Westmeath County Council
In Partnership with
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&
Kildare County Council

KINNEGAD – ENFIELD - KILCOCK

ARCHAEOLOGICAL CONSULTANCY SERVICES
CONTRACT 1

Draft Report On
Archaeological Excavation
At Hardwood 3
County Meath
Licence Number 02E1141

A.C.S Ltd

PROJECT DETAILS

Project	Archaeological Excavation
Road Scheme	M4 Kinnegad–Enfield–Kilcock Motorway Scheme, Contract 1
Archaeologist	Deirdre Murphy
Client	Westmeath County Council, County Buildings, Mullingar, County Westmeath
Site	Hardwood 3, County Meath
Townland	Hardwood
Parish	Clonard
Nat. Grid Ref.	260769, 244641
RMP No.	N/A
Licence No.	02E1141
Planning Ref.	N/A
Project Date	26th August 2002
Report Date	16th January 2004

NON-TECHNICAL SUMMARY

Archaeological test trenching was carried out in advance of construction along the route of the proposed M4 Kinnegad-Enfield-Motorway Scheme. In February 2002 during centreline testing of the proposed route carried out by Ian Russell under licence 02E0108 of Duchas, The Heritage Service, a number of possible archaeological features were identified. The site was subsequently designated Hardwood 3 and was excavated in August 2002 under licence 02E1141.

The principal features excavated on this site consisted of bowl hearths associated with iron smelting. There were seven pits of which four were identified as bowl hearths whilst the other three may have been connected to the industrial process. In addition was a rectangular pit with dimensions of *c*.2.80m by *c*.1.15m with a maximum depth of *c*.0.27m. The pit had an oxidised base and sides and the lower fill consisted of charcoal that had not been disturbed from the time when the wood had been carbonised. It is the survival of this pit and its fill that has allowed similar features on sites in the near vicinity to be identified as charcoal-producing kilns. A shallow ditch formed an enclosure in the southeastern corner of the stripped area. The enclosure is likely to be of fairly recent date. No finds were associated with the other features. Radiocarbon dates provide evidence of activity over a wide period with bowl hearths dated to the Iron Age and the early post-medieval period whilst the charcoal-producing kiln dated to the Early Christian period.

CONTENTS

1. INTRODUCTION

This report gives an account of the archaeological excavation of a site identified at Hardwood 3 (County Meath OS six-inch sheet 46, 645mm from the west margins and 502mm from the south margin, NGR 260769, 244641). Hardwood 3 is located to the south east of Kinnegad and to the south of the Kinnegad–Enfield road in the parish of Clonard, Hardwood townland, County Meath.
A number of possible features were exposed during centreline trenching within the proposed road corridor under licence number 02E0108 issued by *Dúchas* The Heritage Service to Ian Russell. The site was subsequently designated Hardwood 3.
The excavation was carried out in advance of the construction of the M4 Kinnegad-Enfield-Kilcock Motorway Scheme.

2. THE DEVELOPMENT

2.1 The Site

The site was identified during archaeological testing of the M4 Kinnegad-Enfield-Kilcock Motorway Scheme under licence number 02E0108 issued by *Dúchas* The Heritage Service, Department of the Environment and Local Government, to Ian Russell. As the proposed road would have a direct impact upon the site, a full archaeological excavation was conducted under licence number 02E1141 issued to Deirdre Murphy by *Dúchas* The Heritage Service from 26th August -11th September 2002.

2.2 Proposal

Hardwood 3 is located along the proposed route of the M4 Kinnegad–Enfield–Kilcock Motorway. This scheme comprises approximately 35km of motorway commencing to the west of Kinnegad in County Westmeath and continuing in an easterly direction through counties of Meath and Kildare and terminating at the western end of the existing motorway at Kilcock. The route shall include junctions and an interchange and other structures such as over-bridges and under-bridges as required to allow the continued flow of traffic on the existing road network. The proposed scheme ties into the existing M4 to the west of Kinnegad.

3. ARCHAEOLOGICAL EXCAVATION

3.1 Archaeological and Historical Background

Situated in Clonard parish, Upper Moyfenrath barony, County Meath, this townland was referred to as 'Harwood' in the Civil Survey. It is bound on the west and northeast by Kinnegad and Aghamore townland, County Westmeath; on the northeast by Kilwarden townland; on the east by Aghnagillagh and Ardnamullan townlands; on the southeast by Ticroghan townland; and on the west by Rossan townland. The Kinnegad River bounds Hardwood on the north and northwest for a distance of 1.5 miles (2.4km). In 1837, Hardwood comprised 714 statute acres and was the property of Mr. Cokely, a stipendiary magistrate from County Carlow who let the townland in 6–25 acre farms (Lewis 1837). The Ordnance Survey team noted that the land varied in quality with some of it comprising worn-out bog over tillage. The townland contained numerous dwellings, all poor cabins. There was an open graveyard in the centre of Hardwood and a deep ditch had been cut through the townland for the Royal Canal but this was later condemned. The abandoned canal ditch is marked and labelled as such on the first edition OS map of that year (Name Books).

3.2 Stratigraphical Report

Turf and Topsoil C001, Natural Subsoil C002

The field had been used for grain production involving deep ploughing and the topsoil extended to a depth of *c.*0.50m and consisted of a medium brown friable sandy clay/loam. Except where it overlay other features, the topsoil directly overlay the natural subsoil which consisted of compact orange/brown clay with numerous limestone inclusions ranging broadly in size.

Recent Features

Plough Furrows C014 and C017

The underlying features within the site had been considerably truncated by ploughing which possibly extended back to the medieval period but which has caused considerably more damage in recent years with the increased depth of ploughing. The site was traversed by plough furrows that had an average width of *c.*0.40m and they ran generally from north to south. These features were not examined in depth except where they interfered with earlier features.

Enclosure C068, Fill C067 (Figures 5 & 6)

Within the southwestern corner of the stripped area was the corner of a rectilinear enclosure which was bounded by a ditch. The ditch was *c.*0.80m wide and *c.*0.20m deep with a shallow U-shaped profile. The base was irregular in parts and it appeared that the ditch might have been excavated in order to plant a hedged boundary. The fill consisted of medium-brown sandy clay. There was a suspicion that an entrance to the enclosure existed in the northern section of the ditch but this was not pursued due to the modern nature of the feature.

Pit C064, Fill C038

This feature consisted of a rectangular cut to the west of the stripped site. The dimensions were *c.*3.94m running from northwest to southeast whilst the width was *c.*0.98m. The longer sides had vertical faces whilst the form of the short sides made it apparent that this was a machine-cut trench excavated to a depth of *c.*1.00m for no apparent purpose. Its fill consisted of:

C038 Re-deposited natural mixed with topsoil containing a small collection of modern finds.

Oxidised Clay C074

The site was characterised by occasional areas of oxidised clay, burnt red by extreme heat. These features could not be dated or positively interpreted. They may have been associated with the archaeologically-evident industrial processes on the site or with land clearance at a later or indeed earlier period.

Charcoal Spreads C007

Another aspect of the site was the scatter of charcoal spreads. These had no depth to them and were generally small and irregular. It seemed probable that these could have been associated with the tree or scrub burning of land clearance or possibly the traces of features truncated by ploughing in recent times.

Tree Boles and Root Holes C008, C009, C010 (Cut C046), C011, C012, C013, C019, C020, C021, C026, C027, C028 (Cut C066), C031, C032, C039, C040, C041, C047, C048, C059 and C065

A further aspect of the site was the spread of negative features which on excavation proved to consist of tree root holes. These were frequently but not invariably associated with burning of the surrounding clay and some charcoal flecking within their fills. These features were all examined but not definitively recorded once their identity had been discovered. They must relate to a time of land clearance when the previously wooded or forested land was reclaimed for agricultural purposes.

Possible Iron Smelting Features

Pit/Charcoaling platform C055, Burning C077, Fills C029, C053 and C054 (Figure 6)
This feature consisted of a rectangular pit with the longer sides running from northeast to southwest (OD 76.84m). The dimensions were *c*.2.80m by *c*.1.15m with a maximum depth of *c*.0.27m. The pit had rounded corners and the sides sloped gently to an uneven base. The sides and base had been burnt red (oxidised) from severe heat. From the top, the fills consisted of:

C029 Yellow/brown silty clay with occasional small stone inclusions and frequent charcoal flecks.

C053 Soft black silty clay with very high charcoal content and a maximum depth of *c*.0.12m.

C054 This layer consisted of carbonised lengths of wood generally running along the long axis of the pit. The carbonised wood constituted nearly 100% of the deposit with a matrix of black silty clay. The wood came from tree branches and had not been worked.

This pit is one of a number which have been excavated in the vicinity during this current project. The usage of these pits was generally uncertain but the discovery of this pit with the large quantities of charcoal puts the matter beyond doubt that these pits, found in close association with iron-smelting bowl hearths, were excavated as part of the process of turning wood into charcoal. A radiocarbon date range of Cal 720-740 AD and Cal 760-960 AD was returned for this feature.

Bowl Hearths

Smithing Pit C044, Burning C049, Fills C003 and C005. Cut C045, Fill C042 (Figure 7)
This feature consisted of a subcircular pit with a diameter of *c*.1.50m and a maximum depth of *c*.0.25m (OD 76.01m). The sides sloped gently and had been oxidised (burnt red) by extreme heat (C049). The base of the pit appeared to have been disturbed as the oxidised clay did not extend across the base of the pit and a very slight cut was apparent (C045) and this was filled by C042, a grey/brown sandy clay. A radiocarbon date of Cal 1440-1640 AD was returned from C005 the primary fill of this feature. No disturbance was visible in the upper fills of C044. These consisted of:

C003 Yellow/brown sandy clay with occasional small stone inclusions.

C005 Near-black silty clay with a very high charcoal content.

Bowl hearth C052, Burning C073, Fills C022 and C051 (Figure 7)

This feature consisted of a circular pit with a diameter of *c*.0.48m and a maximum depth of *c*.0.18m (OD 76.72m). The sides and base form a bowl with steeply sloping sides. The sides and base had been burnt red by extreme heat (oxidised, C073). A radiocarbon date of Cal 380-60 BC was returned from C051 the primary fill of this feature. From the top, the fills consisted of:

C022 Yellow/orange sandy clay with occasional small stone inclusions.

C051 Grey/brown sandy clay with frequent charcoal inclusions.

Bowl hearth C063, Burning C016, Fills C024, C060, C061, C062 and C070 (Figure 8)
This feature consisted of a circular pit *c*.0.70m in diameter and with a maximum depth of *c*.0.30m (OD 76.60m), the deeper part being a depression in the eastern part of the pit. The sides and base of the pit had been burnt red (oxidised) by extreme heat (C016). From the top, the fills consisted of:

C024 Compact orange clay with slight yellow hue and inclusions of off-white and grey clay. Slag fragments were found at the interface between this layer and the underlying layer.

C060 Medium-brown clay with a red hue. The deposit contained frequent flecks of charcoal and only occasional small stones.

C061 Dark-grey/brown (black) silty clay with a high concentration of charcoal inclusions.

C062 Compact blue/grey clay with occasional small stone inclusions. This layer occurred at the top of the pit and ran around the entire perimeter.

C070 Soft brown sandy clay with a red hue and occasional small stone inclusions. This deposit would appear to be silting within the pit prior to its use as a hearth.

Bowl hearth C034, Burning C072, Fills C023 and C033 (Figure 8)
This feature consisted of a subcircular pit with a diameter of *c*.0.80m and gently sloping sides to a maximum depth of *c*.0.10m (OD 76.80m). The base and sides of the pit had been burnt red by extreme heat (C072) to a depth of *c*.0.04m. From the top, the fills consisted of:

C023 Soft medium grey/brown sandy clay with occasional small stone inclusions and very occasional charcoal flecks.

C033 Black sandy silt with a very high charcoal content.

Bowl hearth C056, Fill C025 (Figure 9)

This feature consisted of an irregular circular pit with a diameter of *c*.0.65m and a maximum depth of 0.08m (OD 76.96m). The sides sloped gently to a bowl-shaped base. There were slight indications of burning (oxidisation) on the base and sides of the pit. The fill consisted of:

C025 Dark-grey/brown sandy clay with occasional small stone inclusions and some charcoal.

Smithing Pit C058, Fill C030 (Figure 9)

This feature consisted of an oval pit with dimensions of *c*.1.50m running from southwest to northeast and *c*.0.90m on the shorter width. The pit had a maximum depth of *c*.0.45m (OD 76.93m) and irregularly-sloping sides. The fill consisted of:

C030 Dark-grey/brown sandy clay with *c*.10% small stone inclusions and occasional charcoal flecks. The fill contained considerable quantities of slag but the lack of any trace of *in situ* burning would suggest that the pit is a dump of slag rather than a hearth.

The pit was excavated into an area of orange/brown sandy clay which proved to be a tree bole (C057).

Depression C076, Burning C069, Fill C004

This feature consisted of a very shallow (*c*.0.01m deep) rectangular depression with dimensions of *c*.0.83m from northwest to southeast by *c*.0.66m. The depression had been burnt red by heat (oxidised, C069) and had evenly rounded corners. The fill consisted of:

C004 Soft dark-brown (black) sandy clay with occasional small stone inclusions and a high charcoal content.

Smithing Pit C075, Fill C006 (Figure 10)

This feature consisted of an oval cut with the longer axis running from east to west and being *c*.1.20m long whilst the other axis was *c*.0.90m. The sides sloped gently to a flat base with a maximum depth of *c*.0.12m (OD 76.061m). Only faint traces of oxidisation on the natural clay were visible. The fill was:

C006 Dark-grey/brown sandy clay with a slight yellow hue. The deposit had occasional small stone inclusions and was rich in charcoal, especially in the eastern part.

3.3 List of Contexts

C001 Turf and topsoil

C002 Natural subsoil

C003 Fill of C044

C004 Fill of C076

C005 Fill of C044

C006 Fill of C075

C007 Charcoal spread/tree root

C008 Charcoal spread/tree root

C009 Charcoal spread/tree root

C010 Charcoal spread/tree root

C011 Fill of C059/tree root

C012 Charcoal spread/tree root

C013 Charcoal spread/tree root

C014 Plough furrows (x3)

C015 Not used

C016 Oxidised clay in C063

C017 Plough furrows (x3)

C018 Not used

C019 Charcoal spread/tree root

C020 Tree root

C021 Tree root

C022 Fill of C052

C023 Fill of C034

C024 Fill of C063

C025 Fill of C056

C026 Tree root

C027 Charcoal spread/tree root

C028 Fill of C066/tree root

C029 Fill of C055

C030 Fill C058

C031 Spread/tree root

C032 Spread/tree root

C033 Fill of C034

C034 Bowl hearth

C035 Not used

C036	Not used
C037	Not used
C038	Fill of C064
C039	Pit/tree root
C040	Burnt spread/tree root
C041	Burnt spread/tree root
C042	Fill of C045
C043	Oxidised clay within C042
C044	Bowl hearth
C045	Re-cut pit in C044
C046	Tree root
C047	Fill of C048/tree root
C048	Tree root
C049	Oxidised clay in C044
C050	Not used
C051	Fill of C052
C052	Bowl furnace
C053	Fill of C055
C054	Fill of C055
C055	Pit/Charcoaling platform
C056	Bowl hearth
C057	Tree bole
C058	Smithing pit
C059	Tree root
C060	Fill of C063
C061	Fill of C063
C062	Fill of C063
C063	Bowl hearth
C064	Rectangular pit
C065	Tree root
C066	Tree root
C067	Fill of C068
C068	Ditch of rectilinear enclosure
C069	Oxidised clay in C076
C070	Fill of C063
C071	Not used

C072	Oxidised clay in C034
C073	Oxidised clay in C052
C074	Oxidised clay
C075	Smithing pit
C076	Depression
C077	Oxidised clay in C055

3.4 List of Finds

The site was remarkable for its paucity of finds. Those that were recovered were modern and were only useful for indicating the very recent date of the features from which they came.

02E01141:053:1	Single fragment of modern pottery
02E01141:038:1-2	Two fragments of glass
02E1141:038:3	One oyster shell
02E1141:038:4	One piece of clay pipe stem
02E01141:038:5-8	Four pieces of modern pottery

3.5 List of Samples

Sample No.	**Context**	**Description**
1	C033	Soil with charcoal content, flotation
2	C061	Charcoal for C14
3	C054	Soil with charcoal content, flotation
4	C025	Soil, flotation
5	C060	Soil, flotation
6	C061	Soil, flotation
7	C006	Soil, flotation
8	C005	Soil, flotation
9	C051	Soil, flotation
10	C004	Soil, flotation
11	C051	Charcoal
12	C005	Soil, flotation
13	C053	Charcoal rich
14	C053	Charcoal rich
16	C029	Slag
17	C030	Slag
18	C060	Slag

20	C025	Slag
21	C060	Charcoal
22	C024	Slag

4. CONCLUSIONS

This archaeological features identified at Hardwood 3 show consistent similarity to features at Hardwood 2, Ardnamullen 1, Kinnegad 2, Rossan 4 and Griffinstown 3. The principal features excavated on this site consisted of bowl hearths associated with iron smelting. There were seven pits of which four (C056, C052, C063 and C034) were identified as bowl hearths whilst the other three (C044, C058 and C075) may have been smithing pits also connected to the industrial process. In addition a rectangular pit (C055) with dimensions of c.2.80m by c.1.15m with a maximum depth of c.0.27m was identified. The pit had an oxidised base and sides and the lower fill consisted of charcoal that had not been disturbed from the time when the wood had been carbonised. It is the survival of this pit and its fill that has allowed similar features on the above mentioned sites to be identified as charcoal-producing kilns.

Four samples from this site were sent for wood identification (Appendix 1). Two were from the fills of bowl hearths (C005 and C051) and the wood used was oak. Two separate samples were from a charcoal burning kiln (C053 and C054) and the wood identified was alder. All four of these samples were sent for radiocarbon dating (Appendix 2) and the results returned gave a date of AD 770-970 and AD720-960 for the charcoal burning pit, BC 380-60 for bowl hearth C052 and AD1440-1640 for bowl hearth C044. Three very distinct periods of activity were represented, spanning the period between the Iron Age and the early post-medieval. Despite the time span all features were probably connected with the metalworking industry.

The majority of features excavated on this site and others in the area have been associated with the iron smelting industry. Amongst these features are rectangular pits measuring on average *c.*2.00 x *c.*1.20m. These pits tend to have rounded corners and an average depth of *c.*0.15m although this measurement is probably not relevant due to truncation of all features by recent deep ploughing. At Hardwood 3 these pits were associated with extensive deposits of charcoal.

Charcoal was the fuel used to smelt iron in the early smelting industry and it is likely that these rectangular pits were used as charcoal burning kilns. The method of turning wood into charcoal must have developed with the advent of metallic technology in the Bronze Age. In this case, the process would appear to have involved the excavation of the pit which was then loaded with timber, possibly to a height of *c.*1.00m. In recent experimental firings, the timber has been placed against a vertical post which was later removed. The timber would have then been covered in straw or bracken and then a layer of earth and possibly turf was laid over the whole pile. Strategic gaps would be created within this top covering in order to aid airflow within the kiln. As stated previously, the vertical timber post would then have been removed and the resultant hole would be filled with charcoal which would then be ignited.

The skill in the creation of charcoal was in controlling the fire within the kiln to create temperatures of c.600c which would drive off water and other impurities within the wood but which would not allow the wood to actually burn. The wood is effectively being roasted in a reducing atmosphere. As the wood is transformed into charcoal, the timber shrinks and causes cracks to appear within the outer earthen case of the kiln. Such cracks as they appear have to be repaired immediately as an uncontrolled ingress of air could cause the whole kiln to explode into flames. The process of turning timber into charcoal takes a number of days and requires twenty-four hour a day supervision. Eventually, the kiln is sealed and the fire is allowed to die out. After a considerable period of cooling, the kiln can be dismantled and the charcoal extracted.

A number of features excavated on this site have been interpreted as bowl hearths or furnaces (Appendix 3). These features were used in the process of making iron from iron ore. The process follows a logical progression in which iron ore is obtained from mining. The ore is then dressed before use. This process involves hammering the mineral nodules to produce smaller pieces whilst removing impurities and/or roasting it in a roasting kiln. This again removes some chemical impurities and makes the ore easier to crush into smaller pieces. The bowl furnace is constructed by excavating a bowl-shaped pit into the ground above which a conical chimney made of clay is frequently built. A hole or holes pierce the sides of the chimney at the base and tubes (known as *tuyeres*) attached to bellows are used to force air into the charged furnace.

The furnace is charged by using charcoal, followed by the prepared ore, followed by more charcoal. The proportion of charcoal to iron ore required must be at least 2:1 but would generally be greater. Once the furnace has been charged and the bellows employed, the temperature within the furnace is raised to *c*.1200 degrees centigrade. The charcoal produces a reducing atmosphere within the kiln and impurities within the iron ore either melt or are burned away, allowing the iron to consolidate and sink towards the bottom of the kiln in the form of a bloom. This consists of a spongy mass of iron particles which will require further treatment. The by-products of this process are ash and large quantities of slag which are frequently still rich in iron. Once this smelting process is complete, the superstructure of the furnace is dismantled in order to gain access to the all-important bloom. This is then cleaned of adhering slag and ash and hammered to drive out impurities. During the next process of forging, heat and hammering will be used to drive out further impurities, cause the iron fragments within the bloom to weld into a solid mass and ultimately produce a tool or weapon.

Although we have recovered the bases of the bowl furnaces and a quantity of slag, there are many elements which might have appeared within the archaeological record but which one must assume have been lost due to the truncation of features and surrounding ground surfaces by recent deep ploughing. Baked clay from the kiln superstructures occasionally appears in the archaeological record. This sometimes contains the imprint of the hole that would have taken the *tuyere.* Likewise, fragments of iron ore, tools and associated occupation debris might occur. None of this type of material has been found on any of the sites excavated during this scheme.

The features excavated illustrate a landscape which was wooded, probably in the form of woodland managed by coppicing. The method of coppicing involves the chopping of wood from a tree in such a manner that the tree is not killed. This coppicing means that the roots of the tree gain great nutrients for the amount of timber they now support. This allows a rapid re-growth of wood on the tree and allows further coppicing to be undertaken as frequently as twelve yearly intervals. A further benefit of coppicing is the thinning of the woodland canopy, thus allowing more sunlight to benefit the individual trees. The coppiced wood is then turned into charcoal and this is then used to smelt iron as described above. The source of the iron ore has not yet been established but analysis of the excavated slag deposits may well provide information on this aspect of the excavation.

This type of industrial activity is by nature transient. The charcoal burner and ironsmith would have had to move from area to area in order to access new supplies of wood as previously coppiced areas regenerated. The lack of any indication of occupation on these sites can be explained. Because of the intermittent nature of the industry, only insubstantial huts would have been constructed as temporary shelters whilst work was ongoing. It seems highly likely that the work was seasonal and that the workers would have returned to more substantial areas of permanent settlement to create the finished products of their work, be it weapons or agricultural implements.

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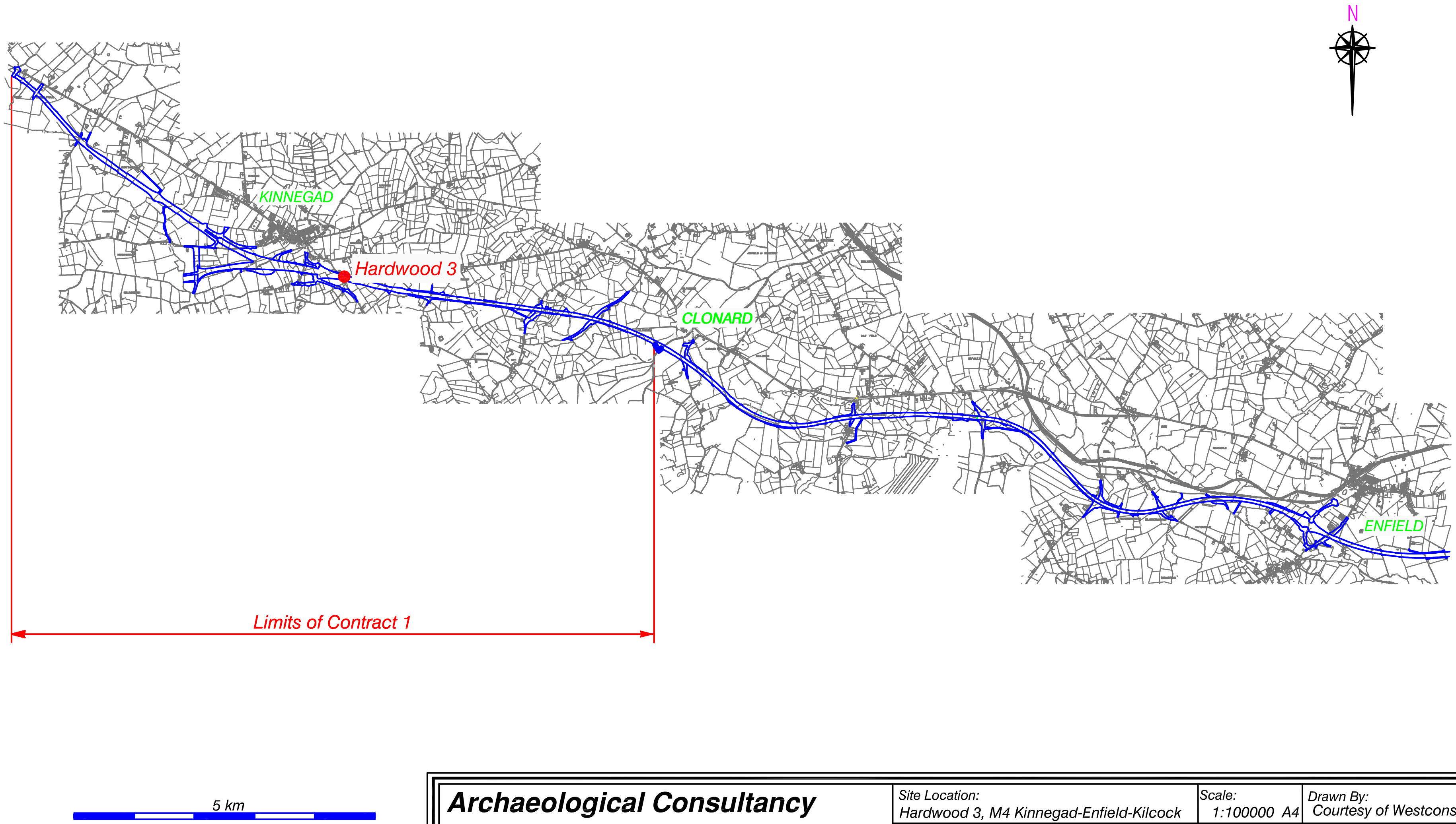
Record of Monuments and Places (RMP), formerly the Sites and Monuments Record (SMR), of *Dúchas* The Heritage Service, Department of Arts, Heritage, Gaeltacht and the Islands, 7 Ely Place Upper, Dublin 2.

Topographical Files of the National Museum of Ireland, Kildare Street, Dublin 2.

Signed:

Deirdre Murphy, Archaeologist

16th January 2004



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	Client: Westmeath County Council	Date: 12 Dec 02	Drawing No.: 01_80_C422

Figure 1: Location of Hardwood 3

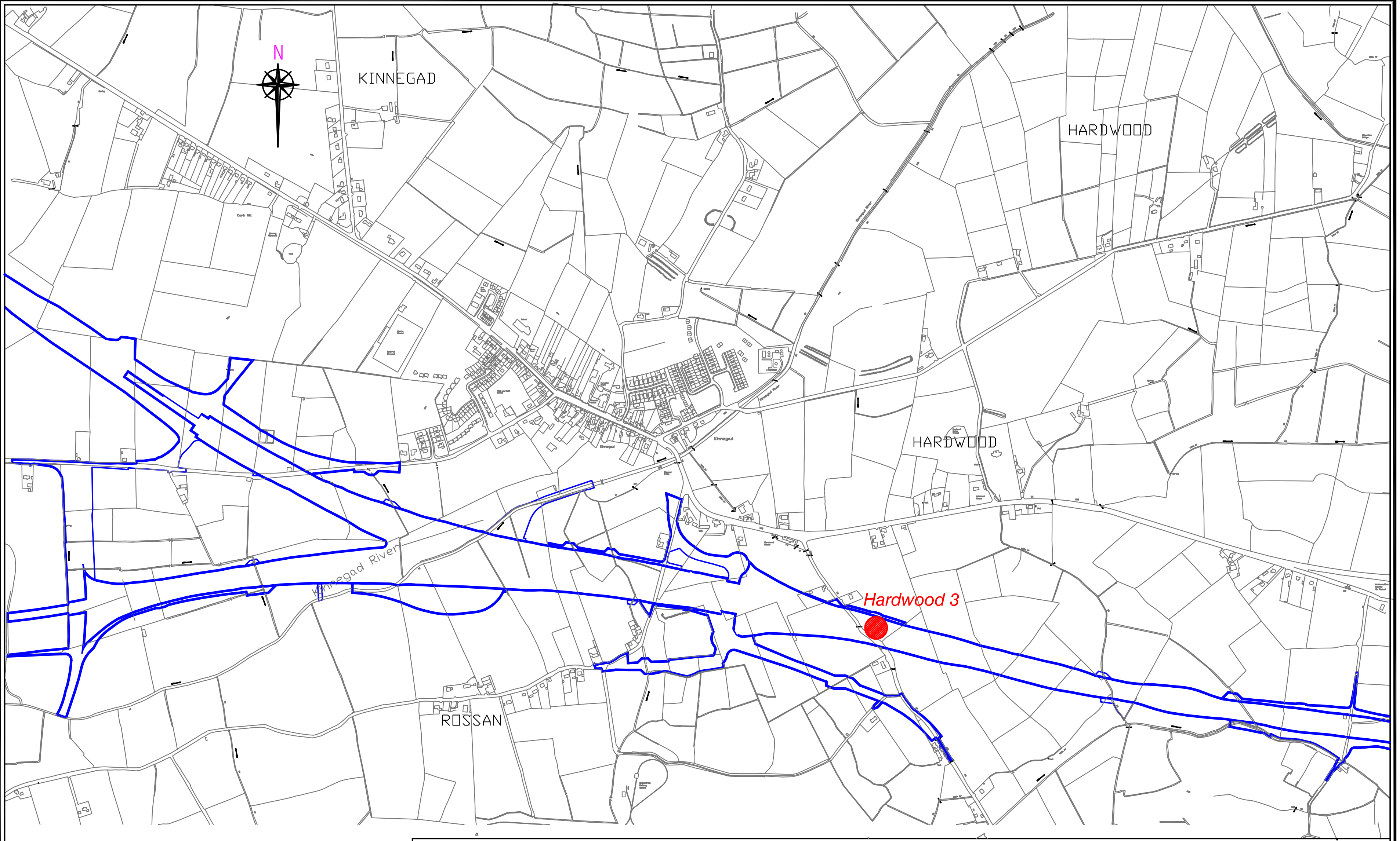

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Figure 2: Detailed location of Hardwood 3

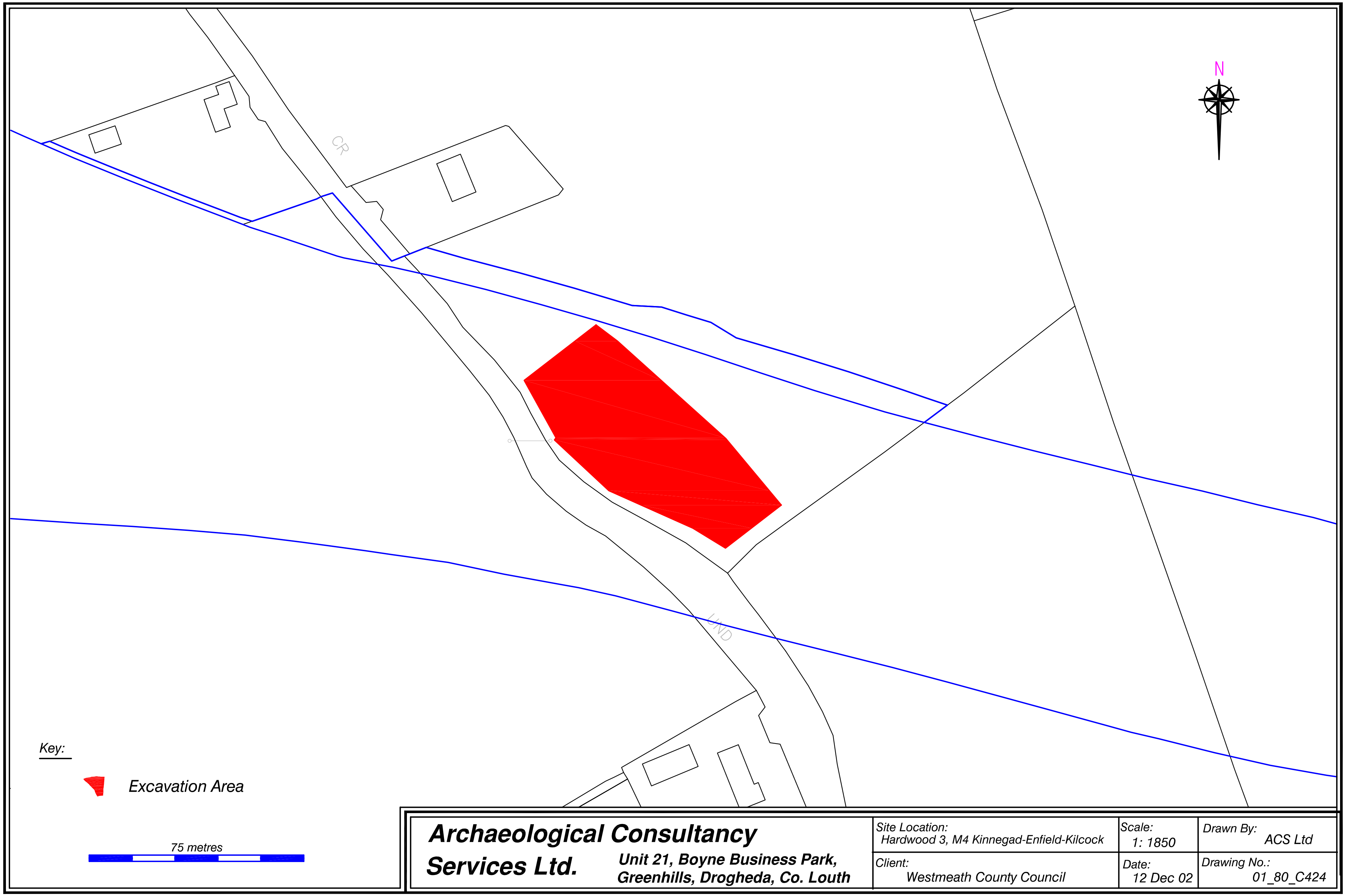


Figure 3: Hardwood 3, area of excavation

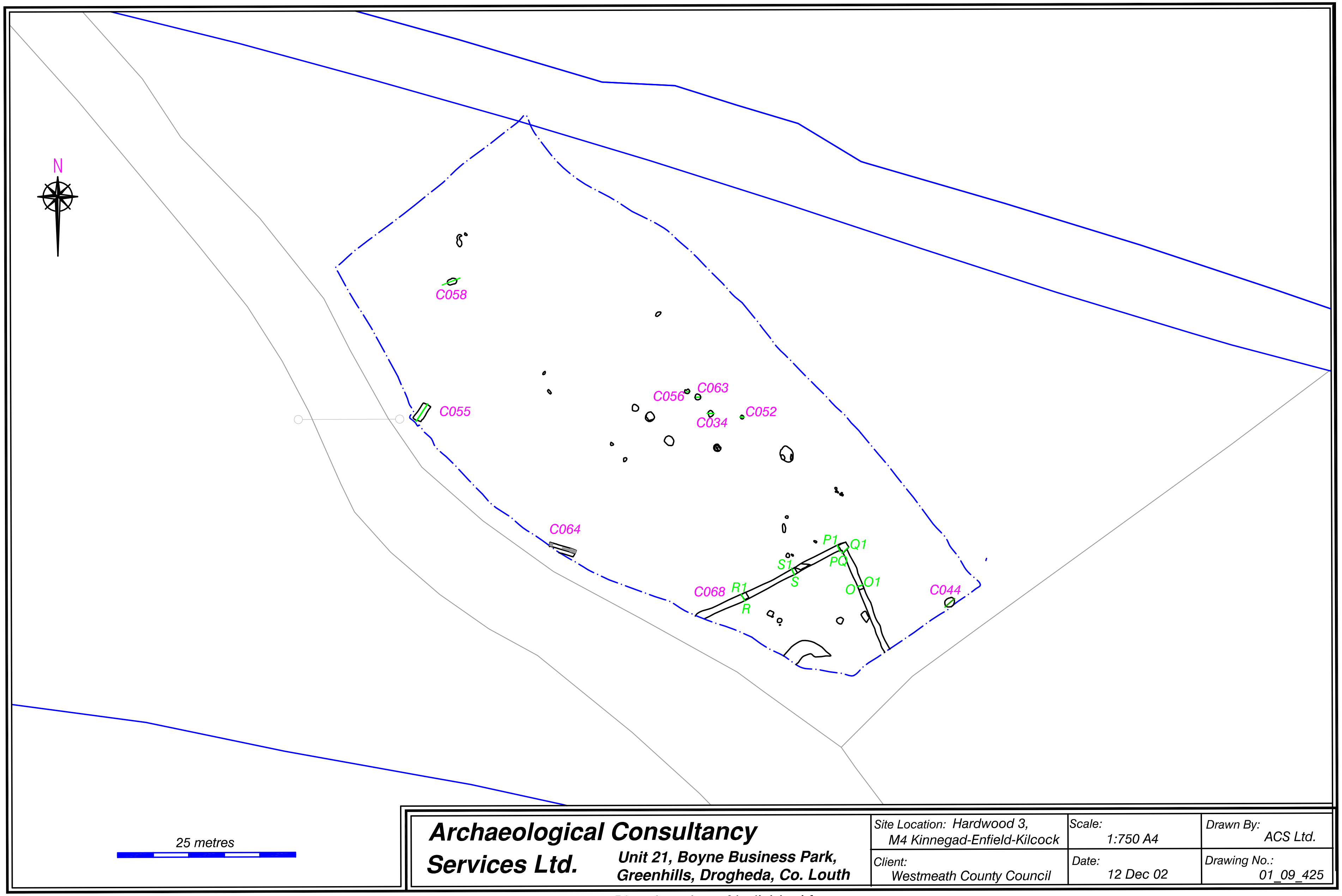
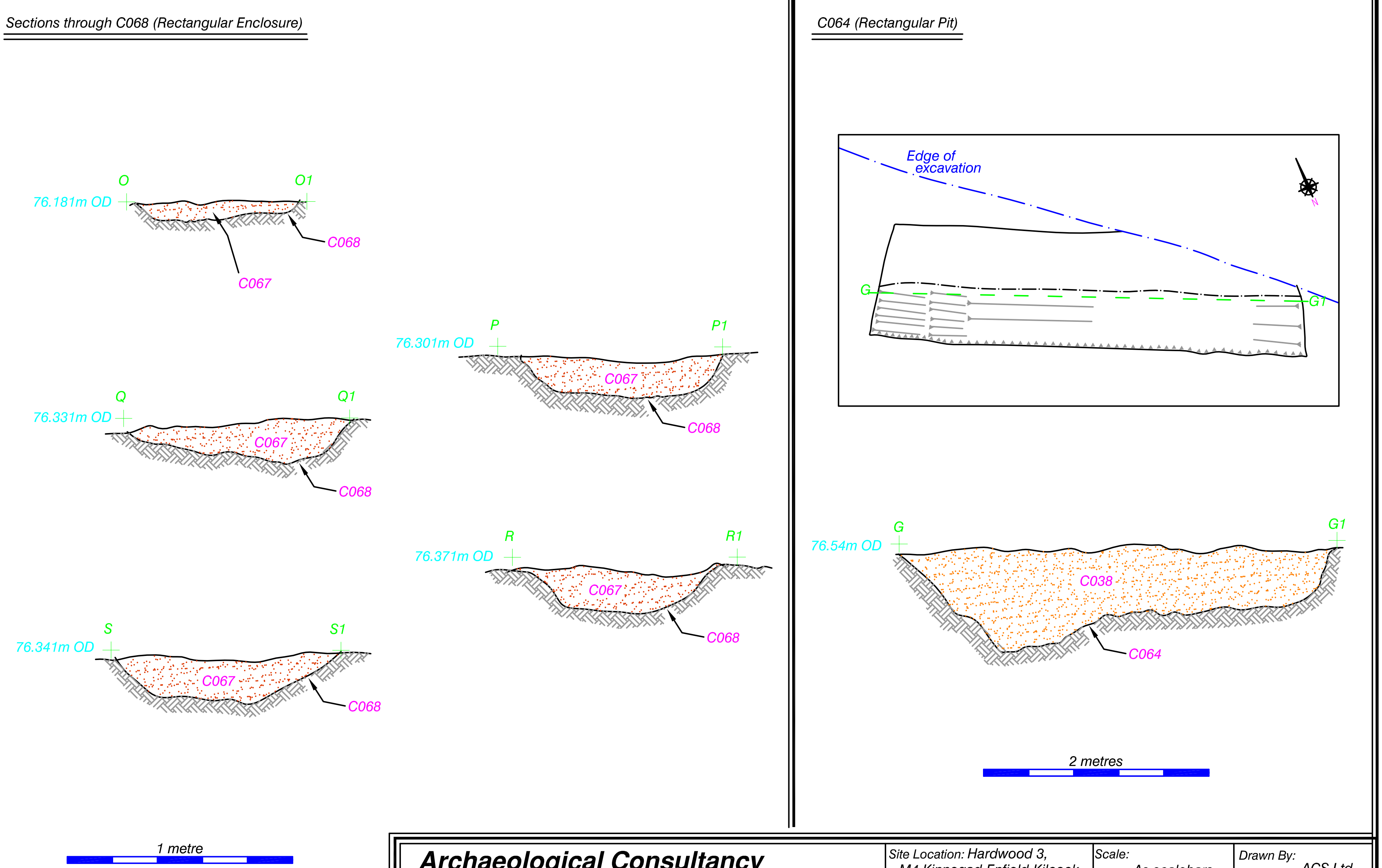


Figure 4: Plan, location of individual features



Archaeological Consultancy Services Ltd. Unit 21, Boyne Business Park, Greenhills, Drogheda, Co. Louth	Site Location: Hardwood 3, M4 Kinnegad-Enfield-Kilcock	Scale: As scalebars	Drawn By: ACS Ltd.
	Client: Westmeath County Council	Date: 16 Dec 02	Drawing No.: 01_80_C426

Figure 5: C068 and C064, sections

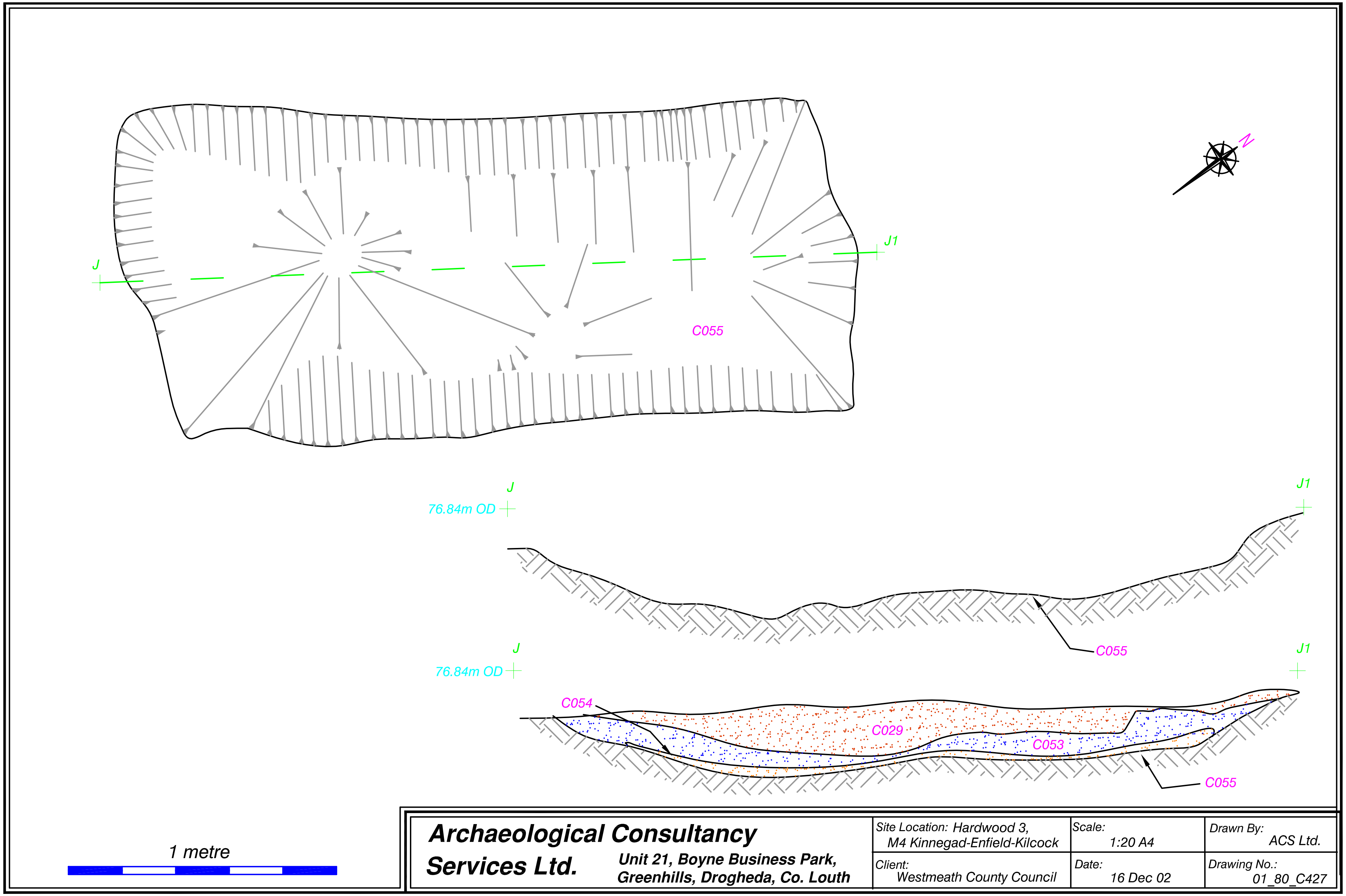


Figure 6: C055, post-excavation plan, section and profile

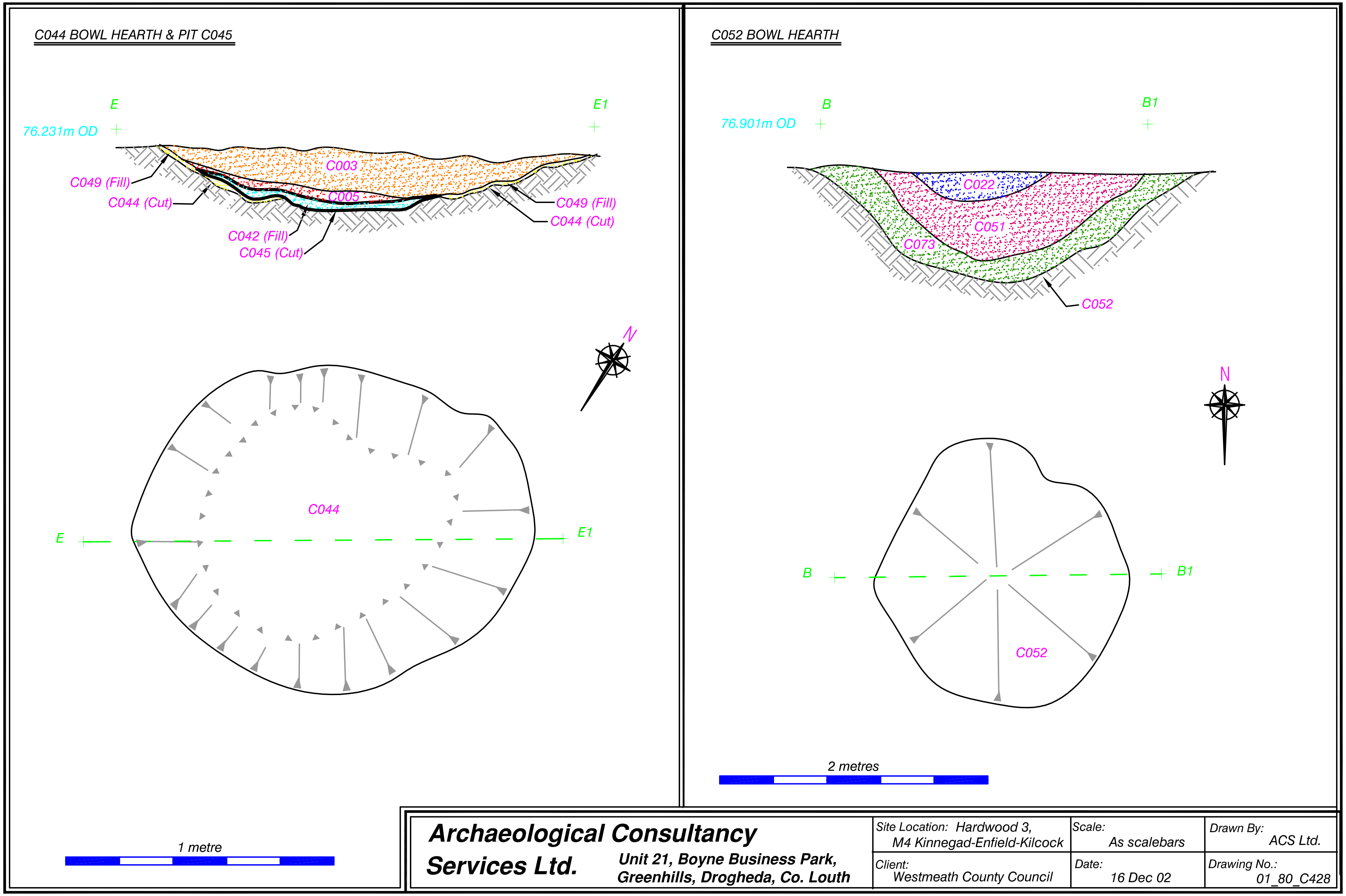
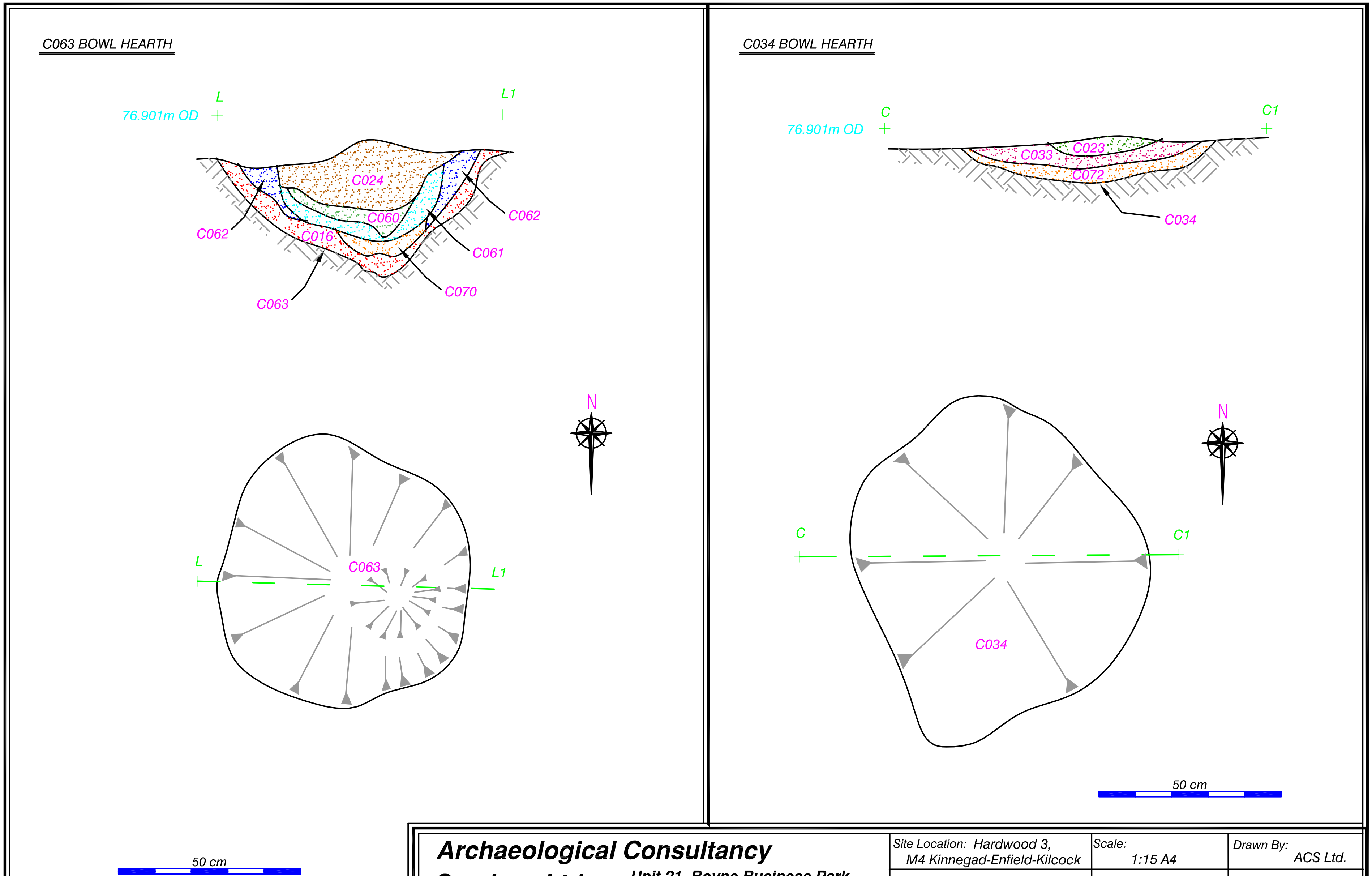


Figure 7: C044 and C052, post-excavation plans, sections and profiles



Archaeological Consultancy Services Ltd.
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Site Location: Hardwood 3, M4 Kinnegad-Enfield-Kilcock	Scale: 1:15 A4	Drawn By: ACS Ltd.
Client: Westmeath County Council	Date: 17 Dec 02	Drawing No.: 01_80_C429

Figure 8: C063 and C034, post excavation plans, sections and profiles

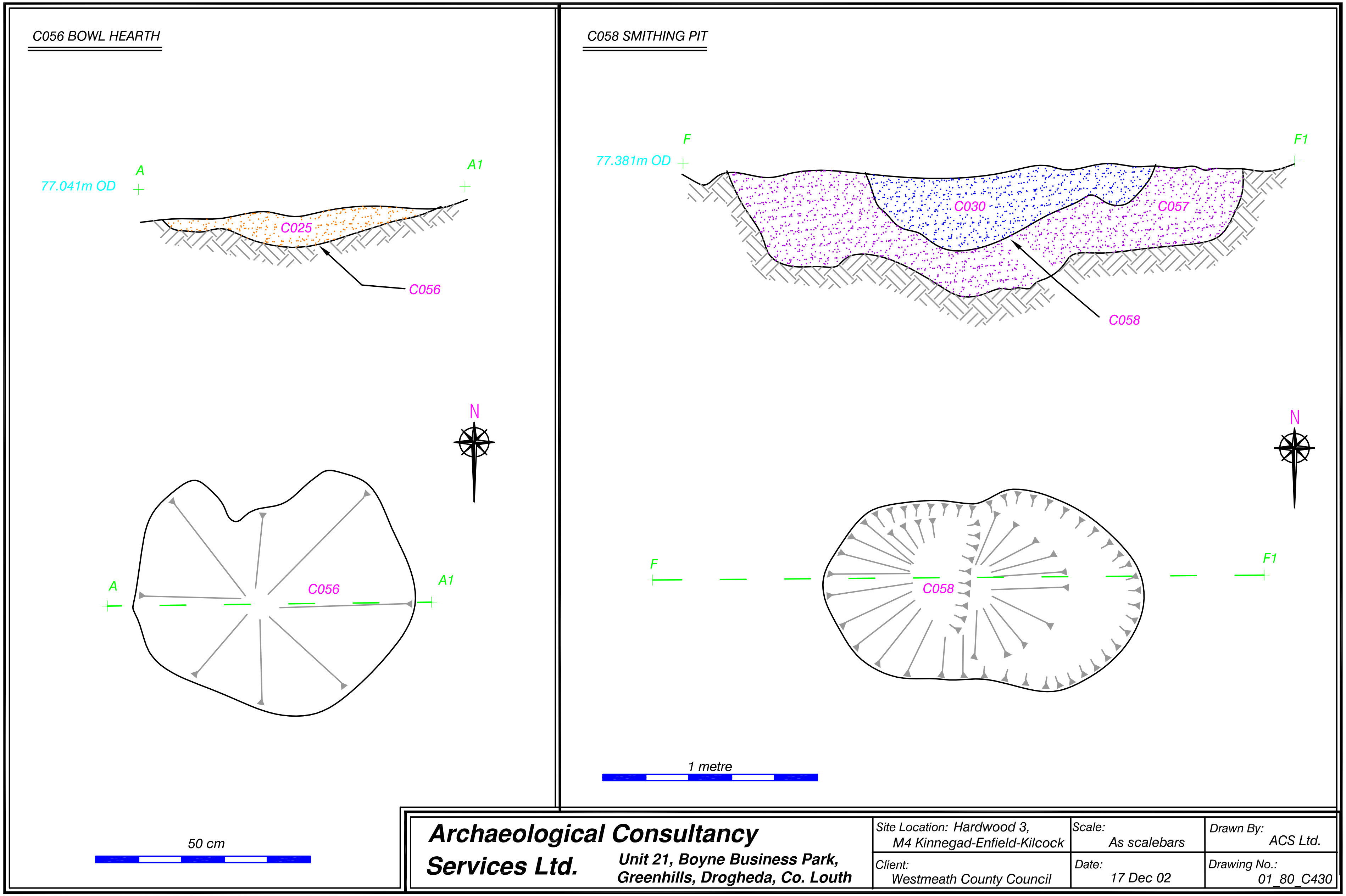
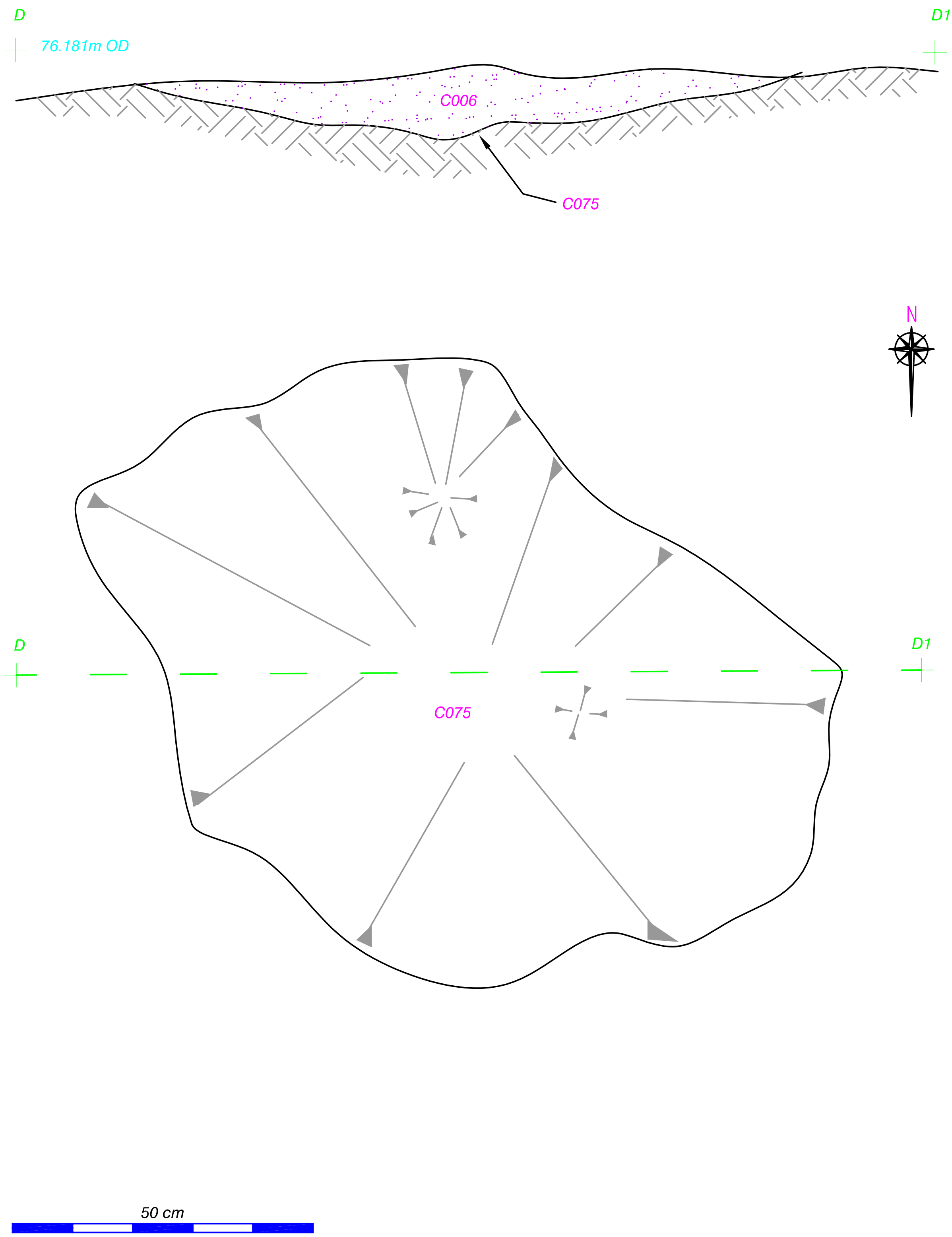


Figure 9: C056 and C058, post-excavation plans, sections and profiles



Archaeological Consultancy Services Ltd. Unit 21, Boyne Business Park, Greenhills, Drogheda, Co. Louth

Site Location: Hardwood 3, M4 Kinnegad-Enfield-Kilcock	Scale: 1:10 A4	Drawn By: ACS Ltd.
Client: Westmeath County Council	Date: 19 Dec 02	Drawing No.: 01_80_C431

Figure 10: C075, post-excavation plan and section.

Plate 1: Enclosure ditch C038 showing area of possible entrance, looking east.

Plate 2: C068, section, looking west.

Plate 3: Pit C064, sectioned, looking north.

Plate 4: Pit C055, pre-excavation, looking north.

Plate 5: Pit C055, sectioned, looking west.

Plate 6: Pit C055, charcoal C054 *in situ*, looking north.

Plate 8: Pit C055, burning C077 *in situ*, looking north.

Plate 7: Charcoal C055, detail, looking east.

Plate 9: Pit C055, post-excavation, looking north.

Plate 10: Hearth C044, sectioned, looking north.

Plate 11: Hearth C044, post-excavation, looking north.

Plate 12: Hearth C052, sectioned, looking north.

Plate 13: Hearth C052, post-excavation, looking north.

Plate 14: Hearth C063, sectioned, looking north.

Plate 15: Hearth C063, post-excavation, looking north.

Plate 16: Hearth C034, part excavated, looking north.

Plate 17: Hearth C034, sectioned, looking north.

Plate 18: Hearth C034, post-excavation, looking north.

Plate 19: Hearth C056, pre-excavation, looking north.

Plate 20: Hearth C056, sectioned, looking north.

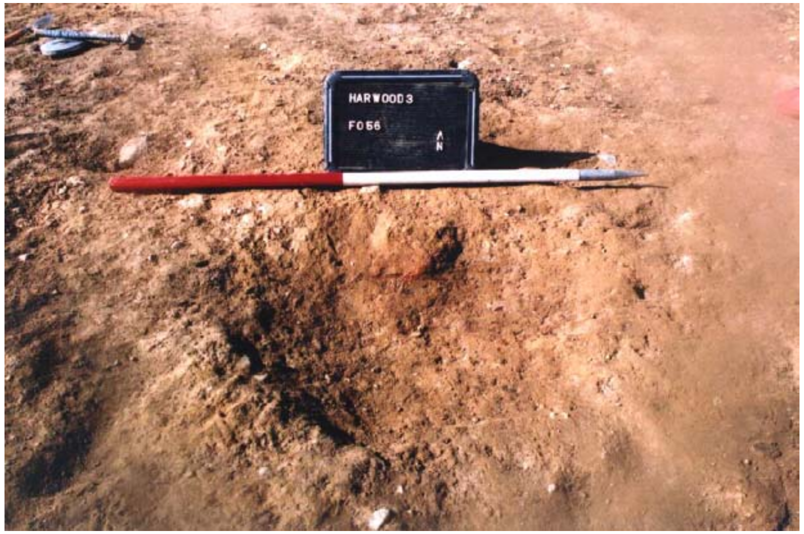


Plate 21: Hearth C056, post-excavation, looking north.


Plate 22: Pit C058, pre-excavation, looking north.

Plate 23: Pit C058, sectioned, looking northeast.


Plate 24: Pit C058, post-excavation, looking northeast.

Plate 25 Depression C075, pre-excavation, looking north.

Plate 26: Depression C075, post-excavation, looking north.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25:lab. mult=1)

Laboratory number: **Beta-177444**

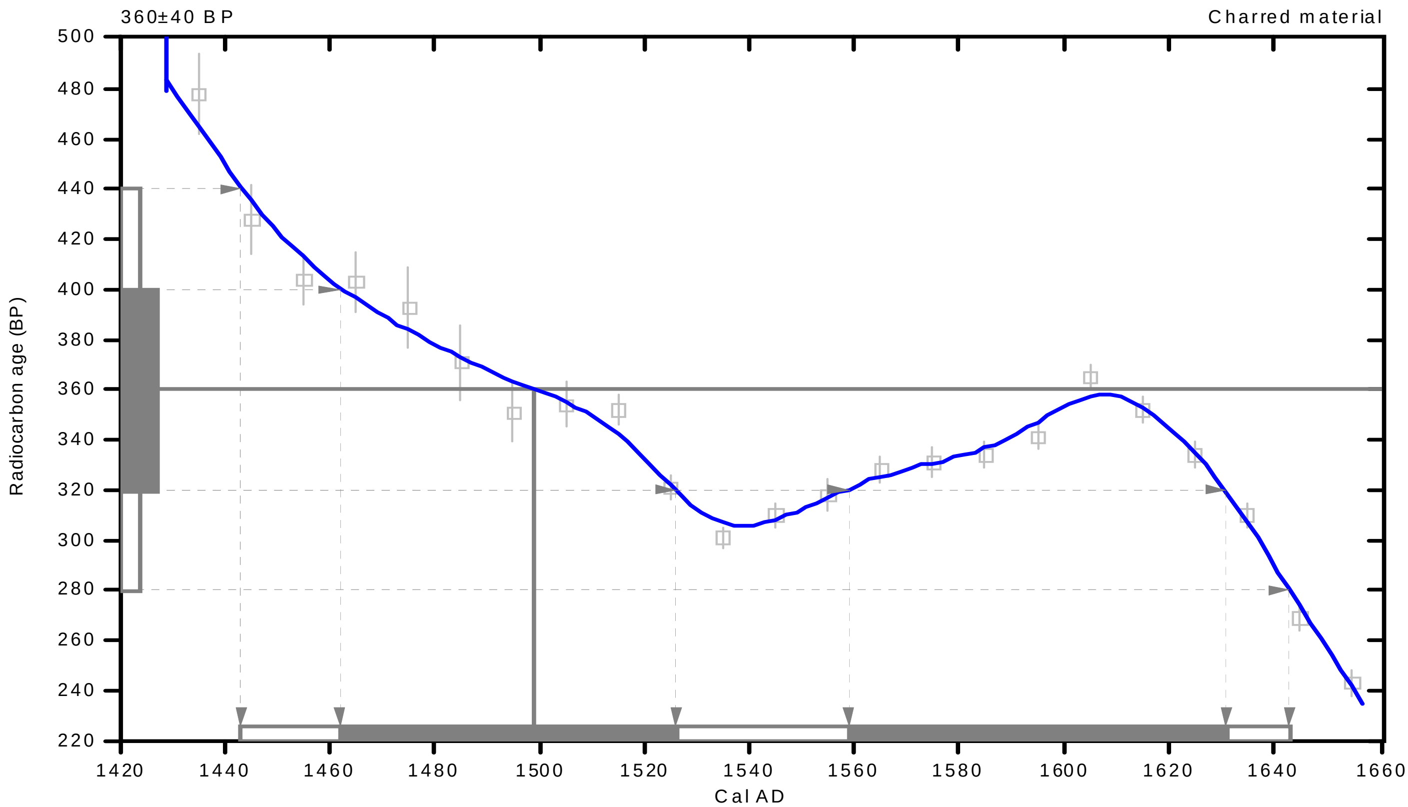
Conventional radiocarbon age: **360±40 BP**

2 Sigma calibrated result: **Cal AD 1440 to 1640 (Cal BP 510 to 310)**
(95% probability)

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal AD 1500 (Cal BP 450)

1 Sigma calibrated results: Cal AD 1460 to 1530 (Cal BP 490 to 420) and
(68% probability) Cal AD 1560 to 1630 (Cal BP 390 to 320)



References:
Database used

Calibration Database
Editorial Comment
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INTCAL98 Radiocarbon Age Calibration
Stuiver, M., et. al., 1998, Radiocarbon 40(3), p1041-1083
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-27.6:lab. mult=1)

Laboratory number: **Beta-177445**

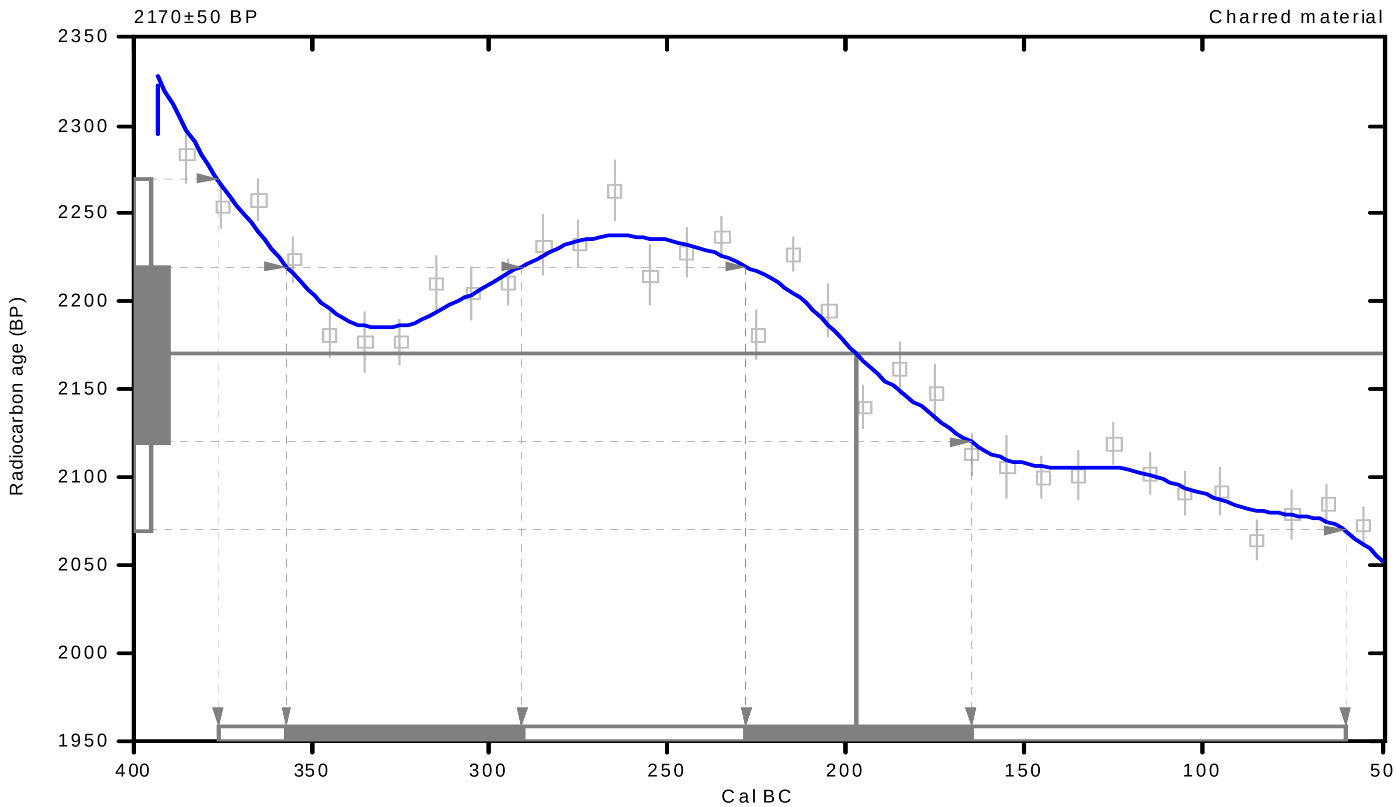
Conventional radiocarbon age: **2170±50 BP**

2 Sigma calibrated result: **Cal BC 380 to 60 (Cal BP 2330 to 2010)**
(95% probability)

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal BC 200 (Cal BP 2150)

1 Sigma calibrated results: Cal BC 360 to 290 (Cal BP 2310 to 2240) and
(68% probability) Cal BC 230 to 160 (Cal BP 2180 to 2120)



References:

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Stuiver, M., van der Plicht, H., 1998, Radiocarbon 40(3), pxii-xiii
INTCAL98 Radiocarbon Age Calibration
Stuiver, M., et. al., 1998, Radiocarbon 40(3), p1041-1083
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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-26.9:lab. mult=1)

Laboratory number: **Beta-177446**

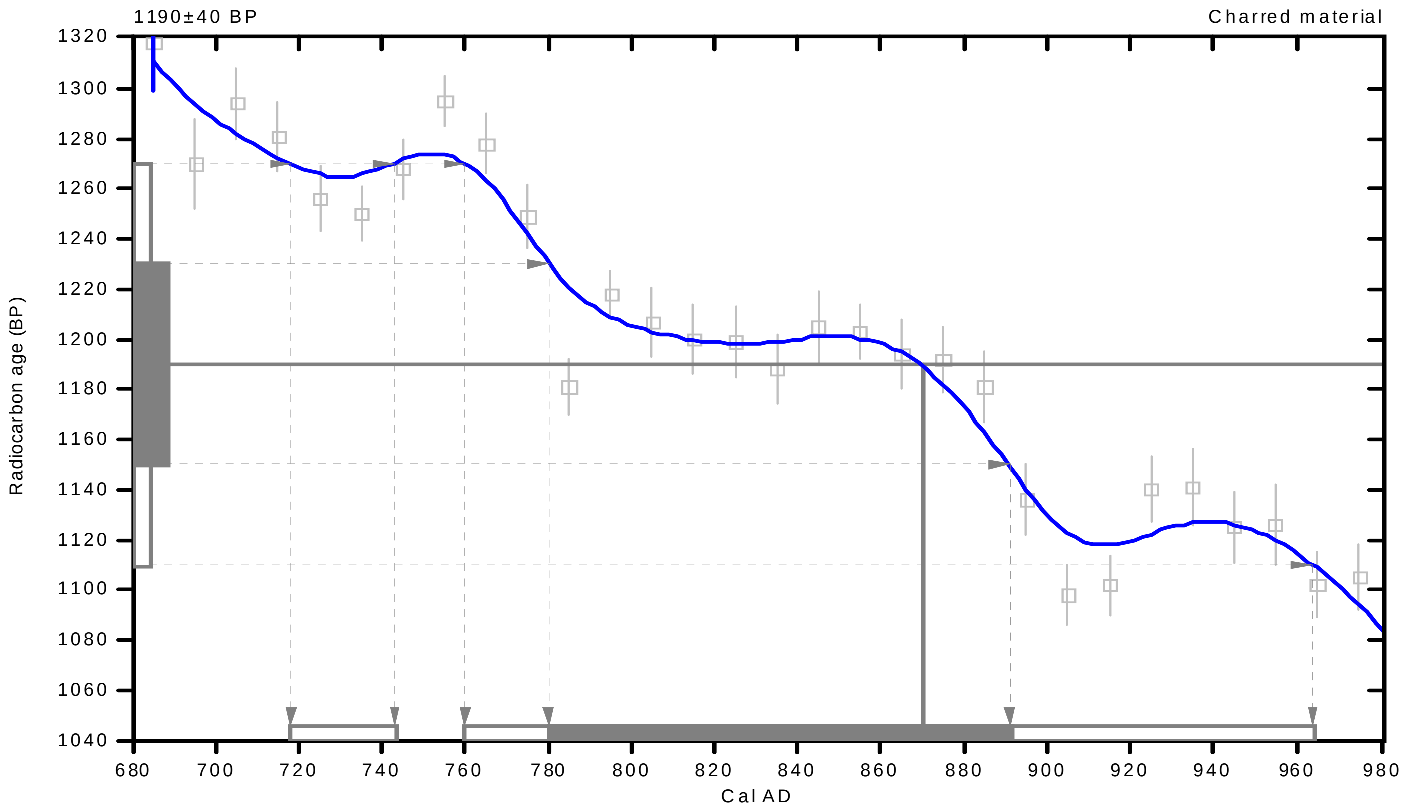
Conventional radiocarbon age: **1190±40 BP**

2 Sigma calibrated results: **Cal AD 720 to 740 (Cal BP 1230 to 1210) and**
(95% probability) **Cal AD 760 to 960 (Cal BP 1190 to 990)**

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal AD 870 (Cal BP 1080)

1 Sigma calibrated result: Cal AD 780 to 890 (Cal BP 1170 to 1060)
(68% probability)



References:

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Editorial Comment
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INTCAL98 Radiocarbon Age Calibration
Stuiver, M., et. al., 1998, Radiocarbon 40(3), p1041-1083
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-26.6:lab. mult=1)

Laboratory number: **Beta-177447**

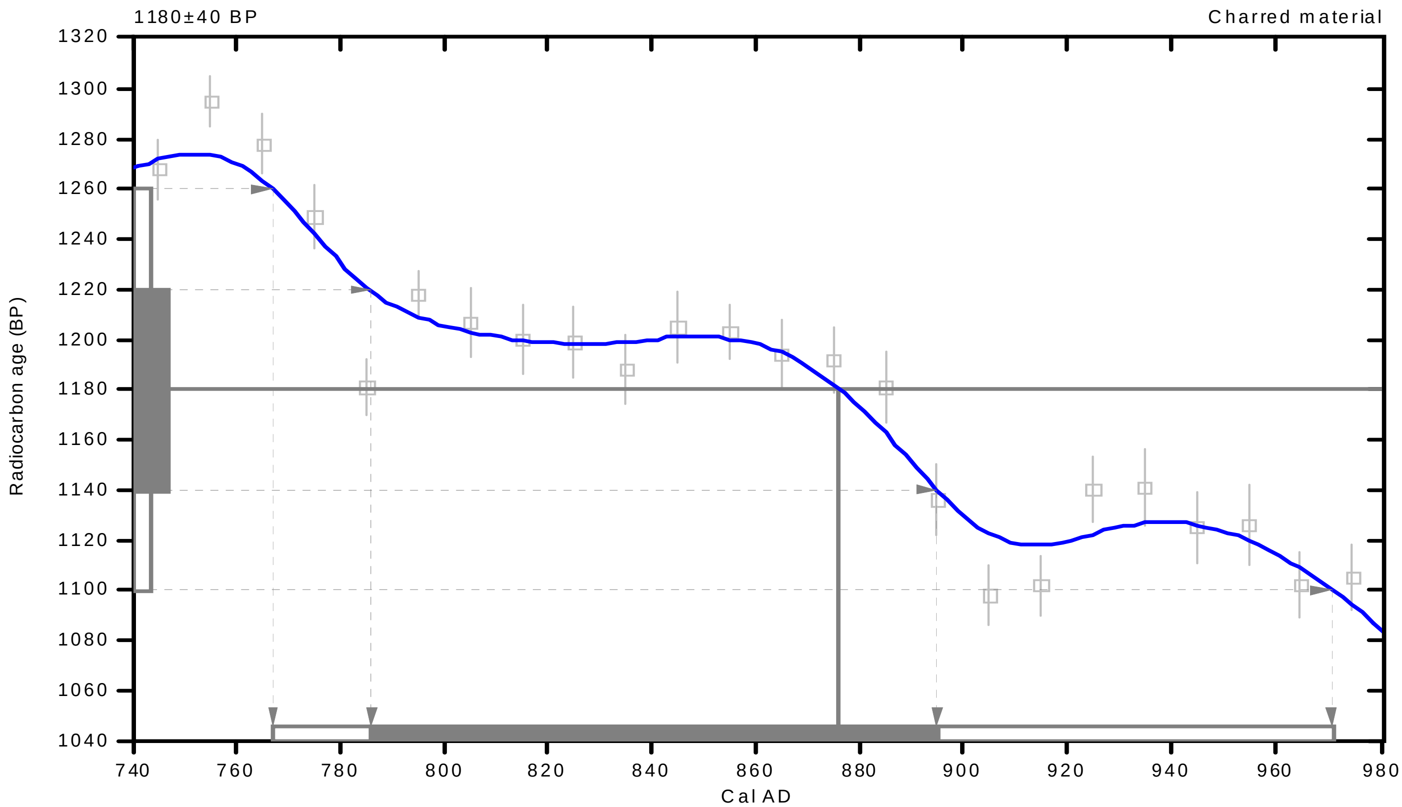
Conventional radiocarbon age: **1180±40 BP**

2 Sigma calibrated result: **Cal AD 770 to 970 (Cal BP 1180 to 980)**
(95% probability)

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 880 (Cal BP 1070)

1 Sigma calibrated result: Cal AD 790 to 900 (Cal BP 1160 to 1060)
(68% probability)



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Scottish Analytical Services for Art & Archaeology

Analysis of Metallurgical Waste from Hardwood III

SASAA 99

This technical report has been commissioned by Archaeological Consultancy Services Ltd, Drogheda, Ireland.

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Analysis of Metallurgical Waste from Hardwood III

by

Effie Photos-Jones

SASAA 99
Scottish Analytical Services
For Art & Archaeology
Glasgow,
Scotland, UK
September 2003

1. Introduction: setting the scene

The site, Hardwood III, was identified during the evaluation of the proposed route of the M74 Kinnegad-Enfield-Kilcock motorway. Most of the features excavated on the site are associated with iron smelting and in one instance charcoal making (*see Table 1 and Figures 1a-1h*). Table 1 presents a summary of all features, dates (when available), shape, dimensions together with contents from which samples have been obtained. Figures 1a-1h show key features like **C063, C056, C054 and C058,** but the dates of the various features are diverse: the charcoal making platform (**C055)** is medieval, one bowl furnace (**C044)** is post medieval, giving a chronological framework AD770-970 to AD1440-1640. However, one particular feature **C052**, a bowl furnace of small diameter dates to the Iron Age (BC 380-360). There is a notable lack of evidence of occupation on the site. It has been suggested that iron smelting is a type of activity that is transient, the charcoal burner and ironsmith moving from place to place to access new supplies of wood (Linnane 2002; Murphy 2003). We will argue against that point, the veracity of which can only be sustained by accumulating archaeological evidence.

The section that follows gives a background into the existing archaeological literature regarding bloomery iron working in Ireland particularly from the Early Christian period onwards with accompanying bibliography. The section is followed by the presentation of typological characterisation of MW, the analytical data and a short discussion of the results. Hardwood III metalworking is then set in the context of the rest of the sites (see Photos-Jones 2003).

Table 2: List of samples, contexts and descriptions thereof

Context Number	ACS Sample Number	Feature Number	ICP soil sample/ PB slag sample*	Description of Context
C024	**22**	**C063**, a circular pit (*see Figures 1a and 1b*)	**HW03 (soil) HAR2 (slag)**	Compact orange clay with slight yellow hue and inclusions of off-white and grey clay. Slag fragments were found at the interface between this layer and the underlying layer. It is one of several fills of pit **C063**, a circular pit.
C025	**20**	**C056**, a pit (*see Figures 1c and 1d*)	**HW02 (soil) HAR1, 1a, 1b (slag)**	Dark grey/brown sandy clay with occasional small stone inclusions and some charcoal. The only fill of pit **C056**.
C029	**16**	**C055** rectangular pit (*see Figures 1e and 1f*)	**HAR5 (slag)**	Yellow/brown, silty clay with occasional small stone inclusions and frequent charcoal flecks. One of several fills from a rectangular pit, **C055**.
C030	**17**	**C058**, a pit (*see Figures 1g and 1h*)	**HW04 (soil) HAR3 (slag)**	Dark grey/brown sandy clay with c.10% small stone inclusions and occasional charcoal flecks. The fill contained considerable quantities of slag but the lack of any trace of in situ burning would suggest that the pit is a dump of slag rather than a hearth. It is the only fill of pit **C058.**
C060	**18** **5 (for slag)**	**C063**, a circular pit (*see Figures 1a and 1b*)	**HW01 (soil) HAR4 (slag)**	Medium brown clay with a red hue. The deposit contained frequent flecks of charcoal and only occasional small stones. Another fill of pit **C063**.

** PB=polished block; ICP soil=soil sample taken for ICP analysis*

2. Bloomery Iron making

2.1 Bloomery Iron making in Ireland: a brief review

The official date for the beginning of the Iron Age in Ireland is 500 BC; however as Waddell (1998) states the period from the first millennium BC to the first few centuries AD is at best unclear. The decline in the use of bronze as the primary metal and the emergence of iron is evident during this period, primarily in artefacts rather than in metal working sites. In short, there exists little evidence for iron-making and working activities in the period from 500 BC to the first few centuries AD. However, from the sixth century AD onwards, there is a dramatic increase in the use of iron, as can be manifested both by the wide range of artefacts found on Early Christian sites as well as the archaeological record of iron working sites

The primary supply of iron during this period is most likely to be bog ore, obtained during the cutting of peat for domestic fuel. It may have also been quarried, as was the case at the Garryduff I ring fort where surface outcrops of Yellow Sandstone or Lower Limestone Shale were available (O'Kelly 1962, 103). In any case such localities could not have been as widespread as those associated with bog iron ores. (Mytum 1992, 230). Analyses of slag taken from the ring-fort at Cush in Co Limerick (O'Riordain 1940) and the rath at Mullaghbane, Co Tyrone (Harper 1972) and actual finds of ore at the settlement of Reask (Fanning 1981) support bog ore as the main source of iron in Ireland at that period (Mytum 1992, 229).

Bog iron ores are non-crystalline iron oxy-hydroxides. They are regenerative sources of iron ore, since they can reform at a considerable thickness over of a period of c. 30 years. They are characterised by the presence of manganese and phosphorus and low potassium and calcium contents (Hall and Photos-Jones 1998). Their wide availability, the fact that they can reform after a cycle of a few decades at the same spot, their high iron content together with the high manganese content which acts as a flux, lowering the melting point of the slag, the small amounts of phosphorus which can be absorbed in the metal, make them particularly useful for early bloomery technology and certainly the most favourite of all iron sources among farmers-smiths (Photos-Jones *et al* 1998).

Bloomery and early blast furnaces depended on large amounts of charcoal as fuel. At St Gobnet's round house at Ballyvourney, Co Cork, charcoal was found to be derived probably from the coppicing of hazel, willow and poplar (O'Kelly 1952). On Church Island, near Valencia, Co. Kerry where no local raw materials were actually available but had to be supplied from the mainland, about 250kg of charcoal were found in a round timber hut along with charcoal and slag within the bottom of a bowl furnace (Tylecote 1986, 187).

Smelting of iron ore was undertaken in a simple bowl furnace; although these furnaces were often not well preserved, it has been suggested that they could have been low shaft furnaces (Tylecote 1986). The furnaces were small pits, such as those found at the ring-fort Garryduff I, lined with clay into which the charcoal and iron ore would be placed (O'Kelly 1962). The slag was not tapped but formed in the bottom of the furnace, explaining why it is referred to as furnace-bottom slag, along with the charcoal while the metallic iron was left to form a bloom. At Ballyvourney in Co. Cork, a major iron production site from the 6th to 13th century AD, not only was this heavy furnace bottom slag found but also glassy slag produced by slag bubbling over from the pits and not solidifying at the bottom of the furnace (O'Kelly 1952). Also discovered at Ballyvourney was a fragment of a tuyere.

Evidence of smelting slag was evident at various sites during the Early Medieval period. These included ring forts like Ballycatten (slag was found in a black deposit dated to around 600AD), or Garranes, Co. Cork (O'Riordain and Hartnett 1943) but also monastic centres such as Laithmore, Tipperary dating to the 7th century (Tylecote 1986, 188). Later sites include Lagore Crannog, which appears to have made a move from decorative bronze working in the 7th century AD to more war-like iron products after the Norse invasion (Tylecote 1986, 188). Evidence of iron smelting in the form of a bowl furnace, bottom slag and glassy slag as well as possible indication of smithing activities (described below) are all dated to two phases of occupation from the 8th – 11th century AD (Hencken 1950).

Although primary (smelting) activities are quite readily identifiable, smithing activities are more difficult to differentiate. Edwards (1996) notes that in past excavations the slag was often not recorded systematically or rarely analysed to provide additional information about the activity that produced it.

Nevertheless, at Lagore crannog there does appear to be evidence for an iron-working floor. All hearth contents were examined and several hearths located together at the site revealed a sufficient amount of particles of free magnetic iron and iron oxide to suggest iron working (Hencken 1950,233).

Although iron production in the period (post-500 AD) was becoming a more every day affair and the technology was readily available to everyone, this does not mean that there was no longer specialisation of the craft. Documentary evidence suggests that the blacksmith was held in high esteem and that the forge was a central part of the community (Edwards 1996, 86). Major iron-working centres are evident in the archaeological record, for example Ballyvourney (O'Kelly 1952), Clogher (Scott 1983), where the forge is located in one of the fort ditches, or the ecclesiastical centre on Church Island, Co Kerry (O'Kelly 1958), where smelting and smithing activities are evident despite the lack of an iron ore supply on the island. Mytum (1992) suggests that many people were using basic iron technology to make and repair simple artefacts but that complex iron artefacts were still being produced by specialised smiths.

The use of the bloomery process continues throughout the medieval period into the post medieval period. The same evidence for smelting and smithing is evident in various medieval sites both rural and urban. At Ballyman, a 14th century iron-working area with associated living area near the church of Glen Murieri, Co. Dublin, the bottom of a furnace bowl was found along with furnace bottom, glassy slag and charcoal (Young, Clark and Barry 1986). A possible anvil stone covered in charcoal and slag dust supports smithing activities on site also. In the country the settlement at Coney Island, Lough Neagh similar finds were made to suggest that the community had established its own iron industry (Addyman 1965).

The introduction of the charcoal operated blast furnace to Ireland in the 17th century, appears to be contemporary with that in Scotland. The presence of English ironmasters and/or settlers interested in industrialising the local iron industry and exploiting the country's natural resources is again evident as in Scotland. Ironworks were established on Sir Walter Raleigh's estates in County Waterford earlier than the 1600s but were overrun by the Irish in 1598 and the town burnt to the ground (Schubert 1957,189). Similar type of enmities were also recorded in Scotland and it appears that the imposition 'from above' of foreign practices on a population well versed in its own way of making iron could only be to the detriment of foreign enterprises. In the early 1600s ironworks many ironworks were established; one of the most profitable partnerships was Richard Boyle and Charles Coot who controlled the largest number of works, for example the furnaces at Cappoquin on the River Black-water built in 1625 (Schubert 1957,190). Industrial development in Ireland however was seriously hindered by the 1641 rebellion when the Irish destroyed all the ironworks, and, although the iron industry emerged again after this period, it never regained the momentum and prosperity of the first few decades of the 17th century. Throughout this period it would appear that the native Irish were still employing the bloomery process rather than the more advanced technology of the blast furnace.

2.2 About bloomery iron making in general

In the bloomery, metallic iron is reduced from its ore while in the solid state, i.e. the iron was never intentionally molten. The technology for melting iron did not develop in Western Europe until the beginning of the second millennium AD. The numerous slag impurities trapped within the iron mass had therefore to be hammered out resulting in a billet that was subsequently shaped or forged into the desired artefact. It is these slag inclusions detected within the metal artefact that a) bear testimony to the bloomery process and b) provenance the source of the raw material (i.e. the type of ore).

Bloomery slags have been traditionally classified as "tapped" and "non-tapped" on the basis of the method of their removal in the course of the smelting operation. When tapped they acquire the characteristic drip-like surface texture. When non-tapped they tend to accumulate around the bloom and/or drip from it, ending up as small/large lumps at the furnace floor. The space allocated for these lumps to form is of course a function of the distance of the tuyere from the furnace floor. The stones set against the wall of Features 1 and 2 (Figure 1d) suggest the likely place for resting of the tuyere. The height from the tuyere to the furnace floor is short, precluding the possibility for a large bloom to form.

Smelting and smithing slags have been traditionally differentiated on the basis of their morphology, primarily the presence or absence of smithing hearth bottoms, but this is at best a first level classification. Chemically slags of the smelting or smithing type are iron-rich (with up to 60-70% iron oxide), crystalline, spongy, dense and brown-black in colour. Such high percentages of iron in the waste product, testify to the inefficiency of the bloomery and the urgency that must have been felt by the iron master of the $13^{th}/14^{th}$ century to convert first to bloomeries which operated by water power and second to the blast furnace. Mineralogically, smelting and smithing slags tend to be similar, but it is on the basis of characteristic fingerprinting elements that a distinction between the two processes, primary and secondary can be achieved. However, in the absence of fingerprinting elements there is little chance for a conclusive statement to be made unless associated evidence like metallurgical ceramics to include fragments of tuyeres, furnace wall or lining, hearth walls etc. can be brought in support of either process.

3. Typological Investigation

There were two contexts sampled with metallurgical waste from pit **C063**: fills **C024** and **C060**. **C024** (Fig. 2a) produced a relatively high quantity (6-7 pieces) of two types of slag, a dense crystalline type and a drippy type as well as a single piece of porous slag. A convex smithing/furnace hearth bottom was also recovered from this context. Lastly, fragments of vitrified and partially vitrified clay were found. The total amount of MW from this context was **3259**gm.

The primary type of metallurgical waste found in context **C060** (Fig. 2b), another fill of pit **C63**, is a drippy slag (3 pieces) but there was also a sample of porous slag. A fragment of vitrified clay was also recovered from this context. There was considerably less metallurgical waste found in this context in comparison to the other context **C024** sampled from pit **C063.** The total amount was **991gm**.

Context **C025** (Fig. 2c), the only fill of pit **C056**, produced 3 pieces of porous slag and 1 piece of dippy type slag. There were also three fragments of vitrified clay. The total amount was **1133gm**.

Lastly context **C030** (Fig. 2d), the fill of pit **C058**, produced the most amount of metallurgical waste at Hardwood III. There were fourteen pieces of both types of dense, crystalline and porous slags and a single fragment of vitrified clay. The total amount from this context was **5732 gm**.

Context **F029** produced only fines weighing **29**gm.

The grand total amount of MW from Harwood III was **11,144 gm**.

Key for the metallurgical waste typology graphs (see Figure 2)

A. Metal Ceramics	
1	Furnace wall fragment
2	Smithing Hearth wall fragment
3	Vitrified clay fragment
4	Partially vitrified clay
5	Other
B. Slag	
1	Porous
2	Dense/crystalline
3	Platy cake
4	Drippy
5	Other
C. Smithing Hearth Bottoms/BI-SHB/Furnace Bottom	
1	Convex/convex
2	Plano/convex
3	Concave/convex

4	Other
D. Other	
CERAMICS	

Table 1: Feature and Contexts

Hardwood III

Charcoaling platforms **Bowl Furnaces** **Smithing pits**

Context	Description	Date	Shape	N-S	E-W	Depth	Other features	Walls and base
F055	Pit	**F054S3:** AD 770-970 **F053S14:** AD720-740	Sub rectangular	2.8m	1.15m	0.27m	3fills **(F029, F053, F054**);side and base oxidised.	Sides sloping gently; even base
F044	Pit	**F05S8:** AD1440-1640	Sub circular	1.5m	1.5m	0.25m	2 fills **(003), (005)**	Sides sloping gently
F052	Pit	**F051S11:** BC380-60	Circular	0.48m	0.48m	0.18m	Fills **(022), (051);** oxidised	Sides steeply sloping
F063	pit	No dates	circular	0.70m	0.70m	0.30m	5 fills **(F024, F060, F061, F062, F070)** contained slag; soil samples	
F034	pit	No dates	sub circular	0.80m	0.80m	0.10m	Oxidised; 2 fills**(023),(033)**	
F056	pit	No dates	irregular	0.65m	0.65m	0.08m	Oxidised; fill (**F025**);soil sample	Sides sloping gently to a bowl shaped base
F058	pit	No dates	oval	1.50m	0.90m	0.45m	Fill **F030**	Irregular sloping
F076	depression	No dates	rectangular	0.83m	0.66m	0.01m	Oxidised; fill F004	
F075	pit	No dates	oval	1.20m	0.90m	0.12m	Oxidised; fill F006	Sloping gently

Figure 1a. Post-excavation photograph of circular pit or hearth **C063** (looking North) (after S Linnane ACS Ltd, pers. comm.).

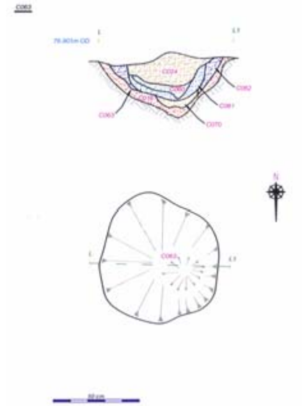


Figure 1b: Section and plan of pit/hearth **C063** (after D Murphy, ACS Ltd, pers. comm.).

Figure 1c: Hearth **C056**, (looking North) (after D Murphy**,** ACS Ltd, pers. comm).

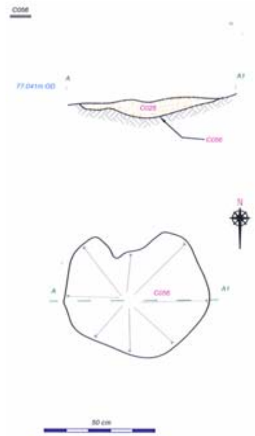


Figure 1d:Hearth **C056**, photographed above (after D Murphy, ACS Ltd, pers. comm.).

Figure 1e: Photograph during the excavation of rectangular pit **C055**, showing charcoal layer **C054** in situ (looking North) (after D Murphy, ACS Ltd, pers. comm.).

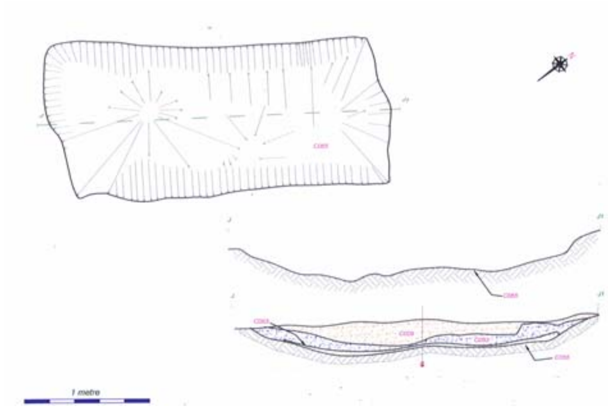


Figure 1f: Plan and section of pit **C055** photographed above (after **D** Murphy, ACS Ltd, pers. comm.).

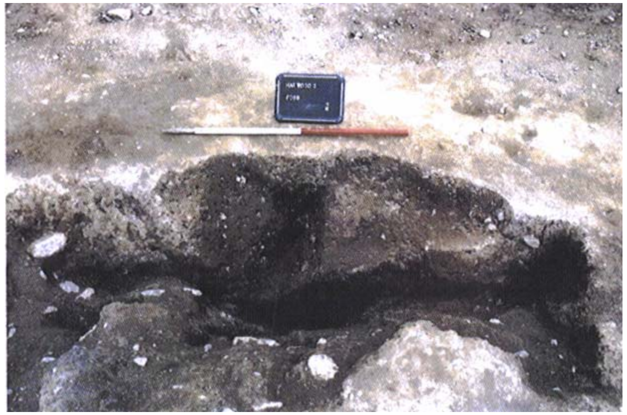


Figure 1h: photograph of pit **C058**, (looking North-east), (after **D** Murph**y**, ACS Ltd, pers. comm..).

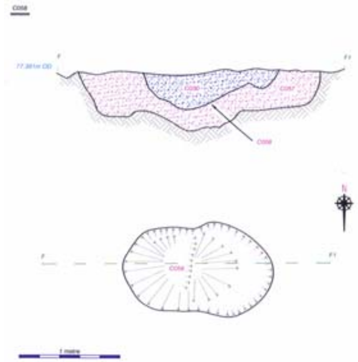


Figure 1g: Section and plan of pit **C058** (after D Murphy**,** ACS Ltd, pers. comm.).

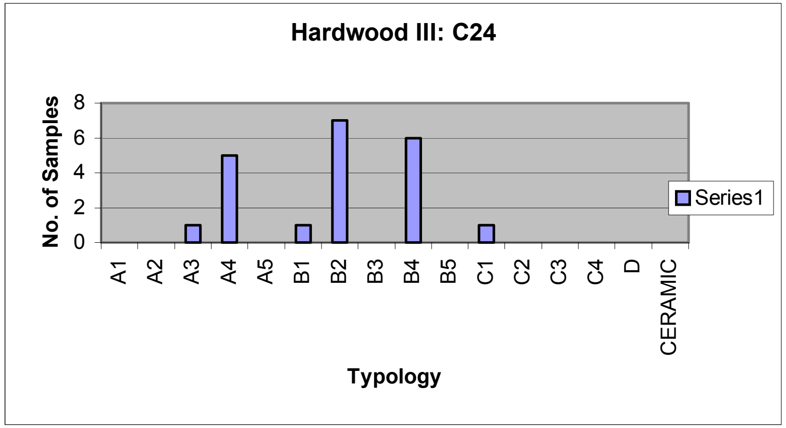


Figure 2a: Graph 1

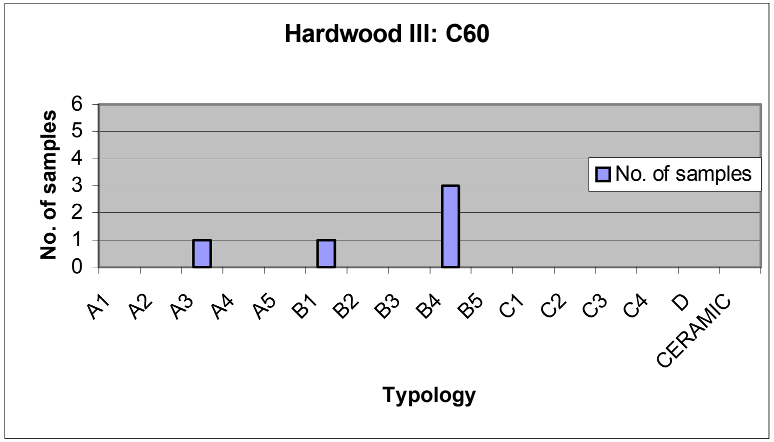


Figure 2b: Graph 2

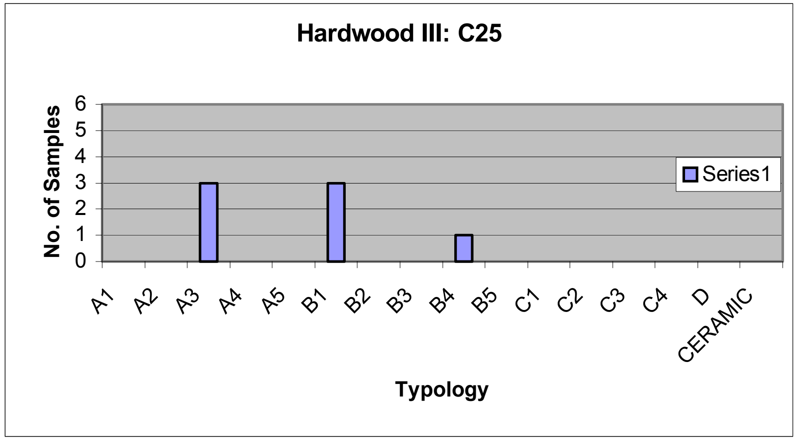


Figure 2c: Graph 3

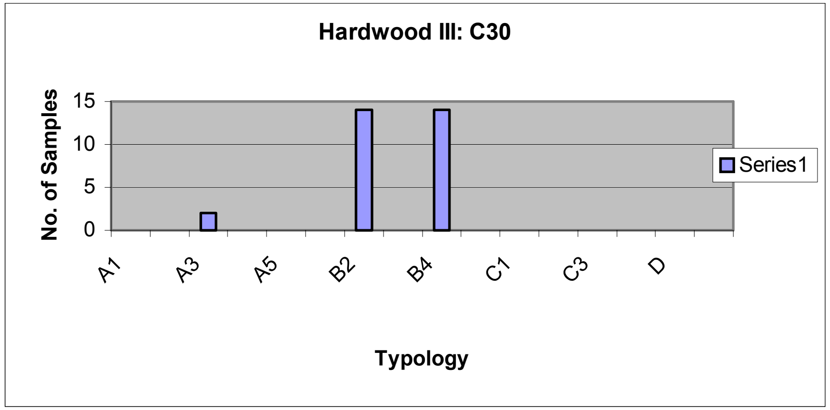


Figure 2d: Graph 4

4. ICP-OES analysis of soils *(Table 3, Figure 3)*

The results of ICP-OES analyses for the three samples of HW01, HW02, HW03 and HW04 have been classified by discriminant analysis (DA) shown in Figure 3. Two groups of samples were set up: soils found within (1) smelting pits/hearths and (2) non-metallurgical (NM) features, both at Johnstown I. DA optimises the differences in composition between these two groups, and then it can take *a priori* ungrouped samples and can assign these individual samples to one or other of the (two) pre-arranged groups. The purpose of the exercise is, in this case, to confirm that the contents of **F024, F025, F030 and F060** are metallurgical in origin. In the event, DA assigned samples **HW01(F060), HW02 (F025)** and **HW03 (F024)** having discriminant function values of –3.493, -2.545 and -1.435 respectively to the smelting pits/hearths group. **HW04 (F030)** with a df value of –0.200 was also assigned to the same group but with lower confidence as it lies in the area of overlap between the smelting pits/hearths group and the NM group, thus providing independent evidence for the archaeological observation that the pit was a dumping ground for slag. For further discussion on statistical treatment of the data see Photos-Jones (2003).

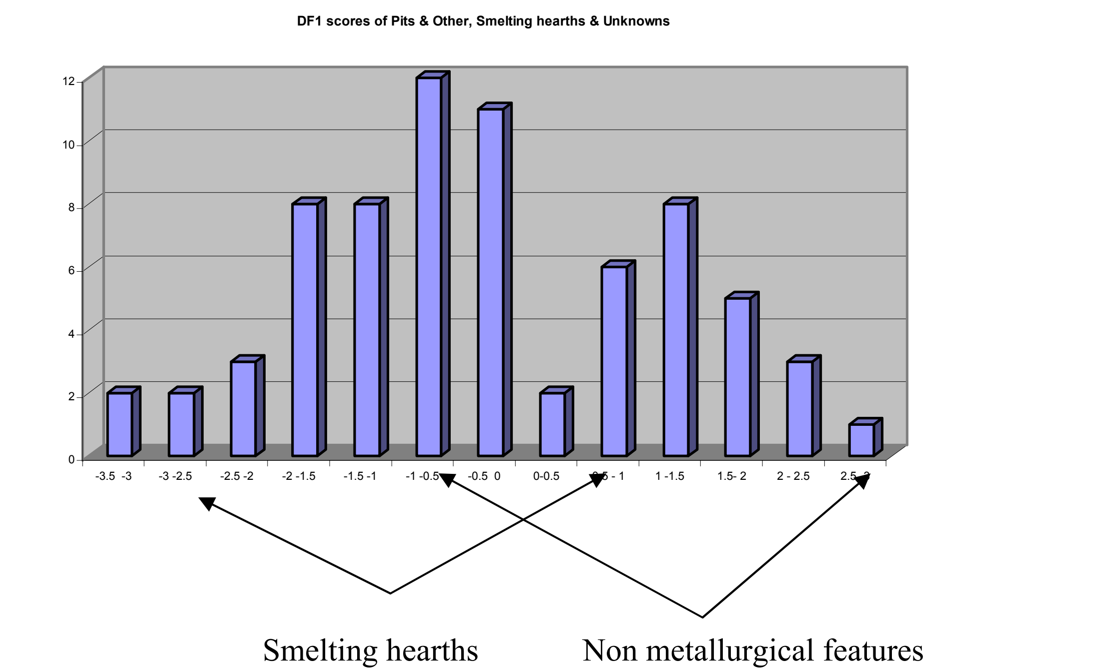


Figure 3: DF1 scores of individual samples belonging to the two groups: Smelting pits/hearths, and non-metallurgical (NM) features. The arrows indicate the ranges of

values of the two groups. HW01-04 are assigned to Smelting pits/hearths, but HW04 with low confidence.

5. SEM-EDAX analysis (*Table 4 and Figures 3, 4 and 5)*

5.1 Sample Preparation

Fragments of slag were sliced across with a diamond-bearing cutting wheel and the section was mounted in metallographic resin, ground with a series of silicon carbide papers and polished with 6 and 3-micron diamond pastes. The polished block was subsequently carbon-coated in preparation for SEM-EDAX analysis (see Table 4). The polished block was examined with the scanning electron microscope (a Leo stereoscan-S360) attached to an ISIS analyser with ZAF correction package. All elements shown in the Table 4 were sought, and the composition given in weight per cent. Internal calibration was carried out using a Co standard. Operating voltage was 20Kev and working distance was 25mm. Typical limits of detection for SEM-EDAX are c. 0.1%wt-0.5%wt. Elements with values below the limit of detection are denoted as nd. The sample was examined with the backscatter detector. A methodology for examination and analysis of metallurgical waste from archaeological sites has been outlined in numerous publications and has been summarised in the English Heritage (2001) publication. Operating conditions for the SEM-EDAX with levels of sensitivity for each element are given above.

5.2 Methodology

Metallurgical slags contain a number of distinct mineralogical phases, which become apparent when the sample is prepared as a polished block and examined under reflected light. These include dendrites of wustite (FeO), long or broken-up needles of fayalite ($2FeO.SiO_2$), angular grains of hercynite ($FeO.Al_2O_3$) and a glassy phase that grows interstitially within the other phases. The interstitial glass may itself, in the process of cooling, precipitate fine grains of fayalite and/or wustite. Not all phases which are present within the smelting slags are seen in the smithing slags, iron oxides (magnetite and wustite) as well as fayalite being the main constituents of the latter.

SEM-EDAX analyses are undertaken first on the entire surface of the polished block, and subsequently on each of the different mineralogical phases. Both sets of analyses are needed. It has been a long-standing SASAA reporting practice to present and publish both sets of data. The rationale behind such practice is that in order for the data to be comparable direct parallels can only be made between phases of similar mineralogical composition. The first type (taken over a mean of three analyses) represents area or bulk chemical analysis and is considered to be representative of the composition of the sample as a whole. As such, it identifies the slag as metallurgical and of the ferrous or non-ferrous variety. The second type is aimed at establishing the composition of each of the mineralogical phases within, thereby identifying the process that generated it. In brief, spot analyses are aimed at establishing whether the slags are of the smithing or smelting variety, and they provide information on the environment, temperature and conditions within the furnace in question.

6. Results and Discussion

The slag is primarily dense and crystalline but also contains fragments of the drippy type; metallurgical ceramics are also evident. The total amount of MW is c.12kg

HAR1A. Single fragment of amorphous lump of slag with metallic core, extensively corroded; brown-black, dense and heavy; highly magnetic. It is a fragment of an un-worked bloom. Blooms are not homogeneous in that they contain both metallic components and slag as shown in the SEM-images below. Analysis showed some manganese but no phosphorus in the metallic phase which has, as expected, weathered quite extensively. The metallic iron is a low carbon iron. But etching of the surface with 2% nital showed localised high and low patches of carbon. Overall the carbon content is compatible with that of wrought iron (c. 0.1% C). Fragments of un-worked bloom have been rather rare in the samples examined so far from the KEK-M4 motorway sites; Hardwood is a pleasant exception to prove the rule that metal - rather than slag- was actually made on site!

Table 3. ICP-OES analyses of Harwood samples; element oxides in percent, elements expressed in ppm

Sample	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	Ba	La	Ce	Nd	Sm
HW01	62.46	4.06	18.87	0.30	1.05	0.22	0.45	0.24	0.24	2.819	705	32	37	40	4.6
	70.11	3.99	14.57	0.29	0.71	0.24	0.50	0.27	0.19	1.456	533				
HW02												20	26	24	3.4
HW03	76.97	4.15	12.26	0.30	0.60	0.27	0.48	0.30	0.19	1.738	588	26	29	31	3.3
HW03	81.72	3.91	8.30	0.29	0.77	0.34	0.58	0.29	0.10	1.182	412	18	22	21	2.3

Sample	Co	Cr	Cu	Li	Ni	Sc	Sr	V	Y	Zn	Zr	Eu	Dy	Yb	Pb
HW01	18	18	27	17	67	6	64	75	53	285	88	1.7	10.1	3.8	32
HW02	16	30	23	20	59	5	62	60	27	180	103	1.2	6.0	2.4	27
HW03	13	29	21	18	47	5	59	61	35	190	121	1.2	7.2	2.7	23
HW03	13	32	25	17	55	4	61	49	21	142	136	0.8	4.7	1.8	26

TABLE 4: SEM-EDAX semi-quantitative analyses of samples from Hardwood III : composition in weight percent; nd = not detected

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	CoO	As_2O_3	SnO_2	Sb_2O_3	BaO	Total
HAR1A Area analysis	nd	nd	3.71	35.6	2.13	nd	0.65	8.83	nd	nd	nd	38.33	13.54	nd	nd	nd	nd	2.16	104.95
HAR1A spot analysis on fayalite	nd	nd	nd	30.1	0.74	nd	nd	3.12	nd	nd	nd	52.94	18.5	nd	1.17	nd	nd	nd	106.57
HAR1A spot analysis interstitial gl.	nd	nd	4.99	39.19	2.89	nd	0.84	13.8	0.57	nd	nd	28.28	11.9	nd	1.15	nd	nd	2.75	106.36
HAR1A metal core	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.42	101.15	nd	0.72	nd	nd	nd	102.29
HAR1A spot analysis on wustite	nd	nd	1.25	9.66	nd	nd	nd	2.33	nd	nd	nd	7.86	79.71	nd	0.86	nd	nd	0.75	102.42
HAR1B Area analysis	nd	nd	0.71	1.17	0.81	nd	nd	nd	nd	nd	nd	nd	100.03	nd	2.33	nd	nd	nd	105.05
HAR4 Area analysis 1	nd	nd	1.49	27.76	0.85	nd	0.28	2.43	nd	nd	nd	20.58	51.49	nd	1.46	nd	nd	nd	106.34
HAR4 Area analysis 2	nd	nd	1.33	25.57	0.81	nd	0.3	2.71	nd	nd	nd	20.36	52.71	nd	1.5	nd	nd	nd	105.29
HAR4 Area analysis 3	nd	nd	1.39	27.54	0.71	nd	0.25	2.54	nd	nd	nd	20.9	51.16	nd	1.78	nd	nd	nd	106.27
Mean	***nd***	***nd***	***1.4***	***26.96***	***0.79***	***nd***	***0.28***	***2.56***	***nd***	***nd***	***nd***	***20.61***	***51.79***	***nd***	***1.58***	***nd***	***nd***	***nd***	***105.97***
HAR4 spot analysis on fayalite	nd	nd	nd	29.7	nd	nd	nd	1.8	nd	nd	nd	24.55	47.53	0.51	0.88	nd	nd	nd	104.97
HAR4 spot analysis on wustite	nd	nd	0.54	0.66	nd	nd	nd	nd	nd	nd	nd	10.76	93.76	nd	1.48	nd	nd	nd	107.2
HAR4 Glass: the P - rich phase s	nd	nd	3.97	12.49	30.65	nd	1.34	45.57	0.69	nd	nd	2.4	6.42	nd	0.98	1.31	1.98	1.97	109.77
HAR4 Glass : the Si Al rich phase	1.6	nd	19.46	35.11	6.9	nd	6.53	15.35	nd	nd	nd	4	14.74	nd	1.03	nd	nd	2.45	107.17
HAR5 Area analysis 1	nd	nd	3.05	25.43	1.54	nd	0.45	5.7	nd	nd	nd	12.16	54.44	nd	1.15	nd	nd	0.88	104.8
HAR5 Area analysis 2	nd	nd	2.85	23.79	1.22	nd	0.25	4.52	nd	nd	nd	11.46	60.29	nd	1.52	nd	nd	0.91	106.81
HAR5 Area analysis 3	nd	nd	2.82	24.96	1.31	nd	0.59	5.49	nd	nd	nd	13.91	54.17	nd	1	nd	nd	0.65	104.9
mean	***nd***	***nd***	***2.91***	***24.73***	***1.36***	***nd***	***0.43***	***5.24***	***nd***	***nd***	***nd***	***12.51***	***56.3***	***nd***	***1.22***	***nd***	***nd***	***0.81***	***105.5***
HAR5 fayalite spot	nd	nd	0.37	31.04	nd	nd	nd	3.59	nd	nd	nd	19.63	51.03	nd	1.25	nd	nd	nd	106.91
HAR5 wustite spot	nd	nd	0.57	nd	nd	nd	nd	0.3	nd	nd	nd	7.1	96.19	nd	1.65	nd	nd	nd	105.81
HAR5 Glass Al Si Ca spot	6.06	nd	31.15	43.74	nd	nd	14.53	0.81	nd	nd	nd	0.45	3.1	nd	nd	nd	nd	nd	99.84
HAR5 Glass: the P- rich phase	nd	nd	15.51	23.87	20.76	nd	1.59	32.46	nd	nd	nd	1.87	12.48	nd	1.07	nd	nd	nd	109.61

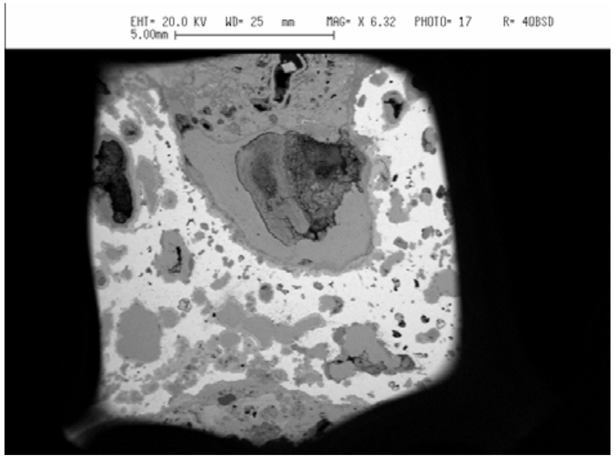


Figure 3a: SEM-BS image of HAR1a (Bar = 5 mm; x 6.32)

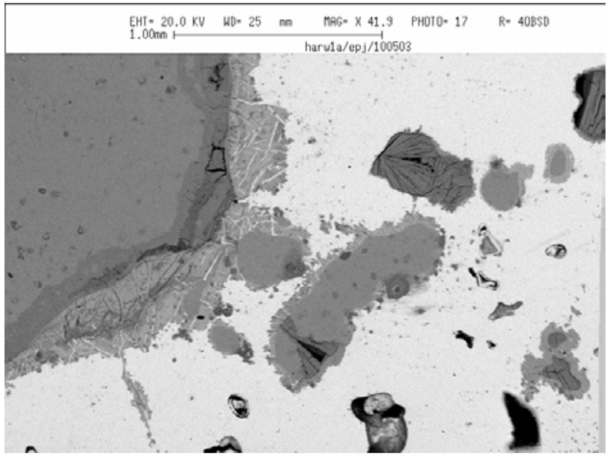


Figure 3b: SEM-BS image of HAR1a showing a close-up of the metallic area. This is a fragment of an unworked bloom (Bar = 1mm; x 41.9)

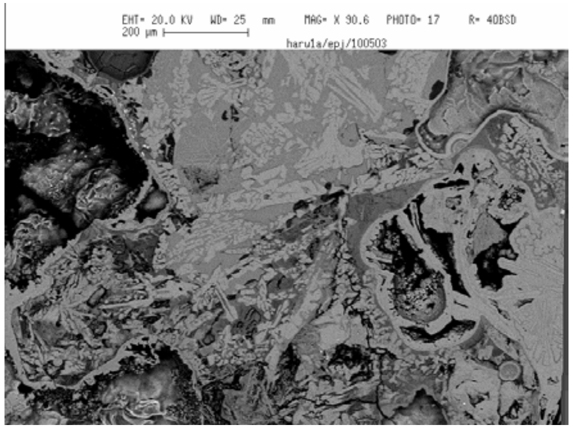


Figure 3c: SEM-BS image of HAR1a showing areas of extensive weathering of the glassy and metallic phases of this bloom fragment (Bar = 200 microns; x 90.6)

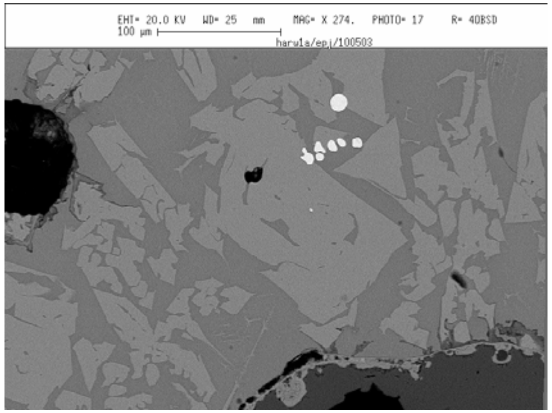


Figure 3d: SEM-BS image of the slag area within this bloom fragment showing dendrites of wustite and fayalite grains.HAR1a (Bar = 100 microns; x 274)

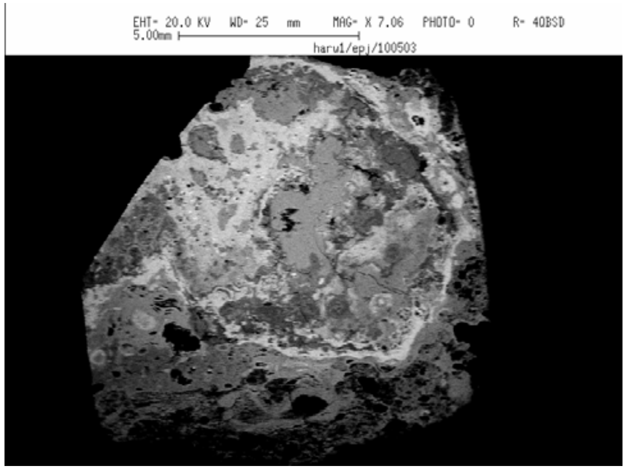


Figure 4a: SEM-BS image of HAR1B (Bar = 5 mm; x 7.06)

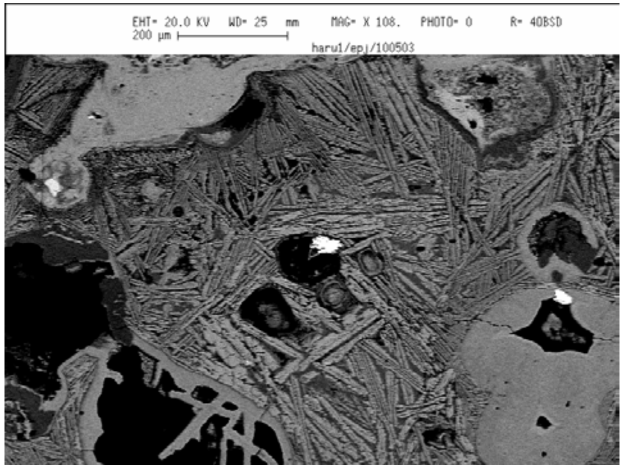


Figure 4b: SEM-BS image of HAR1B (Bar = 200 microns; x 108)

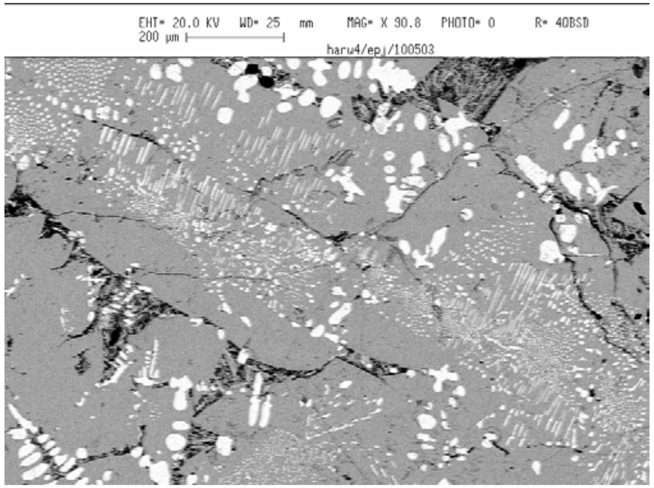


Figure 5a: SEM-BS image of HAR4 (Bar = 200 microns; x 90.8)

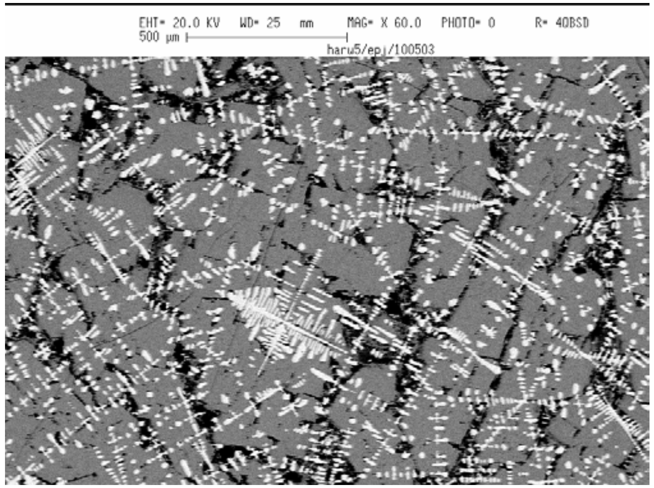
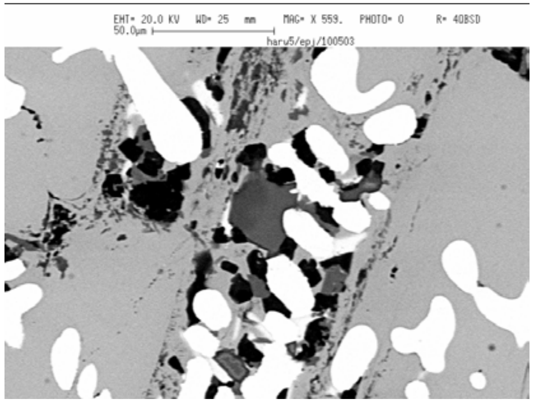


Figure 5b: SEM-BS image of HAR5 (Bar = 500 microns; x 60)

 ***Figure 5c:*** SEM-BS image of HAR5. Apart from fayalite and wustite and the interstitial matrix, there are small grains (less than 20microns across) of calcium phosphate (centre of image). It is unlikely that the origin of this mineral is animal bone. (Bar = 50 microns; x 559)	

HAR4 (a small fragment of drip-like slag) a**nd HAR5** (a small fragment of amorphous, dense and heavy slag) are examples of typical bloomery slag of the fayalite type. Wustite is rather rare, as is the interstitial glass suggesting that the composition of the charge was primarily iron and silica with manganese oxide.

In **HAR5** apart from fayalite and wustite and the interstitial matrix, there are small grains (less than 20microns across) of calcium phosphate with minor iron (centre of image, *Figure 5).* It is unlikely that the origin of this mineral is animal bone; phosphorus probably derived from the bog ore and might be of organic or inorganic origin. The use of peat for preheating - another source for the phosphorus - cannot be excluded, but further work is needed before any conclusions can be drawn regarding the make-up of Irish bog iron ores.

HAR1B is a second fragment of weathered bloom, whose analysis shows that it is mainly iron. Slag, which was enveloping the bloom and retains its characteristic structure of fayalite needles, can be seen in Figure 4a-b.

Features **F052, F063, F034 and F056** have been identified as bowl furnaces; while features **F044, F058 and F075** have been identified as bloom smithing hearths.

There is no difference in the typology, composition and mineralogy of the slag derived from the pits of different dates.

The issue of coppicing of the woodland as advocated by Linnane (2002) and Murphy (2003) needs to be examined in the context of the type of environmental data recovered from the site. Hazel and birch are known to have been coppiced throughout the medieval period and earlier, but does the same practice apply to oak? Oak wood is the one with the highest calorific value and thus best suited for smelting, while hazel would have been used for preheating the bowl in order to dry the base and the clay-lined walls.

It is possible that at Hardwood III there were areas designated as 'industrial grounds' or areas for metal working, on account of their proximity to natural resources, like ore and wood. Hardwood III gave dates to include Iron Age (360-30BC), Medieval (720AD-790AD) and post-medieval (AD1440-1640). The medieval/post-medieval dates are associated with a charcoal-burning platform and a furnace, while the IA date is associated with a bowl furnace.

While tinkers may have been itinerant, iron makers are anything but. It is suggested that the sites excavated along the KEK-M4 represent the remnants of the work of individual farmers-iron makers or groups of them skilled in iron making. They would perhaps gather together at a particular location, designated 'in their mind' for metal working, perhaps on a seasonal basis; these industrial activities may have been an integral part of a farmer's calendar year tasks.

These industrial grounds would not have been designated as such randomly but rather on account of the natural resources in hand. While itinerant smiths carried their own fuel - and they were economical at that - iron smiths would need to err on the larger side. At any rate, the bowl furnace/bloom smithing hearths' demand on the woodland would have been minimal (at least compared to later periods) to necessitate moving to new grounds. Given that the source of iron was local AND regenerative it is unlikely that these farmer/ironsmiths would have travelled beyond the range of their own 'territory'. Therefore the designation of areas as 'industrial grounds' may not be far fetched.

The smithing hearths should be thought of in terms of bloom smithing, that is removal of the slag from the metal core with subsequent shaping of the object in a particular shape, rather than in the conventional image of the hearth of the C19th village smith. The Irish Law Tracts certainly focus on the activities in and around these hearths, the blacksmiths' hearths, but they reveal little about the iron makers' furnaces.

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SPECIES IDENTIFICATION OF CHARCOAL SAMPLES FROM HARDWOOD 3, CO. MEATH (02E1141)

ELLEN OCARROLL

INTRODUCTION

Four charcoal samples were submitted for identification from excavations carried out on a series of bowl hearths (**F**5 & **F**51) and a possible iron-smelting pit (**F**53 & **F**54).

The charcoal was sent for species identification prior to ^{14}C dating and also to obtain an indication of the range of tree species, which grew on or near the site. Charcoal analyses may also provide information on the utilization of certain species for various functions. Wood used for fuel at pre-historic sites were probably sourced from locations close to the site and therefore charcoal identifications will generally reflect the composition of the local woodlands.

METHODS

The process for identifying wood, whether it is charred, dried or waterlogged involves comparing the anatomical structure of wood samples with known comparative material or keys (e.g. Schweingruber 1990). The identification of charcoal material involves breaking the charcoal piece so as to obtain a clean section of the wood. This charcoal is then identified as to species under an Olympus SZ3060 x 80-zoom stereomicroscope.

RESULTS

Table 1: Results from Charcoal identifications

Site no. / Context no.	Site type	Sample no.	Species	Comment
Hardwood 3 Fill of pit	F53	14	Alder	Large bag of charcoal enriched soil- v. little charcoal lumps 337g
Hardwood 3 Fill of pit	F5	8	Oak	201g
Hardwood 3 Fill of pit	F51	11	Oak	39g
Hardwood 3 Fill of pit	F54	3	Alder	530g

The identifications yielded a total of two wood species (table 1). The dominant type was oak with alder also used.

DISCUSSION

There are two species groups present in the charcoal remains (table 1). The samples represented above are indicative of only a small amount of the wood originally collected by the inhabitants for fuel or other functions. The range of species identified from the Hardwood 3 excavations includes large (oak) and smaller type (alder) trees.

Oak was identified from the fill of the pits **F**5 and **F**51. Oak is the most prevalent species identified from bowl hearths and iron processing centres. Oak was the main species identified from iron-smelting activities at Celbridge, site 5 (01E0306) and from the material extracted from the bowl furnaces excavated at site 12 (01E0955), Cherryville, Co. Kildare and at Crabbsland, Limerick (01E0852). Sessile oak (*Quercus petraea*) and pedunculate oak (*Quercus robur*) are both native and common to Ireland. The wood of these species cannot be differentiated on the basis of its microstructure. Pedunculate oak is common on heavy clays and loams particularly where the soil is of alkaline pH. Sessile oak is common on acid soils often in pure stands and although it thrives on well-drained soils it is also tolerant of flooding (Beckett 1979, 40-41). Both species of oak grow to be very large trees (30-40m). The presence of the oak suggests that there was a supply of oak in the surrounding environment at Hardwood. Throughout all periods of prehistory and history oak has been used as structural timbers. Oak has unique properties of durability and strength.

Alder was identified from the fill of the same pit **F**53 and **F**54. Alder makes poor firewood but the charcoal is of excellent quality and formerly formed an important ingredient of gunpowder. The alder along with the oak charcoal may have been used as fuel for the iron-smelting activities, which took place at the site. It is a widespread native tree and occurs in wet habitats along streams and riverbanks. Alder also grows regularly on fen peat. It is an easily worked and split timber and does not tear when worked. Alder is commonly identified from wood remains associated with wet/boggy areas.

CONCLUSIONS

As attested at other similar sites in Ireland the oak would have been deliberately selected for use in the bowl furnaces. Although alder has not been regularly identified from iron-smelting sites its charcoal qualities may suggest it was used in these manufacturing processes. The oak may have been selected from mixed oak woodlands nearby to the sites. Alder suggests a wetland environment and could have grown close to a natural well or on river banks.

Radiocarbon dating

A minimum of 5 grammes of charcoal is needed for a ^{14}C date but 25 grammes is the preferred amount. All the charcoal samples above represent the inner part of a tree of unknown age and it was not possible to tell from identification how much larger, if at all, the whole piece was. This is particularly true in the case of oak as it can grow to an age of about 300 to 400 years. The samples identified could be of a more recent date than the rings represented on the sample. Sample 3, F54 is the most suitable for ^{14}C dating as it is a shorter living species and contains a suitable amount and type of charcoal.

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WOOD SPECIES IDENTIFICATION

OF CHARCOAL SAMPLES FROM

EXCAVATIONS AT

HARDWOOD 3 (02E1141),

CO. MEATH

ELLEN OCARROLL

April 2003