentrated around a semi-circular negative feature against the south edge (plate 5). As a result, Area 3 was extended southwards using the cut of trench [F332] as its boundary. This revealed a further area of surviving early deposits of c 5m x 3m. Most importantly, this extension to the excavation area yielded an in situ iron furnace base slightly truncated by the cut of [F332] on its southern side (plate 6).

Fig 6 shows Area 3 after removal of [302] and slag layers [301, 303]. To the south the "live" area of archaeology is defined by the cut of trench [F332]. The shape of the iron furnace base [F350] is already apparent with pieces of slag [353] lying on edge indicating the circular inner face of the furnace pipe shaft. However, the first clear indication for the furnace was evidence of a tapping channel which drained molten slag down slope, southwards. Severe truncation by the robber trench, which cut the tapping channel at 45 degrees, revealed black cinder and slag on top of vitrified orange brown clay surrounded by a channel base of oxidised red clay.

It was immediately apparent that the superstructure of the furnace had been removed. Only one stone [349] remained in situ and this appeared to have had a "levelling-up" function (fig 7, plate 7). What was remarkable, however, was that the furnace had survived at all amongst the late 19th century disturbance, especially as it had not been covered and protected by slag but lay immediately beneath the modern turf.

The furnace, when excavated, was represented only by its base which took the form of a depression cut into the natural yellow clay [320]. Intense heat from smelting had turned this clay red in a band up to 30cm wide around the top of the furnace depression and up to 10cm deep at its base (fig 4, section E-F). The remains of the furnace shaft [F350] were filled with dark brown silty clay loam [355] mixed with small patches of yellow clay and numerous fragments of charcoal (fig 4, section C-D). This deposit was 25cm deep and sealed a layer of black cinder and slag [357] of a maximum 8cm depth. This had formed at the base of the furnace shaft during its last firing and [357] ran uninterrupted under the site of the tapping arch and along the base of the tapping channel (plate 8).

The tapping arch, through which semi-molten slag was released from the furnace, did not survive in its original state but was evident as a bridge of slag and vitrified clay. Section G-H (fig 4) shows the material that filled the void created by the tapping hole.[372] was a fragmented, biscuity, light orange-red clay that had probably formed part of the furnace tapping arch immediately behind the slag bridge. After the abandonment of the furnace [372] slumped into the tapping hole void. Deposits [371, 356 & 354] sealed [372] and contained many small patches of yellow and red clay together with fragments of charcoal and reduced hard grey clay, stones and some slag, all of which appeared to derive from dismantling/destruction of the furnace.

The tapping channel had a "U" shaped profile c30cm deep and 50cm wide (top) (plate 9) but only survived c 1m in length before being cut by trench [F332]. Its termination has probably been destroyed and it is not clear whether the molten slag ran into a settling pit or was allowed simply to dissipate downhill. The heat from the slag run-off was so intense that the clay base of the channel was semi-vitrified to a depth of 4cm, even as far as 1m from the furnace, forming a very hard, baked light orange brown clay that could only be removed with a chisel. Beneath this and on both sides of the channel the natural yellow clay had oxidised to a light to mid-red colour [359] up to 10cm deep.

The depression forming the base of furnace [F350] measured approximately 70cm diameter by 35cm deep. Major reaction and merging had taken place between slag [353] and clay [352] lining the shaft. The only place where the inner arc of the shaft lining had survived intact was on the west side and here a few loose, small pieces of slag gave way to reveal biscuit-like fabric of mid-grey coloured clay, formed in two arcs, one stepped back a half centimetre from the other. Undoubtedly this was evidence for repair work. The surviving curvature of clay suggested a shaft diameter of 38-40cm. Around the circumference of the shaft the slag varied in thickness and depth, apparently reflecting the varied intensity of heat within this part of the furnace. On the east side and directly opposite the surviving clay lining was the greatest mass of slag. This had completely destroyed any shaft lining material and extended to the base of the furnace depression, being 18cm thick and 30cm deep. The upper surface of this slag lump had a concave depression filled by a circular plug of yellow clay [369] 11cm x 9cm in extent (fig 7). Quite possibly this represents the location of the blast flue where the tuyère was inserted. To the north side of the furnace shaft, more grey (reduced) clay [352] survived behind the slag; its north edge was of circular shape and probably defined the original edge of the furnace bowl/depression.

The remains of the furnace base are too slender to define the character of its superstructure. On the east side of the furnace, a band of heat-reddened clay was sharply defined by a raised, curved edge on its east side (plate 7). This area was immediately under the turf and therefore it cannot be determined whether or not the raised edge is the result of late 19th century disturbance or actually defines the base of the furnace wall. A wall thickness of 35cm may be derived from measuring the width of the outside of the surrounding red clay band to the inner slag face. This may, however, merely reflect the area affected by heat from the furnace and, indeed, the flatly laid stone [349], which may be interpreted as structural, certainly extends beyond the band of red clay. The measurement from the inner shaft face to the outer limit of the stone is 55cm.

The materials forming the remains of furnace [F350] were subjected to scientific analyses which are described elsewhere (p 13-15).

To the north west of furnace [F350] was a thick deposit [344] comprising small to medium patches of yellow and red clay, small to medium sandstones, together with fragments of charcoal and slag. This material filled and overspilled two negative features: a second furnace [F362] connected to a sub-rectangular pit [F304] (plate 10).

The presence of this second furnace was initially indicated by two crescentic bands of baked friable clay [367], bright orange in colour, forming a circular shape immediately to the north west side of furnace [F350] (fig 7). Excavation had already revealed the pit and a tapping channel running into the furnace area (plate 11). A double furnace, sharing a party wall, seemed a possibility but stratigraphic evidence soon dispelled this theory.

On excavation, this second furnace was found to pre-date [F350], being cut by the depression housing [F350]. In section Q-R (fig 5) it was seen that the furnace shaft of [F362] had been backfilled with clay (now oxidised red) and then lining clay (now reduced grey) had been applied to create the shaft for furnace [F350] (plate 12). In plan, it could be seen that the fire reddened clay surrounding [F350] continued uninterrupted over the site of this earlier furnace (fig 7).

Despite being truncated on its south east side by the cut of the depression for the later furnace, [F362] displayed a more complete shaft base than its neighbour (fig 8). There was much less slag adhering to its sides, suggesting less use (plate 13). As with [F350] the slag concentrated on the east side and, again, a concave depression over the thickest part of the slag to the north east indicated the possible location of the blast flue. The slag continued over the tapping arch on the north side and, when removed for analysis, came away in one large piece apart from a small fragment over the arch. The slag obtained a maximum thickness of 11cm and depth of 22cm. The west side of the shaft displayed a particularly well preserved clay lining which was offset three times from repair work (fig 4, section I-J). The diameter of the shaft was 38-40cm. The general shape of the shaft appeared to be ovoid, though this must be treated with caution because of damage to the south east side by truncation and distortion through the presence of slag to the east and north. The depression forming the base of furnace [F362] was 68cm across by 30cm deep.

The gap between the termini of the two orange crescents [367] mentioned above denoted the position of the tapping arch and channel for furnace [F362]. In this instance the beginning of the tapping arch had survived, although the top of the arch was indicated only by a bridge of slag. The void under this bridge and the beginning of the tapping channel were filled with lumps of baked light orange-red clay, smaller lumps of yellow or white clay, sandstone and slag fragments in a humic dark soil [363] (fig 4, section K-L and fig 5, Q-R, plate 14). This deposit was almost certainly destruction debris from the dismantling of furnace [F362]. It sealed a layer of cinder and slag [366] which had formed in the base of both furnace shaft and tapping channel at the time of the last firing.

The tapping channel ran for 70cm north westwards until it entered a sub-rectangular pit or working hollow [F304]. This was the negative feature encountered against the south edge of Area 3 (noted above) before the excavated area was extended southwards. The feature lay in a horseshoe shaped depression which had gently sloping sides. The pit itself had steep edges creating a "U" shaped profile. It was 1.3m long by 1m wide and 35cm deep and its base was stepped with a shelf, corresponding to a large semi-buried rock, and more gentle slope on the north side (fig 8). Two north-east to south-west sections (fig 4, section M-N and fig 5, O-P) were recorded through this feature as well as a north west to south east one (fig 5, section Q-R) to show its relationship to that of the two furnaces.

Further excavation revealed that this hollow had been cut into natural yellow clay. An original function may have been to extract clay to help build the furnace [F362]. A layer of silt and weathered clay [346] had accumulated in the base and sides of the pit before it appears to have been re-used as a collecting pool for slag run off from the furnace [F362]. Initially the tapping channel splayed out in a wide "V" before entering the working hollow but subsequently a large sandstone had been set against the east side of the channel to restrict the outflow (fig 8, plate 15). The clay immediately beneath the cinder and slag layer [366] was vitrified to a distance of c 70cm from the furnace (as in the case of the later furnace's [F350] tapping channel base). The slag in [366] did not extend into [F304] but the cinder did, becoming a finer layer [345] which covered the weathered deposit [346] right up to the lip of the pit.

Three discrete areas of red clay were found close to [F304]. Just beyond the north edge of the pit, on a gentle slope and covered by a thin layer of charcoal and cinder, lay a large patch of fire-reddened clay [347] 54cm by 45cm. A small circular area 10cm in diameter of harder, baked clay of the same colour lay within [347]. A further, rather amorphous, area of reddened clay [348] was located close to the west edge of the pit and a third area [330] lay near to the east edge. [347] provided samples for archaeomagnetic dating which are discussed on pages 16-17. The position of these three "hearth"-like areas strongly suggests a close relationship with the function of the pit itself.

Immediately to the north of [F304] and partly overlying [347] were substantial spreads of charcoal [312, 329, 314, 341, 307] (fig 6). The charcoal was most densely concentrated close to and north of [347]. There appeared to be different deposits of charcoal, some contained small patches of red or yellow clay or fragments of slag. [307] formed a linear, narrow spread which, in plan, could have represented a charred, fallen beam or the top fill of a gulley or building slot. But excavation showed all of these deposits to be very shallow, with a maximum depth of 2cm, and devoid of structural attributes.

All this evidence taken together suggests that red hot embers and slag were being dumped over the sides of the pit in order to allow more tap slag and cinder to flow out of the furnace base unimpeded. In addition, when the furnace was cleaned out after firing charcoal, slag and cinder were shovelled away from the pit area. It is not possible to say whether or not the unwanted waste material was shovelled away only towards the north of the pit, as disturbance has removed evidence from the other three sides.

Furnace [F362] may well have had a relatively short life span. It was certainly disadvantaged by a tapping channel that was cut against the natural slope of the hillside. There would have been a problem with the flow rate of the tap slag into the re-used collecting pit and it is understandable why the furnace was dismantled and a new one built adjacent to it with a tapping channel that followed the contour of the hill slope. When the earlier furnace was destroyed, the rubble partly filled its tapping channel and the collecting pit; subsequently these features were totally covered by debris from the second furnace [F350] and a deposit of slag [303] which may derive from a third as yet unlocated furnace.

Amongst and beyond the charcoal spreads in the north east part of Area 3 were several deposits that, in plan, were potentially upper fills of post holes or pits (fig 6). Only one of these, [F317], proved to be an archaeological feature of any significance (it is shown as a post excavation plan in fig 6). [F317] took the form of a sub-circular, shallow hole, a maximum of 10cm deep, with its south and east sides damaged by root disturbance. This hole was 60cm long by 50cm wide and contained a thin layer of flat sandstones embedded in the natural clay base (fig 4, section A-B, plate 16). Although a few stones were lost during excavation it could be seen by the impression in the clay that these stones formed a roughly rectangular area measuring 46cm x 40cm. The stones lying in the south part of the hole were covered by a light yellow sandy clay of mortar-like hardness with c 50% fragments of charcoal. The rest of the stones were covered by a loose matrix comprising dark brown silty clay loam with 20% small to medium sandstones, 15% small pieces of slag and 15% fragments of charcoal. There was an absence of fire reddened clay around and within this feature.

[F317] could be interpreted as a post-pad, providing a solid foundation for a timber pillar used to support an awning or roof. Unfortunately this feature exists in isolation, except of course for its close proximity to the furnace complex which lies less than 1m to the south. Although there has been a good deal of disturbance in and around Area 3, future research may reveal more features of this type.

Finally, plate 17 shows the furnace area after removal of slag and shaft lining clays for analysis. It shows the depressions which were deliberately dug out of the clay to house the two furnace bases, which also allowed a sub-surface tapping hole and run-off channel.

Area 1

This area, which was examined in 1992, was briefly re-visited in order to completely expose the remnants of a wall [F077] revetting the side of a robbed out hollow located near the south edge of the excavation area (Redhead, 1992, p 7). The stones were tightly concentrated but loosely bonded by a matrix of hard light yellow clay. They formed a linear, slightly concentric band measuring 2.8m long by 1.25m wide (fig 10, plate 18). A hole was located at either end of the long axis but the high level of disturbance makes the origin of these uncertain. If, however, they were post settings associated with the stone work, it is possible that this feature was the base of a windbreak protecting a furnace or other iron working related process.

Area 4

An exploratory excavation was conducted c 10m to the north west of the site identified as Wrigley's furnace (fig 1). The purpose of this investigation was to examine a circular depression identified in the contour survey (fig 2)which also exhibited an anomaly in the magnetic susceptibility survey (see p 4).

An area of 5m x 5m was de-turfed. As with Areas 1-3 lower down in the valley, the topsoil [410] comprised 10-15cm mid brown silty loam on top of a weathered glacial clay. Removal of [401] revealed three distinctive zones of archaeology in Area 4 (fig 9, plate 19).

The bulk of the south half of the trench was archaeologically sterile, containing a consistent layer [412] of mid brown-yellow clay loam with c 20% small fragments of shale and occasional small to large sandstones. This was interpreted as natural.

In the centre of Area 4 was a depression which was formed by a shallow cut of c 20cm on its east side, which ran into a slight gulley on the north side of the hollow. Although the depression appears to have been deliberately cut out of the gentle hill slope, there was no evidence of burning or structures which might indicate smelting activity. Most of the depression was filled with a single layer of small to medium sandstones [411] which sat on top of natural. The gulley to the north was also filled with sandstones [408] but these were much larger and lay at various angles. There was no evidence of structural cohesion or bonding material. Filling the south east side of the depression was a deposit, c 25cm by 1m in area and only 4-5cm deep, consisting mainly of ironstone pieces in mid grey silty clay loam with 20% small fragments of shale [404]. The general impression was that all these raw materials had been dumped or stored in this sunken area.

The eastern third of Area 4, an area defined by the cut of the depression and gulley, was archaeologically more interesting. Another spread of ironstone [403], 90cm by 1.5m in extent, was found just above the edge of the depression and partly slumping into it (plate 20). It was only separated from [404] by a deposit of shale and silty clay loam [410]. The ironstone deposits covered a quite tightly defined area which suggested they had been deliberately dumped from, perhaps, a wheelbarrow or other container. Here, for the first time, was evidence for the nature of the iron ore being smelted in the Castleshaw valley (see conclusion). It was this ironstone that had caused the anomaly in the magnetic susceptibility survey.

Spreading north from [403] and appearing to underlie it was a deposit of mid orange-brown clay sand with 30% small to large fragments of shale, 20% fragments of charcoal and frequent small fragments of ironstone [402]. This material, which had the character of waste/debris was perhaps shovelled clear of an industrial process taking place nearby. The location of that process may be just beyond the east corner of Area 4, for here was a small patch of fire-reddened clay [407] which disappeared under the edge of the excavated area. Two deposits: [405], mid yellow-grey silty clay loam containing around 30% small to large patches of charcoal and c 10% small fragments of burnt red ironstone and shale, and [406] which was similar but with no charcoal, enclosed and appeared to be associated with [407]. Time constraints prevented further investigation of this area.

The eastern third of Area 4 exhibited considerable archaeological potential. [407] was of especial interest. It registered as an anomaly on the magnetic susceptibility survey and could well be the edge of another furnace or perhaps even a roasting pit (given the raw material found near to it). It is intended that this part of Area 4 will be extended and examined in more detail next year.

5. Analysis of Furnace Material

Dr Gerry McDonnell and Paul Maclean of the Department of Archaeological Sciences, Bradford University, are currently conducting a scientific examination of furnace material from this season's excavations. Although their work programme is at an early stage, they have been kind enough to supply the following progress report:

"Interim Report of the Examination of the Metallurgical Residues from Spa Clough, Castleshaw, Greater Manchester

The complete excavation and lifting of the Spa Clough iron smelting furnace enabled a detailed programme of examination and analysis of the slags and residues to be proposed. In order to obtain the maximum amount of information from the residues, detailed recording of the samples has been started. The analysis programme includes a component of routine analysis as well as research into sampling procedures etc. Since they are closely interlinked the routine analysis has proceeded more slowly than usual. Although a large quantity of slag was recovered during the excavation and the slag heap was available for sampling, much of the slag was re-deposited due to disturbance during the construction of the reservoir. Therefore the material removed from the site for detailed study included the following:

1 Representative samples of the large slag deposits.

2 Soil samples from stratified deposits.

The slags were visually examined and are being classified on morphological criteria. There are three major residue types:

a) Tap Smelting Slag

The characteristic morphology of iron smelting slag. The slag is usually black/blue in colour with a ropey flowed upper surface. The slag has a 'high apparent' density, ie. it has few vesicles and contains few inclusions of non-slag material, eg. charcoal, unreacted silica etc. Tap smelting slag occurs in all periods from the Iron Age onwards, but is most common in the Roman and medieval periods. It is formed by the smelter tapping the slag from the base of the furnace, and allowing it to run freely, usually in channels or if into a small pit, resulting in 'frying pan' plates of slag.

b) Furnace Slag

A more viscous slag that has not achieved a free flowing temperature. It is usually characterised by the presence of charcoal impressions. The slag has been retained within the furnace and may contain non-slag material, such as charcoal and unreacted silica/lining materials. This slag probably represents the last material to slag in the furnace operation cycle.

c) Furnace Lining

The furnaces were built of clay, with some stone work, eg. in the tapping arch. The clay lining is attacked in two ways: firstly by the high oxidation temperatures around the tuyère, leading to vitrification of the clay, and often slumping; secondly by reactions between the slag and clay lining. This often results in the inner surface of the lining becoming slagged, which becomes richer in silica as the lining is traversed from inside to outside. Thus there is usually a slagged skin on the inner surface of the furnace in the lower portion of the furnace. This slagged or vitrified lining is robust and survives burial well. The poorly fired or unfired component of the furnace degrades, and thus, except where the base of the furnace survives, the only structural material to remain is the slagged and vitrified lining.

The soil samples from sealed contexts were carefully sieved to recover as much charcoal as possible to enable C-14 to be obtained. However despite extensive sampling insufficient charcoal was recovered. The largest fragments were given to Julie Bond (Dept. of Archaeological Sciences, Bradford) who identified three samples (Contexts [345, 357 and 366] as mature oak (Quercus). One sample [366] had at least eighteen rings. Therefore the charcoal used could have derived from timbers several hundred years old, which means any C-14 dates must be treated with extreme caution. Very few iron smelting sites report detailed charcoal identification. It is surprising that mature timbers were being used since it is expected/assumed that coppiced or pollarded timbers would be used.

The magnetic susceptibility of the soil samples was also measured. Magnetic susceptibility provides a rapid screening method for the identification of contexts containing iron smelting residues (McDonnell, 1992). Previous work has been undertaken on iron smithing sites, and this is the first series of results from an iron smelting site. As expected the results are extremely high (soil usually is in the order of 50 x 10-6 emu), however there are great differences that need to be investigated. For example the function of the 'working hollow' is not yet understood, and examination of the micro-residues recovered from the soil sample may enable the activity to be identified. It should be noted that whilst the primary function of the Spa Clough site was iron smelting, primary smithing, ie. the refining of the bloom to a tradeable billet may also have been undertaken on the site. The magnetic susceptibility work will also provide information when reviewing the geophysical results.

Table 1 - Magnetic Susceptibility Analysis on CW93 Samples

Context	Description	Mag Sus x10-6 emu
[303]	Slag layer	717
[344]	Fill above [F357], in top fill of [F366] (early furnace)	1105
[345]	Working Hollow	1595
[355]	Upper shaft fill [F350]	595
[357]	Base of later furnace [F350]	2762
[357]	Upper fill of [F350]	1300
[366]	Fill of tap arch of furnace [F362]	1471
[366]	Base of slag channel	1541

Current Work

Sections of slag and slag-lining interface are being prepared for detailed analysis by optical and scanning electron microscopy. This will provide mineral phase identification and elemental analyses. It will also investigate the interaction between slag and the clay lining. This work will be completed during the Spring of 1994".

6. Dating of the Site

Two scientific dating techniques were employed on materials associated with the furnace complex. GeoQuest Associates carried out archaeomagnetic dating of burnt clay and slag and Beta Analytic processed two charcoal samples to produce radiocarbon dates.

Archaeomagnetic Dating

Three deposits were sampled for archaeomagnetic analysis: the fire reddened clay area [347] on the north edge of the pit, slag [353] lining the shaft of furnace [F350] and red clay [359] from the side wall of the tapping channel close to the tapping arch. The processing and results of this research are fully presented in Appendix 1.

Undoubtedly [347] provided the best dating evidence:

"Archaeomagnetic vectors in adjoining burnt clay layer 347 were exceptionally well grouped, defining a mean direction consistent with firing in the medieval period. After correction for orientation error caused by the nearby pipe furnace, two archaeomagnetic dates are suggested. These are: 1175-1220 AD or 1430-1460 AD. On the basis of proximity to the reference curve, the former date is preferred" (page 46). The three samples taken from the red clay of the tapping channel also had a concentration of vectors consistent with [347] (p 51).

The slag proved to be an unreliable source for geophysical dating, the specimens exhibiting highly scattered vectors (including three reversed polarity directions) which has been attributed to "magnetic refraction." Whilst this is unfortunate in terms of dating the furnace remains, it does draw our attention to a very interesting phenomenon which sheds light on the differential cooling of the furnace lining. Mark Noel has kindly provided the following description:

"The scatter of archaeomagnetic directions in slag from the pipe furnace is unlikely to be due to rotational disturbance since much of this structure is preserved as a single fused block. Moreover, the presence of reversed polarity vectors would imply extreme rotations which are archaeologically improbable. In this context, the most likely cause of the archaeomagnetic scatter is a 'magnetic refraction' caused by differential cooling within a structure lined with high susceptibility, ferromagnetic material, namely iron oxide slag (Aitken, 1990). Whilst operating at temperatures above the Curie point of c 580° C the furnace lining will have been paramagnetic causing negligible distortion in the ambient geomagnetic field. As the kiln cooled, the susceptibility multiplied rapidly in those regions which passed progressively through the Curie point with the result that the geomagnetic field became correspondingly distorted.

The magnetic remanence is acquired on cooling through the Blocking Temperature which is close to the Curie point for most minerals. Hence, those regions of the kiln which cooled first through the blocking temperature will have acquired a magnetisation preserving the most faithful (ie. least distorted) record of the ancient geomagnetic field. Clearly, the most aberrant archaeomagnetic vectors in the structure are also likely to occur in regions which cooled most slowly and were the last to pass the blocking temperature isotherm.

From this analysis we can infer that the three clay samples near the tapping hole, with consistent geomagnetic vectors, were the first to cool through c 580° C. Scattered archaeomagnetic directions in the furnace lining imply that this cooled inhomogeneously and later."

Radiocarbon Dating

Two samples were submitted for radiocarbon dating. These were taken from: a lens of densely concentrated charcoal [370] within the backfill of pit [F304] and charcoal twig remnants from the fire reddened clay area [090] discovered in Area 1. The results were:

LAB NO.	SAMPLE NO.	RADIOCARBON AGE
Beta-64935	090	720 +/- 60 BP
Beta-64937	370	950 +/- 50 BP

The calibrated age range, using two sigma statistics (95% probability), was:

	090	AD 1221 - 1396
	370	AD 1003 - 1219 (Stuiver & Pearson, 1993)

There is an obvious discrepancy between these dates but it is important to remember that the two samples are not stratigraphically related. Analysis of the charcoal from the furnace area has shown that much of it is mature oak including that in [370] (p 14). Inner wood from an old tree can already be several hundred years old at the time of felling and only the outer rings or bark are likely to produce a reliable date. The sample from [090] is more dependable because it represents charcoaled young wood, ie. a twig.

Taken altogether the results of these scientific dating analyses puts the Spa Clough smelting site firmly in to the later medieval period. Given the supporting evidence of several fragments of Pennine Gritty Ware (albeit unstratified) a late 12th or first half of the 13th century date is suggested. It would appear that a Roman or very late medieval/early post medieval origin can now be dismissed. It is clear, however, that further dating evidence is desirable in order to strengthen the reliability of these proposed dates. Furthermore, it will be necessary to show whether or not Wrigley's furnace, which belongs to a separate smelting site, was contemporary with the complex beside Spa Clough.

7. Conclusion

The 1993 excavations beside Spa Clough successfully located and recorded two iron smelting furnace bases together with an associated working hollow and post setting. These features were preserved under two deposits of slag, one roughly contemporary with the smelting, the other representing upcast from late 19th century digging connected with the construction of the reservoir. The dating evidence puts this smelting activity firmly in the late medieval period, probably at the time that Roche Abbey held the land in Castleshaw Valley. The furnace base revealed by Ammon Wrigley in 1907 has been located and shown by magnetic survey techniques to be a separate site from the one beside Spa Clough some 200m away. An exploratory excavation of a depression adjacent to Wrigley's furnace site revealed both the nature of the iron ore as well as the edge of a potentially significant feature. This season's work has provided a great deal of new information and has gone a considerable way to answering a number of last year's questions. Inevitably this new data has inspired several new lines of enquiry.

Furnace Technology

The location of two in situ furnace bases at Castleshaw enables a comparison with Wrigley's excavation results. His measurement of 3ft 6in (1.07m) for the central shaft diameter (Wrigley, 1907) was quite alarming and would have made the furnace almost unique amongst medieval bloomeries in Britain. Diameters of 38-40cm for the two recently revealed furnace shafts is much more in keeping with other excavated sites. Wrigley's other measurements are quite plausible, ie. a 30cm square tapping hole, a furnace structure wall of 30cm width and a blast flue of 15cm diameter. The lump of slag which apparently formed the base of Wrigley's furnace was found still lying in the depression left by the excavation. It has now been removed for analysis at Bradford University, along with slag and clay samples from the Spa Clough furnaces. Our knowledge of technology and chemical processes in medieval iron smelting is undoubtedly going to increase through this micro-analysis and every effort should be made to facilitate further scientific investigation of materials which will be revealed in next year's excavations.

With reliable data now available on the furnace construction at Castleshaw, it will be possible to compare and contrast this site with other published furnace sites from around Britain.

Other Processes and Structures

The stone foundation or revetting wall exposed in Area 1 and the post pad in Area 3 represent the main evidence to date for structures associated with the smelting process other than the furnaces. No doubt much evidence has been lost at the Spa Clough site from the late 19th century disturbance. It is likely, however, that more 'islands' of surviving archaeology will be found in this area and they may well reveal further evidence of structures.

The area surrounding the Wrigley furnace has great potential for undisturbed evidence for both structures and processes associated with smelting. Indeed, Wrigley's furnace base apparently survived to a height of 0.76m, considerably more than the furnaces beside Spa Clough. Area 4 has already indicated a feature of high potential which must be a priority for next year's research.

Ore Type and Source

The excavation in Area 4 showed that the source of iron ore was not bog iron but ironstone which is carboniferous in origin, being derived from bands within the shales of the Lower Coal Measures which survive on the west slopes of the Castleshaw Valley. It is possible that iron smelters worked their way up the stream beds taking advantage of exposed seams of ironstone. Unfortunately, extensive canalisation of the Castleshaw streams makes it difficult to prove this theory. Micro-analysis will be undertaken on ironstone samples from Area 4.

Fuel Type and Source

Much research is still necessary on the provision and nature of the charcoal used in the Castleshaw furnaces. A brief analysis of some of the charcoal from furnace contexts has already produced unexpected results. It has generally been assumed that charcoal was made from coppiced wood but the presence of mature oak in the Spa Clough furnaces questions this. Extensive analysis of charcoal fragments from the Castleshaw excavations is a priority.

Dating

Results from scientific dating have been very encouraging, especially given the lack of stratified artifacts. Further archaeomagnetic and radiocarbon dating should be used on the Wrigley furnace site which is now established as a separate site from Spa Clough. Very few smelting sites have benefited from duel dating techniques. Radiocarbon dating will depend on charcoal suitability.

It is envisaged that a further, probably final, season of excavation will concentrate mainly on the Wrigley furnace area on Cudworth Pasture, with a small team finishing the slag spoil area at Spa Clough. Future research will include field survey of the Castleshaw Valley to locate other potential furnace sites, examination of Roche Abbey records and comparative studies of other excavated furnace sites in Britain. These, together with results from micro-analysis of furnace materials, geophysical survey and scientific dating should enable the Castleshaw Valley smelting furnace project to make a major contribution to our understanding of smelting technology in the medieval period.

Norman Redhead

December 1993

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Stuiver M & Pearson GW 1993 *Radiocarbon,* Vol 35, 1-23.

Wrigley A 1912 *Songs of a Moorland Parish.*

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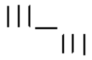
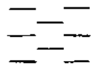
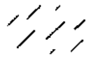
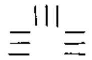
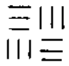
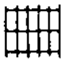
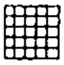
Especial thanks, once again, to Jayne for her support, encouragement and those delicious cakes!

Key to Conventions

Light to mid grey silty clay, 25% orange clay	
Orange-brown clay sand	
Mid yellow-grey silty clay loam	
Yellow-grey silty clay loam and shale	
Light grey clay	
Very dark brown silty clay loam	
Charcoal	
Light to mid brown loam	
Mixed brown loam	
Ironstone	
Light grey reduced clay	
Grey clay (reduced) lining	
Slag [301] in dark grey-brown gritty matrix	
Yellow clay	
Slag [303] in mid to dark red-brown silty clay loam matrix	
Red clay	
Black humic soil and red clay lumps	
Semi-vitrified clay	
Light, compact yellow or white clay	
Furnace slag	
Loose, baked orange clay with black humus	
Baked orange clay lining	
Black cinder and slag	
Dark grey clay	
Dark brown silty clay loam mixed with patches of yellow clay	

Figures and List of Sections

The following sections are shown in Fig 4:

A-B: north facing through [F317]

C-D: north facing through shaft fill of [F350]

E-F: south facing through red clay surrounding [F350]

G-H: south facing through tapping channel of [F350]

I-J: south east facing through [F362]

K-L: north facing through tapping arch of [F362]

M-N: north facing through [F304, F368]

The following sections are shown in Fig 5:

O-P: north west facing through [F304, F368]

Q-R: south west facing through [F304, F362,F350]

S-T: south facing edge of Area 3

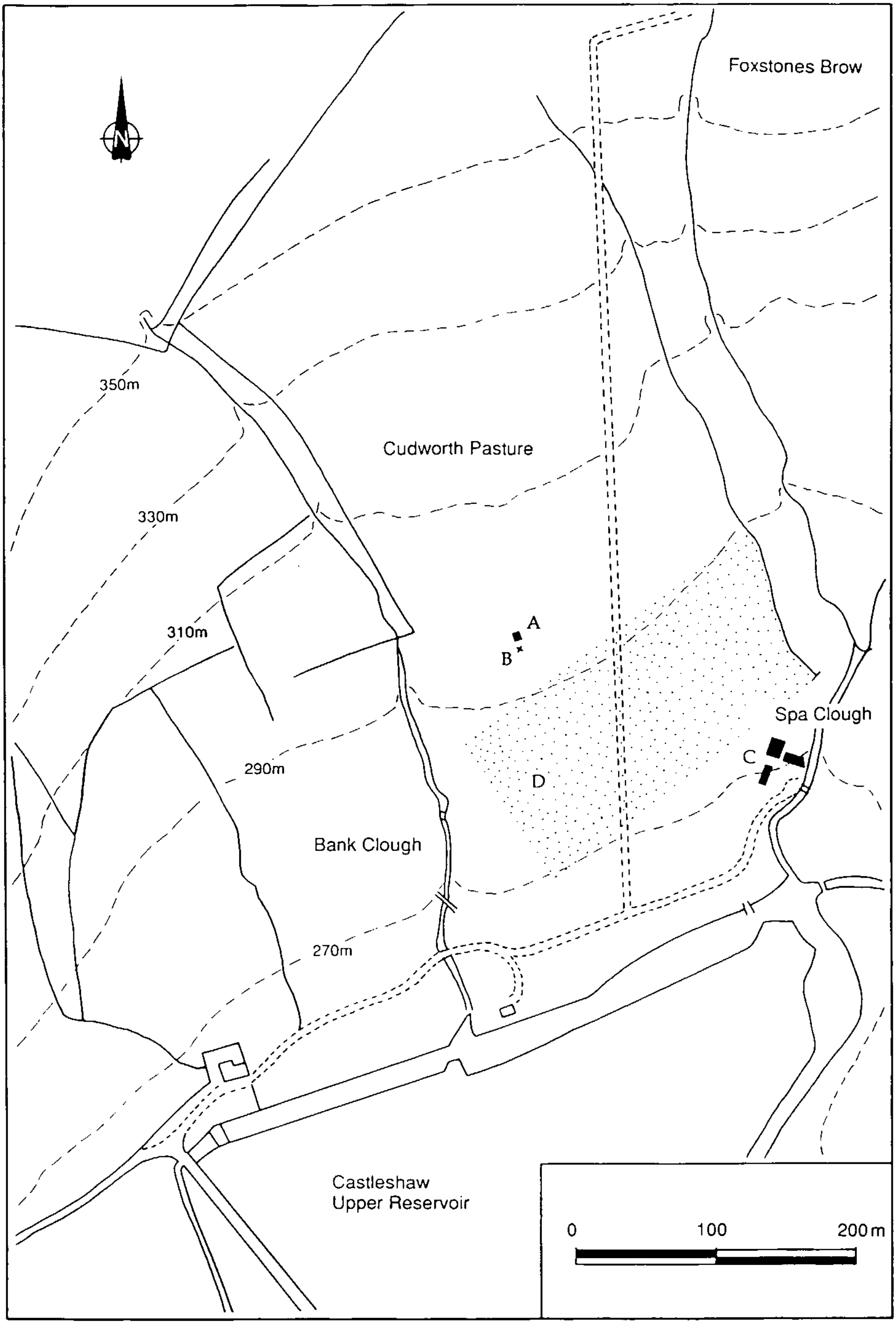


Fig.1 - Location of the Spa Clough and Wrigley furnace sites in the Castleshaw Valley.
Key: A – Area 4; B – Wrigley Furnace; C – Areas 1-3; D – Area of magnetic susceptibility traverses.

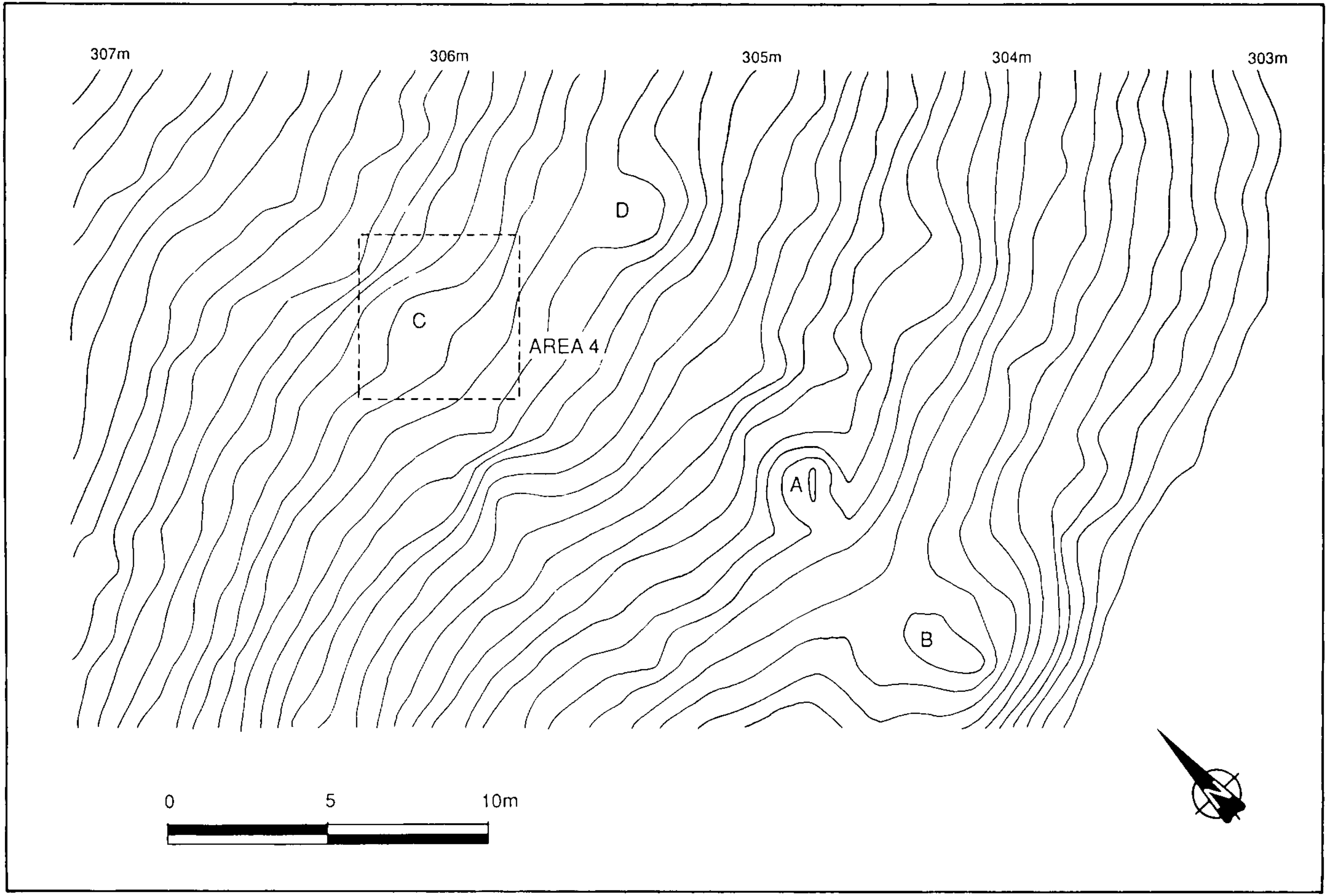


Fig.2 - Contour survey of Wrigley furnace area on Cudworth Pasture.
Key: A – Wrigley furnace; B – slag spoil mound?; C – depression; D – slag spoil?

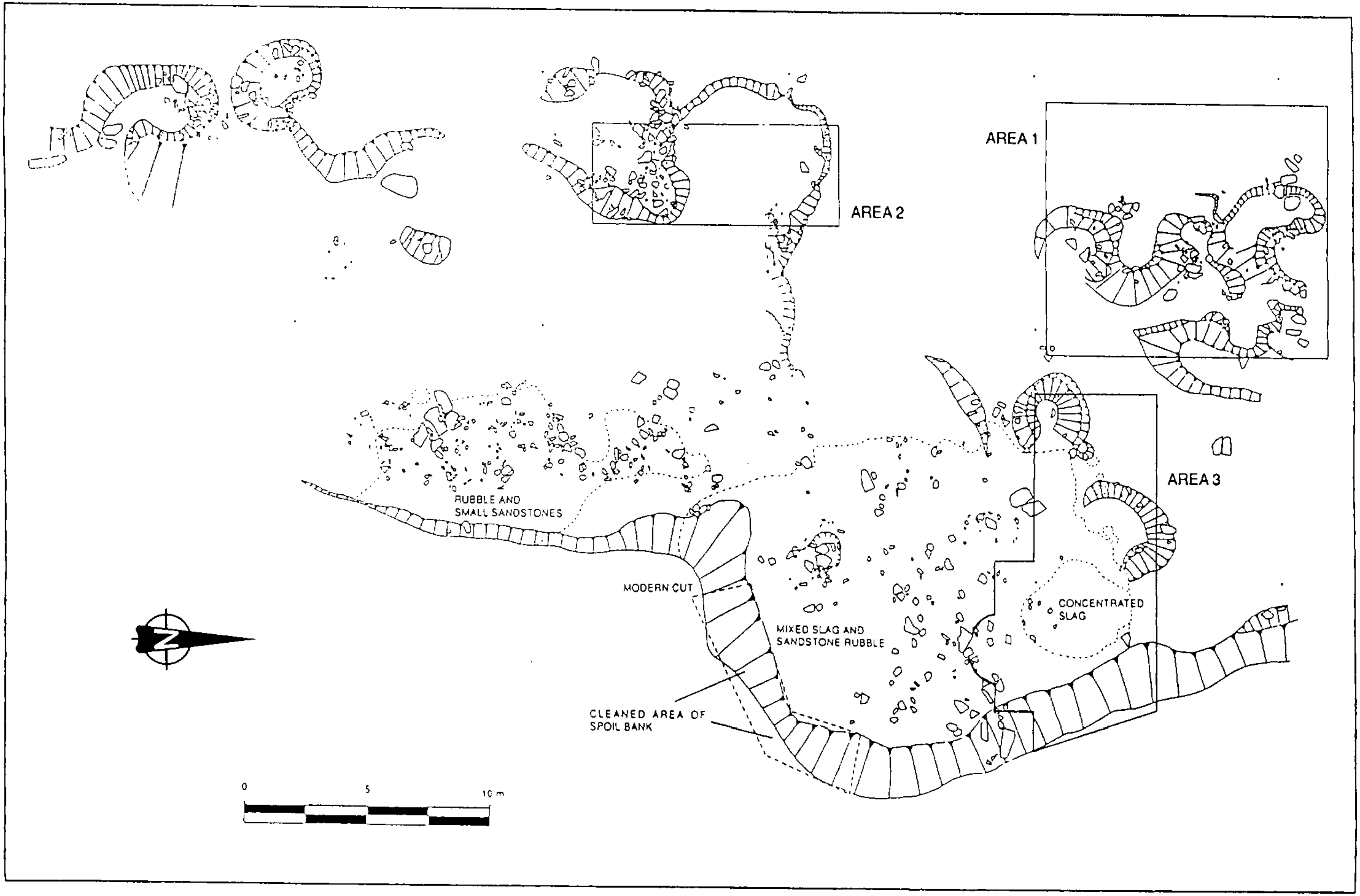


Fig.3 - Surface plan showing slag spoil heap beside Spa Clough and location of Areas 1-3.

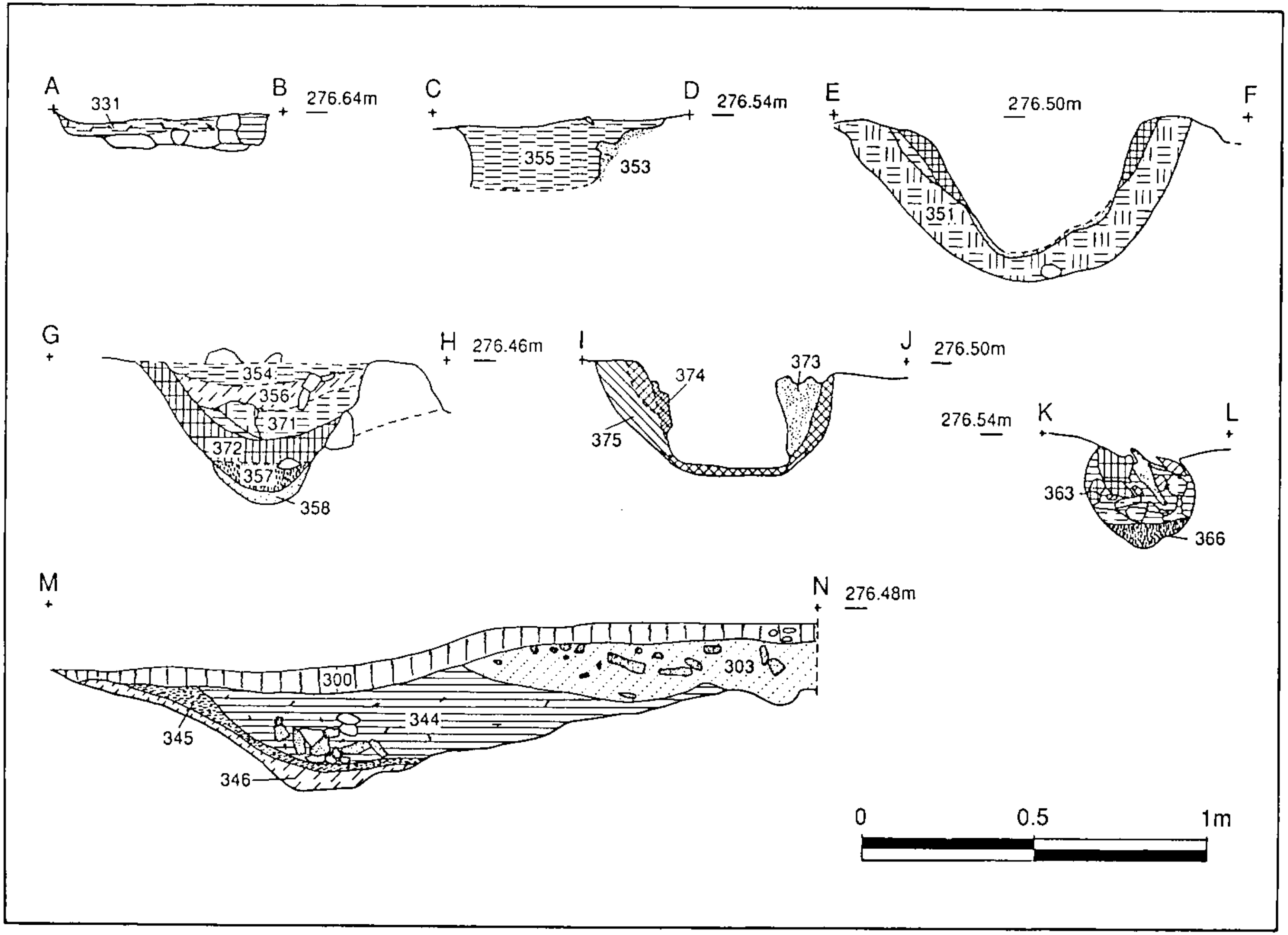


Fig.4 - Sections through features in Area 3. See Figs.6, 7 and 8 for location of section lines.

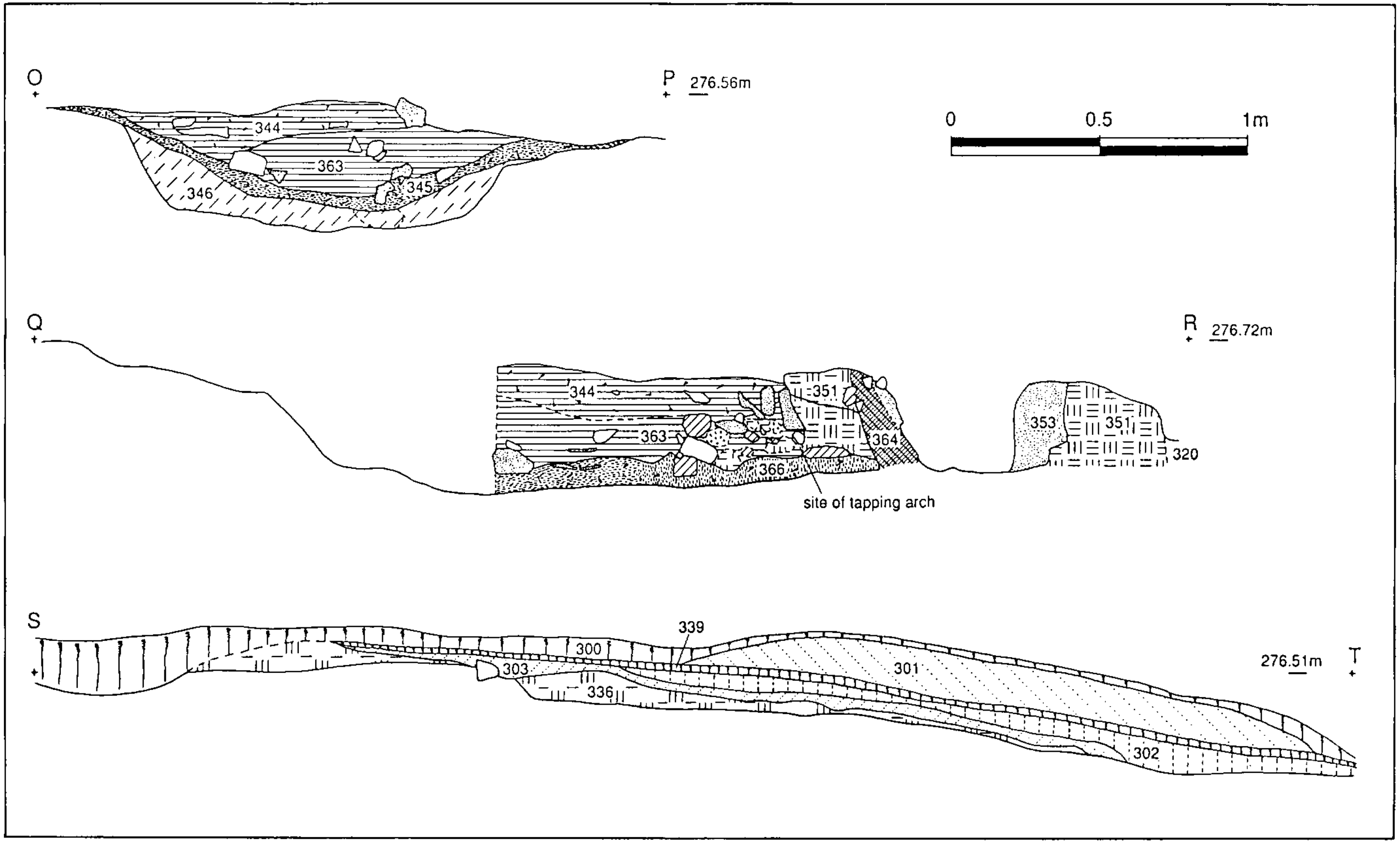


Fig.5 - Sections through features in Area 3. See Fig.6 for location of section lines.

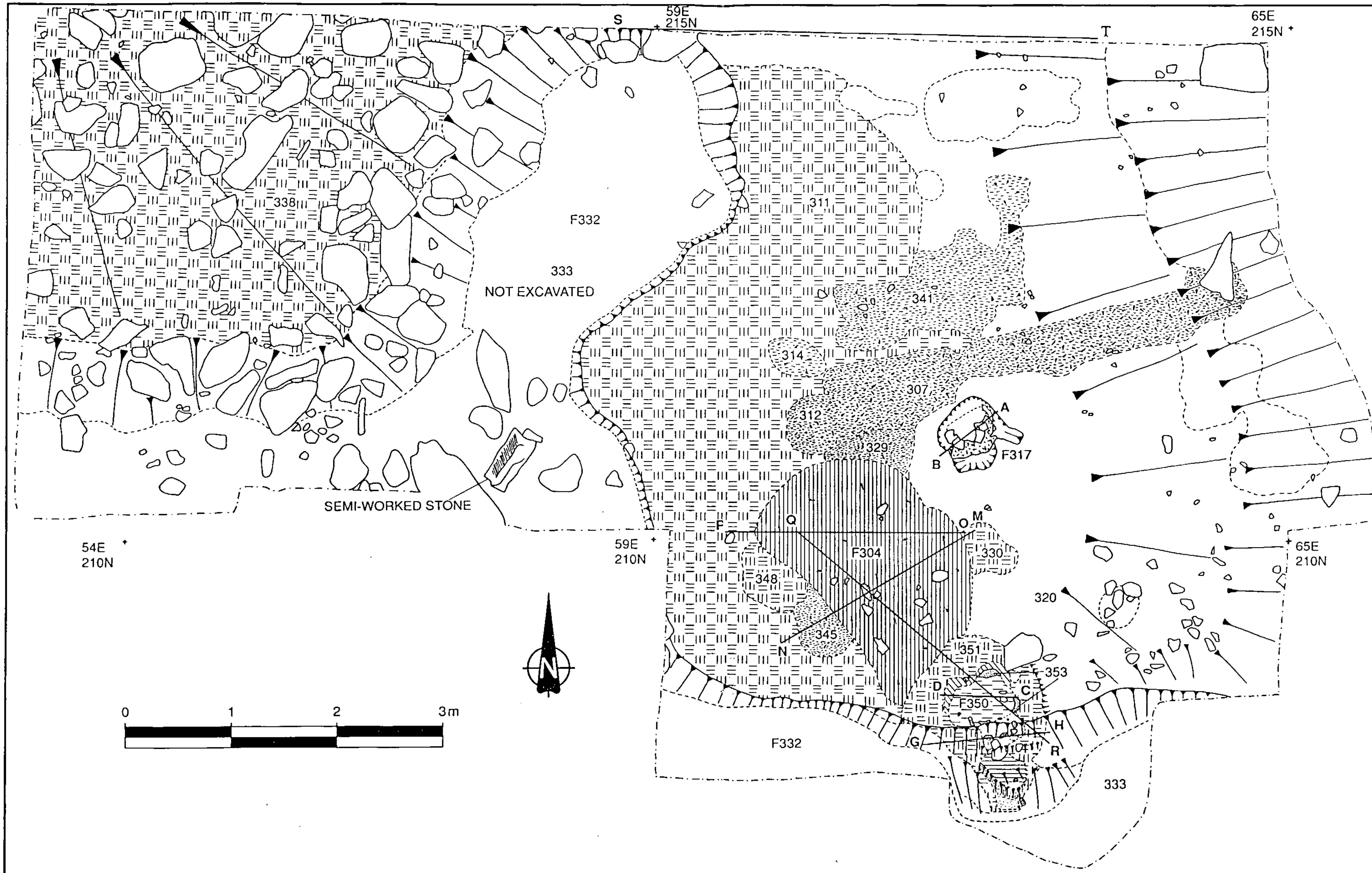


Fig.6 - Plan of Area 3 after removal of [302] and slag deposits [301,303].

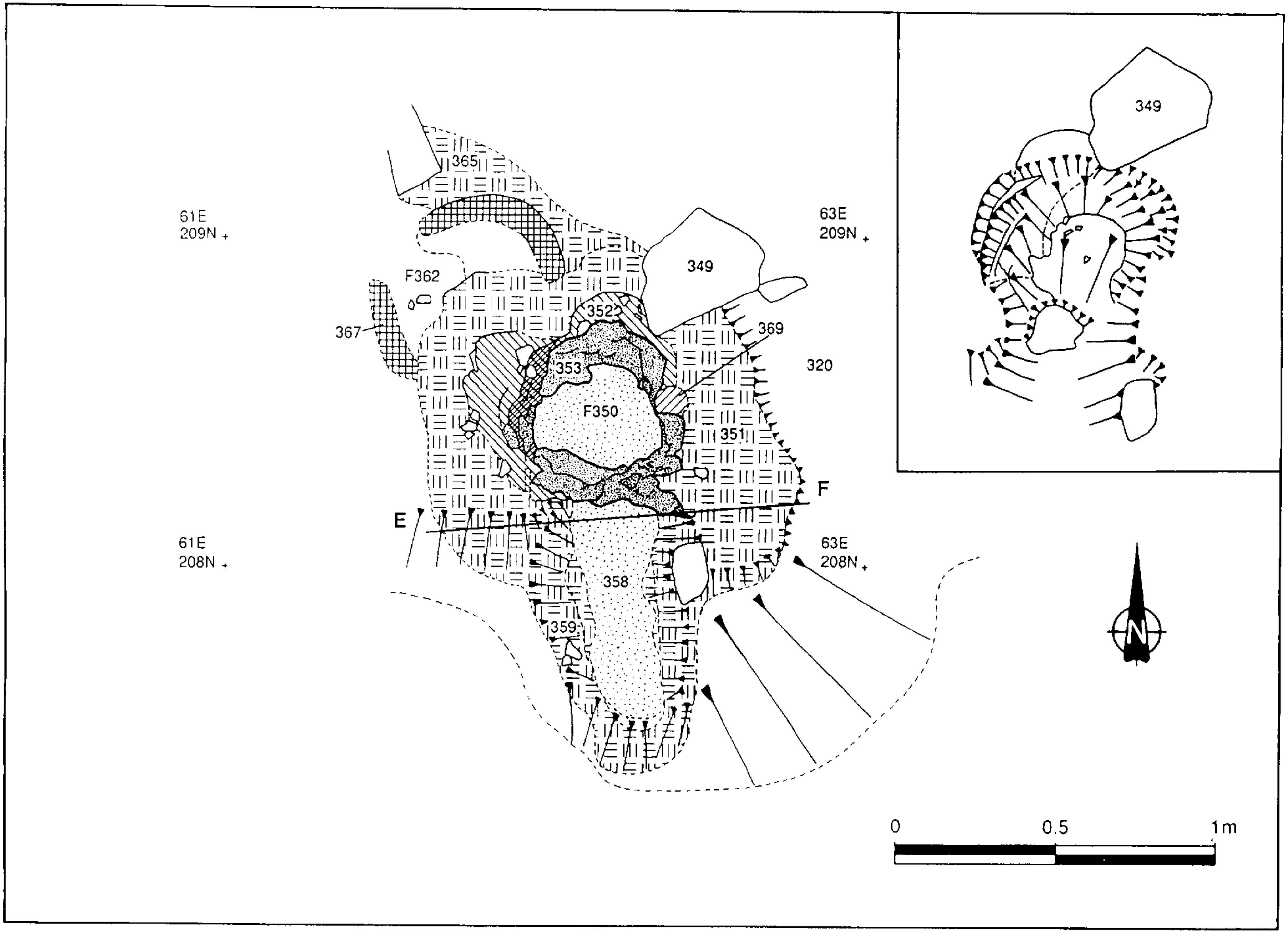


Fig.7 - Plan of furnace base [F350] part excavated. Inset – Plan of [F350] after removal of slag lining.

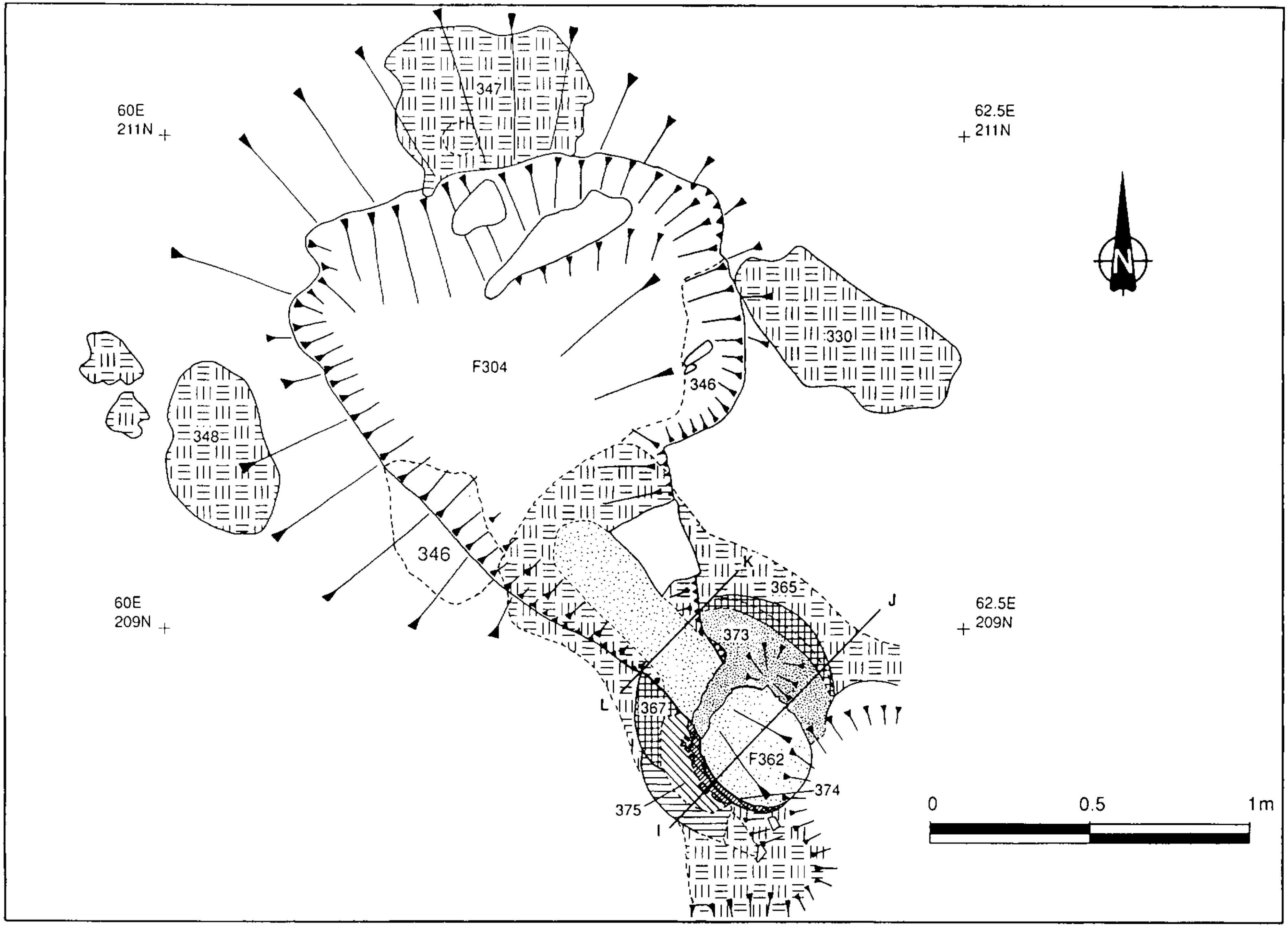


Fig.8 - Plan of furnace [F362] part excavated and pit [F304] post-excavation.

Fig.9 - Plan of Area 4 after removal of [402].

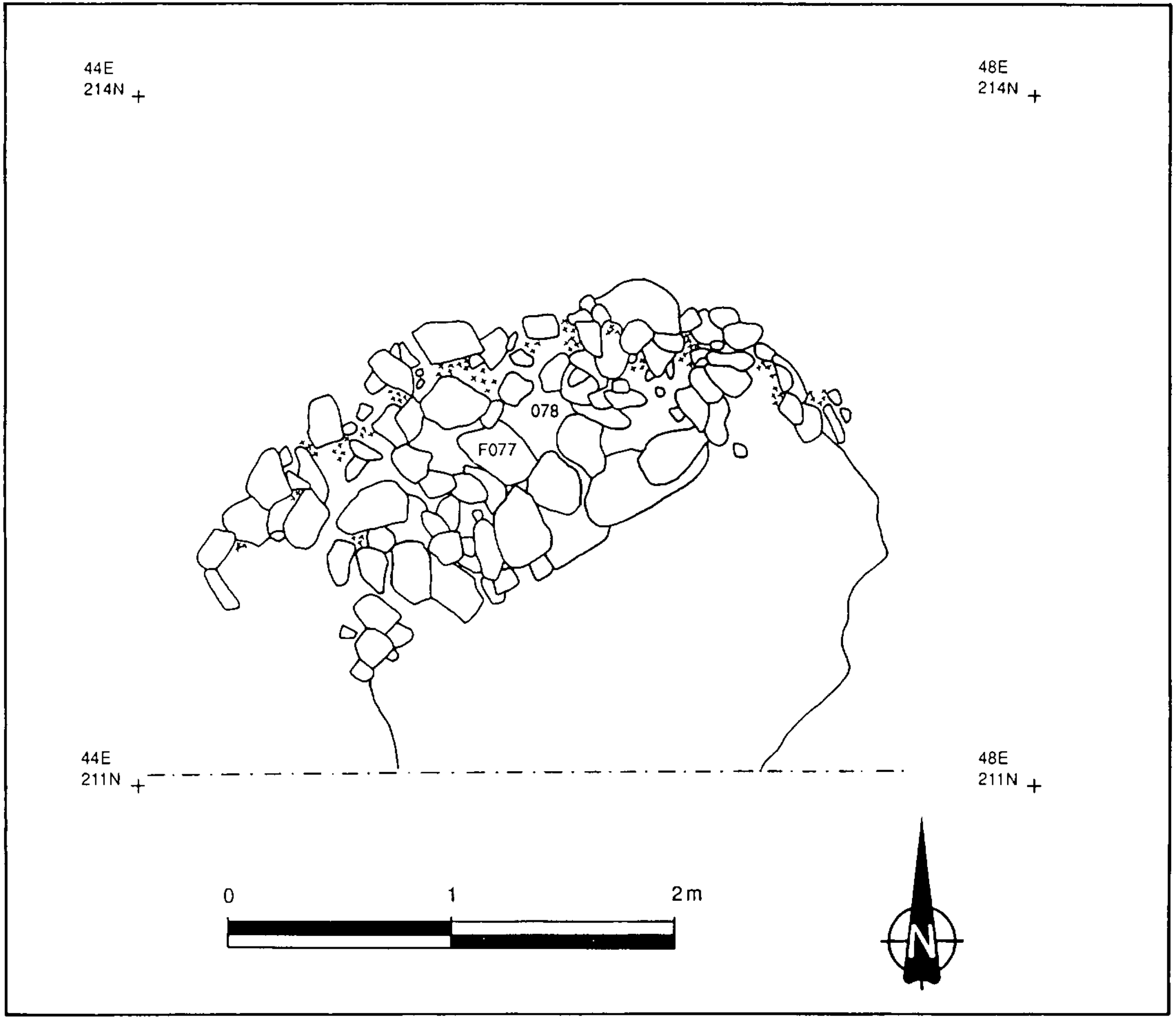


Fig.10 - Plan of stone spread [F077] in Area 1.

List of Plates

16 Post pad [F317] looking west. Scale = 50cm.

17 Area 3 furnace depressions with pit [F304] beyond, looking north, after removal of all shaft lining material for analysis. Scale = 2m and 1m.

18 Bonded concentration of stones in Area 1, looking north. Scale = 2m.

19 Area 4 looking north east. Spreads of charcoal, ironstone and slag occur in the top half of the trench. [407] is arrowed top right. Scale = 2m.

20 Detail showing deposit of ironstone pieces. Scale = 50cm.

Plate 1

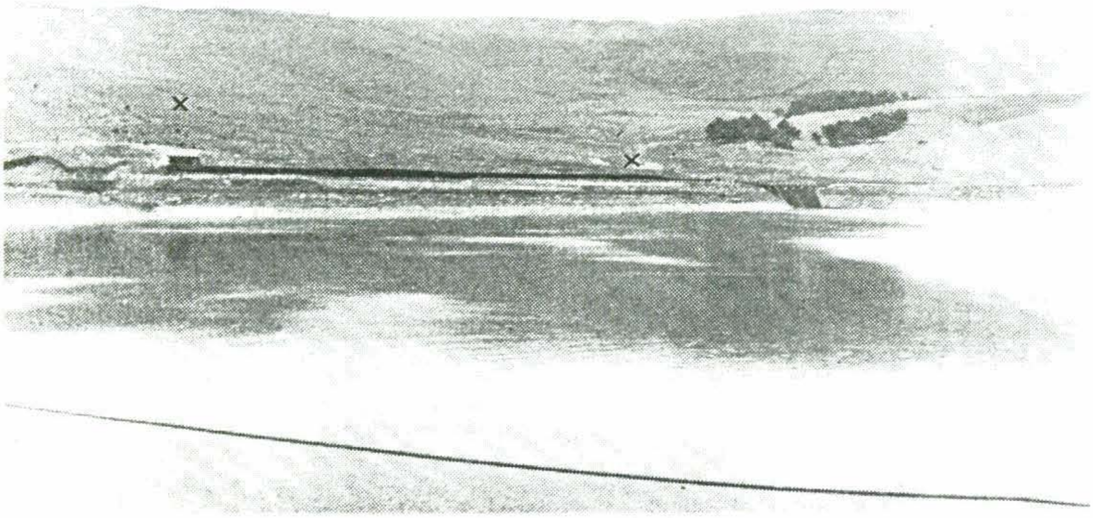


Plate 2

Plate 3

Plate 4

Plate 5

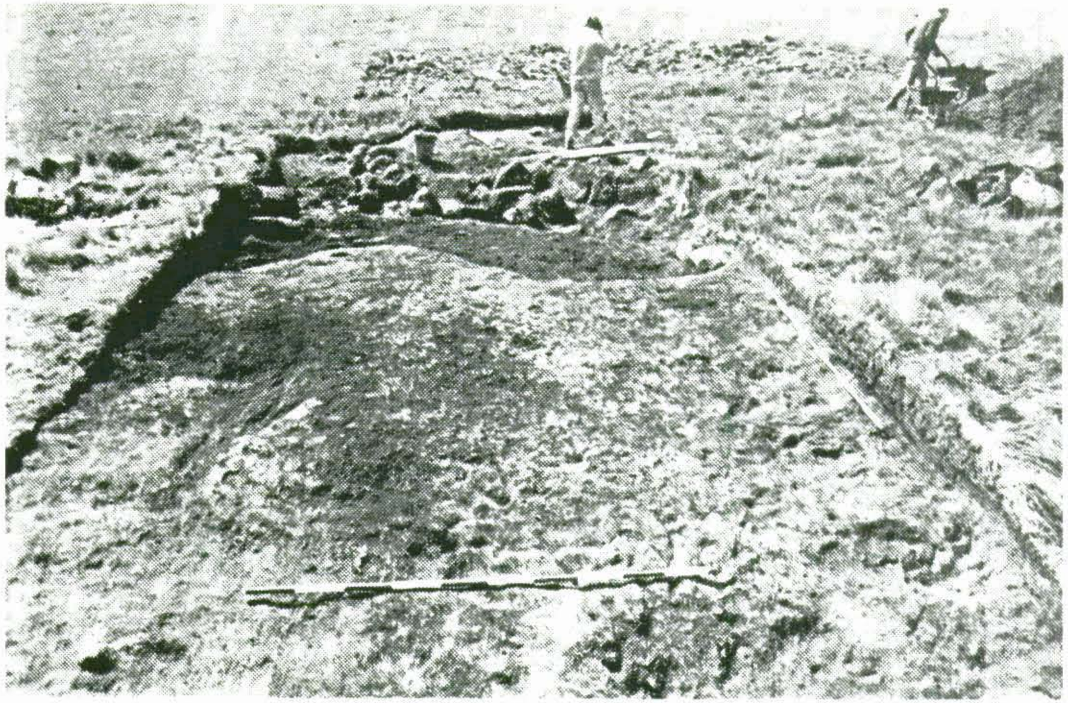


Plate 6

Plate 7

Plate 8

Plate 9


Plate 10

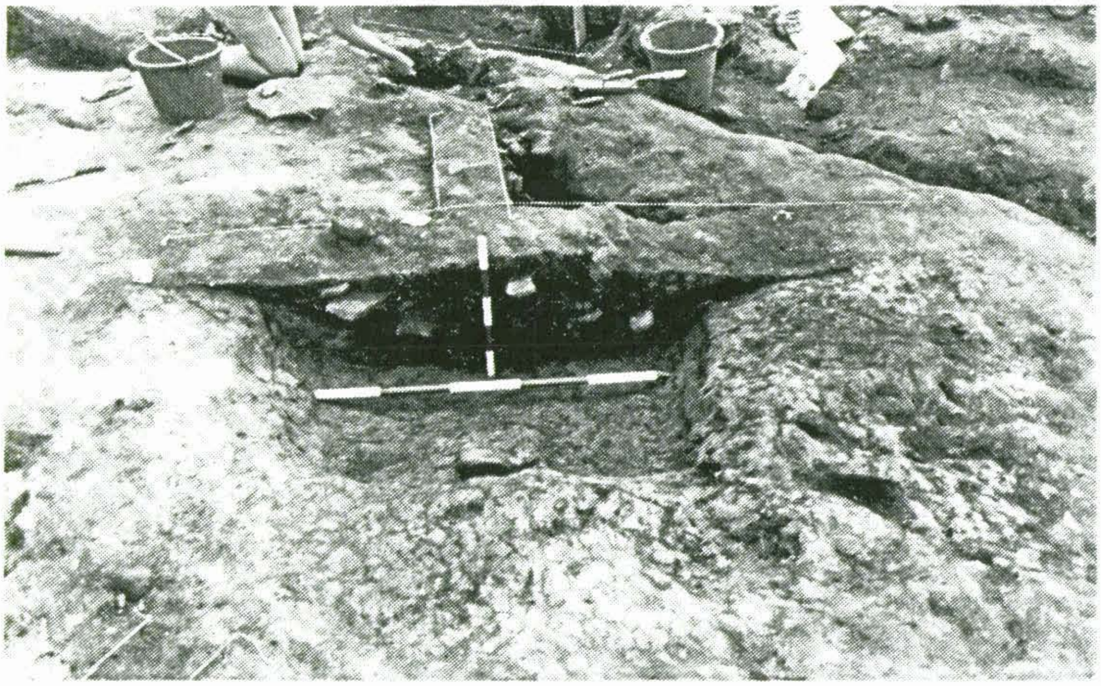


Plate 11

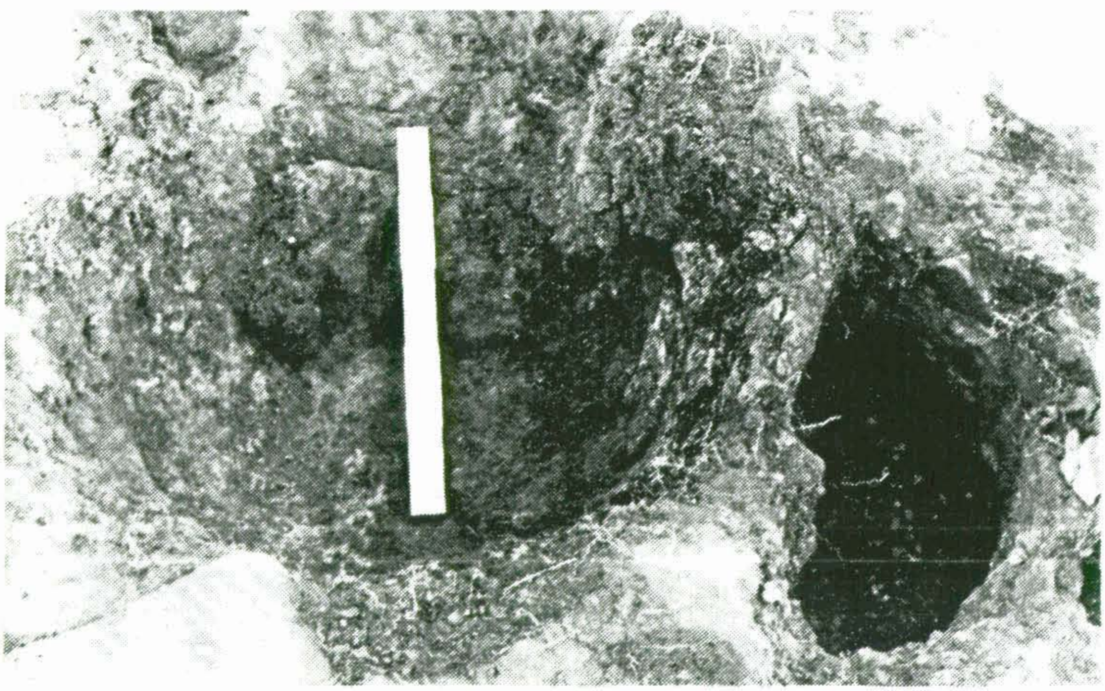


Plate 12

Plate 13

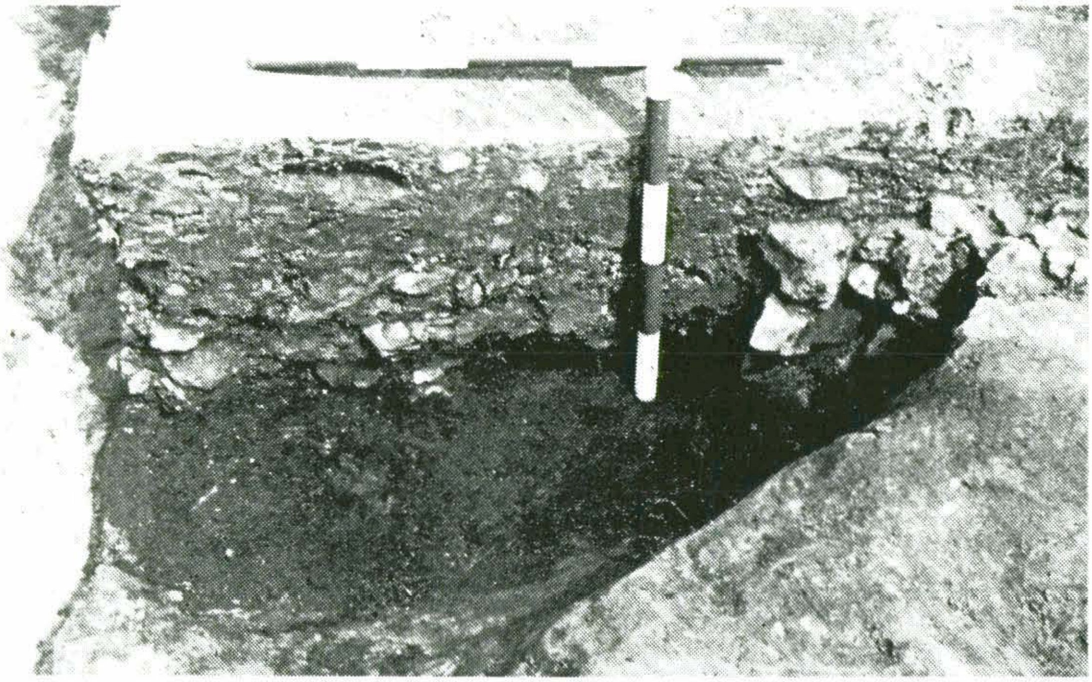


Plate 14

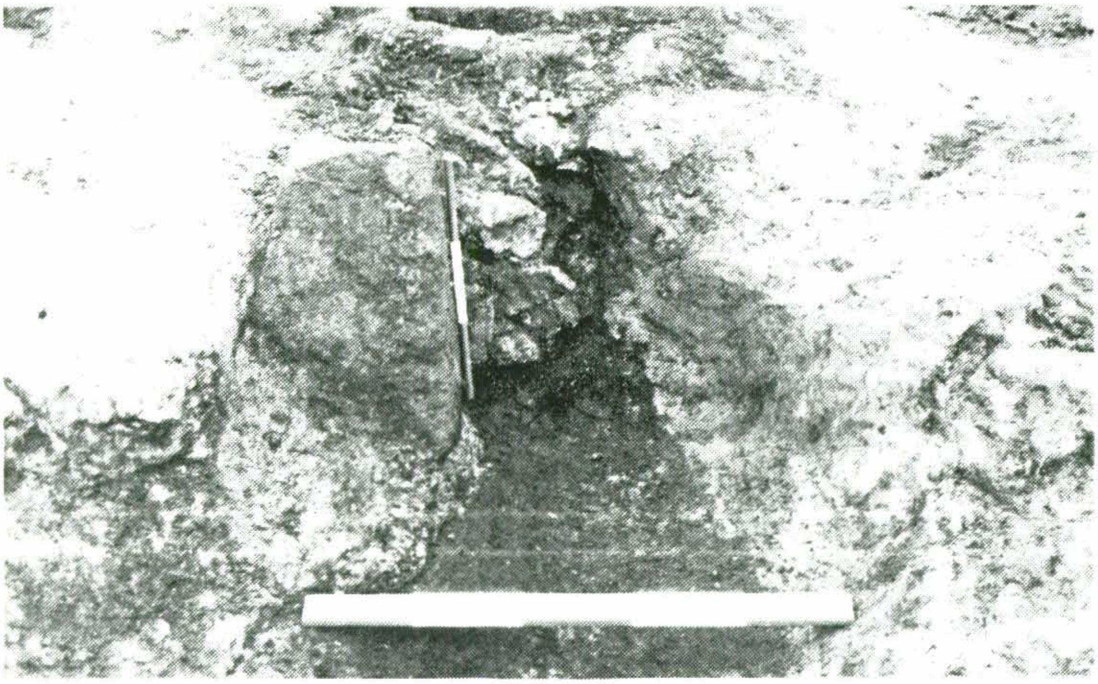


Plate 15


Plate 16


Plate 18


Plate 17

Plate 19

Plate 20

Appendix - Archaeomagnetic Dating Report

ARCHAEOMAGNETIC STUDY OF
CONTEXTS 347, 353 AND 359 AT
SPA CLOUGH, CASTLESHAW

A PROGRAMME OF RESEARCH CARRIED OUT
ON BEHALF OF

GREATER MANCHESTER ARCHAEOLOGICAL UNIT

By

GeoQuest Associates

INTRODUCTION

Recent excavations at Spa Clough, north of the Castleshaw Upper Reservoir in Derbyshire, uncovered a well-preserved pipe furnace, scatters of slag and several areas of burnt clay (Figures 1 & 2). The archaeological evidence suggests that the slopes of Spa Clough were an important site for medieval iron ore extraction and smelting. In order to provide absolute geophysical dates for this industry, pipe furnace contexts 353 (slag lining) and 359 (red clay) were selected for archaeomagnetic dating. An area of redenned clay (context 347, ~2m northwards) was also chosen for evaluation since the function and chronological context of this feature was unclear.

SAMPLING

Oriented specimens of fired clay and furnace slag were recovered using the *button method* devised by Clark, Tarling & Noel (1988) at positions where material was evidently *in situ*. This technique employs a 25mm, flanged plastic disc to act as a field orientation reference, sample label and specimen holder inside the magnetometer. Surfaces were cleared of loose material, then cleaned and dried using a nylon brush and methanol. Buttons were then glued in position using a fast setting epoxy resin (Devcon Rapid) with their surfaces set horizontal with a spirit level. Small beads of plasticene beneath the buttons held them steady while the resin cured. Finally, geomagnetic orientation arrows were marked with reference to a Nautech fluxgate compass, along with a specimen code. The set of orientation arrows were finally checked for parallelism to test for errors due to the bulk magnetisation within each feature. No significant flux distortion was detected in the fired clay of context 347. However, the orientation arrows in contexts 353/359 indicated that the pipe furnace was causing deviations of ~15° in the present Earth's magnetic field, due to the strong theromoremance and magnetic susceptibility in the slag lining. Nevertheless, samples were removed in the hope that their primary thermoremanence had been acquired under thermal conditions in which the fill and lining of the furnace caused negligible flux distortion. This situation can arise when strong thermal gradients are present in such a furnace.

The specimens were dried over a period of 10 days and then consolidated by slow impregnation with a solution of PVA in acetone. Finally, the samples were cut with a diamond saw until each button retained a sample which fitted the standard 25x25mm specimen holder inside the magnetometer.

MEASUREMENT

The natural remanent magnetisation (NRM) of all the samples was measured in a Molspin fluxgate spinner magnetometer (Molyneux, 1971) with a minimum sensitivity of around $5x10^{-9}Am^2$. Remanence directions were corrected for the local geomagnetic variation using data published by the British Geological Survey. Results are plotted on the stereograms of Figure 3 and listed in Table 1. Generally, the NRM of an archaeological material will comprise a primary magnetisation, (in this case presumed to be of thermal origin), together with secondary components acquired in later geomagnetic fields due to diagenesis or partial reheating. Usually, a weak viscous magnetisation is also present reflecting a tendency for the remanence to adjust to the recent field. If the secondary components are of relatively low stability, then removal by partial demagnetisation will leave the primary remanence of archaeological interest. This technique was applied to the specimens from the burnt layer. Samples with typical NRM characteristics from each context were demagnetised incrementally, up to peak alternating fields of 20 and 80mT and the changes in remanence recorded (Figure 4).

At this stage, normal practice is to select an alternating field (a.f.), based on the pilot sample behaviour, which would enable optimum removal of secondary components to isolate the primary remanence in the remaining specimens. However, it was found that the pipe furnace (context 353/359) contained an unstable, two-component magnetisation in which a primary archaeomagnetic vector was not isolated by a.f. demagnetisation. Moreover, the magnetisation in the red clay from context 347 was found to be very 'soft' such that even moderate a.f. demagnetisation would remove a significant part of the archaeomagnetic vector of interest. It was therefore decided to continue the analysis based on NRM vectors.

RESULTS AND DISCUSSION

Intensities of the natural remanence were in the range $2.16\text{-}103.81x10^{-4}Am^2kg^{-1}$. The strongest values were found in the slag lining of the pipe furnace which accounts for the magnetic 'refraction' detected in this feature. Archaeomagnetic vectors in the fired clay feature (context 347) are exceptionally well grouped with a single outlier (sample CAS22). In contrast, archaeomagnetic vectors from slag in the pipe furnace are highly scattered and include three reversed polarity directions. Three specimens of fired clay from adjacent to the tapping hole however, have yielded well-grouped vectors which are consistent with those from context 347. These are enclosed in orange in Figure 3.

The scatter of archaeomagnetic directions in slag from the pipe furnace is thus interpreted as being due to a magnetic 'refraction' within a structure of strong susceptibility undergoing differential cooling. Unfortunately, this phenomenon has rendered this structure unsuitable for magnetic dating. No such refraction is seen in context 347.

ANALYSIS

A standard correction was used to convert the mean archaeomagnetic direction in context 347 (less outlier sample CAS22) to Meriden, the reference locality for the British Master Curve (Noel & Batt, 1990). Figure 5 then compares this vector and associated error envelope to the Master Curve segment 600 AD - 2000 AD. The archaeomagnetic vector is seen to lie inside a loop of the medieval segment of the curve, making a closest approach to a date centred on AD1200. The deviation from intersection with the curve is probably due to the strong remanence of the adjacent pipe furnace causing a small error in the magnetic orientation applied in the field. Since it is difficult to calculate the sign of this error, we suggest instead two possible archaeomagnetic age ranges found by rotating the vector slightly east and west as shown in Figure 5. These are: 1175-1220 AD or 1430-1460 AD. On the basis of proximity to the curve, the former date seems more likely.

CONCLUSIONS

The results of this research can be summarised as follows:

1. Samples from contexts 347 and 353/359 were found to contain thermoremanent magnetisations caused by heating in the archaeomagnetic field.

2. The magnetisation within the pipe furnace slag (context 353) was found to be unstable and very scattered owing to a 'magnetic refraction' of the archaeomagnetic field. Hence it was not possible to date this structure geophysically.

3. Archaeomagnetic vectors in adjoining burnt clay layer 347 were exceptionally well grouped, defining a mean direction consistent with firing in the medieval period. After correction for orientation error caused by the nearby pipe furnace, two archaeomagnetic dates are suggested. These are: 1175-1220 AD or 1430-1460 AD. On the basis of proximity to the reference curve, the former date is preferred.

Note: A programme is currently underway whereby all UK archaeomagnetic data are being used to synthesise a revised Master Curve. Should this lead to revision in the above estimates then we will provide adjusted archaeomagnetic dates as part of this service.

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Credits

Sampling: M.J. Noel
Analysis & report: M.J. Noel
Date: 15/8/93

TABLE 1
ARCHAEOMAGNETIC RESULTS FROM SPA CLOUGH

Sample	LITH	J	D	I	A.F.	D	I
Context	353+359						
CAS1	SLG	7.92	12.9	56.0			
CAS2	SLG	31.75	81.5	48.9			
CAS3	SLG	23.39	330.4	60.6			
CAS4	SLG	2.16	176.8	30.2			
CAS5	SLG	7.45	283.5	45.5			
CAS6	SLG	6.24	18.8	-45.2			
CAS7	SLG	45.12	17.2	42.6			
CAS8	SLG	29.65	269.2	69.0			
CAS9	SLG	103.81	278.4	74.4	SAMPLES TOO UNSTABLE		
CAS10	SLG	7.01	209.2	72.2			
CAS11	SLG	9.43	177.3	-41.4			
CAS12	SLG	4.68	127.0	-12.0			
CAS13	SLG	25.97	307.4	29.3			
CAS14	RCL	30.73	353.2	62.2			
CAS15	RCL	63.52	13.1	66.3			
CAS16	RCL	42.81	5.9	63.0			
Mean of Feature			353.9	77.0			
		alpha$_{95}$ =33.9	k=2.2				
			c.s.e=13.8				
Context	347						
CAS14a	RCL	29.06	8.8	58.6	NONE DEMAGNETISED		
CAS15a	RCL	32.34	8.1	64.7			
CAS16a	RCL	16.76	7.7	60.0			
CAS17	RCL	27.12	10.6	62.8			
CAS18	RCL	7.02	12.6	63.6			
CAS19	RCL	10.82	5.4	67.2			
CAS20	RCL	31.20	15.0	66.1			
CAS21	RCL	10.33	7.5	61.6			
CAS22	RCL	103.77	18.4	53.9	REJECT		
CAS23	RCL	41.67	13.2	59.0			
CAS24	RCL	14.60	12.2	63.2			
Mean of Feature			10.1	62.7			
		alpha$_{95}$ =1.9	k=636.6				
			c.s.e=1.0				
AT MERIDEN			**9.9**	**61.8**			

NOTES:
LITH = Lithology 'RCL' is red clay, 'SLG' is slag. D = declination, I = inclination, J = intensity, $Am^2kg^{-1}x10^{-4}$. A.F. = peak alternating demagnetising field in milliTesla. alpha$_{95}$ is the semi-angle of the 95% cone of confidence, c.s.e. is the circular standard error and k is the precision parameter.

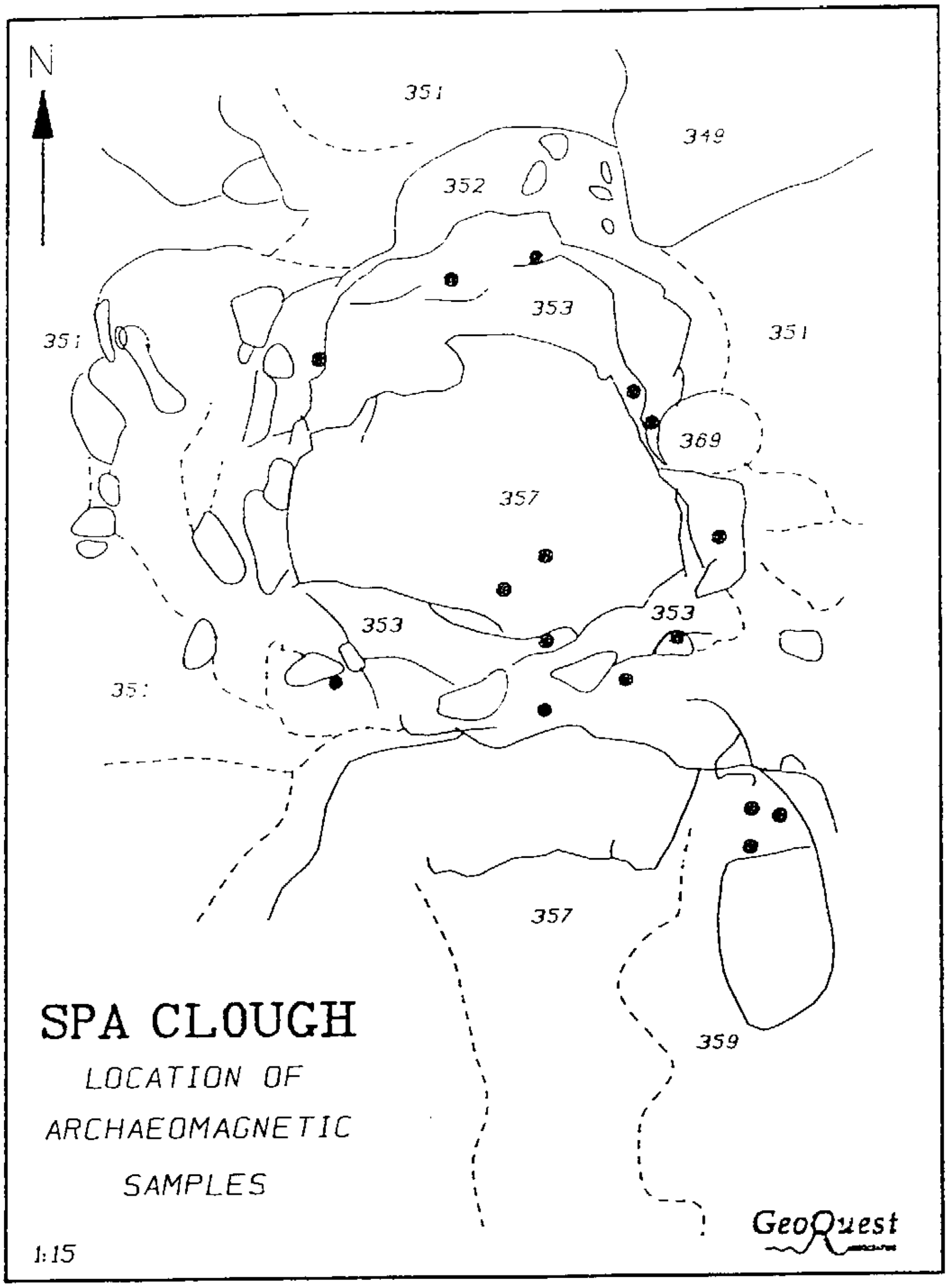

FIGURE 1

Location of archaeomagnetic specimens in the pipe furnace, Contexts 353 & 359, at Spa Clough, Castle Shaw.

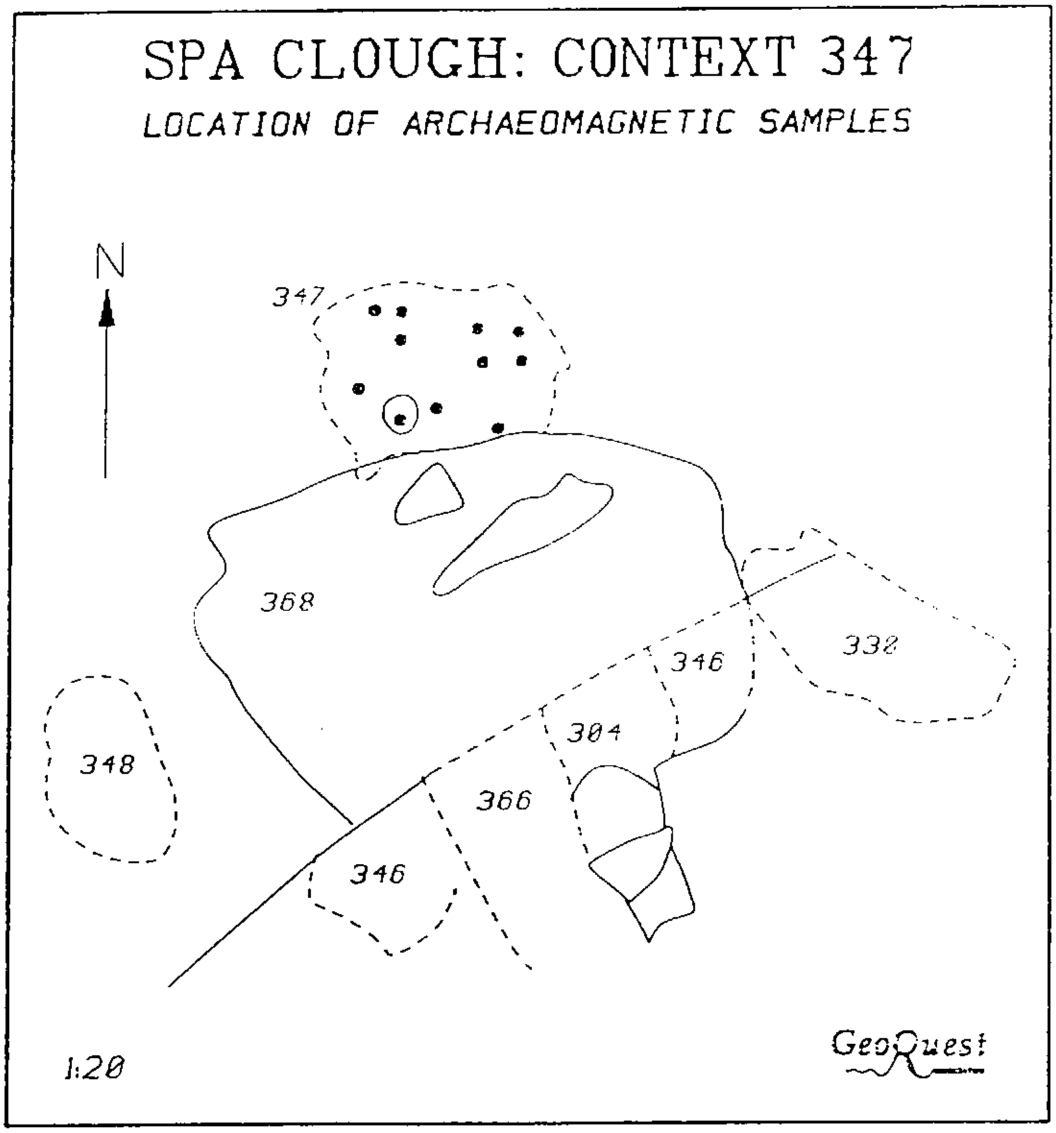

FIGURE 2

Location of archaeomagnetic specimens in the burnt clay, Context 347, at Spa Clough, Castle Shaw.

SPA CLOUGH

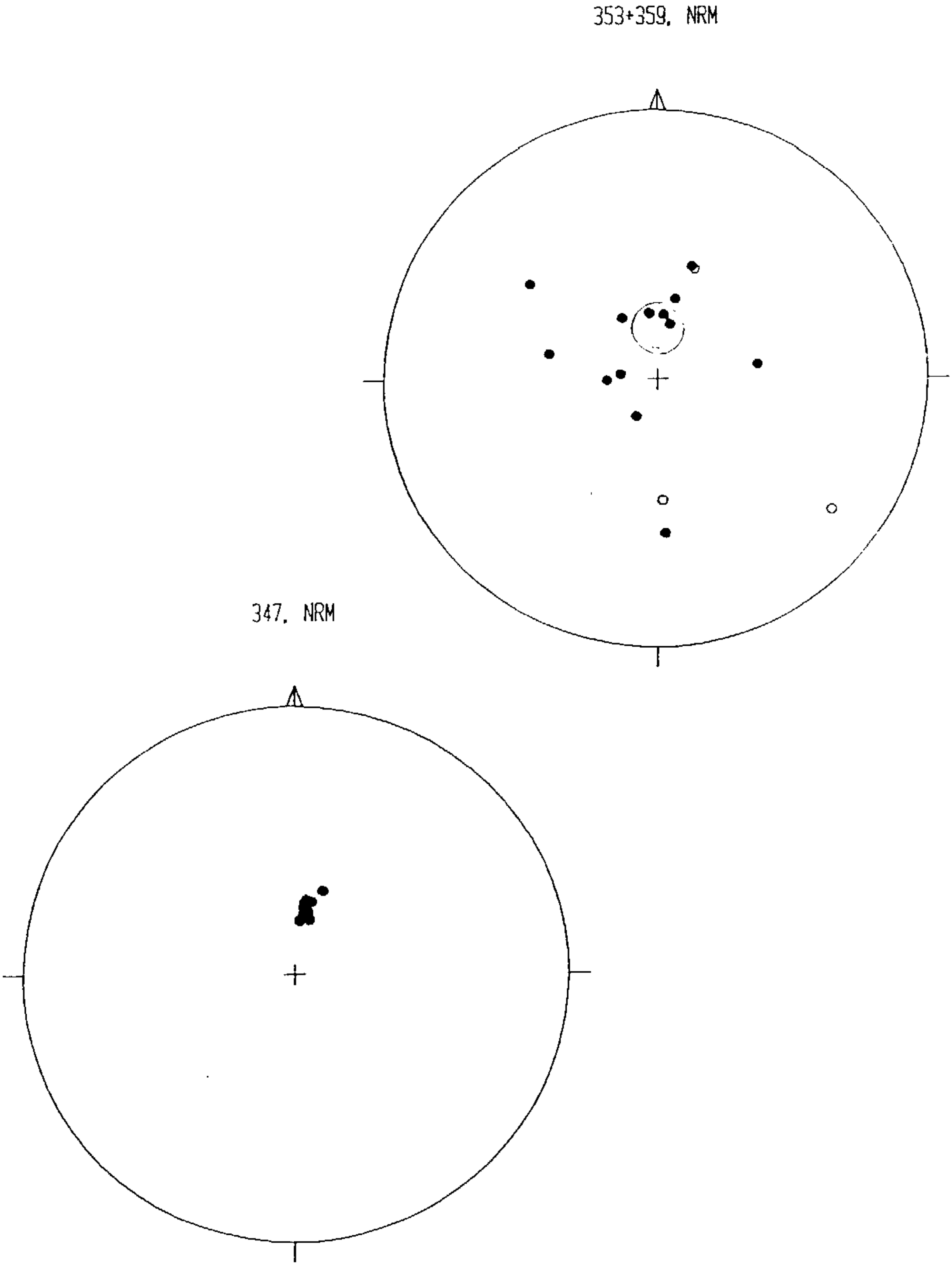

FIGURE 3

Directions of remanent magnetisation within the furnace (top) and burnt clay layer plotted on equal area stereographic projections (lower hemisphere). Samples ringed in orange were from the redenned clay near the tapping hole.

SPA CLOUGH

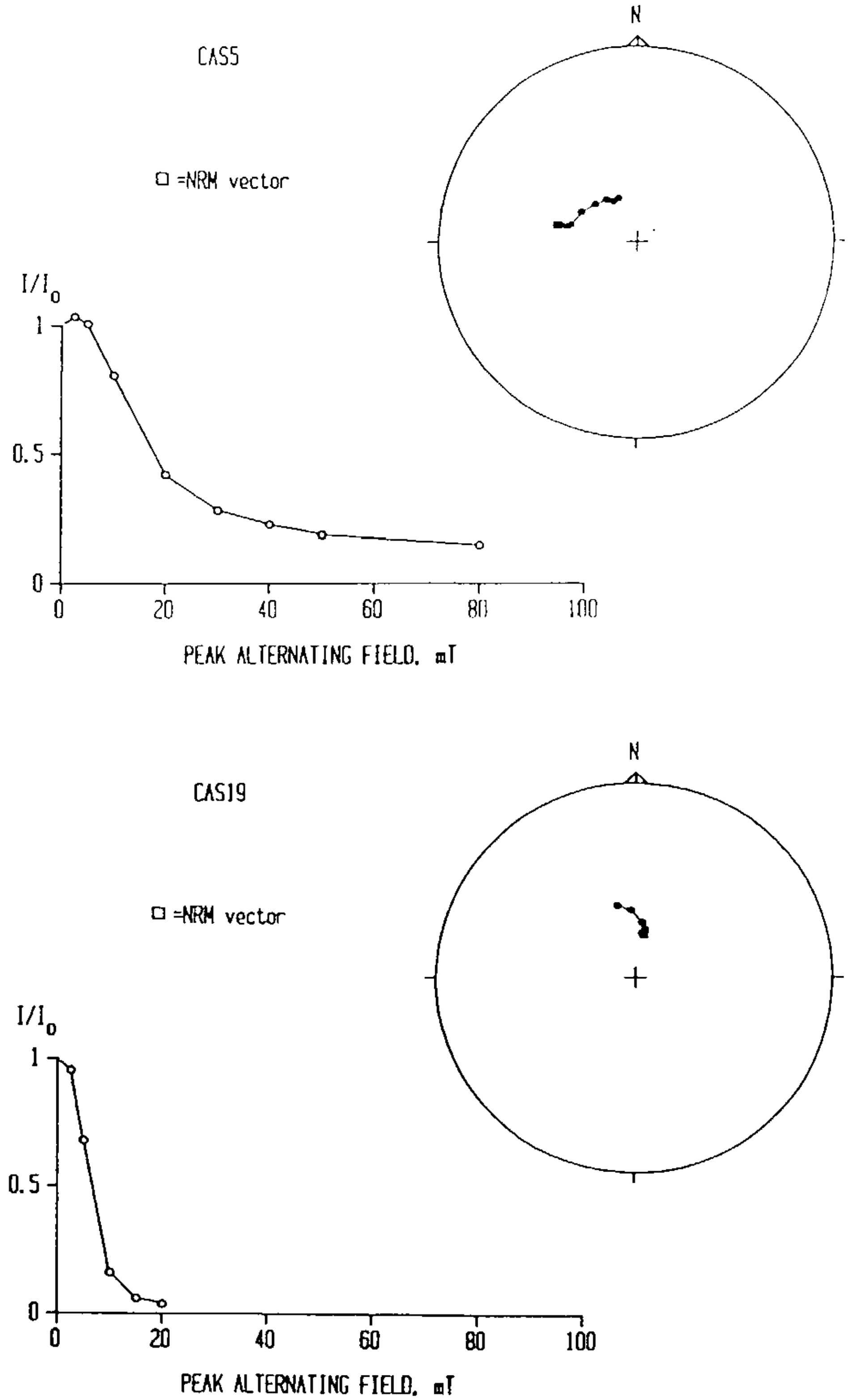

FIGURE 4

Changes in the strength and direction of the magnetisation in pilot specimens during partial demagnetisation (furnace at top). Results are portrayed as normalised changes in remanence intensity with a stereogram.

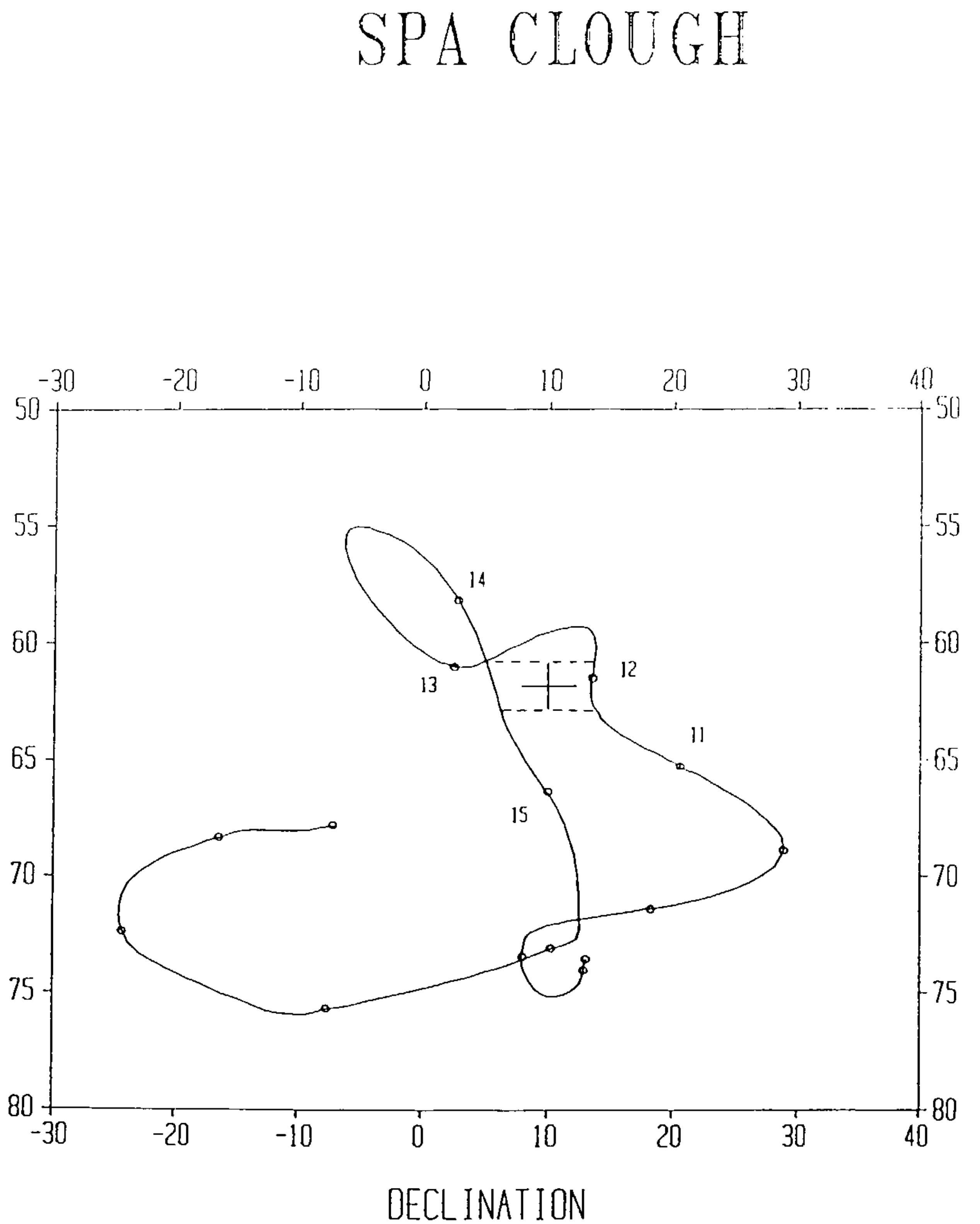

FIGURE 5

Comparison between the mean archaeomagnetic vector in the burnt clay corrected to Meriden (red) and the UK master curve 600 AD - present. The vector is consistent with a medieval firing date.