PRODUCTION AND TECHNOLOGICAL CHANGE:

IRONWORKING IN PREHISTORIC IRELAND

by

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ABSTRACT

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The introduction of iron into Ireland during the 8th century BCE had profound influences on the organization of society, from economic and political networks to the means by which power and status were negotiated. However, the organization of iron production is still relatively poorly understood. This dissertation seeks to explore how iron technology was organized during the Early Iron Age (c. 800 – 400 BCE) and Developed Iron Age (c. 400 – 1 BCE) in Ireland, and uses this context to demonstrate that the development of new technologies can be most clearly understood by investigating the archaeological remains of production practices. Multiple levels of production were investigated in this study by compiling and synthesizing mostly unpublished excavation reports into a relational GIS database. An output from this database is an online webGIS interface which presents the multi-scalar data collected for this dissertation on iron production in these periods in Ireland. Through the evidence for iron production, this project also examines the organization of society in the Iron Age and the interconnectedness of iron technologies and the rest of social life. The application of different methods of data collection and pattern identification further illuminate the actions performed during technological activities. These actions were not only embodied by the individuals involved, at once creating meaning while recreating social life,

but also were part of larger patterns of production across the Irish social landscape. Untangling the influences of technology and the products of technical practices on society provides us with a better understanding of technology itself, while simultaneously exposing the deeply embedded nature of technology within social life as a whole.

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Chapter 1: Introduction

1.1. The Problem

This dissertation will address how iron technology was organized during the Early Iron Age (c. 800 – 400 BCE) and Developed Iron Age (c. 400 – 1 BCE) in Ireland, and how this context demonstrates that the development of new technologies can be most clearly understood by investigating the archaeological remains of production practices. In order to address fully the different types of data utilized in this study, the following research questions were posed to structure the interpretation and analysis.

1.2. Research Questions

1. What level of skill is demonstrated by the remains of iron smelting and smithing?
2. How do patterns of production change through time, from the EIA (c. 800-400 BCE) to the DIA (c. 400-1 BCE)?
3. What was the spatial relationship between iron production sites and other types of sites during this period?
4. Were different aspects of iron production tied to specific topographies and/or locations?

1.3. Archaeological Context

The Early Iron Age (EIA) (c. 800-400 BCE) (Table 1) in Ireland witnessed the introduction of iron technology, which resulted in communities learning to master the properties of iron while simultaneously negotiating a place for this new technology within their existing social, technological, and ideological systems. The EIA has traditionally been referred to as the

Table 1.1 Late Bronze and Iron Age Periods in Ireland.

Irish Chronology	
Late Bronze Age	1200 - 800 BCE
Early Iron Age	800 - 400 BCE
Developed Iron Age	400 - 1 BCE
Late Iron Age	1 BCE - 300 CE

"Dark Age" (Raftery 1994; discussion in Becker 2009) due to the apparent disappearance of the materials and practices that had characterized the Late Bronze Age (c. 1200 -800 BCE): pottery was no longer produced[1], settlements were more ephemeral, certain types of votive deposition ceased, and the organization of craft production changed significantly (Armit 2007; Becker et al. 2008; Cooney & Grogan 1994; Raftery 1994:113). The period remains relatively understudied because archaeologists have traditionally considered investigation a futile endeavor (typified by Barry Raftery's 1994 chapter in *Pagan Celtic Ireland* "The Invisible People"). Reconstructions of the period have traditionally been based on isolated finds, a very limited burial record, and a few highly specialized contexts often referred to as "Royal Sites," leading to an incomplete and potentially misleading view of the period (Becker 2011, 2012b). However, as the modern Irish economy expanded in the late 1990s and early 2000s, infrastructure development resulted in significant archaeological excavation throughout the country, much of which operated through the National Roads Authority (NRA)[2] of Ireland. This influx of archaeological data increased the number of Iron Age sites thirtyfold relative to the number known in the mid-1990s.

Recently, the Iron Age in Ireland has become a focus of scholarly revision (e.g., Armit et al. 2013; Becker et al. 2008; Corlett & Potterton 2013; Dolan 2014; Garstki 2016), but a complete picture of iron production for the period has yet to be articulated fully, much less supported by significant archaeological data. An analysis of early iron production in Ireland not only reveals that new technologies can be best understood by investigating archaeological

[1] Or at least in a way that would identify it as distinguishable from the preceding periods. See Chapter 2 for an example of Iron Age pottery.
[2] Now referred to as the Transportation Infrastructure Ireland (TII).

remains of production practices, but also helps to reconstruct more accurately the impact of the new technology on EIA society and subsequent technological transformations in the Developed Iron Age (DIA).

The organization of iron technology during the EIA presents an interesting case study because of its apparent contrast to earlier metal technologies (especially bronze and goldworking), specifically in terms of procurement and production methods. While this study will focus on the period in Ireland after iron was introduced, examining how older metalworking technologies were organized is useful in reconstructing the organization of iron production during the Iron Age. A key difference is the relative ease with which iron could be obtained compared to tin and copper, the constituent elements of bronze (Champion 1989; Faolain 2004; Henderson 2007). Recent evidence suggests that bog ore was a major source of the iron used during this period, providing a semi-renewable and abundant resource, as opposed to the complex mining processes involved in the procurement of copper (Photos-Jones & Hall 2011; Pleiner 2000). One result of these contrasting procurement strategies was that iron production was very difficult to centralize. This must have had a profound impact on the structure of resource control and the way in which iron production was organized in society. Local communities involved in iron extraction could not control the resource since it was so widespread, nor could elites directly control producers via restricted access to the raw material (Scott 1990:152-153). Resource extraction, in addition to the various practices involved in the creation of an iron object (e.g., charcoal production, smelting, and primary and secondary smithing), were part of a complex system of production in which multiple groups were responsible for different activities. As such, these practices were intimately tied to the rest of life in Iron Age Ireland.

1.4. Theoretical Framework

1.4.1. Technology in Society

This project builds on research that views human technological practice as an inseparable aspect of meaning making, artifact making, and social production. Approaches that focus on how the individual is involved in production highlight the essential embodiment of technological practice, from the initial intentions or anticipatory ideas of the practitioner (Keller 2001:35-37; Keller & Keller 1996:60-88), to the process of making in which form is not simply expressed but comes into being through the act of production itself (Dobres 2001, 2010a; Ingold 2000, 2010). One of the goals of this project is to contribute to scholarship that unravels the embedded nature of technological practices in all aspects of production, from the transfer of technical knowledge, to the pre-production concept of an artifact, to the acts of creation that are both materially and socially inherent in technological practice.

An approach that engages with technology as a socially embedded practice has become necessary as the limitations of a "Standard View" of technology (whereby modernist technological activities are tied directly to human need) were exposed (Pfaffenberger 1992:493-495). Pfaffenberger notes that anthropologists are uniquely situated among social scientists to contend with the inherent sociality of technological activity, though the discipline has traditionally been characterized by a lack of explicit engagement with technology as a social force (1992:493, 2001). This dearth of technology-centered theoretical research has been echoed by others (Bray 2007; Stark 1998:3-5), highlighting the fact that more recent engagements with the topic often present "technologies" as phenomena creating new cultural worlds rather than as foci of research in themselves (Bray 2007:45). It has taken the multi-disciplinary development of science and technology studies to bring the social aspect of technology to the fore (Bijker et al.

1987; Jasanoff et al. 1995; Latour 1993).

1.4.2. Technological Production as Practice

In framing this study, I have taken a practice-based view of human action and technological production (*sensu* Bourdieu 1977). I conceive of technological production as a series of individual actions, and the structure within which the technology exists is (re)created through the performance of said actions (after Giddens' structuration [1984]). In this framework, technological practice is always a social activity, as technology is always/only a social phenomenon. It should be noted that the terms "behavior"[3] and "skilled performance" are interchangeable with social practice or action as they are used in this dissertation. The technological production of iron necessitates numerous choices and actions, from the collection of ore through the smelting and the primary and secondary smithing processes. The actions involved in these productive events are collectively seen in the archaeological record as the remains of production practices. The actions individuals undertook to produce an iron object have also been considered in a framework of innovation and tradition by looking at the physical remains of these production practices. Though not opposed, innovation and tradition are two facets of a production event. As Keller and Keller (1996:9) note, the activity system of the smith rests upon a shared foundation of knowledge (traditions) but is affected by significant diversity. I expand this conception of tradition to include not only the foundation of knowledge by the smith, but also the idealized perception of an iron product by the consumer. The iron product needed to fit into a perceived ideal form of the object, and the success or failure of the production activity, could be judged based on its alignment with this ideal. Though he was speaking to the treatment of oral myths as tradition, Giddens identified the structuration that occurs in the enactments of past ideals as follows: "…tradition is first and foremost embedded in, and the means of

[3] In Schiffer's (1992) conception of the word.

reproduction of, the practices that constitute day-to-day activities" (Giddens 1987:147). In this way, the smith[4] and smelter constructed the context for their own reproduction through their activities. By performing a smelt or swinging a hammer the smith both created what it meant to be a smith while simultaneously maintaining the tradition of the smith. The smith also could deviate from a perceived tradition through innovation.

Innovation played its part in production by providing an element of "newness" or novelty. A substantial technological transition was occurring in the period when iron began to be used in Europe. The physical properties or affordances (Gibson 1979; Knappett 2004) of iron were different from those of bronze and required a change in production techniques. The technology of iron production went through many generations of refinement before the craftsworker could manufacture something suitable for use as a tool or weapon. Through this process of improvement the element of novelty played strongly into the perception of iron in the social world. Each of the different stages of the production process were susceptible to the smith's choices and thus became a possible locus for changes in traditional practices (i.e., innovation). The importance of choice created a delicate balance between innovation and tradition. There was an existing framework, and an understanding, within a society (producer and consumer) as to what made an axe or a hoe. It is therefore the actions of the smith, aligning or not with the existing conceptions of traditional behavior or innovation, that are reflected in the archaeological record.

1.4.3. Iron as a Social Technology

Due in large part to the material focus of the sub-discipline, archaeological theory has

[4] In this dissertation I have used various terms, such as smith and smelter, to describe actors who are involved with the production of iron at different stages. This is with the full acknowledgement that various modes of production are possible for early iron production, including non-specialists, many members of the community being involved with the smelt, or different people responsible for different stages of production.

been contributing more directly to the growing body of research attempting to resolve the false contrast between sociotechnical systems, techniques of production, and material culture. Investigations into the techniques and choices of production highlight the individual steps taken in production that are contingent upon, and products of, technical systems (Lemmonier 1986; 1993:21). More recently, discussions of chaîne opératoire have been focused on the individual agent involved in production, redirecting research questions from determining "what an object meant" to how the practice of production made it meaningful (Dobres 2010a:57, 2010b). Following this approach, I have in part focused on the byproducts of iron production to engage with choices pursued by the individuals involved in smelting and smithing activities. Choices were made concerning what iron ore to use, how to smelt the ore, where to perform the activities on the landscape, and how to form the iron object, and all of these choices were socially as well as technologically motivated (Halkon 2011). There has recently been a push to integrate technical studies of metals with discussions of their social impact (Thornton 2009; 2012), moving past the artificial divide between material studies and anthropological theory. The importance of ironworking byproducts like slag has been emphasized in recent decades. Slag, in an iron smelting context, is the primary waste material. It is the agglomeration of the gangue constituents from the iron ore, and often mixes with ash and charcoal within the furnace. The largest percentage of slag is typically fayalite, an iron and silica compound that flowed in its liquid form away from the metallic iron during a smelt. Much can be said regarding production and technological practice through analysis of slag, furnace remains, and other byproducts of metalworking, which provide direct evidence for production. Some of these studies have demonstrated that specific patterns of production, isolated choices made during production, or the small alterations to production practices over time can be identified using bulk compositional analysis. Rehren et al. (2007) illustrated that by taking into account the entire process of a smelt (types of ore used, charcoal type/amount, furnace type, etc.), the composition of the slag may indicate the specific choices made by the smelter. A consideration of these choices is essential to understanding the whole process of production and the way in which small changes to practices can alter large-scale production techniques over time. Charlton et al. (2010) traced these kinds of innovations through a late Medieval bloomery in Wales, using the bulk composition of the slag recovered as the basis for their conclusions. When these approaches are applied to the archaeological record in Ireland they illuminate production practices at the level of the individual by connecting the composition of slag to the behaviors that created those physical signatures.

Archaeological approaches to technology have the unique ability in anthropology to address the timespan necessary for analyses of technological transformation (Øye et al. 2010; Schiffer 2001, 2011). My dissertation addresses how iron technology in Ireland changed through time, looking at variations in furnace types, types of ores used, and the methods used by the ironworker for smelting and smithing. Past projects in Europe have used slag composition and morphology (Charlton et al. 2010; Paynter 2006, 2007), as well as larger contexts of iron production (Hjärthner-Holdar 2010:172; Hjärthner-Holdar and Risberg 2000, 2009), to investigate technological change and innovation. Changes in the actions made during production have both direct and indirect repercussions within the larger sociotechnical system: new resource locations were used and old locations were abandoned, networks of exchange were broken down and new ones developed, and individual relationships with the processes of production were altered.

It is also necessary to consider the non-utilitarian influences on the processes of iron production. I hypothesize that iron production was recursively involved in both the expression and creation of symbolic meaning. Previous ethnographic and archaeological studies have demonstrated that iron often has a distinct symbolic association at each stage of its trajectory (Childs 1999; Haaland et. al. 2002; Herbert 1993; Hingley 1997; Schmidt & Mapunda 1997), frequently involving sexual metaphors and taboos associated with the smelting process (Barndon 2004; Giles 2007; Haaland 2004). In considering these alternative influences on production practices, my project investigates how locations on the landscape, structures of production sites, or associations with other features were potentially implicated in symbolic actions.

1.5. Methods

In order to address the above research questions (Section 1.2), I have utilized a series of techniques focused on specific aspects of iron production in order to contextualize the practice within Iron Age Irish society. This project is focused on the compilation and synthesis of previously excavated sites that have generated evidence for iron production and have been radiocarbon dated to the EIA and DIA (Figure 1.1; Figure Appendix C.1). Most of the data for this project were taken directly from the unpublished excavation reports that I was able to access directly from the TII or the archaeological consultancy companies that conducted the excavation. Spatial data gathered from unpublished excavation reports were compiled in a GIS database so that patterns of production could be identified from the feature level to the regional level. Thirty-five sites were used as the basis for this project, with a few additional sites analyzed but not included in the dataset (Figure 1.2).

A Microsoft Access database was used to organize the data on three scales: site, feature, slag. This Access database was linked to the ArcGIS database in order to transfer multiple levels of data to the spatial component of the project. Additional information regarding furnace structure and archaeometallurgical analysis was also linked to this spatial database to investigate techniques of individual production and compare them on a country-wide scale. This GIS database was then transferred to an online webGIS interface to allow open access to this data.

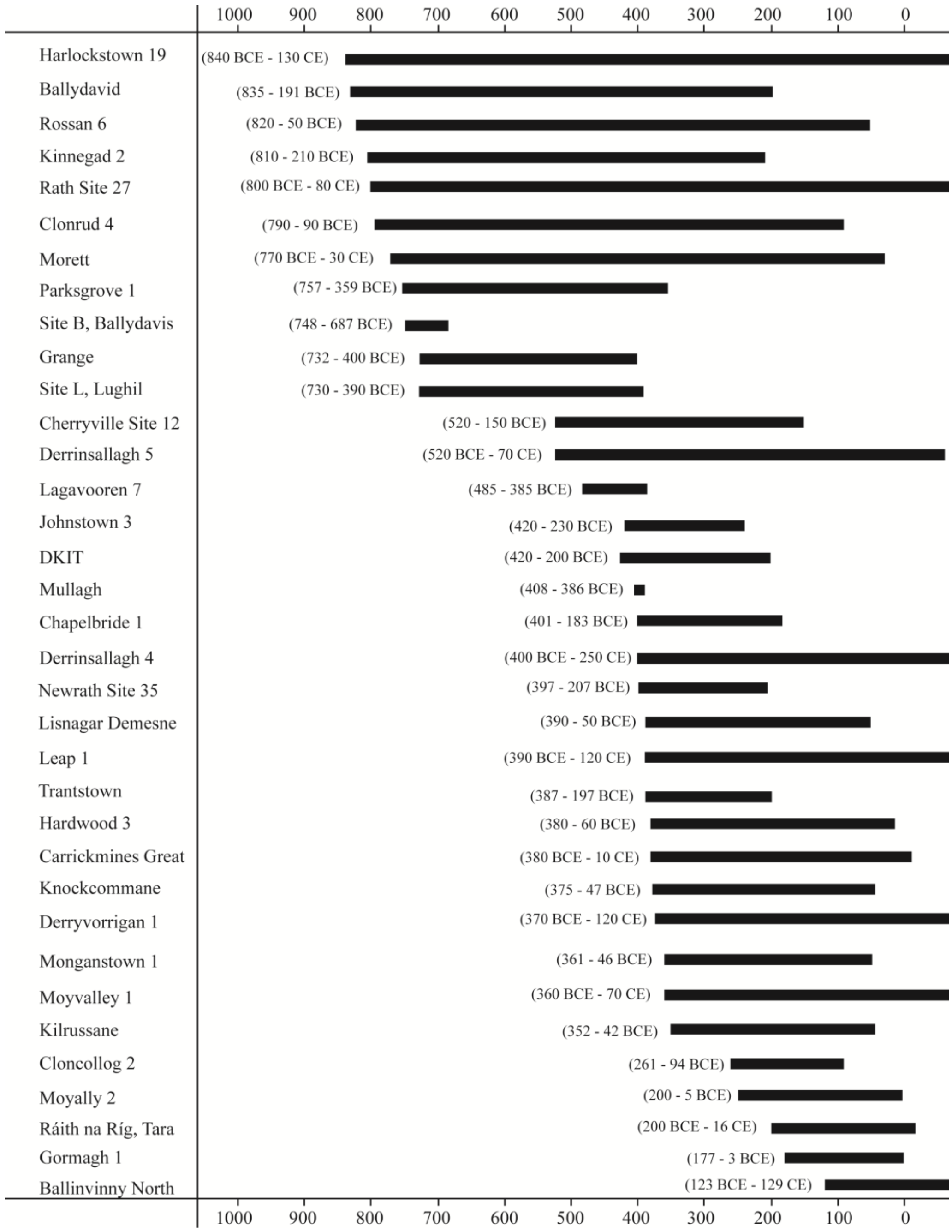

Figure 1.1 The sites used in this dissertation project and their compiled 2 σ ^{14}C dates. (n=35). For full radiocarbon dates see Figure Appendix C.1.

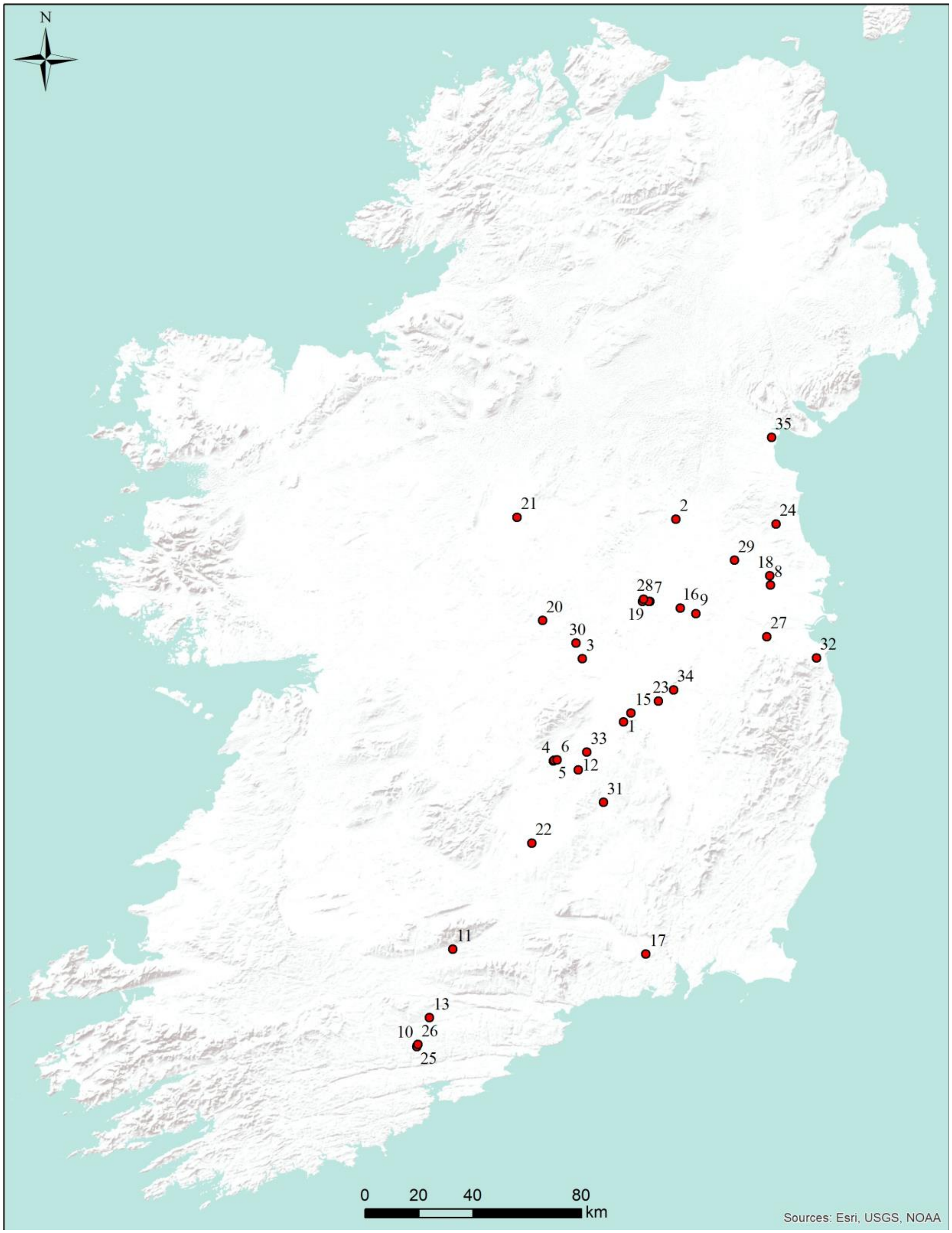

Figure 1.2 Sites used in this dissertation dataset. *1:Ballydavid; 2:Chapelbride 1; 3:Cloncollog 2; 4:Derrinsallagh 4; 5:Derrinsallagh 5; 6:Derryvorrigan 1; 7:Hardwood 3; 8:Harlockstown 19; 9:Johnstown 3; 10:Kilrussane; 11:Knockcommane; 12:Leap 1; 13:Lisnagar Demesne 1; 14:Monganstown 1; 15:Morett; 16:Moyvalley 1; 17:Newrath 35; 18:Rath Site 27; 19:Rossan 6; 20:Moyally 2; 21:Mullagh Site 1; 22:Ballydavid; 23:Lughil; 24:Lagavooren 7; 25:Ballinvinny North; 26:Trantstown; 27:Grange; 28:Kinnegad 2; 29: Ráith na Ríg; 30:Gormagh 1; 31:Parksgrove 1; 32:Carrickmines Great; 33:Clonrud 4; 34:Cherryville Site 12; 35:DKIT*

1.6. Initial Hypotheses

This dissertation addresses the primary research question of how iron production was organized in Iron Age Ireland by investigating a series of more focused questions (section 1.2). At the onset of this project, these research questions were used as the basis for generating some initial hypotheses to explain the expected outcomes of the dissertation project. The hypotheses are presented here and will be revisited in Chapter 5.

1.6.1. What level of skill is demonstrated by the byproducts of iron smelting and smithing?

Rehren et al. (2007) have demonstrated that though underutilized, slag has the potential to shed light on the actions of those involved in smelting and smithing activities. Since these actions collectively made up the event(s) of iron production, the technological practices used in iron production may reveal the skill levels of those producing iron blooms or iron objects. Through the use of a $FeO-Al_2O_3-SiO_2$ ternary phase diagram (discussed in Rehren et al. 2007:212-214), several studies have demonstrated that the bulk composition of slag can be used to identify the temperature at which the smelt took place (Humphries et al. 2009; Iles and Martinón-Torres 2009). Charlton et al. (2010) have identified two optima around which smelting slags tend to cluster that can help to reconstruct the types of conditions that characterized the smelt. Additionally, morphological characteristics of slag differ in their structure. For example, a flowing, liquid structure indicates a tapping-furnace was used (Bachman 1982; Paynter 2007), a furnace type that typically yields a higher volume of metallic iron (Pleiner 2000). The patterns of flow slags can give an indication of the techniques used for the smelt, based on whether the slag is found at the bottom of a slag pit or attached to the furnace wall on the blowhole side (Young 2008b). If compositional differences were identified for slags recovered from similar production sites but at geographically diverse contexts, then regional variation was further interrogated (see for example Paynter 2006). Different techniques of production at contemporary sites indicate that either there were multiple knowledge bases in operation or that several traditions of iron production in Ireland were operating concurrently. Conversely, very little variability across regions could suggest a tight and integrated communication network of iron production, or even travelling craftworkers (Garstki 2016). Information gained from the furnaces themselves indicates that aspects of the production process were tied directly to the skill of the individuals involved in smelting or smithing. For example, Young (2003a) has proposed a revision of the long-held belief that only bowl furnaces were used in Ireland from the Iron Age through to the Early Medieval period (see Chapter 2 for a more extensive discussion). It has been suggested based on a re-examination of the furnaces excavated in the last two decades that people in the EIA and DIA were actually utilizing slag-pit furnaces (Young 2003a), indicating a much more advanced technological capacity for iron production than previously thought.

1.6.2. How do patterns of production change through time, from the EIA (800-400 BCE) to the DIA (400-1 BCE)?

Technologically, there are expectations of change over time in iron production in Ireland. Paynter (2007) used alterations in slag morphology and composition to examine technical changes in furnace types, differences in ores, and types of fuel utilized through the Iron Age in Britain. Additionally, Charlton et al. (2010) used changes in slag chemistry at a single site to investigate innovation of technical practice for Iron Age and Medieval iron production in Wales. Broader ideas about the introduction and subsequent innovation of iron technology have also been discussed in other areas of Europe (Hjärthner-Holdar 2010:172; Hjärthner-Holdar & Risberg 2000, 2009). It is through innovation and improvisation that the imprint of the individual smith is manifested in long-term technological change, a palimpsest of practice through which technological change becomes visible in the archaeological record. If the results demonstrate that there was little change in production methods over time, the explanation may be due to the isolation of Ireland from its Bronze Age place in the Atlantic sphere of interaction (Henderson 2007). If Iron Age peoples in Ireland were no longer involved with the networks that initially brought the technology to Ireland (Henderson 2007), they may have been increasingly cut off from a system of knowledge transfer that continued to spread innovative production methods across Britain and the Continent.

1.6.3. What was the spatial relationship between iron production sites and other types of sites during this period (i.e., settlements and burials)?

It was expected that the GIS database developed in this project would demonstrate a dispersed pattern of production sites across the landscape. If the Iron Age populations were as low density as the archaeological settlement evidence suggests, then it was likely that production sites were not densely concentrated, but were spatially spread out to serve a more dispersed population. Additionally, it was hoped that the patterning visible between ironworking sites and other Iron Age sites would provide the basis for discussions of the symbolic associations and broader social contexts of the new technology. Iron production sites that are found separated from settlement sites may be explained by the non-utilitarian associations with iron technology, as attested in the ethnographic and historical records of this activity. Iron technological practices cannot be understood solely as a sequence of isolated techniques, but must be viewed through the lens of the symbolism that may have saturated those practices (Childs 1999; Hingley 1997:9). Previous ethnographic and archaeological studies have demonstrated that significant symbolic associations characterize the production of iron (Bardnon 2004; Giles 2007; Haaland 2004;

Haaland et. al. 2002). This process, where ore is transformed into bloom, has been symbolically associated with reproduction and birth in some cultures (Giles 2007; Hingley 1997), through references to the shape and function of the furnace and associated apparatuses (Giles 2007:401). There may have been taboos associated with who had access to the smelt, as is attested in these societies (Herbert 1993). Additionally, the technical practices may even have been imbued with notions of death, decay, and transformation stemming from the type of fuel used for the fire (see Gansum 2004 for the use of bones as fuel), which may account for the association of ironworking with burial sites (Dolan 2012).

1.6.4. Were different aspects of iron production tied to specific topographies and/or locations (hills, lowlands, settlement interiors/exteriors)?

For both economic and symbolic reasons, it was expected that different types of locations were used for different aspects of ironworking. In his analysis, Dolan noted that smithing sites dating to the Iron Age appear to be found frequently on hilltops (2012:155-156, 2014). Conversely, it was anticipated that smelting sites would be situated near sources of iron ores, potentially bogs in many cases (discussed in Photos-Jones & Hall 2011). It is economically more beneficial to smelt large amounts of ore at the source rather than carrying it across the landscape, especially if the current evidence for settlements is an accurate representation of the low population density. Based on this evidence, it was also expected that primary smithing (the initial treatment of the iron bloom) was taking place at the same sites or very near the smelting sites for similar reasons (Dungworth et al. 2012). Consequently, the locations of the different places of production would have had significant implications for how the technology or resource was controlled (if at all), its role in networks of exchange, and the social role of the individuals involved in the production practice.

1.7. Research Significance

This project focused on how iron technology was organized in Iron Age Ireland and how production changed over time. Even with the current influx of new data, the reconstruction of Iron Age Ireland based on archaeological evidence is still limited. This is in part due to the availability and accessibility of the new large dataset. The goal of this project was to take a nuanced and detailed approached to interpreting the archaeological data for Iron Age society by focusing on one aspect of it. The focus specifically on iron production illuminates a facet of society that represents a significant technological, economic, and possibly political shift from the LBA to the EIA. Yet by looking specifically at the evidence for iron production, this project also examined the organization of society in the Iron Age, and the interconnectedness of iron technologies and the rest of social life.

While the prehistoric context has its own particular features, this issue also bridges the humanistic disciplines that struggle with the socially embedded nature of technological development, and its recursive influence on social life more generally. Michael Brian Schiffer has noted that due to the embedded nature of technology in all aspects of social life, "research on technological change is nothing less than the study of behavior change – *and vice versa*" (2011:5 emphasis in text). This dissertation addresses the same topic – the changes and static patterns visible in the archaeological record as *technology* are in fact representing patterns and changes in social practice.

The artificial divide between material studies and the production of society through practice can be overcome by providing a material basis from which to interrogate techniques of production and their socially potent nature. Through the analysis of technical practices of ironworking in Ireland, this project moves beyond conceptualizations of technological production as merely a means towards an end, or as a separate subsystem within society, and instead investigates production as an enactment of social life where practice, symbolism, ways of being, and performance are all manifest in tangible products. By using these different methods of data collection and pattern identification to better understand iron smelting, I am able to speak to the actions performed during technological endeavors. These actions were not only embodied by the individuals involved, at once creating meaning while recreating social life, but also were part of larger patterns of production across the Irish social landscape. The effects of the actions taken during production are traced through different scales of technology, leading to a discussion of how technology can be transformed over time by small-scale alterations in production. Those involved in iron production were active in teaching and learning communities as well, utilizing the experience and choices of others to improve their craft (as Wenger discusses communities of practice [1998, 2000]). By comparing patterns seen in the archaeological record during the EIA to those of the DIA, this study provides a uniquely diachronic perspective on the discussion of how technological practice can be transformed at multiple levels. The repercussions of this type of investigation span time, space, and media. As a distinctly social activity, technology is implicated in the constitution of social life in all places and times.

By utilizing a multi-scalar approach to understanding the organization of iron production in Iron Age Ireland, this project highlights the way actions taken at small scales can impact multiple dimensions of technological practice and social life. The research questions addressed in this dissertation, as well as the data utilized, benefit greatly from a multi-scalar approach. By this I mean that the context investigated here has the potential to illuminate different aspects of the study of technology: the reconstruction of the practices utilized during each production event focuses on the scale of the individual site, the reconstruction of all of these sites focuses on the organization of production within a society, and the comparison of these reconstructions across time focuses on technological change within a society. Rather than a singular focus on an individual production event or artifact, or on technological change in isolation, this study addresses both in conjunction with one another. The online GIS interface created for this project further expands this aspect of multiple scales in the presentation of data, allowing the user access to information on both the site and feature scale.

The Iron Age in Ireland witnessed significant social, economic, environmental, and lifestyle changes, and the development of iron technology was embedded with, if not a catalyst for, some of these changes. Untangling the influences of technology and the products of technical practices on society provides us with a better understanding of technology itself, but also exposes the deeply entangled nature of social life as a whole.

Chapter 2: Background

2.1. History of Research

2.1.1. Early Archaeological Research in Ireland

The empirical observation of Irish monuments during the Enlightenment was the foundation for a lasting interest in the remains of ancient Ireland during the seventeenth century (Waddell 2005). Some of the more detailed early investigations of Ireland's ancient monuments were completed by Thomas Molyneux in the early eighteenth century, centered largely on the thesis that many of the forts, towers, and stone monuments in Ireland were the work of Danes (1726). Around this same time, archaeological artifacts were being collected at a repository of the Dublin Philosophical Society (following the model of the Royal Society of London), followed soon after by the Royal Irish Academy in the late eighteenth century (Waddell 2005:44-51). Around the turn of the eighteenth century, the Ordnance Survey of Ireland and the Royal Irish Academy contributed significantly to the systematic study of ancient Irish monuments. It was during this time that numerous regional offshoots of the Royal Academy were established, further enhancing the popularity of antiquarianism in Ireland.

As in much of western Europe, Jens Worsaae's Three-Age System was slowly adopted in Ireland following his visit to the Royal Irish Academy in 1846 (Waddell 2005:137). This framework for organizing Ireland's past into three, materially-based phases was opposed by some who suggested a "Pagan, Christian, and Anglo-Irish" alternative (Fergusson 1872; Wakeman 1848). It took large evolutionary-based artifact studies in the mid to late nineteenth century for the Three-Age System to gain widespread acceptance, which then allowed a more standard chronology to be established. These studies, combined with the adoption of John Lubbock's 1865 publication, *Pre-historic Times*, set the stage for the development of a non-Biblical chronology in Ireland, which subsequently led to the birth of modern archaeology in the country.

At the turn of the nineteenth century, George Coffey was appointed the first Keeper of the Royal Irish Academy's collection of antiquities at the Antiquities Division of the Dublin Museum of Science and Art (Waddell 2005:180). Numerous collections were gathered into a centralized place for scholarship and research, marking a turning point for the field and making Coffey the first professional archaeologist in Ireland. Coffey did much to develop the theme of the connection between Ireland and the Continent while writing on many subjects in Irish prehistory, especially the connection with "Celtic" peoples (Coffey 1904, 1910). Coffey, as well as his successor, Edmund C. R. Armstrong, was a proponent of the standardization of cataloguing museum artifacts, and both had a strong research focus on the Iron Age in Ireland. Following the establishment of large research museums in Ireland, the University College Dublin and University College Cork both appointed their first Chairs of Celtic Archaeology in 1909, R.A.S. Macalister and Bertram Windle respectively (Waddell 2005:191). Macalister was an extremely influential figure in modern Irish archaeology, producing many works outlining the prehistory of Ireland, and was also very influenced by the Medieval Irish literary sources, discussed below. Around this same time, Oliver Davies, Sean Ó Ríordáín, Estyn Evans, and Adolf Mahr all left their mark on the development of archaeology in Ireland, some for more notorious reasons than others[1] (Waddell 2005; Mullins 2013).

Throughout the 20th century, the discipline of archaeology developed much as it did elsewhere in Europe, as more archaeological data in the form of excavations and artifacts provided

[1] As in the case of Mahr and his connection to the Nazi Party (Mullins 2013).

fodder to counter interpretations of prehistory by previous generations. Just like any archaeological context, the Irish Iron Age demonstrates that contemporary interpretations are shaped largely by the history of research and the political or ideological motivations of scholars and institutions. Interpretations, reconstructions, and research questions on the prehistory of Ireland, and specifically the Iron Age, have been very much influenced by the Medieval Irish literature, the fragmented nature of the early archaeological record, and the associations assumed to exist between Ireland, Britain, and the Continent through a "Celtic" connection. It is therefore important that the trajectory of these lines of thought are traced in order to judge accurately how contemporary archaeologists reconstruct the Iron Age in Ireland.

2.1.2. History of Research on the Iron Age

2.1.2.1. The Influence of Medieval Literature

One thread running through the history of research on the Iron Age in Ireland is the idea that the tales of heroic pre-Christian people in Medieval literature are representative of Iron Age Ireland. These works of literature, consisting of poetry, histories, and sagas, were written down possibly as early as the eighth-ninth centuries, but definitely by the 11th century CE. While there are groups of stories that highlighted the 'fifths' of Medieval or prehistoric Ireland (Munster, Leister, Ulster, Connacht, and Meath)[2], the most prominent and most utilized as a connection to Irish prehistory is the selection of stories known as the Ulster Cycle (Carney 2005). It is in this cycle that the longest and arguably most famous saga is found, the *Táin Bó Cúalgne* (The Driving of the Cattle of Cuailgne). Another influential Medieval work on the development of archaeological thought in Ireland is the *Lebor Gabála* (Book of Invasions), also known by its longer title *Lebor Gabála Èrenn* (The Book of the Taking of Ireland). Although the *Lebor Gabála*

[2] Ó Cróinín notes, "at no time in the historical period did the political division represented by the word cóiced, 'a fifth', have a tangible existence" (2005:187). There is no actual record of what constituted these regions and kingdoms.

does not survive in its original form, these stories about the peopling of Ireland by successive groups of migrants through its prehistory are found in numerous twelfth and fourteenth century manuscripts (Carney 2005). The *Lebor Gabála* and the Ulster cycle have had a significant influence on the way Ireland's history has been viewed, specifically through a Biblical lens[3], and has shaped the way interpretations of the Irish Iron Age were initially developed and incorporated with the archaeological record.

Nothing illustrates the prevailing idea that the literary sources acted as remnants of an Iron Age past better than the influential, and now highly critiqued, lecture by Kenneth Jackson, *The Oldest Irish Tradition: A Window on the Iron Age*. Concluding his lecture, Jackson states, "…if we want to know what it was to be a late La Tène Celt, and what life in the Early Iron Age was like, we can get some notion of it by reading the Irish Ulster cycle of hero stories" (Jackson 1964:55). This was by no means a new proposal in Irish archaeology, and despite not being an archaeologist himself, Jackson raised some interesting points for the time about the possibilities for remnants of cultural practices being represented in the literature (although his comparison of the Ulster Cycle with Homer's *Iliad* is definitely problematic [Koch 1994]). The impact of these literary sources on archaeological interpretation can be traced to at least the mid-nineteenth century, when antiquarians such as William Wilde and George Petrie specifically connected the archaeological evidence with the literary tradition (Waddell 2005). In the early 20th century William Ridgeway, the Disney Professor of Archaeology at Cambridge at the time, strongly associated the world of Cú Chulainn and the *Táin Bó Cúalgne* with the world of the La Tène Iron Age Celts (1906). He found, as did others at the time, a strong connection between the material culture being recovered that depicted La Tène motifs and the description of material in the heroic

[3] The *Lebor Gabála* has its roots in a biblically-based notion of the movement of ancient peoples.

narratives. Edmund C. R. Armstrong published the first detailed papers outlining the phases of the Irish Iron Age, which he referred to as the Hallstatt Period and La Tène Period (1923, 1924), following Continental Iron Age nomenclature. Armstrong notes, "The La Tène culture in Ireland is contemporaneous with the Heroic period: the epoch whose manner of life is revealed by the Irish prose sagas of the Ulster cycle, notably the *Táin Bó Cúalnge*" (1924:2). To support further the historical nature of the Ulster Cycle, Ridgeway and Macalister dug at Rathcroghan, Co. Roscommon (commonly identified with the *Tain*'s Queen Meave[4]) in 1913, although these investigations were never published (Waddell 2005:190). Macalister continued to follow this line of thinking in subsequent work (1916, 1935), and noted "the shields, swords, chariots, etc. described in the Saga of the Táin are comparable with the corresponding objects found buried in the graves of warriors of that period" (1916:501). The idea of a close connection between the Táin and the Irish La Tène Iron Age persisted up through the 1980s (Caulfield 1981), and still influences how archaeologists today interpret the Iron Age in Ireland (and elsewhere in "Celtic" Europe [e.g., Arnold 1999]). Archaeologists working at Iron Age sites that have been linked to these places with robust mythical pasts have since had to deal with negotiating a perceived prehistory preserved in Medieval literature, from Tara to Navan Fort to Rathcroghan (Newman 1997; Lynn 1997; Waddell et al. 2009; respectively).

However, in the time since Jackson's lecture this "window" has received significant criticism from different disciplines dealing with Irish pre- and proto-history (e.g., Aitchison 1987; Carney 1983; Koch 1994; Mallory 1992; Raftery 1994). J. P. Mallory has illustrated how the swords described in the Ulster cycle are comparable to swords of the Viking period rather than anything from prehistory (1992). I would argue along with Raftery that,

[4] Medb was the queen of Connacht in the Ulster Cycle stories.

> if we examine the La Tène objects found in Ireland and set them against the descriptions in the tales we find there is no detailed correspondence. In fact a systematic search through the sagas suggests that in no single instance can it be assumed that material descriptions reflect the reality of Irish Iron age archaeology. Nowhere can we be certain that such descriptions do not derive from the contemporary world of early medieval Ireland. (1994:16)

These stories may have had ties to pre-Christian behavior in the Late Iron Age, or earlier. However, given the period of over 1600 years between the beginning of the Iron Age and when these narratives were written down, they should be used as possible analogies *if* the archaeological record appears to fit rather than as *a priori* demonstrations of structures and behaviors in the Iron Age. Furthermore, the literature focuses largely on unique events and elite individuals. So even if these stories represent some form of Iron Age society, they skew the reconstructions of the period towards an elite segment of society at the expense of a majority of the population living during that period.

2.1.2.2. The Celtic Question

Following the decline of the Roman Empire, the idea of a European "Celtic" ethnic group mostly disappeared. In the eighteenth century, linguists began to build evolutionary language models to account for modern day linguistic patterns, identifying Celtic languages as a branch of Indo-European. Canon Bourke was an early proponent of the "coming of the Celts" theory for the peopling of Ireland in the second half of the nineteenth century (Bourke 1887). Coffey's work on the direct connection between continental "Celtic" peoples, in the form of La Tène material and monuments, reinforced this connection for the movement of biologically-distinct people into Ireland during the Iron Age (Coffey 1910). In different ways, the influence of Coffey and Bourke largely established the pervading theory on the "Celticization" of Ireland by an invasion of Celtic peoples from the Continent. This idea proved to be a fundamental aspect of early archaeological research on the Iron Age. It was the merging of disciplines, in the form of linguistics, racial theory, and archaeology, that provided the body of evidence suggesting movement of people(s) and culture(s) from central Europe to the west during the Iron Age. Following the diffusionist paradigms that emphasized eponymous ancestral languages, the similarities between Gaelic, Welsh, Cornish and Breton were determined to be indicative of a common language family (Collis 1996:103). This language family was deemed "Celtic," based on the resemblances to reconstructed forms of the languages (mostly through place-names) spoken by the people whom the Greeks called Keltoi (MacAulay 1992:2). Due to this presumed linguistic connection, and furthered by the classical sources and similarities of the material culture that dated to the Iron Age in Continental Europe, a unified Celtic identity became the dominant paradigm.

Coupled with the connections made between the linguistic and archaeological evidence, literary sources, in the form of the *Lebor Gabála,* were also used to support a movement of peoples into Ireland during the Iron Age. In Macalister's early work, he suggests that the Medieval Book of Invasions preserved remnants of different migration episodes into Ireland, specifically the Milesians (as they are referred in the Book of Invasions), now called the Celts (1916). Following the paradigm at the time, Macalister argues that, "there were two races in the country – a subject and a dominant. The subject race, a short dark people, were the Stone Age aborigines. The dominant race, a tall fair people, Teutonic in blood but Celtic in speech, had come in at the beginning of the Iron Age" (1916: 506). Macalister further develops this line of reasoning in one of his books, *Ancient Ireland* (1935), by arguing that the Halberd-People were displaced by the Sword-People (also Beaker-People), who were displaced by an unnamed early Iron Age culture, who were then displaced by the 'Men of Iron,' who were likely Celtic-speaking Teutonic peoples. This migrationist view of culture change was of course not unique to Ireland, but undoubtedly influenced the development of Iron Age archaeological research until quite recently. Following

Waddell's (1978) critique of the invasion model, others have suggested that the archaeological evidence tends towards continuity rather than upheaval stemming from the movement of people (Cooney and Grogan 1994; Raftery 1994). The archaeological evidence no longer supports a large-scale migration into Ireland during this period, and the critiques[5] of the term "Celtic" itself have been fairly vociferous in recent years (Chapman 1992; Collis 2003; Cunliffe and Koch 2010; James 1999; Ó Donnabháin 2000). The implicit connection between Continental "Celtic" peoples and the Iron Age Irish have created some longstanding ideas on Iron Age Irish life (such as a social order with warrior-elites at the top) that may be one day supported by archaeological evidence but currently such a reconstruction is rather tenuous.

2.1.2.3. The Problem with La Tène

In his 1983 book on the La Tène in Ireland, Raftery states,

> The problems relating to a study of the La Tène material in the country are enormous, stemming, as they do, not only from the virtual absence of significantly associated or stratified artifacts, but also from the high proportion of objects which are devoid even of a provenance….Furthermore, the use of an art style as a dating criterion is at the best of times unreliable, but in an insular context, where conservatism, individuality and long continuity are inevitable, the uncertainties are greatly magnified. (1983:4-5)

Until relatively recently, much of the material that was used to characterize the Iron Age in Ireland either had no provenience or was found in deposits that made it very difficult to provide a secure date. The absence of archaeologically recognizable pottery in the Iron Age compounded the problem of dating other artifacts since ceramic chronologies often act as the basis for developing associated archaeological phases (Raftery 1995). As mentioned above, it was the similarity between artifact styles seen in Britain, the Continent, and Ireland, that originally gave rise to a Hallstatt and La Tène terminology in the country (Armstrong 1923). Since most of the La Tène pieces lack stratigraphic contexts or absolute dates, their dating has been based on similarities with

[5] See discussion of Celtoskeptism in Sims-Williams (1998).

objects in Britain and elsewhere in Europe where the La Tène style is more prevalent. Of course, such a comparative dating technique creates the problem of reliability by not taking into account a "lag time" in the transfer of stylistic motifs, or independent, insular development of stylistic patterns.

The lack of securely datable pieces is clear when one reads through Raftery's *A Catalogue of Irish Iron Age Antiquities* (1983) or *La Tène in Ireland: Problems of Origin and Chronology* (1984). At the time of publication, these studies represented comprehensive catalogs of all the materials available for the reconstruction of the Irish Iron Age. In almost every entry Raftery has to preface the typological discussion with a statement such as: "A discussion of spearheads in Iron Age Ireland is severely handicapped by the virtual impossibility of dating isolated examples" (1984:108). This demonstrates the extreme difficulty posed by using material defined as La Tène to reconstruct the lifeways of the Irish Iron Age peoples – without secure dates or context a fibula could have been worn by someone in the first century BCE or in the fifth century CE.

Coupled with the difficulty of dating unprovenienced artifacts, some of the "Iron Age" artifacts that were found during scientific excavation have recently been called into question. The site of Rathtinaun, Co. Sligo was a *crannóg* site excavated in the early 1950s by Joseph Raftery, demonstrating occupation from the LBA to the early historic period (Raftery 1994). Dowris metalwork, the characteristic LBA metalwork for Ireland, was found in association with some iron artifacts, which has been used to argue for a transitional LBA-IA site (Raftery 1994:34-35). However, some of these iron artifacts (specifically a crosier-headed stick-pin) have recently been identified as having an early Medieval date (Becker 2012b:7). Additionally, Jacqueline Cahill Wilson (2012) has argued that many of the artifact types that have traditionally been used to characterize the LIA and early Medieval period were part of an inaccurate typology and chronology (stemming in part from Hugh Hencken's excavations [1938, 1950]). These examples tell us that without extensive secure stratigraphic contexts for which these La Tène, or Hallstatt, artifacts can serve as type fossils, the use of ornate Iron Age metalwork as an indicator of Iron Age life will continue to be problematic.

2.1.3. Celtic Tiger and the Excavation Boom

Archaeologists are now in a better position than ever to move beyond some of the biases of the last few centuries. In the second half of the 1990s through the mid-2000s, Ireland underwent a significant boom in economic development. During this period, large infrastructure projects involving the National Roads Authority of Ireland expanded the national road system significantly (Figure 2.1). The expansion of roads led to significant Phase I – Phase III work in association with these construction projects. The result of these investigations was that for the first time, large numbers of archaeological sites were identified in a largely random sample. While sites from throughout history and prehistory were identified during the road schemes, the archaeological record of the Iron Age certainly benefited significantly from this expansion. The 2008 Heritage Council Project, *Iron Age Ireland: Finding an Invisible People*, identified over 200 sites that dated to the Iron Age using radiocarbon, dendrochronology, or find associations[6] (Becker 2012b; Becker et al. 2008). Since that time the number of Iron Age sites is likely closer to 300. This is in stark contrast to the small number of sites dated to the Iron Age prior to the Celtic Tiger[7], as exemplified by Raftery's 1994 chapter "Invisible People." As discussed above, much of the dating of Iron Age material and sites was tenuous in the absence of sites with deep stratigraphy necessary to develop widespread artifact chronologies. The large number of ^{14}C dates that were gathered and processed

[6] This project was limited to excavations conducted prior to 2004.
[7] The Celtic Tiger is term used to describe the economy of the Republic of Ireland from the mid-1990s to early 2000s, which experienced rapid growth.

during this period in Irish archaeology (Becker et al. 2011) drastically changed the way that the prehistoric record could be interpreted (see for example McLaughlin et al. 2016). Isolated or otherwise undiagnostic sites (which includes many of the ironworking sites) could actually be placed into an Iron Age chronology. These excavations and this period of economic growth provided an enormous new dataset that has been transforming the way the Iron Age in Ireland is reconstructed.

Figure 2.1 TII motorways and location of sites used in this project.

It is also prudent to keep in mind the excavation bias that this type of large scale construction produces. As seen in Figure 2.1, most of the sites identified in this project are along the major motorways in Ireland. Roads themselves are typically built to follow specific geographical patterns, often flat lands and around difficult terrain. Therefore, archaeological sites that are not otherwise identified on the surface, and are not in a position on the landscape that would be used for a motorway, may not be easily discovered. This bias should be acknowledged, but at the same time we can still work with the data we have to create the most parsimonious interpretations.

2.2. History of Iron Archaeometallurgy Research in Ireland

For a number of reasons, the history of archaeometallurgical analysis, specifically for the Iron Age, has been limited in Ireland. Until recently, most of the ironworking reconstructions for Ireland were based on research conducted elsewhere. Analyses and furnace typologies from continental Europe have had a significant influence on the way the archaeological evidence of iron production in Ireland has been interpreted. The earliest accounts of ironworking that attempted to discuss the history of iron production were mostly based on written sources and contemporary technologies witnessed by antiquarian travels to other parts of the world (Rondelez 2014a). One example of these contemporary techniques was the Catalan Furnace, which was a large open-hearth furnace with the capability for slag-tapping identified in the Iberian Peninsula. As Paul Rondelez (2014a:3) rightly points out, the identification of this furnace influenced how later researchers viewed iron and iron production. Using the Catalan Furnace as a proxy for "primitive," and therefore "ancient" technology, the bowl furnace was seen as the earliest incarnation of bloomery smelting furnaces throughout Europe. The early excavations of furnaces in Europe (e.g., Kluseman 1924; Mushet 1822; Percy 1864; Quiguerez 1866; Swank 1892) helped to establish an evolutionary trajectory for the technology, from open-hearth (bowl) furnaces to blast furnaces.

These evolutionary models of furnace techniques have had a major influence on how iron production has been interpreted in the archaeological record. Oliver Davies first introduced the term bowl furnace to describe the circular, clay-lined hearth features discovered in archaeological contexts in Europe (1935). This classification of a type of smelting furnace was utilized during Irish excavations in the first half of the 20th century by influential archaeologists like Hencken (1939) and Ó Ríordáin (1942). The evolutionary typology continued to be utilized through the mid-20th century, from Coghlan (1956) to Schubert (1957). In part to test the potential processes involved in smelting with a bowl furnace, experimental archaeometallurgy was first undertaken in the mid-20th century (e.g., Cleere 1972; Coghlan 1941; O'Kelly 1961; Sadzot 1956; Wynne and Tylecote 1958). This tradition of experimental archaeometallurgy has persisted since then, and continues to provide significant new information on reconstructing prehistoric ironworking structures. Much of what is currently known about early smelting and smithing was initially identified during experimental work, and the findings continue to impact the way the archaeological record is interpreted (Crew 1991, 2013; Crew and Charlton 2007; Crew and Salter 1991; Crew et al. 2011). Furnace typologies were modified and refined as more archaeological evidence came to light – bowl furnaces were seen as being non-slag tapping[8] and pre-Roman (Tylecote 1976) for example, but were subsequently dropped as a designation (Tylecote 1981, 1986). Until recently the prevailing thought was that bowl furnaces were the earliest structure of iron smelting, specifically in Ireland (Pleiner 2000; Scott 1990).

Doubts have recently surfaced regarding the use of bowl furnaces in early iron smelting in Ireland. Crew and Rehren (2002) first raised this question when analyzing the metallurgical remains from Tara, Co. Meath, and Tim Young (2003a) has followed their lead. The objection to the bowl furnace classification stems from the shape of this furnace type as it is excavated – steep sides as opposed to sloping sides – and the formation of the slag. An open bowl furnace would not yield the accumulation of slag at the bottom of the pit, often found in the recently identified

[8] Slag tapping refers to the technique of removing the fluid slag from a bloomery furnace through a hole in the furnace. See Section 2.3 for further details.

examples in Ireland discussed in this dissertation. However, due in part to its long history embedded in the discipline, the concept of a bowl furnace as the standard structure for iron smelting in early Ireland remains. Many excavation reports[9] still include references to bowl furnaces, often in spite of archaeometallurgical analyses reporting to the contrary.

As I have outlined above (2.1.2), the history of archaeological research was one dominated by a few specific themes that shaped archaeological inquiry in Ireland for a century and a half. One avenue for looking into Iron Age ironworking in Ireland was to identify trends in the literary sources. B.G. Scott (1983, 1988, 1990) has dealt extensively with the literary evidence for ironworking and the blacksmith, and how the sources related to the archaeological evidence in the later Iron Age and early Medieval periods, though unfortunately there has never been a "smith-history" recorded for Ireland. At the same time, the basis for these sources has not been archaeologically attested in the Iron Age, especially not the very beginning of iron production in Ireland. Nevertheless, Scott's *Early Ironworking in Ireland* (1990) was essential for establishing a foundation on which later studies can build. This publication was the first, and to date is the only, comprehensive treatment of the available data for iron production during the Iron Age and early Medieval period in Ireland.

Since the increased excavations of the last decade, several works have addressed various aspects of early iron production in Ireland (Carlin 2008; Dolan 2014; Photos-Jones and Hall 2011; Wallace and Anguilano 2010). Additionally, a number of the sites excavated through the National Roads Authority projects have been preliminarily analyzed by consulting companies such as GeoArch and Scottish Analytical Service for Art and Archaeology, among others.[10] Unfortunately, due to funding issues, many of these analyses were limited in scope and few have been published

[9] Some used in this dissertation.
[10] Rondelez (2014b); Dowd and Fairburn (2005); Fairburn (2006;2009); Cosham (2009); Keys (2010).

(*pers comm.* 2014 Tim Young [GeoArch]). Brian Dolan's 2012 PhD dissertation (University College Dublin), *The Social and Technological Context of Iron Production in Iron Age and Early Medieval Ireland c. 600 BC – AD 900*, is the only other comprehensive review of the more recently excavated sites along the new roadway projects[11]. Although Dolan was able to compile a large number of new sites dating to these periods, his project extended into the early Medieval period, which limited the detail that could be addressed in each period[12]. In this respect, significant research remains to be conducted on the ironworking sites discovered in the last decade and a half. My dissertation has compiled and synthesized the newly discovered sites in detail at multiple scales, from the site level to the metallurgical remains.

2.3. Iron Production

2.3.1. Basics of the Technology

I will focus here specifically on the production of bloomery iron, as this was the technique utilized during this period of Irish prehistory. The production of an iron object from a source of raw material involves several steps: resource collection/processing, smelting, primary smithing, and secondary smithing. Iron is available in different forms in Ireland, specifically as a chemical compound, largely with oxygen, carbon, and sulphur, which form iron oxides, carbonates, and sulphides, respectively (Scott 1990:9). These iron ores need to be processed in order to generate metallic iron, which can then be worked into usable iron objects. The production of the metallic iron from the ore is known as smelting, which is the chemical reaction between the iron oxides and a reducing agent (during this period in Ireland the agent is carbon monoxide, created by

[11] Paul Rondelez (2014a) also recently completed a dissertation (University College Cork) that contains much of the recent data, but his focus was in late Medieval ironworking.

[12] The second volume of this dissertation was only recently made accessible online (February 2017), and the data proved extremely robust. The data collected in the course of my own dissertation work overlaps considerably with the data presented by Dolan, which supports the quality of these data. However, based on the scope and focus of the projects, the interpretations differ widely.

burning charcoal) that takes place within a furnace (Scott 1990). A significant difference between iron smelting and other types of metal smelting in prehistory is that the output from the furnace is not molten iron, but rather a solid state. This solid state product is called a raw bloom, and it is this raw bloom that can be initially worked into a piece of metallic iron (known as primary smithing) and then subsequently worked into an iron object (known as secondary smithing).

When at room temperature, iron atoms are structured as a lattice arrangement in a body-centered cubic form known as ferrite (Scott 1990). During temperature changes the crystalline structure of iron transforms. Between 912°C and 1540°C the iron structure changes to a face-centered cubic lattice known as austenite, above which the iron reaches its melting point (Scott 1990). In addition, at around 800°C iron can be reduced as solid metal from its oxides, however this still leaves the problem that most iron ores contain additional compounds other than iron (Scott 1990:15). The heating of the iron ore to different temperatures allows the separation of iron from the unwanted, gangue materials (mostly silicates). Smelting that is carried out around 1200°C allows the iron particles to reduce from the iron oxides and combine to form a raw iron bloom, a mass of metallic iron mixed in with some slag. It should be noted, however, that the temperature ranges to create fluid slag or iron can be adjusted with the addition of carbon or other compounds. It was around or below this temperature that most bloomery smelting was taking place in Ireland during the Iron Age.

2.3.2. Resource Acquisition

In contrast to some other raw materials used in prehistory (e.g., copper and gold), iron was rarely mined in ways that leave visible traces. Geological and chemical processes acting on iron-bearing minerals result in a concentration of iron near the surface, in weathered outcrops, in the upper levels of other metal ores, or in easily-exploitable bodies of water or bogs (Pleiner 2000).

Ores are found in a number of different forms: limonites, goethites, heamatites, magnetites, siderites, and pyrites. The type of ore mainly utilized in prehistoric Europe was limonite, which is a product of weathering of the upper oxidation level of chalcopyritic copper ores (Pleiner 2000:88). Due to the early adoption of copper technology, these deposits would have been known in antiquity, and they are widespread. The most common type of iron ore used in much of Northern Europe, including Ireland, is what is known as bog iron. Bog iron ores are sedimentary deposits of iron hydroxides and limonites that are found in river flood plains, blanket bogs, river banks, lakes, and marshes. The iron content of these ores is often relatively low, but they are easily reducible, allowing them to be readily extracted through the smelting process.

Due to their availability, bog iron ores were the ideal source to take advantage of during early iron production, especially in Ireland. These ores tend to have a high phosphorus content (from 0.5 – 3%) and similar to other limonite ores, a higher manganese content than other iron ores (Pleiner 2000). These signatures can be identified through chemical analysis of the slag produced by smelting the bog iron ore. Effie Photos-Jones and A.J. Hall have proposed an interesting alternative to the idea that standard bog iron ores were utilized in Ireland during the Iron Age (2011). They suggest that early smiths could have been utilizing iron seepages, where groundwater seepages that are heavy in iron emerge from the ground (often at the boundary of bogs). These seepages eventually consolidate and dry out, creating solid bog iron ore. However, the seepages are regenerative, allowing for repeated "harvesting" of the iron (Photos-Jones and Hall 2011). Unfortunately, the archaeological remains of the prehistoric use of iron seepages in smelting furnaces would be very difficult to identify and would likely only remain as a component of soil-fill and the metallurgical waste (Photos-Jones and Hall 2011:629). However, while these seepages could have been a useful source of ore during this period, more examples of raw ore have been found in smelting contexts than previously thought[13], and it is likely that a number of different ore types were utilized.

Another resource necessary for the production of iron is the fuel on which the smelting furnaces and smithing hearths run. When wood is burned slowly in an environment with limited access to air, it releases water and other parts of the wood[14]. Between 200°C - 480°C these various substances are lost from the wood and it becomes charcoal, containing 78 – 92 % carbon (Pleiner 2000:115). The type of tree used for charcoal by early smelters and smiths would largely depend on the varieties available, but generally hardwoods were preferred for charcoal. In Ireland, this meant that oak was the most widely used wood for charcoal, as well as hazel and to a lesser extend alder (see section 4.4). Interestingly, despite oak being the most frequently utilized wood variety for charcoal in antiquity, during a series of experimental tests oak was noted as being the least satisfactory charcoal, compared to alder and birch (Crew 2013:31). It was found that the oak charcoal burned less readily than the other two woods, and the hot zone stayed closer to the front wall of the furnace (Crew 2013:31). The widespread use of oak, even if alder or birch would have produced a better charcoal, suggests something else may have been involved in the choice to use particular woods for different pyrotechnic activities.

There are two main methods for producing charcoal: free-standing charcoal heaps or piles, and charcoal pits. The principles for both methods are the same: a large stack of wood is assembled and covered almost completely with fern fronds, followed by clay or soil. Once the fire is lit, any holes are covered up and the pile is left to burn. The pile method could take 6 – 8 days to transform into charcoal, while in a pit it could take 3 - 4 days (Pleiner 2000:119). The size of the wood likely varied but based on reconstructions of traditional methods, wood was cut into roughly meter long

[13] See Chapter 4 and Rondelez (2014).
[14] Gases, essential oils, wood turpentines, alcohol, acetic acids, terpenes, and tars.

pieces[15] (Kelley 1986), generally the same length as the width of the charcoal pit (Emrich 1985). Using traditional charcoal pits, the yields did not typically exceed 15% by weight of the original wood (Emrich 1985:21). Various experimental smelts have identified the ratio of charcoal to iron bloom in weight at around 10:1 to 15:1 (Crew and Salter 1991; Pleiner 1969, 2000). This ratio is also assuming a roughly 1:1 ratio of charcoal to ore, although even more charcoal would have been necessary to preheat and maintain the temperature of a bloomery furnace. The creation of the charcoal was a necessary, labor intensive process, that required considerable wood to create small amounts of iron. The success of a smelt was largely dependent on having enough charcoal to maintain a high enough heat to create liquid fayalitic slag, and it would therefore be impossible to complete the smelt without the production of charcoal as a preliminary step.

2.3.3. Smelting Techniques

As outlined above, the process of bloomery smelting is undertaken to remove the metallic iron from the surrounding materials found with it as iron ore. To succeed in isolating the metallic iron from the siliceous slags, one needs an enclosed space filled with ore and charcoal fuel, as well as a source of air. As Radomír Pleiner (2000:141) has outlined, an enclosure used to smelt iron must meet the following conditions: be capable of resisting temperatures up to 1400°C, provide a means to supply air from the outside and exhaust gases out, and allow physical space for the separation of slag and the removal of the final iron bloom. Depending on whether an induced-draught furnace or forced-draught furnace was used, the smelting process could take 10-50 hours, or a few hours, respectively. The presence of a bellows could also drastically reduce the amount of ore required to yield similar results in an induced-draught furnace (Pleiner 2000:141).

Of course, the primary purpose of smelting iron is to separate the bloom from the slag, and

[15] The charcoal pits identified in this project measured from a meter to a little over two meters long, so the wood pieces could not have been longer than two meters.

the success of this process is largely based on the structure of the furnace. The furnace could be built in such a way as to allow only the removal of the slag and bloom as a conglomerate after the smelt was complete. This process was likely used with what are known as bowl furnaces. Bowl furnaces are often considered the most technologically simple means of smelting iron ore in which an open hollow is cut into the ground and lined with clay. It would have required a forced draught to maintain such high heat in an open enclosure, increasing the manpower required to complete the smelt (Pleiner 2000:145). The resultant metallic iron was distributed throughout the slag, making the separation of the iron from the slag difficult and leading to a significant loss of the final product.

Furnaces could have also been built with mechanisms for separating slag from iron bloom during the smelt. One approach to removal of the slag is to build a slag-tapping furnace that allows the slag to move down the furnace where it can be tapped in liquid form through a hole at the base of the furnace. Pleiner has suggested that it would have required a high amount of skill to successfully tap molten slag from a furnace due to the high likelihood of losing heat and halting the smelt (2000:142). The smelter would have required intimate knowledge of the smelting process to know exactly when enough molten slag had accumulated and then would have opened the taphole to remove it.

The second approach to separating slag during the smelt is to allow the molten slag to flow through the pores of the iron bloom into the pit-base of the furnace, in what is called a slag-pit furnace. The slag at the bottom of the slag-pit created a block of slag that maintained the concave shape of the furnace bottom, often found merged with part of the furnace lining (Pleiner 2000:149). A low-shaft slag-pit furnace would have been filled with alternating layers of ore and charcoal, with a base of brushwood. The basal part of the slag-pit would fill with a sinter-like layer, made up of the fine ore particles, charcoal, ash, sand, and ceramic fragments (Young 2008b). The hottest zone of the furnace would be around the blowhole, and this is also where the bloom would form. Fluid fayalitic slag would also be the most prevalent around this hot zone, causing the walls to contain flows of slag that are sometimes mistaken for tap slag. Other types of slag are also generated through various means within the slag-pit, and come to rest in the basal part of the pit. There are in fact other types of furnaces known in late prehistory and into the Medieval period elsewhere in Europe, including various types of shaft-furnaces and domed furnaces (Pleiner 2000), however these types do not relate to the context discussed here.

A major problem with identifying specific types of furnaces in an archaeological context is that the superstructure rarely survives later taphonomic processes. Specifically, it is at times difficult to determine if the furnace was an open bowl-furnace or enclosed as a shaft furnace. As Tim Young notes, the superstructure of a shaft furnace is often made of unfired clay, which disintegrates quickly, leaving no archaeological trace (2003a). Additionally, the stratigraphy of any prehistoric site is often truncated through years of taphonomic processes, which leaves only the base of the furnace *in situ.* However, there are some indications that the remains of simple concave furnace structures were originally slag-pit furnaces rather than bowl furnaces. The steep sides of a furnace base are one indication that the original furnace was a slag-pit furnace rather than a simple bowl furnace. Also, the deposition of the furnace bottom or slag mass gives an indication of the original furnace stratigraphy – the bloom must have been above the slag mass, so if the slag mass is near or at the surface of the furnace base, then the superstructure must have extended above the excavated surface (Young 2003a). While it is indeed a difficult task to identify specific furnace types from the limited remains available archaeologically, categorizing all early Irish furnaces as bowl furnaces is at this point no longer tenable.

2.3.4. Smithing Techniques

The raw iron bloom that was the resulting of the smelting process still had a significant amount of slag mixed in with it. Additional heating of the bloom/slag conglomerate (primary smithing) was required to continue to remove this slag and make the metallic iron workable. In its simplest form all that was needed was a heat source made up of charcoal and the conglomerate, but a depression or pit was often created to control the heat source. These hearths can often be confused with the remains of smelting furnaces (Pleiner 2000:216). The reheating of the bloom/slag mass results in the waste solidifying at the bottom of the hearth in disk-shaped cakes (called plano-convex block [PCBs] or smithing-hearth cakes [SHC]), and produces solid iron hammer-scale (Pleiner 2006). The conglomerate is forged enough to remove a majority of the excess slag from the smelt and consolidate the iron.

The end result of the primary processing is a bar of iron or ingot that can then be forged into an iron object through secondary smithing. Throughout Europe, iron ingots took a variety of shapes: bipyramidal bars, "currency" bars, sword-shaped bars, or flat bars (Pleiner 2006). This starting stock can then be worked through a series of heating and cooling episodes, during which the iron is hammered and shaped (Manning 1995; Pleiner 2000; Scott 1990). Tools that ranged from anvils, tongs, hammers, setts and chisels, to punches and drifts were used by the smith to shape iron artifacts (Pleiner 2006; Scott 1990:21). Unfortunately, the tools used in secondary smithing are almost never found in secure archaeological deposits during the Iron Age in Ireland and are rare in Continental Iron Age contexts as well, indicating either curation over generations or some type of ritual deposition.

2.4. Archaeological Context

This dissertation project is focused on the Early and Developed Iron Age in Ireland, a relatively understudied part of Irish prehistory that until recently has provided little archaeological evidence for social interpretations. The dates used to mark the beginning and end of the Iron Age in Ireland are continuously being modified. In the past, the absence of substantial archaeological material for the period between roughly 800 – 300 BCE led many to believe that the Iron Age proper did not begin until the third-second centuries BCE. As discussed above, the influx of archaeological data in recent decades has greatly expanded the number of sites and material dating to this previously poorly understood period. Yet even as more information accumulates, questions still remain about how to define the Iron Age and its temporal subdivisions. It can be argued that the Iron Age designation is an arbitrary one, useful more as a heuristic device to delineate periods into more understandable units. On the other hand, the Iron Age could also be said to begin at the time when iron was first used, worked, or produced on a wider scale in Ireland. For the purposes of this dissertation, I am using an altered Iron Age chronology used by Becker et al. in their study, *Iron Age Ireland*, in 2008 (see Table 1) – with the proviso that the introduction of iron to Ireland may have occurred prior to, or after, 800 BCE. I have pushed back the date for the beginning of the Iron Age from Becker et al.'s chronology, from 700 to 800 BCE, following the practice used by some of the NRA projects (e.g., Carlin et al. 2008). The evidence for an earlier introduction and use/production of iron will be discussed in this dissertation. The sections that follow lay out the cultural context for the Late Bronze Age (LBA), Early Iron Age (EIA), Developed Iron Age (DIA), and Late Iron Age (LIA), respectively. While the main focus of this dissertation is the EIA and DIA, it is important to situate this evidence within the larger temporal context.

2.4.1. Late Bronze Age Context

The LBA in Ireland is best characterized by Bishopsland, Roscommon, and Dowris phases gold and bronze metalwork (Becker 2013; Cahill 1995; Cooney and Grogan 1994). Hoarding and the intentional deposition of metal artifacts in irretrievable contexts peaked during this period in Ireland as in other parts of Europe, though such deposits were an important activity throughout the Bronze Age (Becker 2006). A large proportion of metalwork from this period has been found in contexts suggesting votive deposition, specifically bogs (Cooney and Grogan 1994:163). The metalwork deposited during this period appears to exhibit some regional pattering (Cooney and Grogan 1994; Eogan 1974). A northern group[16] of metalwork was identified by Eogan (1974) and Cooney and Grogan (1994), while a different group has a southern distribution[17]. However, this southern/northern distribution does not hold true for all bronze and gold types (Cooney and Grogan 1994:170-172). The rise in exceptional bronze and goldworking during the Dowris Phase has led some to think of this period as one of wealth and power consolidation (e.g., Waddell 2010). It is likely that metalsmiths were linked very closely to persons of considerable power, with the social or physical capital to commission these pieces, as well as regional and extra-regional networks in place to obtain resources.

Burials dating to this period are rare and mostly utilize a burial rite that includes ring-ditches or ringbarrows; a few sites also contained flat cemeteries, pit burials, or cairns (McGarry 2008:209). This variation appears to have extended to the realm of the living, as settlements ranged from enclosed roundhouses like Chancellorsland, Co. Tipperary (Doody 1995, 2000), lake settlements such as Knockalappa, Co. Clare (Grogan et al. 1999), to fair-sized hilltop enclosures such as Dún Aonghasa, Co. Galway and Haughey's Fort, Co. Armagh (Mallory 1995).

Settlement data and material assemblages suggest that during the LBA, Ireland was involved in a wide network of cultural and economic exchange (Henderson 2007; Waddell 1991). Contact with communities outside of Ireland would have expanded the possibilities for resource

[16] This consisted of lock-rings, gorgets, bowls, and Class II horns.
[17] This consisted of sleeve-fasteners, striated rings, buckets, Class I horns.

procurement[18], elite relationships, and broadened the networks of knowledge in which ideas could be transferred. It is possible that for unknown reasons, the networks of communication that had linked Ireland to the rest of the Atlantic world were no longer available or used during the beginning of the Iron Age (Henderson 2007). Perhaps this disruption in Atlantic connections was responsible for, or a byproduct of, some of the patterns we see in the EIA and DIA, discussed below.

2.4.2. Early and Developed Iron Age Context

2.4.2.1. Climate

The interaction between people and their environment is quite significant, and changing climate can have major repercussions for many aspects of society, especially industrial activities like iron production. During the eighth century BCE there was a deterioration in the Irish climate, from a dry phase during the LBA to a cold/wet period (Armit et al. 2014; Swindles et al. 2013). This climate shift is not just an Irish phenomenon but is recorded for much of Northern Europe, as well as elsewhere in the world (van Geel et al. 1998). Based on reconstructions of water tables and humification records from peatlands, it has been demonstrated that this climate shift was accompanied by an increase in bog growth due to the rapid increase in precipitation and/or change in temperature. Interestingly, this shift to a cooler and wetter climate may have also coincided with the sharp rise in ^{14}C levels that affected the precise dating of early EIA sites throughout Europe (van Geel et al. 1998).

While it does appear that there was a climatic transition at the beginning of the EIA, the question remains to what extent this impacted the way of life in Ireland during this time. In a recent study, the large number of sites that were ^{14}C dated during the economic boom of the late 1990s

[18] The tin used in Irish bronzes was likely procured from Cornwall.

and 2000s were compared with climate proxies (Armit et al. 2014). Over 2,000 ^{14}C dates were included in this study, ranging from 1200 cal. BCE to cal. 400 CE (Armit et al. 2014; Becker et al. 2011). There appears to be a peak in human activity from 1050 – 900 BCE, a subsequent decline in activity around 800 BCE, and a rapid fall up to 750 BCE (Armit et al. 2014: 17046). This seems to correspond to pollen records that demonstrate a peak in farming activity in the late eleventh century BCE followed by a decrease from the ninth to eighth centuries BCE (Molloy 2005: Plunket 2009). Armit et al. conclude that the decrease in population (as represented by ^{14}C dates) began *prior* to the climate downturn (2014:17046). However, I would add that even if a rapid climate shift did not directly cause a population change, it could have had a significant impact on lifeways that over time resulted in differing patterns of occupation, manifesting in the archaeological record as lower activity levels.

2.4.2.2. Transition

The transition from the LBA to the EIA is one of the least understood periods in Irish prehistory. The EIA was long known as the "Dark Ages" of Irish prehistory due to the lack of significant archaeological evidence. The striking paucity of material from this period is typified by the absence of ceramics. It has long been noted that any sites dating to the Iron Age lack pottery (Raftery 1994, 1995). This phenomenon may be due to a lack of distinguishable wares that has resulted in mis-dating particular deposits – in other words, Iron Age peoples may have in fact used ceramics but the lack of stratigraphically well-defined sites obscures this. One recent example that counters the long-held theory of an aceramic Iron Age is the site of Ballycullen, Co. Dublin. Excavated in 2003, some smaller pieces of ceramics were found in likely association with a "farmstead" structure that spans the EIA – DIA (Larsson 2012). Larsson notes that, "the fabric is similar to that of the late Bronze Age vessels, and the sherds have no additional morphology or decoration that might suggest a specific or even general date range" (2012:15).

For much of the last century, the prevailing thought was that the people characterized by the Dowris Phase metalwork were largely displaced, and it was only with the arrival of La Tène material in the third century BCE that Irish society began to leave any significant archaeological traces. As elaborated above, peatland and pollen records indicate a climate shift in the eighth century BCE (Armit et al. 2014). However, as Armit et al. concluded, the newly available ^{14}C-dated sites do not support a rapid decline of activity during this climate shift, though they do show a gradual decline in activity throughout the EIA (2014:17046). The prevailing thought amongst archaeologists is that there was relative population continuity between the LBA and the EIA, but also a gradual change in behaviors. This continuity is demonstrated by a number of sites with dates from both the LBA and Iron Age periods (Becker et al. 2008:51). From the 2008 Heritage Council-funded project, 59 individual sites were ^{14}C dated to the EIA (up through the 2004 excavations), down from 65 sites in the LBA (Becker 2013; Becker et al. 2008).

2.4.2.3. Settlement

The concept of "settlement" is less than straightforward when discussing the EIA. To begin with, there still were no settlements larger than what can be called a "homestead" or "farmstead." This of course limits the patterns or variability that can be recognized in the archaeological record. A variety of settlement site types are known from the Iron Age, including unenclosed settlements (post-built, circular or sub-circular in plan), enclosed settlements, hilltop enclosures (what have also been called hillforts), and lake settlements (Becker et al. 2008). One possible unenclosed structure from the EIA was identified at Ballinaspig More, Co. Cork (returning dates of 360 – 280/ 240 – 60 cal. BCE; 790 – 390 cal. BCE) (Danaher 2012), while another unenclosed settlement with two structures was found at Coolbeg, Co. Wicklow (returning dates of 760 – 400 BCE; 380

– 160 BCE [Frazer 2012]) (Figure 2.2). Hilltop enclosures pose another interesting dilemma when reconstructing Iron Age settlements. These site types, which are often categorized as univallate hillforts, multivallate hillforts, or promontory forts, do not correspond to the eponymous phenomenon in Britain and the Continent. They were long considered solely an Iron Age phenomenon (Raftery 1976), though radiocarbon dates show a more complicated history. They mostly begin to appear on the landscape in the Late Bronze Age, with a longer occupation that in some cases extend into the early Medieval period (Becker et al. 2008). Dún Aonghusa, Co. Galway, Rathgall, Co. Wicklow, Donegore, Co. Antrim, Raffin Fort, Co. Meath, and Clogher, Co. Tyrone all had dates that indicate there was some level of occupation there during the EIA, although they were occupied in other periods of prehistory as well (Becker et al. 2008). In some cases, it appears that there is only evidence of industrial use at hillforts during this period in the Iron Age (Crew and Rehren 2002; Grogan 2005:244; Raftery 1969; Warner 2000).

Figure 2.2 EIA settlement sites discussed in the text.

The second complicating factor when discussing EIA settlements is the more ephemeral nature of many of the identified sites. Sites which have provided an EIA radiocarbon date are frequently not what one would traditionally call a "settlement." Sites that have produced evidence of simple hearths, pits, cereal-drying kilns, or burnt mounds demonstrate human activity during this period but do not provide significant evidence to allow the reconstruction of settlement patterning. Sites such as Cloghers, Co. Kerry (Becker et al. 2008), Claristown 4, Co. Meath (Russell 2003a), Kilsharvan 5, Co. Meath (Russell

2003b), or Cloongownagh, Co. Roscommon (Henry 2000) are all examples of isolated pits with no other associated features whose ^{14}C dates provided evidence for EIA activity (Figure 2.3). I will make a note here that the term "isolated" may in fact be misleading. Many of the recently identified sites that were discovered during major infrastructure programs were given separate site designations and license numbers, per standard practice. However, many of these sites may have in fact been part of a landscape of Iron Age occupation. Take for example the above-mentioned Claristown 4, Co. Meath; found in the vicinity was a site with two pits and two hearths dating to 340 – 320 cal. BCE (Claristown 3), and a very interesting site with Neolithic and Iron Age ring-ditches, multiple burials from the DIA and early Medieval period, and an Iron Age structure (Claristown 2 [Russell 2012]). It is outside of the scope of this dissertation to investigate all of the larger landscapes of occupation for the Iron Age, although this was done for the ironworking sites and their landscapes. So until all of the Iron Age sites recorded from the NRA (and other infrastructure) projects are analyzed systematically for clusters of activity on a landscape, the EIA pattern of occupation will continue to be dominated by "isolated" sites.

Figure 2.3 EIA non-structural evidence for occupation discussed in the text.

Taking the evidence as it now stands, the EIA appears to have been a period of dispersed population without any significant agglomeration. One suggestion for the lack of significant numbers of settlements (as compared to the LBA or even the DIA) is that the EIA was a time when people became more mobile, adopting a more nomadic lifestyle (Armit 2007; Becker 2009, 2012a; Dolan 2014; Raftery 1994). Raftery noted that if tents became the dominant form of housing, the associated materials would leave little or no archaeological evidence (1994:113). However, he also presents the caveat that there is no original Irish word for tent (Raftery 1994:113). This possible lifestyle should be carefully considered as an explanation for the paucity of EIA settlement sites, but of course absence of evidence does not always translate to evidence of absence. A movement towards itinerancy would require a substantial shift in lifestyle, specifically in how food is procured. Such a change towards a more pastoral focus, in contrast to agriculture, is a possibility, as some have noted a shift towards pastoralism at the end of the LBA (Plunkett 2009). In conjunction with this, there is evidence of woodland regeneration following large scale clearance in the LBA (McDermott et al. 2001; Molloy 2005).

However, more recent secondary evidence of agricultural activity (like cereal-drying kilns or querns) suggests that farming did not cease at the onset of the Iron Age, which would have made living an itinerant lifestyle difficult. The influx of recent excavation data has provided a number of new examples of Iron Age cereal-drying kilns, such as the DIA site of Cookstown, Co. Meath (Clutterbuck 2012). These kilns were used to process grains for a variety of purposes, in addition to grinding grains with a stone quern. Rotary querns were introduced to Ireland during the Iron Age and represented an impressive upgrade from the saddle quern. For a long time, the evidence for arable agriculture during this period was sparse (Monk 1986). The increase in archaeobotanical data from more recently excavated sites is now beginning to highlight patterns of land use and the types of crops that were utilized during this period. At the site of Cookstown, Co. Meath, carbonized cereal grains, in the form of barley and wheat, were found in association with possible ritual ring-ditches (Clutterbuck 2012). Also the patterns of change from the Neolithic to the Iron

Age at Kerloge, Co. Wexford, suggested that a wider range of cereals (as compared to foraged foodstuffs) were being utilized, such as naked barley, hulled barley, hulled wheat, and oats (McLoughlin 2012). The rise in barley and oats in the LBA and Iron Age, and the decline of wheat, may have a basis in the deteriorating weather ca. 800 BCE, as barley especially can thrive in colder and wetter conditions than wheat (Monk et al. 1998).

The settlement evidence does expand in the DIA, as compared to the EIA. Cóilín Ó Drisceoil and Emma Devine (2012) have identified eight settlement sites with house structures that have produced ^{14}C dates spanning the DIA. We could also add Coolbeg, Co. Wicklow (Frazer 2012) to this list. Additionally, as is the case for the EIA, the indirect evidence for settlement activity greatly outnumbers the discoveries of house structures proper. The lack of a single settlement type continues during this period, with occupation continuing at some enclosed sites like Haughy's Fort, Co. Armagh, or Johnstown 1, Co. Meath (Becker et al. 2008). Additionally, there are a number of more ephemeral activity sites that only include pits, hearths, or industrial activities. As the evidence now stands, there does not appear to be any change in settlement type through these two early phases of the Iron Age.

Although the settlement record shows a fairly dispersed population, there are indications that at various times people were gathered together for larger building projects. The preserved trackways of the Iron Age demonstrate the ability of large groups of people to gather together and construct a means of transport across otherwise unpassable terrain[19]. The Corlea trackway in Co. Longford, the most famous of these examples (Raftery 1994, 1996), dates to 148 BCE. It consisted of large timber beams laid sesquentially for upwards of 2km – a minimum of between 200 and 300 large oak trees were required for the construction of this trackway (Raftery 1994: 99, 1996) (Figure

[19] I.e., bogs.

2.4). Another large trackway dating to the end of the DIA was found at Annaholty Bog, Co. Tipperary (Taylor 2012), as well as some smaller examples (Raftery 1996; McDermott et al. 2009). Similar examples of large construction projects are demonstrated by large earthworks such as Black Pig's Dyke, Co. Monaghan or the Dorsey, Co. Armagh, that both date to the EIA and DIA (Lynn 1989, 2012; Raftery 1994:83-88; Waddell 2010:379-382).

Figure 2.4 Large Iron Age construction projects.

2.4.2.4. Burial

The burial record for the Iron Age has also benefited greatly from an increase in rigorous excavations in the last 20 years. Raftery had previously argued that there were no burials in Ireland that could be dated to the early part of the La Tène period (i.e., DIA), largely due to the lack of archaeologically visible 'type fossils' (1994:199). In his 2008 dissertation, Tiernan McGarry identified 31 burial sites that dated to the EIA or DIA, though this number may now be larger with the influx of new sites in the last decade. The dominant burial rite appears to have been cremation, mainly in ring-ditches or ring-barrows (McGarry 2008). The difference between a ring-barrow and a ring-ditch is not always clear, as a ring-ditch may very well be a truncated ring-barrow. A ring-barrow is defined by an internal mound and external bank, neither of which is found in a ring-ditch. For this period, many more ring-ditches have been identified, and the cremations are found in either the ditch fill or at the center of the ring-ditch (McGarry 2009). However, if it is true that ring-ditches are truncated ring-barrows, then this would explain why the burials are only found below the surface level in a central cremation or ditch fill. It may also be why the number of individual burials found dating to the Iron Age remains so low, because the barrows that may have held additional burials have since been destroyed. The difficulty in defining ring-barrows as an Iron Age phenomenon is that they were used through the Neolithic and Bronze Age (Mount 2012; Waddell 2010), meaning that without significant excavation the exact number of Iron Age ring-barrows remains unknown. One interesting trend in ring-ditch distribution that has recently come to light is the prevalence of penannular ring-ditches in the south. James Eogan has noted that of the 15 comparable ring-ditches to the DIA site of BallyBronoge South, Co. Limerick, all are found in the southern half of the country (2012). This pattern stands in contrast to the distribution pattern of La Tène metalwork, which is mainly concentrated in the north (Raftery 1983, 1994). The cause of this disparity is still unknown, but as more is revealed about the EIA and DIA the basis for these patterns will hopefully become more clear.

In addition to the prevalent rite of cremation burial in a ring-ditch, EIA and DIA burials have also been discovered in flat cemeteries (e.g., Raheenamadra, Co. Limerick), cairns (e.g., Carnkenny, Co. Tyrone), or associated with other significant features (e.g., Navan Fort and Tara). These burials stand out in contrast to the "normal" burial rite, though again, the relatively low number of burials during the whole period makes any suggestion of normative burial traditions problematic. The low number of burials so far discovered for this period may also indicate the use of a less archaeologically visible mode of deposition – for example, excarnation or cremation followed by the spreading of ashes would leave essentially no archaeological evidence (Dolan 2014: 364).

To complicate the burial picture even further, some sites have yielded evidence for the re-use of older monuments. A DIA ring-ditch was constructed right over an earlier Neolithic ring-ditch at Claristown, Co. Meath, for example, which was then covered with a stone mound or cairn

(Russell 2012). Incidentally, this site was also used for early Medieval burials amongst the Neolithic and Iron Age ring-ditches. Additionally, the ring-barrows at Rathdooney Beg, Co. Sligo were shown to be both Neolithic and DIA in date (Mount 2012). McGarry found that 20 burial sites that were used between 1300 BCE – 400 CE also produced dates from the Neolithic to Middle Bronze Age (2008: 51). This reuse demonstrates the cultural palimpsest characteristic of the Irish landscape and highlights the difficulty in dating sites purely based on typology or grave goods, which are often lacking completely.

Probably the most well-known burials from this period are the so-called bog bodies. Human remains have been found in various peat bog contexts throughout Ireland, dating back into the Neolithic and through to the later Medieval period (Brindley and Lanting 1995). Though up to 40 total bog bodies may date to the Iron Age, currently only six have been ^{14}C dated to the Iron Age (Kelly 2006). This phenomenon, which is also widespread across other areas of northern Europe, could have represented a number of different burial practices, from sacrifice to murder to demarcation of land boundaries (Cunliffe 2004; Glob 1974; James 1993; Kelly 2006; Parker Pearson 1999).

2.4.2.5. Ritual

This period cannot be discussed without addressing the so-called 'royal sites' of the Irish Iron Age: Tara, Co. Meath, Navan, Co. Armagh, Knockaulin, Co. Kildare, and Rathcroghan, Co. Roscommon. Tara, one of the best known archaeological sites in Ireland, was in later periods associated with the High King of Ireland (Bhreathnach 2005). The first recorded survey of the monuments at Tara can be dated back to the Book of Leinster, ca. 1160 CE, though the Medieval names were reassigned to the various monuments in the nineteenth century by John O'Donovan and George Petrie as part of the Ordnance Survey (Waddell 2010:340). With over 30 features still visible on the landscape, and many more visible through various other non-intrusive techniques (Newman 1997; O'Sullivan et al. 2013), the landscape of Tara is a prime example of an Irish archaeological palimpsest. For example, "The Mound of the Hostages" is the Medieval name given to one of the main monuments on the landscape that excavation has shown to have begun as a Neolithic passage tomb[20], covered with a cairn ca. 3000 BCE, which later included adjacent burials in the DIA (Grogan 2008; Newman 1997; Waddell 2010). The Tara landscape was used throughout Irish prehistory and into the early Medieval period for funerary and other ritual activity.

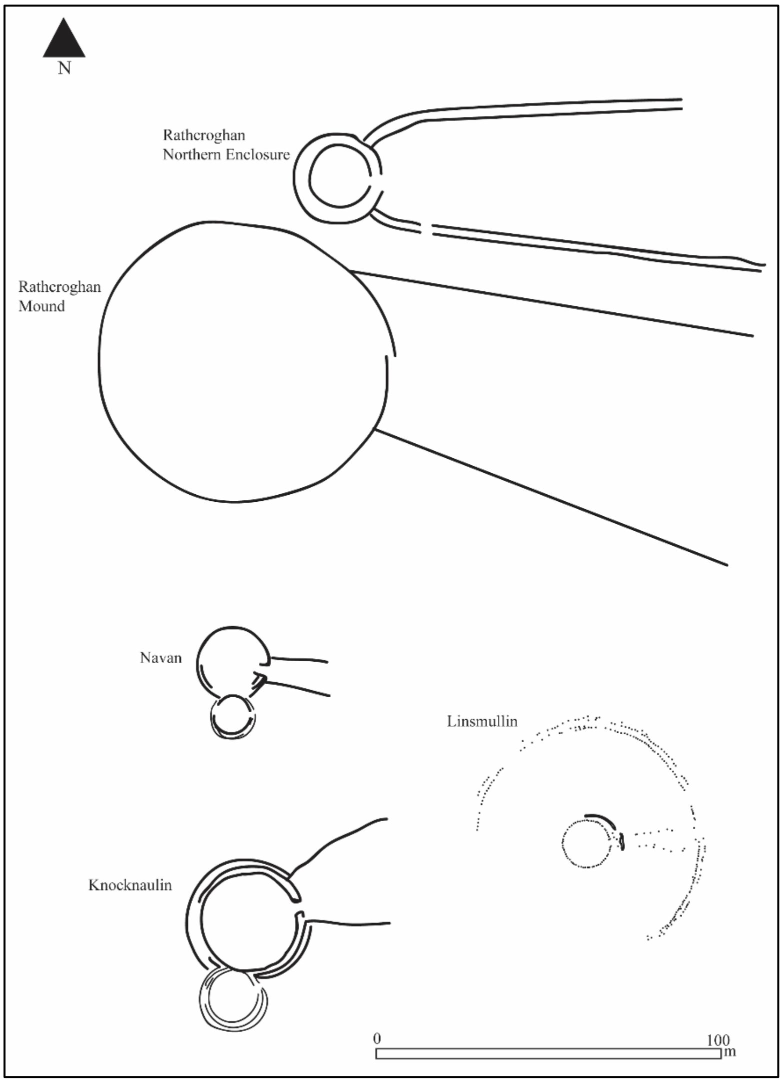

Figure 2.5 Schematic plan maps of Iron Age ceremonial sites (after Lynn 1997; Waddell 2010; O'Connell 2013).

[20] Beneath the mound itself was also part of a ditch enclosure that ^{14}C dates to 3500-3000 BCE (Waddell 2010).

The Navan complex in Co. Armagh is considered to be the archaeological manifestation of Emain Macha from the Ulster cycle. Similar to Tara in its expansive archaeological landscape, over 40 individual sites make up the Navan complex. Monument building on the landscape begins around 1300 BCE with the construction of Haughey's Fort[21] and the King's Stables[22] (Lynn 2003; Mallory and Lynn 2002; Waddell 2010:348). After Haughey's Fort is abandoned c. 900 BCE, there is evidence for some minor DIA occupation (Mallory and Lynn 2002). Navan Site B was first built as a ditched enclosure and subsequently as a "figure-of-eight" post structure in the DIA, and was later cleared at the end of the DIA to create a massive, 40-meter diameter timber structure (Mallory and Lynn 2002:533). This enormous structure was then filled with limestone boulders and covered with sod to create a large mound. A similar set of construction phases to those at the Navan mound can be found at one of the other "ritual centers," Knocknaulin (Figure 2.5). Knocknaulin, Co. Kildare is linked to the royal center of *Dún Ailinne* and shares the "figure-of-eight" structure type that was seen at Navan. During the 1968-1975 excavations, the large hilltop enclosure revealed a number of phases of Iron Age use. The 'Rose' phase of the site produced a very similar structure to the sub-mound features at Navan Site B, possibly even larger[23], while in the proceeding 'Mauve' phase a large timber structure replaced the previous one[24] (Johnston and Wailes 2007; Lynn 2003). The 'Rose' phase at Knocknaulin produced ^{14}C dates ranging throughout the DIA, as at Navan (Johnston and Wailes 2007: 180). And similarly to these other ceremonial sites, there appears to be multiple periods of use, illustrated by the recently identified large enclosure that pre-dates the Iron Age bank and ditch (Johnston et al. 2014). A similar

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[21] A trivallate hillort.

[22] An artificially built pond where both human and animal bones have been recovered (Lynn 1997)

[23] The southern ditches at Knocknaulin were 15-20m in diameter (10-13.5m at Navan); northern elements were 27-36m in diameter (20-25m at Navan) (Lynn 2003).

[24] This was similar to the 40 meter structure at Navan Site B.

landscape to Tara is also seen at Rathcroghan, Co. Roscommon, linked to *Cruachain*, the legendary seat of Queen Maeve from the *Táin Bó Cúalnge*. The Rathcroghan landscape contains over 60 different sites, including close to 30 burial mounds and numerous enclosures (Waddell 2010; Waddell et al 2009). The central feature of this complex is Rathcroghan Mound, Ráth Crúachan. Geophysical survey of the mound has demonstrated that beneath the mound are the remains of a structure very similar (though considerably larger) to the 'figure-of-eight' structures at Navan and Knocknaulin (Waddell et al 2009) (Figure 2.5). There are a number of other occupation phases at the mound, once again similar to both Navan and Knocknaulin. Unfortunately, only minimal excavations have been conducted at this site (Waddell 1988), so the precise dating of the construction phases is still unknown.

While these large scale ceremonial sites have been the focus of much archaeological research, largely due to their connection to the Medieval sources, some recent discoveries have expanded what is known about ritual in the Iron Age. During part of the construction of the M3 motorway between Dunshaughlin and Navan, evidence of a large timber structure was uncovered dating to the EIA-DIA transition (O'Connell 2012, 2013; Prendergast 2012). The Lismullin enclosure in Co. Meath lay roughly three km from Tara. It included an outer enclosure measuring 80m in diameter, an inner enclosure of 16m in diameter, and a post-laid 'entrance way' leading from the inner enclosure outwards (O'Connell 2013) (Figure 2.5). The ^{14}C dates place this site slightly earlier than the other major ceremonial sites, and it is unique in that it was not constructed on a large hill. The discovery of this site raises the possibility that these large gathering places or ceremonial sites may have been more common than previously thought, and did not solely exist in the form described in later Medieval texts. While it is not in the purview of this dissertation to go into detail about ceremonial or ritual behavior in this period, what these demonstrate is that there was a clear delineation between inside and outside, providing a large space for gatherings and often a demarcated path for moving from within to without.

The large assemblages of people that may have occurred at the ceremonial sites discussed above constitute one aspect of ritual life during the Iron Age – small scale deposition of goods into irretrievable places may have been another. The deposition of metalwork in bogs, lakes, and rivers during the Bronze Age has been known for a long time. Immediately following the LBA, there appears to be a cessation of votive deposition of metalwork in watery contexts, with a revival in the practice during the DIA (Becker 2012b; Cooney and Grogan 1994:180). The lack of substantial deposition in the EIA may be explained in various ways. Votive deposits could have continued but in the form of more perishable material than metalwork. Also, the gap in deposition is directly linked to the appearance of La Tène material – the context for the discovery of La Tène metalwork in Ireland is overwhelmingly from watery contexts (Cooney and Grogan 1994:197; Raftery 1983, 1984). This connection should once again be considered in the context of the lack of reliable dating for these artifacts (see 2.1.2.3). Additionally, there still exists the possibility that Dowris type gold and bronze metalwork continued to be deposited into the EIA, but since these hoards or single finds are mostly dated typologically they appear to be part of an earlier depositional phase (Cooney and Grogan 1994). Regardless of the possible discontinuity, there appears to exist a similar practice of placing metalwork into irretrievable contexts during the DIA for non-utilitarian purposes.

2.4.2.6. Social Organization

The influence of the Medieval written sources (Section 2.1.2.1) has also done much to structure the way archaeologists have presented the organization of society during the Iron Age. The notion of a strict hierarchy reminiscent of that represented in Medieval Irish literature has been critiqued in recent years (Dolan 2014; Ehrenreich 1991; Giles 2007; Hill 1995, 2012). Dolan has suggested that if the people during the Iron Age in Ireland were practicing a more itinerant lifestyle and increased transhumance, it would be unlikely that the social structure was "triangular"[25] (2014:369). Some alternatives include heterarchical structures (Dolan 2014; Ehrenreich 1991, 1995) or 'flat corporate' societies focused on community (Hill 2012). The emphasis on communal projects/gathering places like the linear earthworks, trackways, or ceremonial structures does in part support a more community-based social system, as does the lack of recognizable social differentiation in the burial and settlement record. However, there is still the consideration of the fine metalwork that was produced, especially in the DIA, which could have acted as a manifestation of power inequality (Armit 2007). Countering this claim, Hill argues that an elite object like a torc "may have symbolized the status and power of the larger group that the wearer represented – a symbol of office not a personal status symbol" (2012:256). This may account for the paucity of material buried with individuals – these objects were not representative of the individual and therefore not suitable for deposition with the dead. As the archaeological record now stands, I see a change in organization from the LBA to the Iron Age, with the focus of life being more insular (in terms of Ireland as well as the family unit). In the course of the DIA stronger community or regional interactions emerge again, manifested in ceremonial sites and communal works. Throughout this time there were likely individuals with greater social capital and power, but the form which this would have taken is still unknown.

2.4.2.7. Iron Objects

As noted above (Section 2.2.3), this period in Irish prehistory suffers from a lack of provenienced iron artifacts. Despite this, we still have a range of artifacts that appear to date from the EIA into the DIA based on comparisons from contexts outside Ireland. Iron Age Irish peoples

[25] By triangular he and others mean that most of the population was at the 'bottom' of the economic/political/power ladder, while a few individuals were at the top.

utilized a wide suite of iron objects that ranged from weaponry to everyday implements. In terms of weaponry, swords and spearheads appear to have been produced within Ireland at least during the DIA, and likely earlier (Raftery 1983:83-96,109-110). The size and shape of the swords suggest a specific Irish type, with a short blade compared to contemporary British or Continental examples (Raftery 1983). Unfortunately, all but two of these iron swords were found in wet sites: Knocknaulin (Johnston and Wailes 2007:89) and the burial at Lambay Island (Cooney and Grogan 1994:197-198).

Iron was also used to produce a variety of axeheads, such as looped socketed axes, unlooped socketed axes, shafthole axes, and adzes (Raftery 1983; Scott 1974, 1990). One of the most securely dated unlooped socketed axe was found in the pre-bank (DIA) fill at the Ráith na Ríg, Tara (Roche 2002). These implements in many ways mirror their bronze counterparts from earlier periods and are what Scott has referred to as skeuomorphs (1990). It can be assumed that the smiths responsible for the production of these iron objects were at least very familiar with the shape and structure of these bronze objects and may also have been creating the bronze versions. In addition to these axes, other iron tools were produced in this period: sickles, chisels, files, billhooks, shears (Raftery 1983). The uses of iron for purely utilitarian purposes are less likely to have made their way into the archaeological record. Iron nails were likely produced during this period, for example, although most of the recovered nails from reliable stratigraphic contexts have been dated to the LBA and Early Medieval period. The lack of substantial undiagnostic iron artifacts dating to the EIA and DIA almost certainly is due to the difficulty in identifying or dating such pieces. For many of the reasons listed above, finished iron objects were not analyzed for this dissertation. However, the ability to produce a wide range of iron objects will be considered in the larger discussion of the organization of iron production in the EIA and DIA.

2.4.3. Late Iron Age Context

The last third of the Iron Age has also benefited from the influx of research and excavation, as was the case for the EIA and DIA. Approximately 400 sites can now be dated to the LIA, with a variety of site types represented (Dowling 2014:151). House structures are typically post-built roundhouses, with no apparent distinguishing features compared to preceding periods. The enclosures and house structures are one aspect of settlement data now available for the LIA – various pits, hearths, kilns, or metalworking features have also been found dating to this period that provide additional information about settlement patterns. Pastoral activities and cereal production are both evidenced in the settlement record, such as the keyhole-shaped cereal kiln associated with the settlement enclosure at Baysrath, Co. Kilkenny (Channing 2012; Dowling 2014). The higher proportion of cereal-drying kilns dating to the LIA, and distribution of settlement activity, has led to the suggestion that people were more settled during this period than in the preceding EIA and DIA[26] (Dowling 2014:154). A main theme that we can see looking at LIA settlement is continuity, both with the preceding periods and with the early Medieval period. Recent excavations are demonstrating that many Medieval ringforts and crannogs were built on top of or right next to earlier Iron Age settlements (Dowling 2014:171; O'Sullivan and Breen 2007). Additionally, there are a number of examples of re-used LBA monuments during the LIA, such as Mooghaun (Grogan 2005) and Rathgall (Raftery 1994). Similar to the DIA, the main burial practice was cremation associated with ring-ditches or barrows, or pits (McGarry 2008), with some unique inhumations re-emerging as a burial rite around the Meath-Dublin region (Eogan 2012; O'Brien 2012; Schweitzer 2005).

This continuity with the DIA is also demonstrated by the ongoing use of the larger

[26] As opposed to a mobile lifestyle discussed above.

ceremonial sites, like Navan and Tara. The Rath of the Synods at Tara was constructed in the second century CE, incorporating an earlier burial mound surrounded by a multivallate boundary; excavations have produced a number of native and foreign materials (Bayliss and Grogan 2013; Grogan 2008). Interestingly, the passage tomb at Newgrange reemerges as an important cult site during this period, as demonstrated by numerous depositions of high-quality Roman material near the mound. However, even though continuity of ritual or communal sites on the landscape may have been occurring, there is also some evidence for the influence of outside forces, in the form of connections with the provincial Roman world. The recently completed *Late Iron Age and 'Roman' Ireland* project supported by the Discovery Programme has highlighted the need to reconsider how Ireland fits into the Roman world during this period, and the misconceptions that have hindered archaeological research in this period (Cahill Wilson 2014). Recent isotopic testing has demonstrated that there were indeed people moving from Britain or the Continent to Ireland during this time (Cahill Wilson et al. 2014; Cahill Wilson and Standish 2016), in addition to the quantities of Roman material found in Ireland that had previously been labeled as 'intrusive' (Cahill Wilson 2014). The new view is that this part of the Roman frontier was much more fluid and multifaceted than previously thought, as people and objects moved across the Irish Sea for complex reasons.

Chapter 3: Methods

3.1. Introduction

The goal of this dissertation is to investigate how iron technology was organized during the Early Iron Age (c. 800 – 400 BCE) and Developed Iron Age (c. 400 – 1 BCE) in Ireland, and how this context demonstrates that the development of new technologies can be most clearly understood by investigating the archaeological remains of production practices. To address these topics adequately, a series of research questions were posed to explore the different scales of production and their social ramifications: 1) What level of skill is demonstrated by the remains of iron smelting and smithing? 2) How do patterns of production change through time, from the EIA (c. 800-400 BCE) to the DIA (c. 400-1 BCE)? 3) What was the spatial relationship between iron production sites and other types of sites during this period? 4) Were different aspects of iron production tied to specific topographies and/or locations?

In order to investigate each research question specifically, while addressing the larger picture of iron production in Ireland, I utilized an interconnected set of research methods to approach the topic of interest at multiple scales. The main component of this project was to compile and synthesize all of the existing excavation data available to reconstruct the production of iron during the EIA and DIA. Prior to the Celtic Tiger infrastructure boom in the late 1990s into the 2000s[1], there were no sites that could be reliably dated to the EIA or DIA that had produced evidence for iron production[2]. All the sites that were utilized for this research were excavated after

[1] See Chapter 2, Section 2.1.3.
[2] An exception to this may be at Knocknaulin, where slag indicative of smithing appeared to have been associated with IA phases (Johnston and Wailes 2007).

the late 1990s, and most have not been published in any form other than as preliminary or final excavation reports filed with the National Monuments Service and the contractor. Sites were chosen based on their radiocarbon dates – providing a range within the EIA or DIA – and the presence of structural evidence of some level of iron production: a smelting furnace or smithing hearth (Table 3.1). Other sites were identified that produced slag remains that dated to the period in question, however because the lack of structural evidence for production limited the reconstruction that would have been possible, these sites were not included in the final analysis. Each of the sites used for this project was digitized into a Geographic Information System (GIS), and each of the site features was linked to an associated Microsoft Access database. This three level relational database also included a table for recording features at these sites, as well as a separate table for the slag recovered from these sites (discussed in detail below). The GIS and associated database allowed queries to be completed to directly address the research questions presented above.

Table 3.1 List of project sites and chronological dates, ordered by chronological date, earliest to latest.

Site Name	County	License Number	Date
Clonrud 4	Laois	E2167	LBA/EIA
Site B, Ballydavis	Laois	03E0966	EIA
Grange	Dublin	13E0435	EIA
Kinnegad 2	Westmeath	02E0926	EIA
Lagavooren 7	Meath	00E0914	EIA
Site L, Lughil	Kildare	03E0602	EIA
Morett	Laois	03E0461	EIA
Parksgrove 1	Kilkenny	99E0597	EIA
Rossan 6	Meath	02E1068	EIA
Site AR 26, Ballydavid	Tipperary	E2370	EIA/DIA
Cherryville Site 12	Kildare	01E0955	EIA/DIA
Marshes Upper Area 16	Louth	02E0201	EIA/DIA
Moyvalley 1	Kildare	02E1088	EIA/DIA
Mullagh	Longford	09E0311	EIA/DIA
Derrinsallagh 5	Laois	E2181	EIA/DIA/LIA

Hardwood 3	Meath	02E1141	EIA/Medieval
Carrickmines Great	Dublin	02E0272	DIA
Chapelbride 1	Meath	E3172	DIA
Cloncollog 2	Offaly	E2850	DIA
Gormagh 1	Offaly	11E87	DIA
Johnstown 3	Meath	02E1094	DIA
Kilrussane AR 27	Cork	01E0701	DIA
Knockcommane	Limerick	E2342	DIA
Leap 1	Laois	E2131	DIA
Monganstown 1	Westmeath	E2771	DIA
Moyally 2	Offaly	E2672	DIA
Newrath Site 35	Kilkenny	04E0319	DIA
Ráith na Ríg, Tara	Meth	97E300	DIA
Site 27, Rath	Meath	03E1214	DIA
Trantstown AR 29	Cork	01E0501 AR29	DIA
Ballinvinny North AR26	Cork	01E0501 AR26	DIA/LIA
Lisnagar Demesne 1	Cork	03E1510	DIA/LIA
Derrinsallagh 4	Laois	E2180	DIA/LIA
Derryvorrigan 1	Laois	E2193	DIA/LIA
Harlockstown 19	Meath	03E1526	DIA/LIA

I should note here that in my attempts to conduct a multi-scale project to identify production patterns and the role of iron production in IA Irish society, the initial dissertation project included an aspect of direct morphological and compositional slag analysis. However, this aspect of my dissertation had to be modified and could not be carried out as originally planned. During the initial research trip in 2015 that was organized in association with the National Museum of Ireland Collections Storehouse outside of Dublin, I planned to have the museum staff pull out all of the slag recovered from the sites identified in the survey of excavation reports and I planned to begin analyzing the samples in preparation for taking samples for XRF compositional study. However, the collections staff determined during this research visit that they did not have the material. After additional investigation, I discovered that standard procedure was to bury the slag after preliminary analysis had been completed – per the recommendations of the achaeometallurgist and the National Roads Authority. Only a few sites with slag (still above ground) currently exist, and most of that slag is housed with the individual contract companies that performed the excavation, not with the National Museum. After this discovery, I decided not to include the compositional analysis of slag from this project. The main research questions for my dissertation remained the same and the other methods were only slightly altered. Most of the sites used in this dissertation did include preliminary archaeometallurgical analysis of the slag recovered from the sites, and in some of these cases compositional testing was involved. The data from these tests were utilized in the discussion that follows, but were only available for certain sites. The slight change in methods did not affect the nature of the dissertation, as my goal was always to investigate iron production as a social practice, intertwined with the rest of society during this period, and was not framed as a strict materials analysis. By utilizing the data (plan and profile maps, excavation documentation, specialist analysis, etc.) already available through the process of excavation and preliminary analysis, I have employed a holistic approach to studying this technological practice in Iron Age Ireland. A GIS and a relational database served as the main platforms to organize and analyze this material. The following sections will outline the methods developed for this project in more detail, and provide a rationale for each step of the process.

3.2. Excavation Reports

In the advance of new road, light rail, or other development projects in Ireland, an archaeological component of an environmental survey is typically conducted to identify any areas of archaeological significance that may be affected by development. If archaeological monitoring warrants it, further excavation is conducted and an excavation licence is provided. Excavations in Ireland are licensed through the National Monuments Service in the Department of Arts, Heritage and the Gaeltacht (Dublin). As a stipulation of the excavation license, a full excavation report is submitted after the completion of the excavation. These reports are largely confined to a standard format that includes a general archaeological survey of each area, detailed descriptions of the excavated features/contexts, find inventories, plan and profile maps of the site, and specialists reports (if applicable/available). I gained access to these reports through the NRA (now the TII), which allows researchers access to all submitted excavation reports, as well as from some private archaeology consultancy firms[3]. In all, 35 sites formed the basis of this study (Table 3.1).

3.2.1. Dating of Sites

Dating and chronology have long been an issue when studying this period in Irish prehistory. To begin with, much of the material culture used to characterize Iron Age life in Ireland was recovered as isolated finds or in hoards, in watery deposits or during peat cutting, or with no provenance at all (Becker 2012b; Raftery 1983). Because much of this material was not found in secure contexts or in stratigraphic association with larger sites, dating these objects has often been based on British or Continental comparatives (see Chapter 2 for more discussion of this history). In addition to the problems with dating material during this period, contexts or finds that have traditionally been used in archaeology to date sites (e.g., burials with significant grave goods, ceramics) are largely absent. The large-scale infrastructure projects of recent years collected significant numbers of radiocarbon dates, which for the first time has allowed the temporal placement of more ephemeral sites lacking significant material culture[4]. Due largely to these development-led projects, there are now over 700 ^{14}C dates available for sites dating to the EIA and DIA (Armit et al. 2013; Becker et al. 2011). Sites in this corpus of EIA-DIA dates that have evidence for some type of iron production served as the basis for this study. It is necessary to point

[3] Archaeological Consultancy Services Unit; Courtney Deery Heritage Consultancy; Irish Archaeological Consultancy.

[4] Ephemeral sites without diagnostic material/structures dominate the Iron Age landscape in Ireland.

out that many of these sites were used over long periods of time, some ranging as far back as the Neolithic. As such, it is sometimes difficult to associate the ironworking features specifically with a particular radiocarbon date taken recovered from the site. In many cases the sample used for ^{14}C dating came from a furnace, but for some sites the case has to be made to associate the production events with a ^{14}C date (Table 3.2). Unfortunately, due to the non-diagnostic nature of the finds, the ^{14}C dates are the only way to date these sites. A total of 35 sites were included in this project whose ^{14}C dates lay within the range specified (Table 3.1). Table 3.1 presents the compiled Iron Age dates from each site, often combining numerous radiocarbon samples. I have used the 2 sigma calibrated dates for all ^{14}C dates utilized in this dissertation.

There were a total of 127 radiocarbon dates recovered from the 35 sites used in this project (see Appendix C). Of these, 92 dates fit into the general LBA/EIA to DIA/LIA chronological span used in the dissertation (Figure Appendix C.2). In of the numerous projects from which this data was gathered, a number of laboratories were used to process the radiocarbon dates. Furthermore, a variety of sample types were utilized for ^{14}C dating. This information is provided in Appendix C as aggregated figures and tables. All radiocarbon dates are provided in BP ± form, and were calibrated using OxCal v4.3.2 (Bronk Ramsey 2009, 2017). The IntCal13 calibration curve was used for 120 of the ^{14}C dates (Reimer et al. 2013). However, the uncalibrated dates of seven of the ^{14}C dates compiled as part of this larger dataset were not able to be recovered. This was due to the excavation publication not containing the radiocarbon report at the time it was accessed for this project. For these instances, the dates are included but separated in the figures and tables in Appendix C.

Another major issue that should be made explicit is that many of the samples used for carbon-dating came from oak charcoal, which can often be affected by the "old-wood effect"

(Warner 1987). All wood sampled is, by its nature, older than when it was used or deposited. Coupled with sampling from long-lived plants like oak trees, it is possible that ^{14}C samples are providing dates older than their actual period of use. There have been suggestions for how to correct for any error based on this effect (Warner 1987). For this dissertation, no such correction was conducted, based in part on the idea that if trees were cut down immediately before charcoal production, then the effect would be minimal[5].

Table 3.2 List of sites indicating which contained an ^{14}C sample recovered from a furnace, ordered by chronological date, earliest to latest.

Site Name	County	Date	14C Furnace Sample
Clonrud 4	Laois	LBA/EIA	Yes
Site B, Ballydavis	Laois	EIA	Yes
Grange	Dublin	EIA	Yes
Kinnegad 2	Westmeath	EIA	No
Lagavooren 7	Meath	EIA	Yes
Site L, Lughil	Kildare	EIA	Yes
Morett	Laois	EIA	No
Parksgrove 1	Kilkenny	EIA	Yes
Rossan 6	Meath	EIA	Yes
Site AR 26, Ballydavid	Tipperary	EIA/DIA	Yes
Cherryville Site 12	Kildare	EIA/DIA	Yes
Marshes Upper Area 16	Louth	EIA/DIA	Yes
Moyvalley 1	Kildare	EIA/DIA	Yes
Mullagh	Longford	EIA/DIA	Yes
Derrinsallagh 5	Laois	EIA/DIA/LIA	Yes
Hardwood 3	Meath	EIA/Medieval	Yes
Carrickmines Great	Dublin	DIA	Yes
Chapelbride 1	Meath	DIA	Yes
Cloncollog 2	Offaly	DIA	Yes
Gormagh 1	Offaly	DIA	No
Johnstown 3	Meath	DIA	Yes
Kilrussane AR 27	Cork	DIA	Yes
Knockcommane	Limerick	DIA	Yes
Leap 1	Laois	DIA	Yes
Monganstown 1	Westmeath	DIA	Yes
Moyally 2	Offaly	DIA	Yes
Newrath Site 35	Kilkenny	DIA	Yes
Ráith na Ríg, Tara	Meath	DIA	Yes

[5] This caution when applied to metallurgical charcoal is somewhat overblown, since coppiced trees were the likely the source of much of the charcoal (Rondelez 2014a: 23).

Site 27, Rath	Meath	DIA	Yes
Trantstown AR 29	Cork	DIA	Yes
Ballinvinny North AR26	Cork	DIA/LIA	Yes
Lisnagar Demesne 1	Cork	DIA/LIA	No
Derrinsallagh 4	Laois	DIA/LIA	Yes
Derryvorrigan 1	Laois	DIA/LIA	No
Harlockstown 19	Meath	DIA/LIA	Yes
Total # of sites with furnace dates = 30 (85.7%)			

3.3. Building of GIS

One of the main components of this project was a multi-scale GIS that contained information on the sites in the project sample and the individual features excavated at those sites. The software used for this GIS was ESRI ArcMap 10.3.1. The projection used for this project was IRENET95 Irish Transverse Mercator (ITM), the geographic coordinate system for Ireland that optimizes the UTM for the island (Figure 3.1). The process of creating each element of the GIS is described below. To organize the GIS files analyzed in this study, I utilized a personal geodatabase that centralized the shapefiles in a single file system folder with a unified coordinate system.

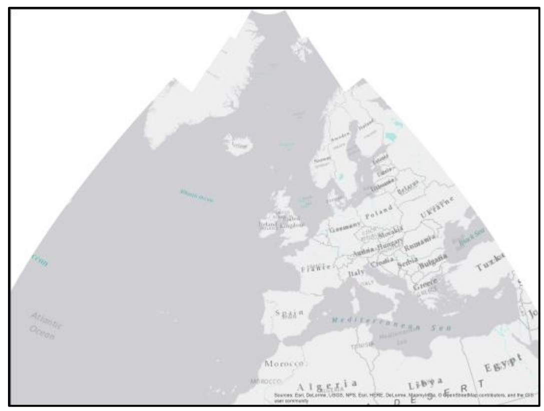

Figure 3.1 Irish Transverse Mercator Projection.

3.3.1. Georeferenced Maps

All plan maps from the sites used in this study were georeferenced into the project GIS using ArcMap. The process of georeferencing consists of placing a map (or other file) into a "real" space – a coordinate system. Almost none of the individual maps that accompanied the excavation reports used for this project included geographic coordinates, meaning it was difficult to simply georeference the site-level maps (Figure 3.2). Instead, I developed an approach to georeferencing the maps by beginning with the largest scale map and working down to the feature-level. Each map was converted into a .jpeg file and imported into ArcMap. Beginning with the largest scale map available, I manually georeferenced the map using the “Add Control Points” tool in the georeferencing toolbar – this consisted of clicking on a known point on the map, and clicking on that same point on the ArcMap basemap (Figure 3.3). After adding four to six control points, the large-scale map would be properly scaled and georeferenced. This same process was then repeated for the next size map, moving down to the smallest scale map provided. Depending on the site, there may have been as few as three scales of maps to be georeferenced, or as many as 15. The more complex the site, the more maps were needed.

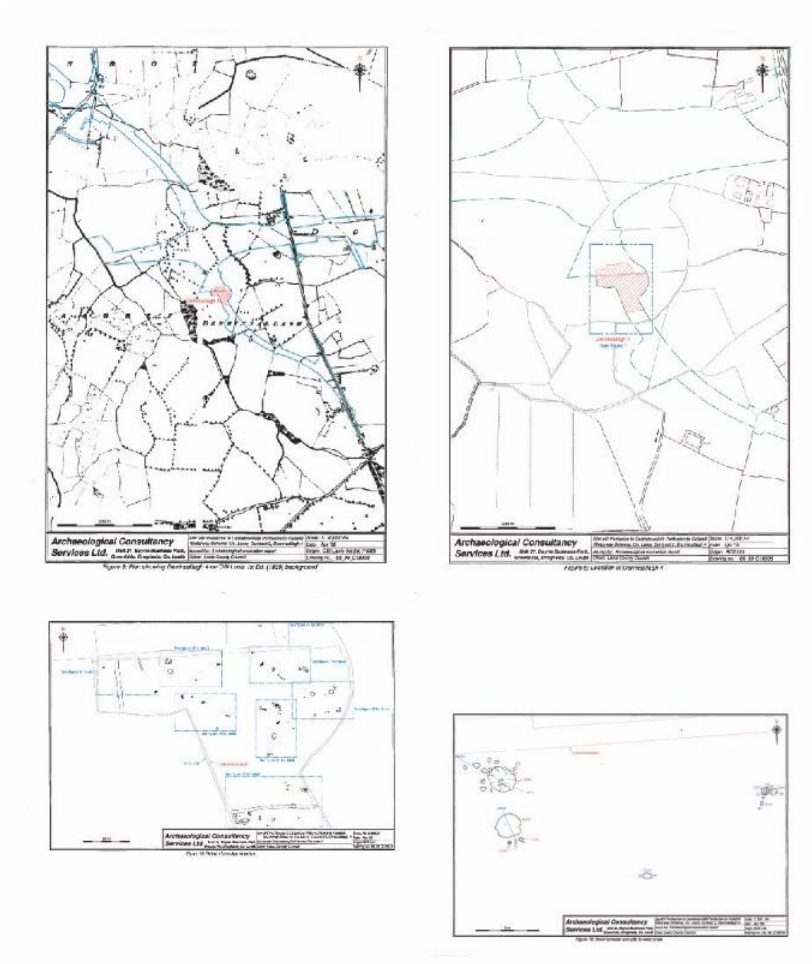

Figure 3.2 Example of different scale maps used to digitize project sites
(Maps from Lennon 2009a).

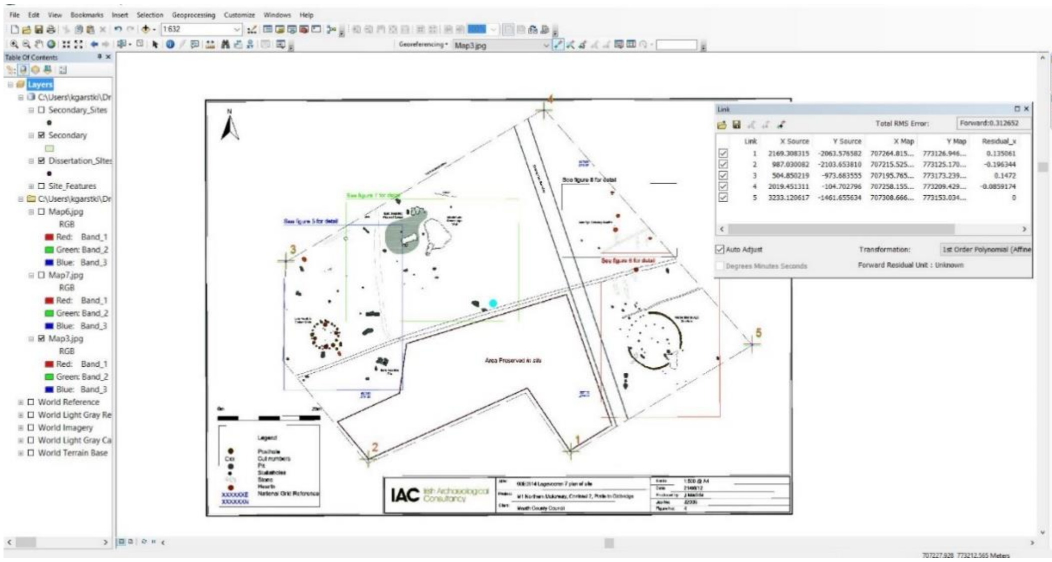

Figure 3.3 Screenshot of georeferenced site plan map in ArcMap. Georeferencing toolbar in the top center of screen; link table on right side listing control points.

3.3.2. Project Shapefiles

Two main shapefiles were produced to store the data for this dissertation: Dissertation Sites, and Site Features. Dissertation Sites is a general point shapefile created to visualize the larger, site-level scale of iron production (Figure 3.4). This shapefile is represented by a single point for each site in the dissertation project. Each site was given a unique entry that included information for the attribute fields “Site_Name” and “Site_Licen.” The site licence field acts as the main link to the Microsoft Access database, discussed below. This is a unique number given to each site by the National Monuments Service, so it provides an unambiguous designator for each of the sites included in this analysis. The Site Features shapefile is constructed of polygons that represent each individual feature identified and mapped during the excavation of the sites included in this analysis. Once all of the maps were georeferenced into the proper coordinate system (ITM), each feature was digitized as a separate polygon within a single shapefile. This consisted of using the polygon construction tool in the Editor toolbar to trace each feature mapped by the excavators of each site (Figure 3.5). Each completed polygon represents one distinct feature and consists of one entry in the Site Features shapefile (Figure 3.6). Each polygon includes attribute fields for site license number and feature number, allowing each feature to be linked to the corresponding database. After the polygon for each feature was created, I manually entered in the feature number and site licence information into the editable attribute table.

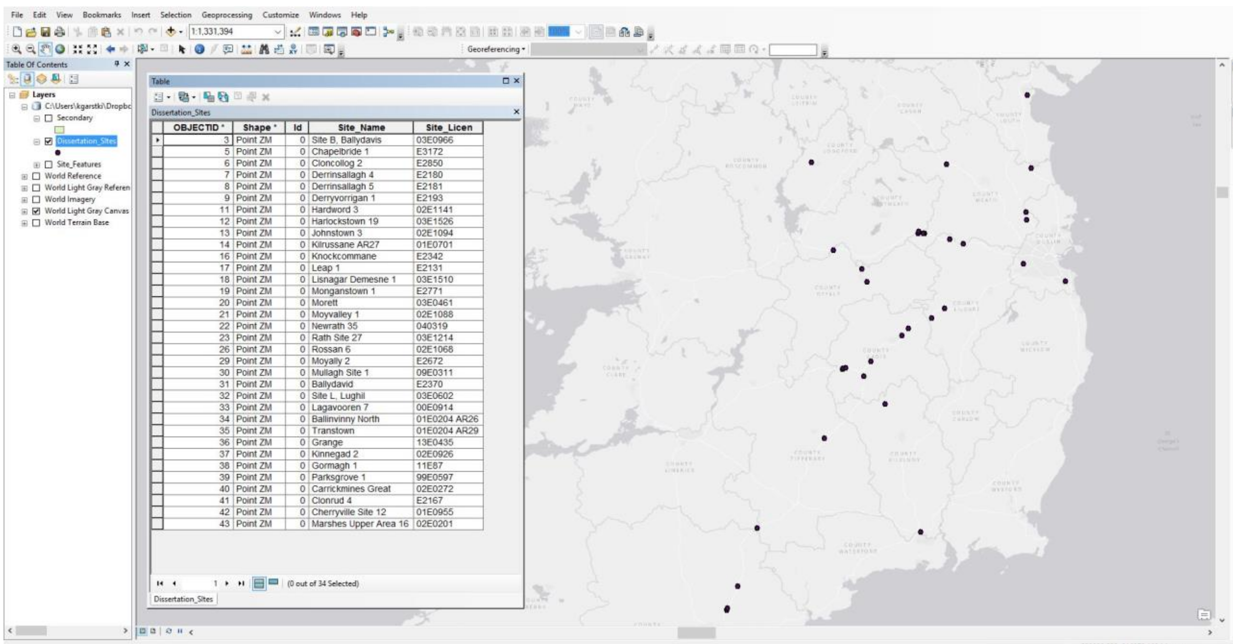

Figure 3.4 Screenshot showing the Dissertation Sites shapefile with associated attributes table, in ArcMap.

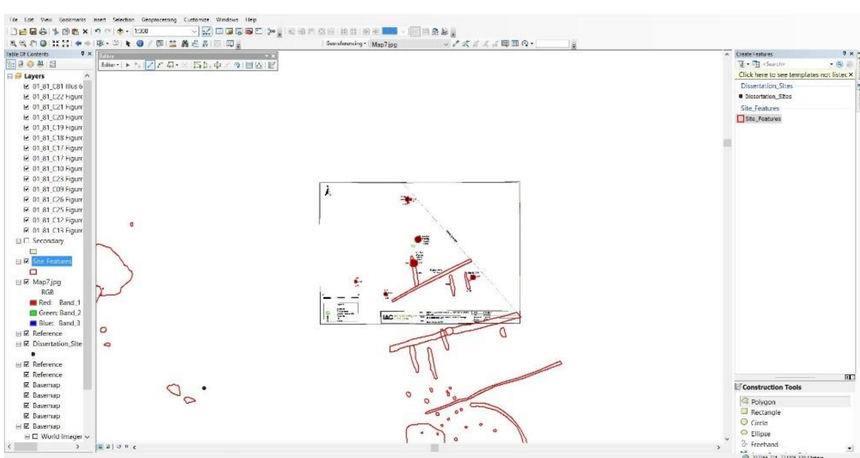

Figure 3.5 Digitizing individual site features using the Editor toolbar in ArcMap

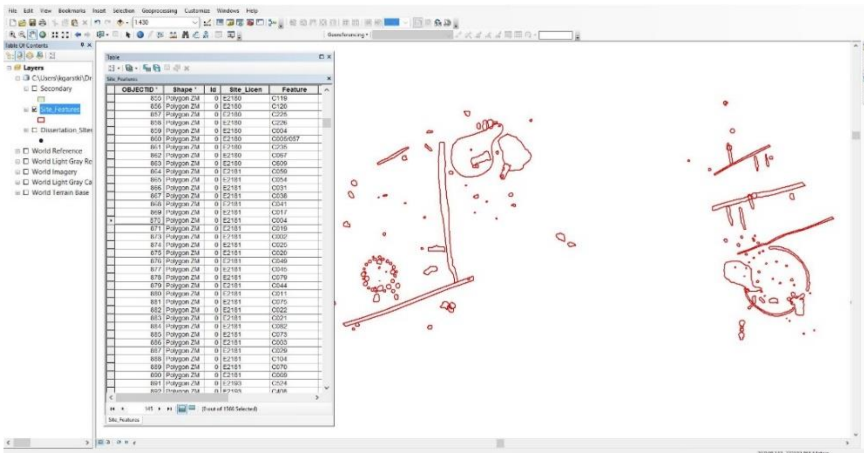

Figure 3.6 Screenshot showing the Site Features shapefile with associated attributes table, in ArcMap.

3.4. Relational Database

In order to store the data gathered from the excavation reports relating to the sites, features, or slag analysis, I utilized a relational database created in Microsoft Access. This database consists of three distinct tables that each addresses different scales of the production process that were considered in this dissertation. The site-level table addresses larger patterns across the landscape, as well as the comparison of features within a site. The Ironworking Sites table includes relevant data about the location, excavation, and contents of each site in this study – it also included brief summaries of each site that can be seen in Appendix A. This table was linked to the Dissertation Sites shapefile and used as part of the project GIS. The Access database also included a Context/Feature table, which represented each individual context identified at each of the project sites. The feature/context-level table addresses patterning visible within features of a singular site, as well as between features across different sites. Last, a table of analyzed slag is included in this dataset, culled from the completed archaeometallurgical reports. With these three aspects of the database, I was able to look at the multiple scales of production patterns for this period, and combine the data with a spatial component through the GIS (Figure 3.7).

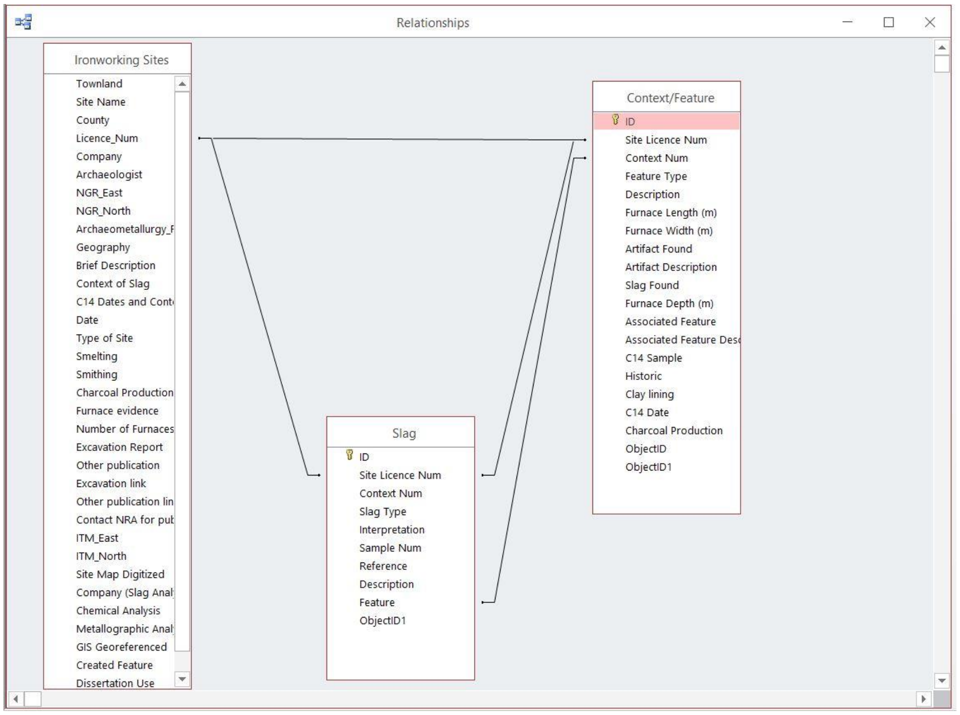

Figure 3.7 Screenshot of Access database table relationships.

3.4.1. Ironworking Sites

The Ironworking Sites table contains information on each site included in this dissertation (Figure 3.8). Below I have outlined each field that was defined for this study:

- Townland – This is the smallest geographic division of land in Ireland. This field provides a general geographic identifier for the site.
- County – This is the largest geographic division of land in Ireland.
- Site Name – This field indicates the name given by the excavators[6] to the specific site used for this dissertation project. It usually consists of the Townland name and a sequenced number assigned during a roadway construction project (e.g., Cloncollog 2).

[6] In most cases. Some sites that were identified earlier than the recent excavation boom have longer histories of their place names.

- Licence_Num – This is the unique identifier provided for each specific site by the National Monuments Service, Department of Arts, Heritage & the Gaeltacht.
- Company – This field lists the consultancy that conducted the excavation (if applicable).
- Archaeologist – This field lists the archaeologist responsible for the excavation of the site.
- NGR_East – This number field lists the Easting National Grid Reference[7] coordinate for the site.
- NGR_North – This number field lists the Northing National Grid Reference coordinate for the site.
- ITM_East – This number field lists the Easting Irish Transverse Mercator coordinate for the site.
- ITM_North – This number field lists the Northing Irish Transverse Mercator coordinate for the site.
- Geography – This field provides a brief description of the topographical location of the site.
- Brief Description – This field consists of a long summary (ca. 200 – 500 words) of the whole site.
- Type of Site – This field is a simplified drop-down list for a general classification of the site: Isolated Metalworking, Structure, Burial, Burial/Structure, Enclosure.
- Number of Furnaces – This field lists the number of structures (smelting furnaces or smithing hearths) that were identified at this site.

[7] The National Grid Reference is a geographic coordinate system originally implemented by the Ordnance Survey. It has been replaced by the ITM coordinate system but was retained in this database for continuity.

- Date – This field provides a drop-down list for the dating of this site: LBA/EIA, EIA, EIA/DIA, DIA, DIA/LIA.
- C14 Dates and Context – This text field lists the context number for the radiocarbon samples taken at each site, which constitute the primary source of chronological evidence used in this project.
- Excavation Report – This is a yes/no field that indicates if the excavation report was the data source for this site.
- Excavation Link – This is a hyperlink field that links directly to the excavation report file on the computer running this database. It is only used when using the database is showed on the same computer where the excavation report files are stored.
- Archaeometallurgy Report – This is a yes/no field that indicates if an archaeometallurgist specialist report was conducted and included in the final report of the excavation.
- Chemical Analysis – This is a yes/no field that indicates if any compositional testing was conducted on the slag recovered from the site.
- Metallographic Analysis – This is a yes/no field that indicates if any metallographic analysis was conducted on the slag recovered from the site.
- Company (Slag Analysis) – This field lists the individual or company who was responsible for the archaeometallurgical specialist report, if applicable.
- Smithing – This is a yes/no field that indicates if there is evidence for iron smithing at the site.
- Smelting – This is a yes/no field that indicates if there is evidence for iron smelting at the site.
- Charcoal Production – This is a yes/no field that indicates if there is evidence for charcoal

production at the site.

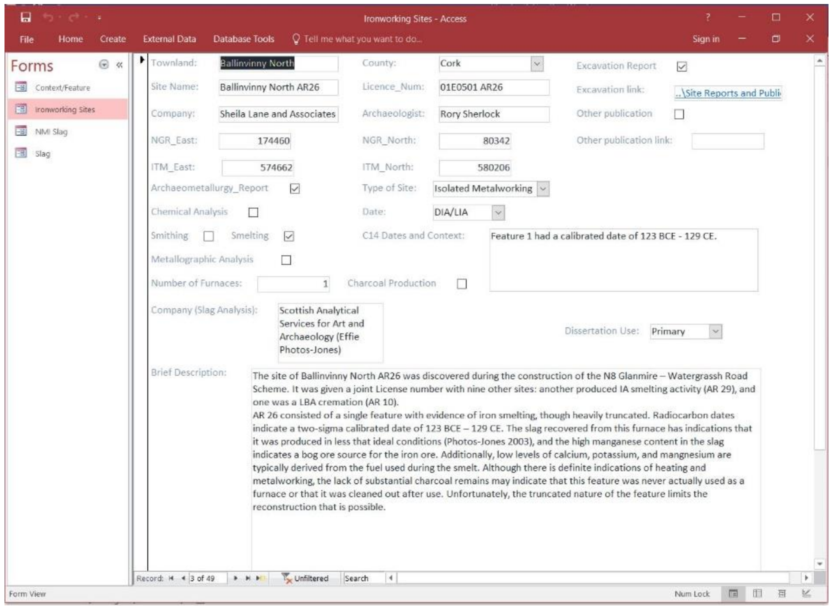

Figure 3.8 Screenshot of form view of Ironworking Sites Access table.

3.4.2. Context/Feature

The Context/Feature table of the database records data relating to each of the features identified during the excavation of each site included in this analysis (Figure 3.9). Each field listed in this table is outlined below:

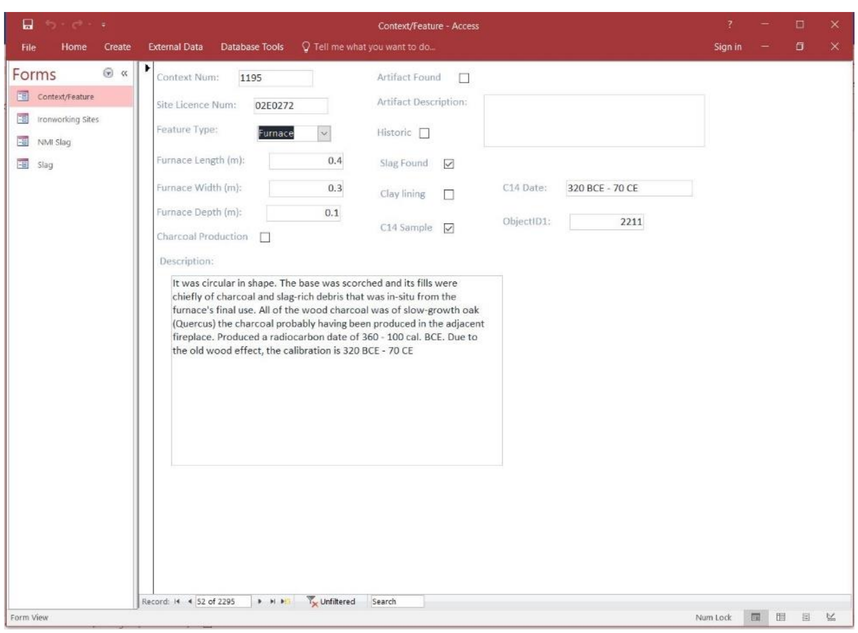

Figure 3.9 Screenshot of form view of Context/Feature Access table.

- Context Num – This field provides the context number given to each “cut” in each excavation. The typical methodology in these excavations is to provide a unique number for each context excavated within a specific feature. Due to this, there may be multiple context numbers representing fills from one feature. For this database, I used the context or feature number used on the excavation plan maps accompanying the final excavation report – the number used was almost always the context number for the “cut” of the feature.
- Site Licence Num - This is the unique identifier provided for each specific site by the National Monuments Service, Department of Arts, Heritage & the Gaeltacht. The licence number for the site from which each feature was found is listed here.
- Feature Type – This is a drop-down field that provides the type of feature represented by each table entry: Furnace, Trench, Ditch, Structure, Enclosure, Wind Break, Burial, Burial Enclosure, Pit, Post/Stake, Hearth, Trough, Deposit, Burnt Spread, Linear Feature, Furrow, Modern, Historic, Bioturbation, Smithing Hearth, Corn-Drying Kiln, Ring-Ditch, Stone Socket, Stone, Post-and-Wattle Fence, Waterhole, Flue, Fire Pit, Metalled Surface, Sunken Metalled Surface, Raised Grain Storage, Gully, Terrace, Kiln, Bellows, Timber, Drain, Working Surface.
- Description – This is a long text summary of the feature presented in the record. This text is often taken directly from the text in the excavation report.
- Furnace Length (m) – This field records the length in meters for the feature, if it is listed as a furnace.
- Furnace Width (m) - This field records the width in meters for the feature, if it is listed as a furnace.
- Furnace Depth (m) - This field records the depth in meters for the feature, if it is listed as

a furnace.

- Slag Found – This is a yes/no field indicating if slag was recovered from the feature on record.
- Artifact Found – This is a yes/no field to identify if any artifacts were recovered from this context.
- Artifact Description – This text field was used to include a brief description of the artifact recovered from this context, if applicable.
- C14 Sample – This is a yes/no field indicating if a radiocarbon sample was taken from this feature.
- C14 Date – This is a text field providing the date range for the radiocarbon date in 2 sigma, if applicable.
- Historic – This is a yes/no field that indicates if the feature has a historic, rather than prehistoric or medieval, date or association. This field allows me to remove these features from any meaningful analysis, either in the database or in the GIS.
- Charcoal production – This is a yes/no field that indicates if there was any evidence that a particular feature was involved in charcoal production. This additional field is used instead of another "Feature Type" because the pits used for charcoal production are sometimes ambiguous, and it is more reasonable to name them simply "pits."

3.4.3. Slag

The Slag table of the database records data related to each of the samples of slag identified during the excavation of each site used in this project (Figure 3.10). Some sites either did not include a metallurgical analysis, or I was not able to gain access to those reports. Each field used in this table is outlined below:

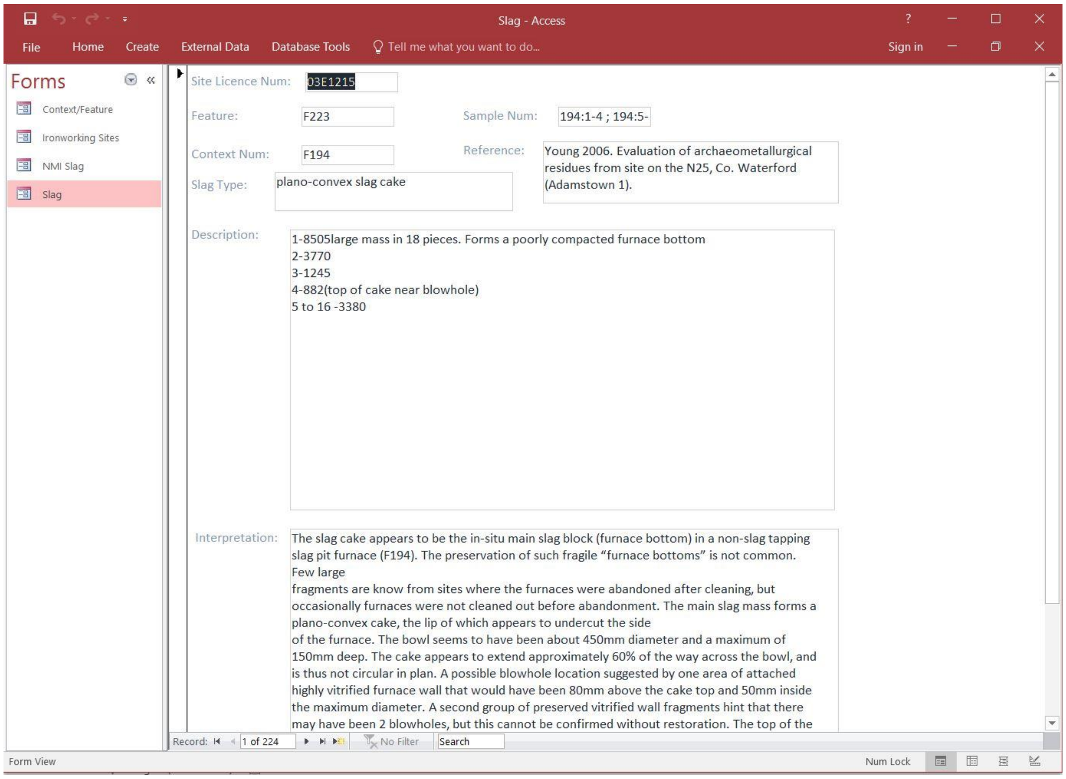

Figure 3.10 Screenshot of form view of Slag Access table.

- Site Licence Num - This is the unique identifier provide for each specific site by the National Monuments Service, Department of Arts, Heritage & the Gaeltacht. The licence number for the site from which each slag sample was recovered is listed here.
- Feature – This field lists the context/feature number from which the slag sample was recovered, assigned to each “cut” in each excavation. The typical methodology in these excavations is to provide a unique number for each context excavated within a specific feature. Due to this, there may be multiple context numbers representing fills from one feature. For this database, I used the context or feature number used on the excavation plan maps accompanying the final excavation report – the number used was almost always the context number for the “cut” of the feature. This field corresponds to the “Context Num” field in the Context/Feature table of this database.

- Context Num – This field lists the specific context from which the slag sample was recovered. As mentioned above, each fill for each feature received its own context number – this is the number that the archaeological sample is linked to. However, since there may be multiple contexts for each feature, it is necessary to include a field for the "Feature number" and the "Context number."
- Slag Type – This short text field is for recording the type of slag present in the sample (e.g., smelting slag, undiagnostic slag, sinter, vitrified lining, ore, etc.). It should be noted that not all of the samples recorded in this table are actually slag, but could also be different residues from iron production that were recovered from the sites.
- Sample Num – This field is the record of the sample number given to the slag sample in the excavation report, so that it can be cross-referenced with the original excavation report or archaeometallurgical report.
- Reference – This field contains the bibliographic reference for the archaeometallurgical report that analyzed this sample.
- Description – This is the brief summary of the contents of the sample, as described by the excavators or by the specialist.
- Interpretation – This long text field provides more explanation of the significance of any of the samples, if applicable.

3.5. Link database to GIS

In order to make the GIS more dynamic and able to address the quantity of data available for these production sites, I proceeded to link the tables created in the Microsoft Access database to the two shapefiles discussed in Section 3.3. Two methods were used to link the information recorded in the Access tables to the spatial data in ArcMap: Joins and Relates. The Join function in ArcMap works to append data from an outside source to the attribute table of a shapefile. Using this tool, I established a connection between the tables created in Access with the shapefiles in the project geodatabase. While it is possible to link a full Access database through an OLE DB Connection in ArcGIS, due to the limited scale of my dissertation database the complexity of this process was unnecessary. Instead, I exported each of the database tables from Access as Microsoft Excel files, and in the process removed some of the less data-oriented fields.[8]

For this project, two Joins were used within the geodatabase. The Ironworking Sites table (Section 3.4.1) was exported as an Excel file and linked to the Dissertation_Sites shapefile using the Join tool (Figure 3.11). The field, "Site_Licen," was used to link the Ironworking Sites table and the Dissertation_Sites layer. This field was used due to its unique identifier. The other Join used in this geodatabase was intended to link the Context/Feature table with the Site_Features layer. The linkage for these two data files was more complicated due to some redundancy in Feature Number and in Site Licence Number[9]. I decided to utilize a unique Object ID for each feature in the dataset that would correspond to each feature digitized in the Site_Features layer. However, due to the way both the GIS and Access databases were created, I could not simply import the unique ID from the Access database (due to the problem with linking the

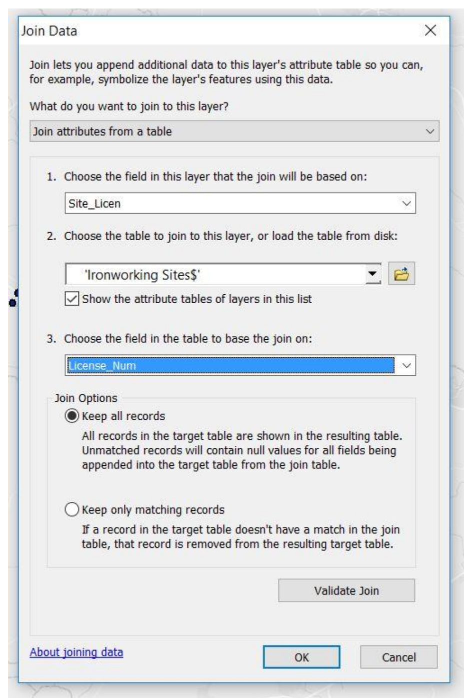

Figure 3.11 Join tool in ArcMap.

[8] By this I mean fields that were used largely to organize the data, such as links to the excavation reports or presence/absence of an archaeometallurgical report.
[9] There were multiple features per site, and multiple sites utilized the same naming conventions.

tables discussed above). Instead, I used the unique ID automatically generated by ArcMap for each new feature created in Sites_Features to import into the Access database. Once the Object ID field was updated in the Context/Feature table, it could then be Joined in ArcMap to the corresponding field.

In addition to the two Joins created using the Ironworking Sites and Context/Feature tables, a Relate was used to link the Site_Features GIS layer with the Slag table from the Access database (Figure 3.12). While Joins work to append the data fields from one table to the attribute table of a layer within ArcMap, Relates merely create a relationship between an external table and a GIS layer. Relates are optimal when one is creating a "one-to-many" relationship, as in the case of the Slag table. This means that one record in the GIS, in this case a single feature, will be linked to many records from another table, such as the slag samples that populate the Slag tables. Since many samples were often taken from a single feature, each Slag table record does not match a unique identifier in the Site_Features layer. When a Relate is used to link these data, the fields are not appended to the attribute table in Site_Features – the Slag data is only available when working within the attribute table. For example, a query can be initiated that highlights all of the appearance of plano-convex furnace bottoms in the Slag table and the associated features will be highlighted in the GIS.

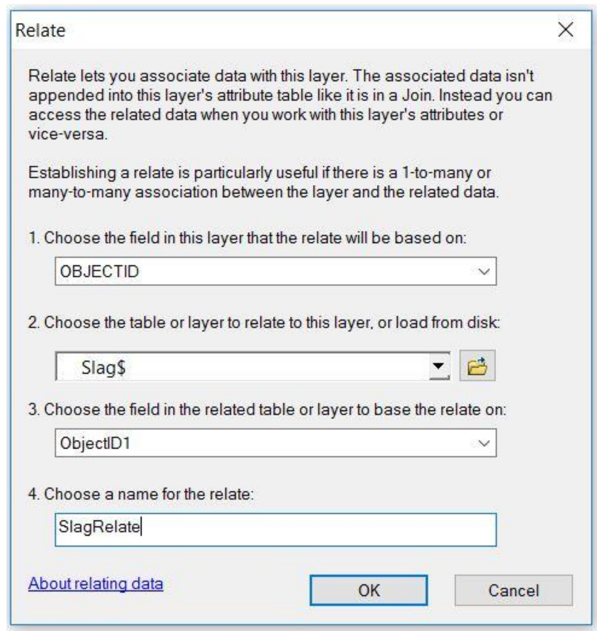

Figure 3.12 Relate tool in ArcMap.

3.6. Data Analysis

The data collected for this dissertation (Section 3.2-3.4) all address different aspects of the main research question: how was iron production organized in Ireland during the EIA and DIA? These data were analyzed to address this question utilizing the features in Access and ArcGIS, combined with a qualitative investigation of each individual site. While each approach focused on the specific research questions outlined in Section 1.2, they all contribute to the question of how production was organized and the impact on society during this period in Irish prehistory.

3.6.1. Database Queries

The hierarchical structure of the Access database allows the data to be easily accessed across the different tables, and thus provides the capability for queries of the data to identify patterns in the sites, features, or recovered slag. Querying the database is an effective way to calculate and summarize the desired data from various linked tables. Querying these within Access allows me to address Research Questions 1[10] and 2[11]. “Skill” is a difficult aspect to measure quantitatively, however, I am using a utilitarian metric based on the idea that the better an individual(s) is at producing more iron yield with fewer resources, the more skill they possess. By summarizing the data recorded in the database that relate to the specific process of production, be it smithing or smelting, the level of skill demonstrated can be approximated. In addition, the summary queries are used to identify patterns of production change through time. Aspects of the furnace morphology recorded in the Context/Feature table and the slag sampled from the furnaces are compared with the specific ^{14}C dates from each context or the general chronology provided for the site.

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[10] What level of skill is demonstrated by the remains of iron smelting and smithing?
[11] How do patterns of production change through time, from the EIA to the DIA?

3.6.2. GIS Patterns

The GIS database, when linked with the Access tables (Section 3.5), provides similar capabilities to the Access queries, but adds to them the ability to visualize potential spatial patterns. Working within the attributes of the shapefiles, I use the Select by Attributes feature to query specific patterns – both those queries used in Access and unique ones specific to identify spatial patterns. The multi-scalar nature of the dataset allows me to search for patterning on the slag or context-level to visualize and represent it on the site-level. Furthermore, I can also visualize patterns of furnaces within an individual site. These analyses allow me to address Research Questions 3[12] and 4[13].

Using the Select by Attributes tool allows me to visualize appearances of different furnace morphologies across sites, the presence of structures and other domestic features, or burials associated with the ironworking evidence. The distribution of these features across the landscape speaks directly to the question of how iron production sites related to one another spatially, specifically as they relate to the type of topography in which they are found. Using Digital Terrain Models (DEMs) obtained under Creative Commons Attribution 4.0, produced by NASA's Shuttle Radar Topography Mission (SRTM)[14], I was able to transfer the raster elevation cell data to the attributes of the Dissertation_Site shapefile. With this additional elevation data, I am able to draw basic conclusions about the types of topographies in which these iron production sites were discovered.

3.6.3. Qualitative Comparative Analysis

The nature of many of the data used in this project unfortunately does not allow a direct

[12] What was the spatial relationship between iron production sites and other types of sites during this period?
[13] Were different aspects of iron production tied to specific topographies and/or locations?
[14] The elevation data was taken at approximately every 90m, so the resolution is somewhat limited.

quantitative analysis to be carried out. That is, much of the data recorded in the database or found within the excavation reports cannot be easily queried or made searchable. For example, the full description of the site is not a searchable category because the entry is too complex. A portion of the analysis of the 35 sites used for this dissertation was therefore conducted by comparing the unique features or patterns discernable while investigating the excavation reports. This was in part done with the aid of the summaries of the sites presented in Appendix A. While this approach allowed me to address all of the research questions posed in this dissertation, it specifically provided support for the 1st and 4th research questions. The question of the skill level demonstrated by the persons involved with iron production based on the morphology of the furnace can provide a reliable indication of the capabilities to produce a high yield. While some of the furnace characteristics were recorded in the Context/Feature or Slag tables, other aspects could not be recorded in this way. For example, the way in which the sides of the furnace pit sloped, the nature of the deposits within the furnace, and the distribution of slag or other metallurgical residues will all influence the way the furnace is interpreted. As the furnace, and corresponding residues, make up the most direct evidence we have for the process of iron production in this period, understanding the nuances of the archaeological remains of a furnace is necessary for addressing the level of skill associated with production during this period. This aspect of the analysis addresses the larger question of how iron production was organized during this period of Irish prehistory. As will be discussed in the chapters that follow, the organization of production was not necessarily standardized, and as such the patterns and associated features were not always evident.

3.6.4. Compositional Analysis

Following the excavation of many of the sites used in this project, archaeometallurgical samples were sent to specialists or companies to conduct various types of archaeometallurgical analysis. In all cases where an archaeometallurgical report was produced and accessible, a morphological analysis was conducted to report on the types and forms of slag and other residues recovered from a particular site. To support the initial recording, some reports contained metallographic analyses using an electron microscope. In some of these cases, in addition to morphological and metallographic analyses, major element analysis was conducted. The sites for which I had access to these findings were also used to investigate the formation of the slag, and as a result the scenarios in which the smelting process occurred.

When available, these data were entered into a ternary diagram of FeO – SiO_2 – Al_2O_3. Charlton et al. (2010) have discussed how such a diagram can model thermochemical behavior of ironmaking slags (also see Bachmann 1982). Since these oxides make up the primary components of most iron slag, they are best suited to test the formation of the slag. This diagram (Figure 3.13), adapted from Levin et al. (1964), identifies theoretical optima for producing fluid fayalithic slag while maintaining a minimal amount of heat (Charlton et al. 2010:365). Labelled Optimum 1 and Optimum 2, these locations indicate ideal combinations of recipes/furnace construction for producing a high yield with minimum fuel. Recipes that increase fuel to ore ratios lead to a chemistry close to Optimum 1 (Tylecote et al. 1971). This ratio is also often more prone to making iron blooms with a higher carbon content, close to cast iron, though the method suffers from the possibility of having the slag solidify in the furnace due to a lack of FeO (Charlton et al. 2010; Tylecote et al. 1971). Optimum 2 indicates recipes with lower fuel to ore ratios, decreasing the reducing atmosphere in the furnace and lowering the metallic yield. In this case the slag maintains its ability to separate easily from the bloom around 1200 °C (Charlton et al. 2010:357). This optimum would theoretically require less charcoal to smelt the iron but the iron yield would be lower. Visualizing the chemical data from the sites included in this study using this type of diagram provides an indication as to the skill level of the ironworkers acting at these production sites, manifested through the metallurgical residues.

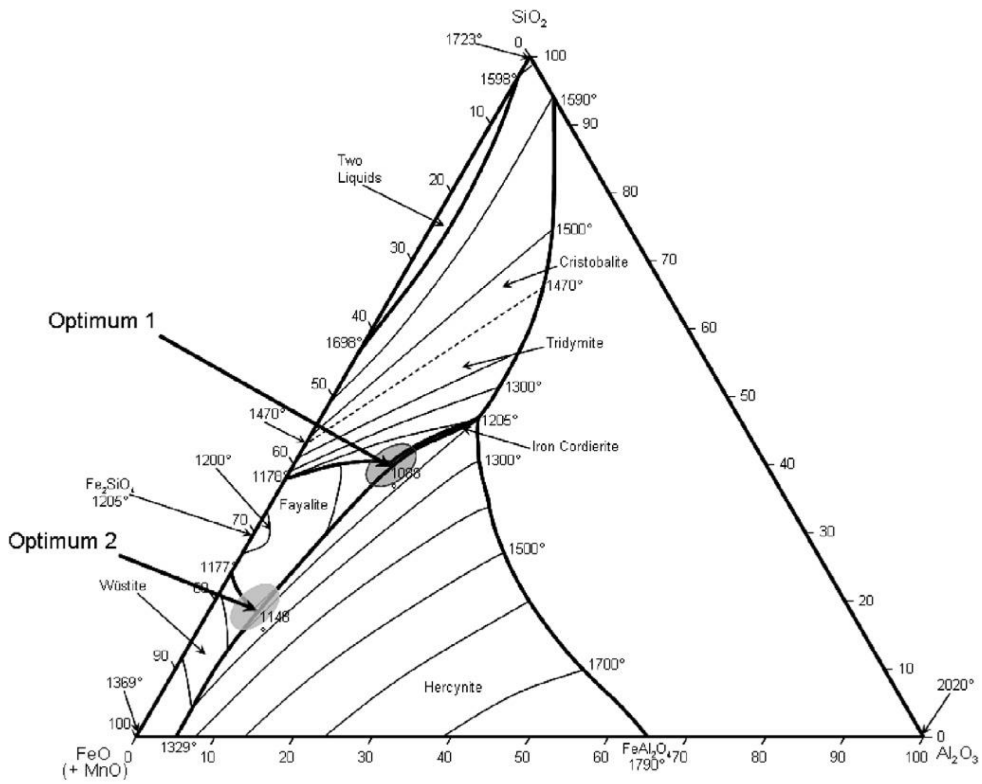


Figure 3.13 A representation of a FeO – SiO_2 – Al_2O_3 ternary system (from Charlton et al. 2010; adapted from Levin et al. 1964).

3.7. Creation of Website GIS Database

In order to add to the emerging knowledge base for the Irish Iron Age, one of the goals of this dissertation was to develop a way to easily disseminate the data that were compiled and organized for this project. Attempts to reconstruct this period of Irish prehistory have been hampered by the fact that much of the new excavation data is still largely unpublished, limiting access to new archaeological information recovered in the last two decades. Although the TII is working to remedy some of this lack of accessibility by providing an open access database for unpublished excavation reports from NRA projects (*pers comm*. 2016 Michael Stanley), there is still no central database for scholars to search for sites specifically by time period or site type (e.g., Iron Age ironworking sites).

To aid in the increasing access to and usability of these data, I have developed an online interface to engage with the spatial and summary data collected for this project. All of this work was done through the use of the University of Wisconsin-Milwaukee's access to ArcGIS online. UWM has an account through ESRI that allows users to develop and store layers and maps online, as well as accessing some of the more advanced tools available for ArcOnline.

Within the "My Content" section of UWM's ArcOnline, I was able to create a map using the shapefiles originally created though the desktop version of ArcGIS (Section 3.3) (Figure 3.14). One layer was added that contained all of the sites used for this dissertation. Additional layers were added that contained the individual feature shapefiles for each site. Unfortunately, ArcOnline does not allow shapefiles with more than 1000 features, so each group of site features was entered as its own layer.

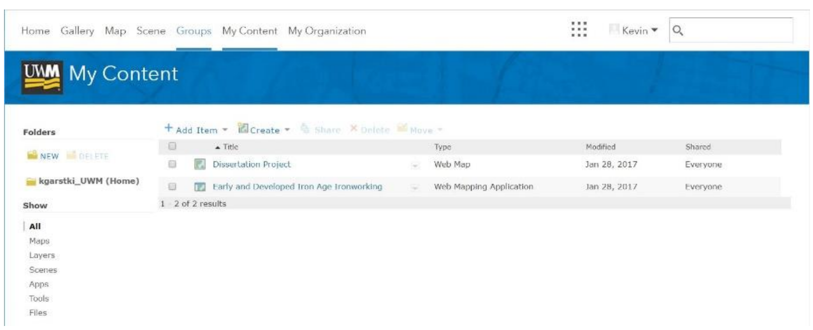


Figure 3.14 Maps and web application in ArcOnline.

Once all of the shapefile layers were uploaded to ArcOnline under my account, I created a web application for the use of these data. Using the Web AppBuilder for ArcGIS, I was able to customize the interface to include a number of specifications that ranged from layout to the types of widgets to include (Figure 3.15). Due to the nature of the data, I decided not to include significant analysis tools, making the application more of a presentation interface. In this way the spatial data, coupled with limited summaries of the sites, can be accessed using a multi-scalar approach.

Figure 3.15 View of website being developed in Web AppBuilder for ArcGIS.

The final step in the creation of the website involved access to UWM’s WebGIS server. Through the University, I was granted server space on the GIS-specific server, which hosts student and faculty projects. Through this access, I also was provided with a unique URL and access to my own website project folder on the server. Although I could have gone through the process of coding an entire website from scratch, using code from ArcGIS to create a map interface, the most straightforward approach was to download the web application files created using the Web AppBuilder and upload them to my server folder. After disabling login qualifications for the application, no further alterations were needed. The Early and Developed Iron Age Ironworking in Ireland map interface (Figure 3.16) can be found at http://webgis.uwm.edu/kgarstki/.

Each site record contains all of the pertinent information regarding the ironworking activities found there, which can be accessed either in the attributes table (seen at the bottom of the image in Figure 3.16) or by clicking on the site. Zooming in to the site level, all the features identified during the excavation will be visible, symbolized by their specific feature type. Clicking on each feature will provide the user with information regarding furnace type, if applicable, ^{14}C dating, and the presence of artifacts or slag.

Figure 3.16 Website developed for this dissertation project.

Chapter 4: Analysis

4.1. Smelting and Smithing Features

4.1.1. Furnace Types

The archaeological evidence for smelting iron recovered from the study sites included in this project largely took the form of clay-lined pits, some with thick oxidized soil surrounding them, as well as medium - heavy concentrations of slag and charcoal (or charcoal stained soil). Of the 35 sites included in the study, 30 provided this kind of evidence for smelting. These features represent the remains of smelting furnaces, 115 in total (Table 4.1). The remaining five sites only produced evidence for iron smithing, which will be discussed below (Section 4.1.2). All of these features were excavated in the last 20 years, illustrating how little was known about early iron smelting in Ireland[1] before the development boom began. The absence of previous archaeological data to work from has made the interpretation of these features, both during and after the excavation, difficult. Recently, there has been a significant critique of the 'bowl furnace' categorization of these features uncovered in the last two decades (Chadburn 2006; Crew and Rehren 2002; Fairburn 2006; Young 2003a). In light of these critiques, the data available for the smelting furnaces identified in this project were analyzed for evidence of any recognizable patterns of production. The 115 smelting furnaces were then organized into the following categories based on evidence for similar techniques of iron smelting: non-slag tapping slag-pit furnaces, non-slag tapping arched slag-pit furnace, and unknown furnace.

[1] Save for Scott (1990).

Table 4.1 Summary Total of Ironworking Features

Feature type	Total Number	% of total furnace
Non-slag tapping slag-pit furnace	66	57.4
Non-slag tapping arched slag-pit furnace	11	9.6
Unknown smelting furnace	38	33
Smithing Hearth	13	

4.1.1.1. Non-slag tapping slag-pit shaft furnace

To date, there is no evidence for slag tapping in features dating to the Iron Age in Ireland. Slag tapping occurs when the liquid slag is raked out/removed from the furnace while the furnace is still in use. This practice requires an opening near the bottom of the smelting furnace, for which there is no archaeological evidence in Ireland. It can therefore be assumed that the features we interpret as smelting furnaces had some other way of making sure the slag and iron bloom remained separate during the smelt. One way to do this is to use a pit in which the slag collects above the charcoal and ash at the base of the pit. A bloom must have space to form above the slag mass, and the blowhole be above that since no subterranean blowholes have been discovered, creating the hot zone where the ore was smelted above the surface of the ground (Figure 4.1). This means a shaft would have been necessary for this feature to work (Young 2003a:2). Due to the formation processes just described, and based on the slag assemblages collected during excavations, it has been argued that there is no possible way for the uncovered features to have worked like a ‘bowl furnace’ (Young 2003a). Slag assemblages from these furnaces, as well as the shape of the basal pits, mirror contemporaneous examples from Britain that have been studied in detailed and experimentally reconstructed (Crew 1991). Slag-pit furnaces appear to be the best interpretation for many of the features identified in this project, 66 of the 115 features (Table 4.2).

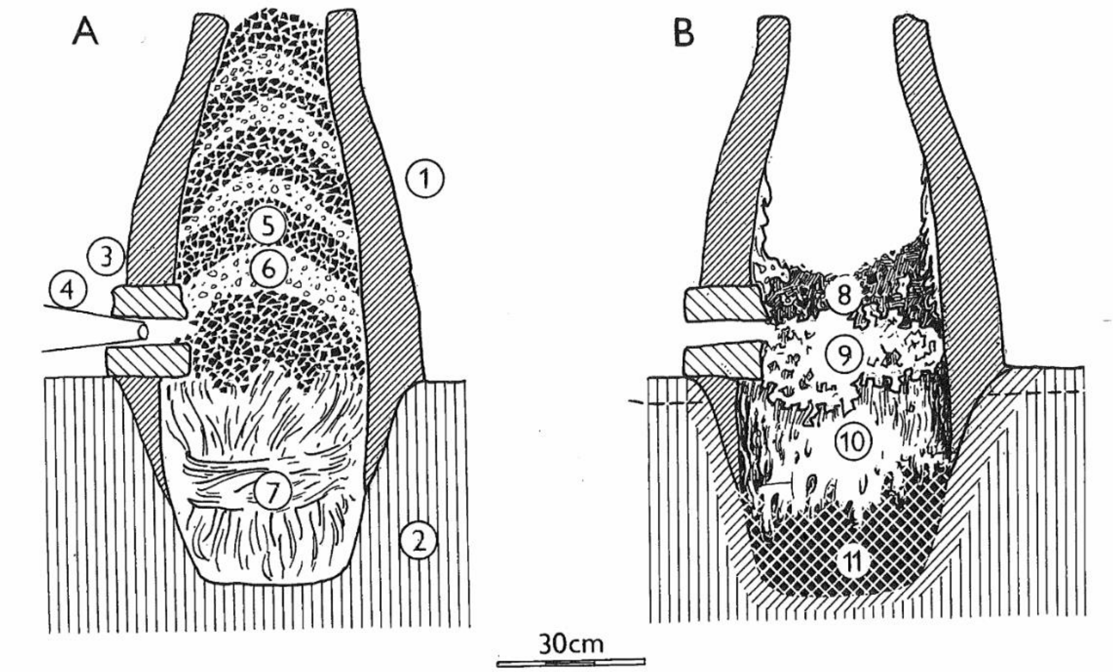


Figure 4.1 Schematic of slag pit furnace before a smelt (A) and after a smelt (B). 1–Shaft; 2-Virgin Soil; 3-Tuyére blocks; 4-Bellows; 5-Charcoal; 6-Iron ore; 7-Straw or brush wood; 8-Furnace slag; 9-Iron bloom; 10-Slag bloc in the pit; 11-Charcoal with ash (Pleiner 2000:150).

Table 4.2 Slag pit furnaces recorded in the sample, ordered by site date, earliest to latest.

Site Name	Site Licence Number	Context Number	C14 Date	Site Date	Furnace Length (m)	Furnace Width (m)	Furnace Depth (m)
Clonrud 4	E2167	F005	790 - 500 BCE	LBA/EIA	0.46	0.43	0.17
Clonrud 4	E2167	F003	360 - 90 BCE	LBA/EIA	0.46	0.41	0.17
Site B, Ballydavis	03E0966	C015	748 - 402 BCE	EIA	0.34	0.33	0.58
Site B, Ballydavis	03E0966	C017		EIA	0.28	0.28	0.1
Grange	13E0435	C6	732 - 400 BCE	EIA	0.36	0.33	0.15
Kinnegad 2	02E0926	F28		EIA	0.38	0.4	0.3
Lagavooren 7	00E0914	C164		EIA	0.9	0.82	0.13
Lagavooren 7	00E0914	C141	520 - 380 BCE	EIA	1.09	0.97	0.15
Site L, Lughil	03E0602	F18		EIA	0.35	0.35	0.19
Site L, Lughil	03E0602	F30		EIA	0.58	0.35	0.08
Site L, Lughil	03E0602	F7		EIA	0.58	0.35	0.2
Morett	03E0461	C140		EIA/DIA	0.37	0.37	0.19
Morett	03E0461	C141		EIA/DIA	0.56	0.56	0.28
Morett	03E0461	C142		EIA/DIA	0.67	0.67	0.18
Rossan 6	02E1068	F084	370-50 BCE	EIA	0.78	0.76	0.42

Site AR 26, Ballydavid	E2370	C157	765 - 416 BCE	EIA/DIA	0.46	0.42	0.29
Site AR 26, Ballydavid	E2370	C118		EIA/DIA	0.8	0.68	0.25
Site AR 26, Ballydavid	E2370	C142		EIA/DIA	0.52	0.5	0.21
Site AR 26, Ballydavid	E2370	C161		EIA/DIA	0.3	0.46	0.48
Cherryville Site 12	01E0955	F2	520 - 150 BCE	EIA/DIA	0.46	0.46	0.22
Cherryville Site 12	01E0955	F6		EIA/DIA	0.54	0.4	0.09
Cherryville Site 12	01E0955	F7		EIA/DIA	0.48	0.48	0.25
Cherryville Site 12	01E0955	F8		EIA/DIA	0.45	0.45	0.08
Mullagh	09E0311	F6	409 - 386 BCE	DIA	0.66	0.63	0.65
Derrinsallagh 5	E2181	C070	520 - 350 BCE	EIA/DIA/ LIA	0.25	0.25	0.25
Carrickmines Great	02E0272	1195	320 BCE - 70 CE	DIA	0.4	0.3	0.1
Cloncollog 2	E2850	C007	261 - 94 BCE	DIA	0.6	0.6	0.32
Kilrussane AR 27	01E0701	F2	352 - 42 BCE	DIA	0.5	0.4	0.16
Kilrussane AR 27	01E0701	F1		DIA	0.57	0.5	0.2
Kilrussane AR 27	01E0701	F3		DIA	0.56	0.63	0.15
Kilrussane AR 27	01E0701	F4		DIA	0.38	0.31	0.08
Knockcommane 4700.1b	E2342	F3	375 - 182 BCE	DIA	0.42	0.4	0.15
Leap 1	E2131	F007		DIA	0.4	0.4	0.1
Monganstown 1	E2771	C47		DIA	0.54	0.54	0.5
Monganstown 1	E2771	C57		DIA	0.54	0.5	0
Monganstown 1	E2771	C60		DIA	0.8	0.6	0.35
Monganstown 1	E2771	C63		DIA	0.76	0.62	0.5
Trantstown AR 29	01E0501 AR29	F5	387 - 197 BCE	DIA	0.55	0.55	0.35
Trantstown AR 29	01E0501 AR29	F1		DIA	0.42	0.41	0.36
Lisnagar Demesne 1	03E1510	C41		DIA/LIA	0.46	0.41	0.12
Derrinsallagh 4	E2180	C609	100 BC - 80 CE	DIA/LIA	0.8	0.6	0.33
Derrinsallagh 4	E2180	C125		DIA/LIA	0.55	0.55	0.25
Derrinsallagh 4	E2180	C226		DIA/LIA	0.55	0.5	0.32

Derrinsallagh 4	E2180	C014		DIA/LIA	0.75	0.46	0.4
Derrinsallagh 4	E2180	C015		DIA/LIA	0.4	0.37	0.2
Derrinsallagh 4	E2180	C398		DIA/LIA	0.54	0.5	0.44
Derrinsallagh 4	E2180	C019		DIA/LIA	0.75	0.7	0.32
Derrinsallagh 4	E2180	C020		DIA/LIA	0.38	0.38	0.12
Derrinsallagh 4	E2180	C023		DIA/LIA	0.7	0.7	0.55
Derrinsallagh 4	E2180	C010		DIA/LIA	0.65	0.5	0.03
Derrinsallagh 4	E2180	C135		DIA/LIA	0.4	0.4	0.34
Derrinsallagh 4	E2180	C016		DIA/LIA	0.55	0.55	0.2
Derrinsallagh 4	E2180	C656		DIA/LIA	0.95	0.5	0.3
Derrinsallagh 4	E2180	C018		DIA/LIA	0.54	0.53	0.19
Derrinsallagh 4	E2180	C119		DIA/LIA	0.72	0.72	0.38
Derrinsallagh 4	E2180	C120		DIA/LIA	0.67	0.67	0.24
Derrinsallagh 4	E2180	C225		DIA/LIA	0.65	0.6	0.45
Derrinsallagh 4	E2180	C266		DIA/LIA	0.4	0.4	0.27
Derrinsallagh 4	E2180	C299		DIA/LIA	0.5	0.5	0.3
Derrinsallagh 4	E2180	C126		DIA/LIA	0.41	0.41	0.25
Derrinsallagh 4	E2180	C127		DIA/LIA	0.63	0.4	0.2
Derrinsallagh 4	E2180	C492		DIA/LIA	0.7	0.65	0.52
Derrinsallagh 4	E2180	C008		DIA/LIA	0.6	0.62	0.35
Derryvorrigan 1	E2193	C157		DIA/LIA	0.42	0.4	0.37
Derryvorrigan 1	E2193	C92		DIA/LIA	0.6	0.6	0.4
Derryvorrigan 1	E2193	C57		DIA/LIA	0.45	0.45	0.27

Slag-pit furnaces were identified at 22 of the 35 sites analyzed. The decision to classify these features as non-slag tapping slag-pit low shaft furnaces was based on a number of factors. The structure of such pits is largely regular across these features: steep sides, sometimes vertical or undercut, and a mostly flat base. They are largely circular, with close to a 1:1 ratio of length to width. These characteristics were identified in excavated examples and through experimental archaeometallurgy in Britain and the Continent (Clogg 1999; Crew 1991; Halkon 1997; Pleiner 2000; Young 2003a). It should be noted that within the slag-pit furnace category,

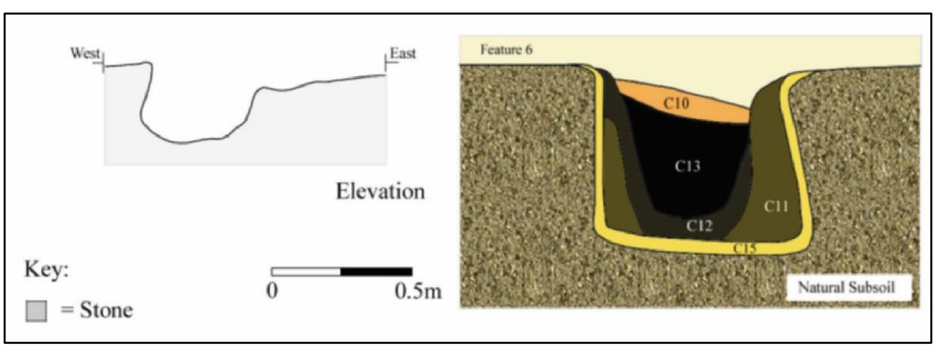


Figure 4.2 F5 from Trantstown AR 29; *left*: profile map, *right*: schematic of section (Sherlock 2005a).

the morphology and deposits of the remaining basal pit of the furnace vary considerably in this sample. However, Figures 4.2 and 4.3 demonstrate some key features of this type of furnace. Figure 4.2 shows the profile map drawn in the field following the excavation of F5 at Trantstown AR29, in addition to a stylized image of the deposits in profile. In this case, a clay lining was used in the pit of the furnace (C15), and the "lid" (C10) described

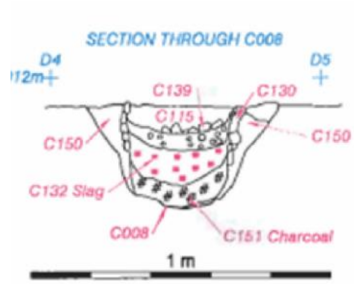


Figure 4.3 Section of C008 from Derrinsallagh 4 (Lennon and Kane 2009a).

in the excavation report likely represents the remains of the collapsed superstructure (Sherlock 2005a). Figure 4.3 shows the section of one of the numerous furnaces identified at Derrinsallagh 4. This feature illustrates the vitrified clay lining surrounding the pit (C130), the heavy charcoal-rich fill at the bottom of the pit (C151), and the heavy slag layer just above that (C132). These two examples demonstrate some of the main diagnostic features of this furnace type, although there is some variability across the other 64 furnaces.

As mentioned above, the dimensions of the slag-pit furnace are largely circular in plan view. Figure 4.4 shows a plot of the furnace widths vs. lengths as an indication of the circular structure of the furnace, with a 1:1 length to width ratio indicating a circular feature. This plot illustrates a nearly 1 slope, meaning the bulk of the 66 identified slag-pit furnaces are basically circular in plan. A few of these features appear to be outliers from the trend. As indicated in the figure, C656 from Derrinsallagh 4 has a much more elongated shaped than many of the other furnaces, at 0.95m x 0.5m. One potential reason for this is that it actually represents modified version of a slag-pit furnace, which will be discussed below (Section 4.1.1.2). Since it mirrors the individual feature (C397) excavated in lab conditions at the same site (Young 2008a), Young (2008d) suggested this might be the case. However, another factor in its large size may actually be the way the feature was originally recorded in the field. The oxidation of the soil surrounding the pit was extensive, and was recorded as the outline of the feature; however, the actual pit of the furnace was closer to 50-60cm. I would argue that instead of C656 (and its paired furnace, C609) representing an arched slag-pit furnace complex[2], it simply represents two slag-pit furnaces that were used contemporaneously.

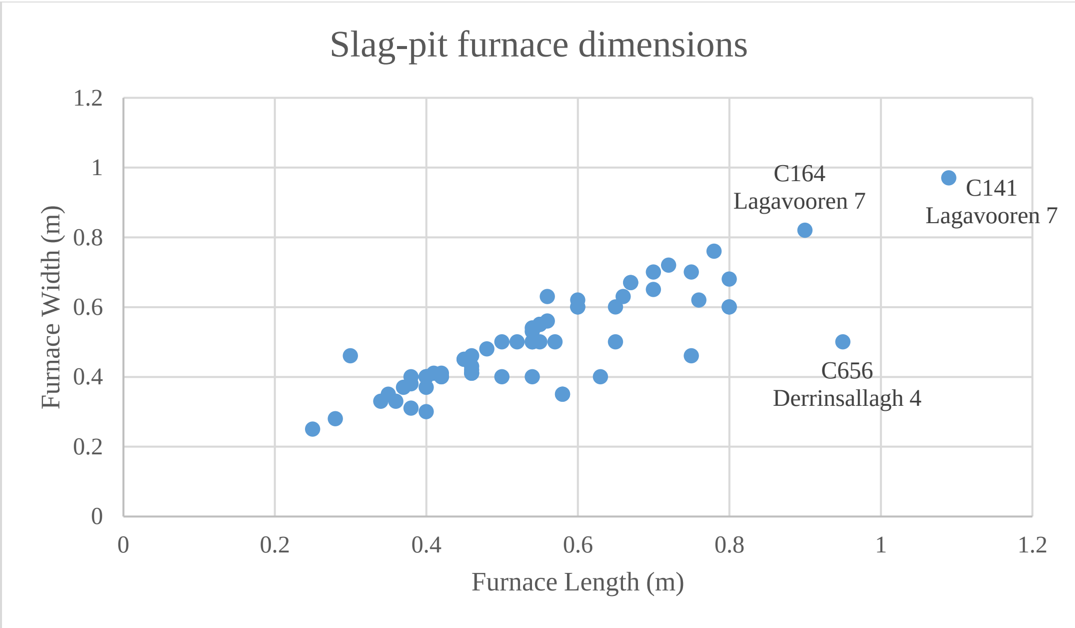


Figure 4.4 Plot of slag-pit furnace dimensions.

The largest cluster of furnace sizes ranges from c. 35 cm to 80 cm in diameter, yet some outliers skew large or small. In addition to C656 mentioned above, two furnaces are on the large side for a slag-pit type. Both outliers were from the site of Lagavooren 7. The slag assemblages produced by these two features indicates their formation in a non-slag tapping furnace. However, it may also be possible that the slag recovered from these features came from a secondary deposit (Young 2011a). It should be noted that Lagavooren 7 also produced two more features of similar,

[2] This is a modified slag-pit furnace with an arched opening that allowed slag to be cleaned out and the bloom to be recovered, discussed in detail in Section 4.1.1.2.

if slightly smaller, size that could be identified as furnaces, but the slag samples were never analyzed (Stafford 2012).

The smallest two furnaces identified as slag-pit furnaces belong to the sites of Site B, Ballydavis (C017) and Derrinsallagh 5 (C070). Although small, both features produced slag assemblages that suggest slag-pit furnace morphology, with slag running down the sides and across the bottom of the basal pit (Young 2009b, 2012a).

4.1.1.2. Non-slag tapping arched slag-pit shaft furnace

From 2005 through 2006, the site of Derrinsallagh 4 in Co. Laois was excavated in preparation for the M8 Portlaoise to Castletown Motorway Scheme (Lennon and Kane 2009a). This site represents the largest prehistoric iron production site in Ireland, with upwards of 44 smelting furnaces. One of these furnaces, C397, was lifted *en bloc* in order to perform an excavation of the feature off site. The excavation and analysis was carried out by Dr. Tim Young of GeoArch (Young 2008a). Based on this analysis, we now know of a variant of the non-slag tapping slag-pit furnace in which a furnace arch, mostly or completely below the original surface, connect the furnace pit with a separate working hollow (Figure 4.5). In plan view, this furnace would have had a “figure-of-eight” shape, although the excavators at the time did not identify the “spread” C402 as being part of this feature as a working hollow. This working hollow could have served to initially work the bloom recovered from the furnace through the arch, or to simply dump the cleared charcoal and slag from the used furnace. The arch provides access to the inside of the furnace for slag clearance, repair of the superstructure, repair/cleaning of the blowhole, or removal of the bloom (Young 2008a:210). The arch was about 16cm above the bottom of the slag pit, so it could not have been used for tapping the slag since the slag has to be tapped during its liquid state and would settle in the base of the furnace.

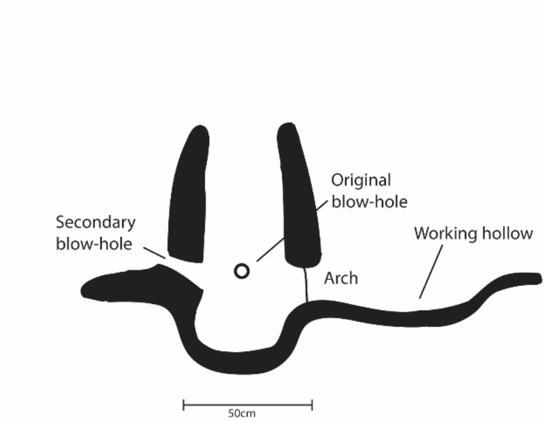


Figure 4.5 Schematic of arched slag-pit furnace.

Unfortunately, C397 remains the only furnace with an arch that has been recovered from this period[3]. However, it has opened the possibility of interpreting other furnaces in this way, even without an intact arch. Table 4.3 presents the possible furnaces identified in the project sample that could be remains of non-slag tapping arched slag-pit furnaces, on the basis of the remains of a secondary, contiguous working hollow. Including C397 from Derrinsallagh 4, ten possible features represent similar technologies (note that C216 and C65 are both listed at the bottom of the table – these likely formed a single furnace and associated working hollow, not two furnaces). One additional set of features that could have also acted like a slag-pit furnace and a working hollow at Derrinsallagh 4 is represented by C005 and C057. As can be seen in Figure 4.6, C005 could have acted as a slag-pit furnace, connected to the smaller pit, C057. The morphologies of these features are very similar to the description of C397.

Figure 4.6 Section profile of C005 and C057 from Derrinsallagh 4 (Lennon and Kane 2009a).

[3] A very complete slag-pit shaft furnace was recovered at Grange 2, Co. Meath, including a basal arch (Kelly 2011). The site dated to the Early Medieval period.

Table 4.3 List of non-slag tapping arched slag-pit furnaces, ordered by site date, earliest to latest.

Site Name	Site Licence Number	Context Number	C14 Date	Site Date	Furnace Length (m)	Furnace Width (m)	Furnace Depth (m)
Kinnegad 2	02E0926	F25		EIA	0.95	0.93	0.45
Site L, Lughil	03E0602	F9		EIA	1.8	0.4	0.2
Morett	03E0461	C172		EIA/DIA	0.65	0.65	0.15
Monganstown 1	E2771	C40/C74	361 - 113 BCE	DIA	1.3	0.5	0
Moyally 2	E2672	C7	173 - 5 BCE	DIA	0.98	0.6	0.15
Derrinsallagh 4	E2180	C397		DIA/LIA	0.4 (1.15)[4]	0.32	0.35
Derrinsallagh 4	E2180	C005/057		DIA/LIA	1.21	0.64	0.43
Derryvorrigan 1	E2193	C169/64		DIA/LIA	0.49(1.23)	0.44	0.17
Derryvorrigan 1	E2193	C56		DIA/LIA	1.15	0.7	0.35
Derryvorrigan 1	E2193	C85		DIA/LIA	0.74	0.57	0.28
Derryvorrigan 1	E2193	C216		DIA/LIA	0.55	0.55	0.26
Derryvorrigan 1	E2193	C65		DIA/LIA	0.5	0.5	0.3

Four of these furnaces were uncovered at the site of Derryvorrigan 1, within 1.5km of Derrinsallagh 4. These four sets of features were originally described as ‘figure-of-eight’ furnaces (Lennon and Kane 2009b). C169 was associated with C64, and C216 was associated with C65. It is suggested that C64 acted as the working hollow for C169, while C216 was the working hollow for C65 (Young 2008e). C85 and C56 were each identified as singular features, and both seem to have been made up of two adjoining pits, one larger than another. However, the overall shape of

[4] The parentheses in Furnace Length entries indicate the length when the working hollow is added.

C56 does not correspond as closely to the suggested morphology of a slag-pit furnace, and may not in fact be a smelting furnace at all (Young 2008e:205).

Features C40 and C74 may have made up a similar type of furnace as the arched slag-pit type see at Derrinsallagh 4. C40 was a circular slag-pit furnace, approximately 0.55m in diameter, while C74 extended out from the furnace pit. The fill in C74 included possible pieces of a clay furnace superstructure, slag, and charcoal, but not *in situ* (Lehane and Johnston 2009). This extension of C40 could have acted as a working hollow in which the slag-pit was cleared out, or even used for partially working the iron blooms.

As seen in Figure 4.7, F25 at Kinnegad 2 had a step-like structure to it, elongating its dimensions. The actual pit of the furnace was closer to 0.5m in diameter, fitting well into the typical range of the other slag-pit furnaces in this study. It may be that this stepped aspect of the feature acted as a way to remove slag from the pit. However, just as with most of the other features in this section, there was no indication of an arch in the furnace lining.

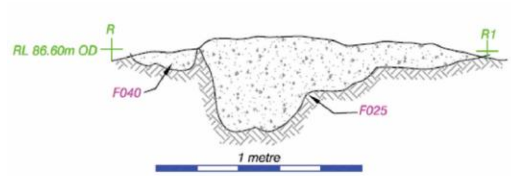


Figure 4.7 Section of F25 from Kinnegad 2 (Bayley 2009).

Site L, Lughil produced one furnace that may fit this category: F9. It was unfortunately largely truncated. This feature raises the largest questions with regard to its use as an arched furnace, although it does appear to be two pit features connected on one side, one larger than the other, with indications of iron smelting. At the site of Morett, C172, together with C142, could have acted similarly to an arched furnace and an adjoining working hollow (Young 2011b). At Moyally 2, C7 also represents a furnace that was initially recorded as a single feature but was likely a single furnace and its associated working hollow (Figure 4.8). Although no arch in the furnace lining was found, these two features could have worked in a similar way as described for a slag-pit furnace (left side in Figure 4.8) with a connected working hollow (right side in Figure 4.8).

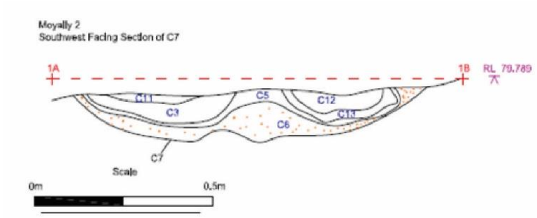


Figure 4.8 Section of C7 at Moyally 2 (Cotter 2011).

4.1.1.3. Unknown

The category of furnace types that is the second most numerous is the "Unknown" furnace type, with 38 furnaces (Table 4.4). These features fall into this category for a number of reasons. While the morphology of the pit and/or the slag indicates that these features were smelting furnaces, their exact nature cannot be determined. In some cases, the remains of the furnaces were truncated during machine stripping in the course of archaeological monitoring. In other cases, the remains of the furnaces were limited due to other taphonomic processes, or were not recorded in any detail, limiting the interpretations possible. Note that the recorded furnace depth in Table 4.3 is very low, averaging under 20cm[5], with some as shallow as six or seven cm.

Table 4.4 List of features of Unknown type, ordered by site date, earliest to latest.

Site Name	Site Licence Number	Context Number	C14 Date	Site Date	Furnace Length (m)	Furnace Width (m)	Furnace Depth (m)
Site L, Lughil	03E0602	F22	730 - 390 BCE	EIA	0.6	0.6	0.15
DKIT	02E0201	C11	420 - 200 BCE	EIA/DIA	0.38	0.39	0.09
Site AR 26, Ballydavid	E2370	C172	374 - 191 BCE	EIA/DIA	0.69	0.63	0.31
Site AR 26, Ballydavid	E2370	C167		EIA/DIA	0.45	0.4	0.3

[5] This number is actually skewed high due to C056, which was 80cm deep.

Hardwood 3	02E1141	C052	380 - 60 BCE	EIA/Medieval	0.48	0.48	0.18
Hardwood 3	02E1141	C034		EIA/Medieval	0.8	0.8	0.1
Hardwood 3	02E1141	C056		EIA/Medieval	0.65	0.65	0.8
Hardwood 3	02E1141	C063		EIA/Medieval	0.7	0.7	0.3
Johnstown 3	02E1094	C5	420-230 BCE	DIA	0.26	0.26	0.17
Johnstown 3	02E1094	C4		DIA	0.37	0.32	0.2
Newrath Site 35	04E0319	35053	397 - 207 BCE	DIA	0.4	0.3	0.12
Newrath Site 35	04E0319	35050	351 - 209 BCE	DIA	0.3	0.3	0.25
Newrath Site 35	04E0319	35008		DIA	0.42	0.4	0.11
Newrath Site 35	04E0319	35010		DIA	0.5	0.43	0.11
Newrath Site 35	04E0319	35051		DIA	0.8	0.7	0.3
Newrath Site 35	04E0319	35060		DIA	0.5	0.43	0.11
Site 27, Rath	03E1214	F89	50 BC - 80 CE	DIA	0.28	0.32	0.17
Ballinvinny North AR26	01E0501 AR26	C3	165 - 123 BCE	DIA/LIA	0.36	0.32	0.06
Derrinsallagh 4	E2180	C009	50 BC - 240 CE	DIA/LIA	0.7	0.5	0.25
Derrinsallagh 4	E2180	C017	10 BC - 250 CE	DIA/LIA	0.74	0.66	0.34
Derrinsallagh 4	E2180	C021		DIA/LIA	0.3	0.28	0.15
Derrinsallagh 4	E2180	C004		DIA/LIA	0.75	0.4	0.28
Derrinsallagh 4	E2180	C022		DIA/LIA	0.7	0.63	0.25
Derrinsallagh 4	E2180	C012		DIA/LIA	0.77	0.4	0.15
Derrinsallagh 4	E2180	C427		DIA/LIA	0.3	0.3	0.1
Derrinsallagh 4	E2180	C429		DIA/LIA	0.46	0.43	0.16
Derrinsallagh 4	E2180	C080		DIA/LIA	0.25	0.25	0.07
Derrinsallagh 4	E2180	C081		DIA/LIA	0.16	0.16	0.13
Derrinsallagh 4	E2180	C133		DIA/LIA	0.7	0.7	0.15
Derrinsallagh 4	E2180	C168		DIA/LIA	0.58	0.4	0.12
Derrinsallagh 4	E2180	C437		DIA/LIA	1.15	0.6	0.18
Derrinsallagh 4	E2180	C121		DIA/LIA	0.9	0.78	0.37
Derrinsallagh 4	E2180	C134		DIA/LIA	0.74	0.58	0.2

Derrinsallagh 4	E2180	C393		DIA/LIA	0.5	0.44	0.17
Derrinsallagh 4	E2180	C400		DIA/LIA	0.5	0.4	0.3
Derrinsallagh 4	E2180	C422		DIA/LIA	0.48	0.45	0.1
Derrinsallagh 4	E2180	C432		DIA/LIA	0.5	0.5	0.1
Harlockstown 19	03E1526	F96	100 BC - 130 CE	DIA/LIA	0.7	0.54	0.12

There are several explanations for the “Unknown” category in this sample of smelting furnaces. Many, if not most, of these may actually have been slag-pit furnaces (Section 4.1.1.1). The dimensions of many of the Unknown type furnaces fit the pattern of a generally circular shape (Figure 4.9). The slope pattern falls within that seen in Figures 4.4 and 4.9, indicating a largely circular shape for these furnaces. One of the major outliers in this sample is C437, which had a rectangular shape. This feature was originally identified by the excavators as a bowl furnace that was “truncated” and only contained a single fill, making it difficult to assign it to a precise typological category (Lennon and Kane 2009a). It is also possible that some of these features were not actually used for smelting, but were pits used for metallurgical refuse, smelting hearths, or some other feature associated with iron production. Furthermore, some of these features may be indicative of a different technological type, not otherwise documented. However, due to the lack of definitive data suggesting more than their functions as smelting furnaces, to identify all or some of these features as a specific type of furnace would be irresponsible. With the addition of more archaeological data in the coming decades, it is possible that these features will be able to be assigned more specifically to a particular type of furnace technology or other aspect of iron production.

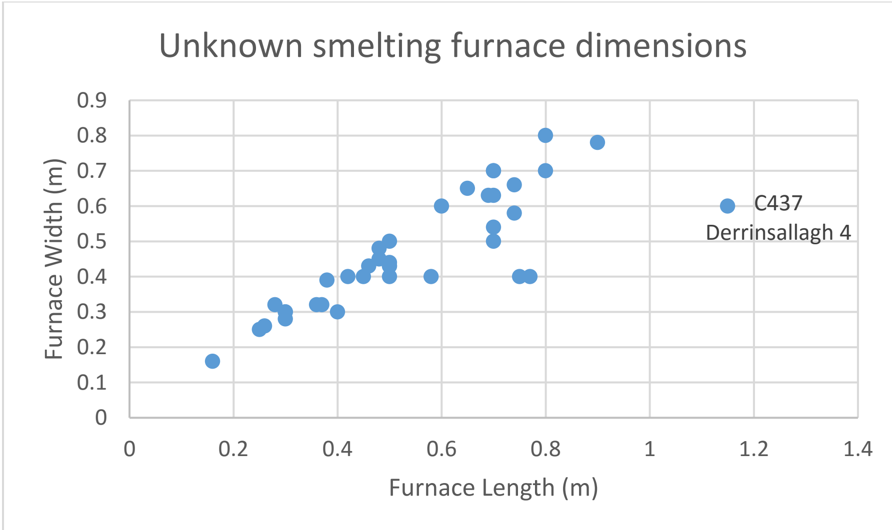


Figure 4.9 Dimensions of the unknown type of smelting furnaces.

4.1.1.4. Paired or Grouped Furnaces

One interesting pattern in some of the EIA and DIA iron production sites is the presence of clusters or pairs of smelting furnaces. In all, 20 groups of furnaces have been identified in the project sample, consisting of groups of two (11), three (4), and four furnaces (5) (Table 4.5). The criterion that was used to identify these groups were as follows: the furnaces had to be within one meter of one another - Table 4.5 shows the distance between furnaces in the far right column. Only one grouping of features came close to the meter distance; the furnaces at Hardwood 3 were 0.9m from one another. Most of the groupings of furnaces were within 20-30cm of each other.

Table 4.5 Clusters of smelting furnaces. Asterisk indicates that all furnaces in the group are of similar size. Listed in site alphabetical order.

Site	Feature Numbers	Distance from each other (m)
Ballydavis*	C015/C017	0.35
Clonrud	F005/F003	0.15
Derrinsallagh 4*	C400/C492/C398/C397	Touching/.3/.8
Derrinsallagh 4*	C299/C127/C126/C125	Touching/.15
Derrinsallagh 4*	C134/C168/C133/C135	.6/.15/.35
Derrinsallagh 4*	C023/C022 - C021/C020	.1/.22
Derrinsallagh 4*	C017/C018/C019	Touching
Derrinsallagh 4*	C121/C119/C120	0.13

Derrinsallagh 4*	C080/C081	0.3
Derrinsallagh 4*	C225/C226	0.1
Derrinsallagh 4*	C656/C609	0.05
Derrinsallagh 4*	C014/C016	0.05
Derrinsallagh 4*	C008/C009/C010	0.065
Hardwood 3*	C056/C063	0.9
Johnstown 3*	C4/C5	0.4
Kilrussane	F1/F2/F3/F4	0.35/0.5/0.2
Lughil	F18/F7	0.17
Morett	C142/C141/C140	.15/.25
Newrath	35010/35008	0.11
Trantstown AR29*	F5/F1	0.07

An additional aspect of the paired furnaces is that many of the groupings display similar size within a grouping (see for example Figure 4.10). The sizes of the smelting furnaces, within c. 5cm, remain consistent between groupings. The groups that contained similarly sized furnaces are identified in Table 4.5 with an asterisk in the left column. Following this, it may also be the case that groups of four furnaces actually represent two pairs of furnaces. An example of this possibility is seen in one group from Derrinsallagh 4 (Figure 4.11). This figure shows two sets of furnaces, C020/C021 and C022/C023. The disparity in sizes between the two groups is evidenced in the image, with one group closer to ca. 35cm in diameter and another about 70cm in diameter. While

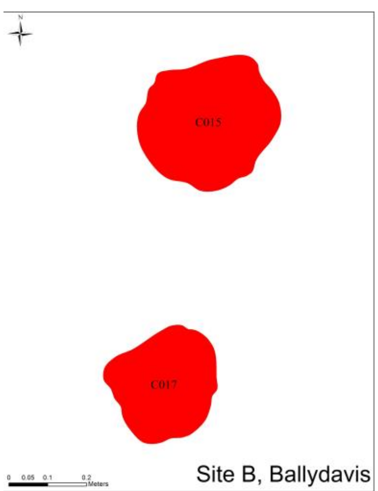


Figure 4.10 Group of pair furnaces at Ballydavis.

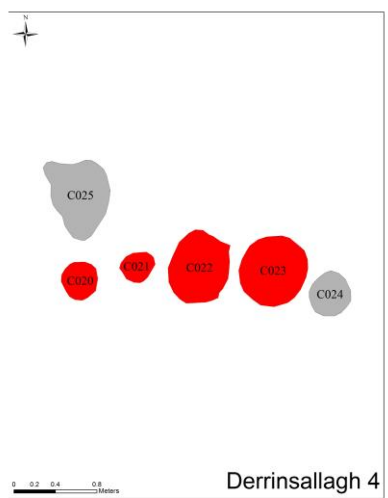


Figure 4.11 Two groups of paired furnaces at Derrinsallagh 4.

most of the other groups of four furnaces demonstrate more similar sizes, this case suggests that these groups of four may have actually been multiple pairs.

The interpretation of these paired furnaces may be difficult, considering only one group of these features produced multiple ^{14}C dates, Clonrud 4 (Kane 2009a). However, these dates do not overlap at all; F005 was dated to 790 – 410 cal. BCE, and F007 was dated to 360 – 90 cal. BCE. There is then no direct dating evidence that these groups of furnaces were used contemporaneously; however, there is also no evidence that the other groups were not in use contemporaneously.

4.1.2. Smithing Hearths

The identification of a primary or secondary smithing hearth is quite difficult based solely on morphology of the feature in the field. Neil Fairburn has noted that the smithing of a bloom can be conducted anywhere, since all that is needed is enough heat so that the bloom is red-hot and soft enough to "squeeze" out the remaining slag (2005:81). An open hearth or forge can achieve such temperatures without a larger structure being needed to maintain a high heat. In the sites included in this study, 13 features were identified that may have been used for primary or secondary smithing, at ten different sites (Table 4.6). The sizes of the features vary significantly, even within individual sites (e.g. Rossan 6 and Hardwood 3), with some as large as 3.5m in length and others as small as 0.68m. However, these features are almost all out of the range of the smelting furnaces discussed above. The shapes also vary, ranging from mostly circular to rectangular. The reasons for identifying each of these features as being used in smithing are largely specific to the individual feature. In three cases, hammer scale was discovered among the deposits of the feature. C8 at Parksgrove 1 contained hammer scale within its fill (Stevens 2005:16), as did F7/8 at Chapelbride (Danaher and Ginn 2008:2). Feature 38 at Ráith na Ríg, Tara contained various residues and other indications of smithing, which included hammer scale and smithing hearth cakes (Crew and Rehren 2002). Interestingly, this feature and its immediate surrounding area produced evidence for bronze and glass working as well.

Table 4.6 List of possible smithing hearths, listed in order of Site Date, from earliest to latest.

Site Name	Site Licence Number	Context Number	C14 Date	Date	Length (m)	Width (m)	Depth (m)
Rossan 6	02E1068	F087	820-780 BCE	EIA	3.54	3.22	0.44
Rossan 6	02E1068	F086		EIA	1.48	0.73	0.21
Kinnegad 2	02E0926	F42		EIA	1.1	0.52	0.17
Parksgrove 1	99E0597	C8	757 - 685 BCI 661 - 649 BCI 543 - 359 BCI 273 - 261 BCI	EIA	1.2	1.2	0.3
Hardwood 3	02E1141	C044	1440-1640 CE	EIA/Medieval	1.5	1.5	0.25
Hardwood 3	02E1141	C058		EIA/Medieval	1.5	1.5	0.9
Hardwood 3	02E1141	C075		EIA/Medieval	1.2	0.9	0.12
Chapelbride 1	E3172	F7/8	401 - 206 BCE	DIA	0.68	0.57	0.11
Moyvalley 1	02E1088	C016	360 BCE - 70 CE	DIA	1.5	0.7	0.25
Gormagh 1	11E87	C33		DIA	1.2	1	0.32
Moyally 2	E2672	C10		DIA	1.32	0.92	0.17
Ráith na Ríg, Tara	97E300	38	200 BCE - 16 CE	DIA	2	2	0.3
Site 27, Rath	03E1214	F75		DIA	2.25	0.75	0.25

Rossan 6 produced evidence for two smithing hearths, one of which was ^{14}C dated quite early. Based on the SEM-EDAX analysis, Photos-Jones suggested that these two features, F087 and F086, could have only been used for smithing (2003b: 14). At Moyvalley 1, a singular feature was also tentatively identified as a smithing hearth (Carlin 2008). The feature is rectangular in plan, with vertical sides and a flat bottom (O’Hara 2003b), unlikely to have been used as a furnace pit. A feature (F42) of similar shape and dimensions was uncovered at Kinnegad 2, which is also likely to have been used for bloom smithing (Photos-Jones 2003a). Additionally, F75 at Rath, Site 27, was similarly shaped, though larger than the above examples. Based on the size and shape, it is unlikely that it was used as a smelting furnace, and it has therefore been suggested that it was used as a smithing hearth (Photos-Jones 2009). Both features from Gormagh 1 and Moyally 2 (Figure 4.12) are also of rectangular shape with vertical sides and flat bottoms, without significant slag recovered from the fills (Bayley 2009; Bayley and Walsh 2011). It was concluded by Photos-Jones that C10 at Moyally 2 was likely used for bloom smithing.

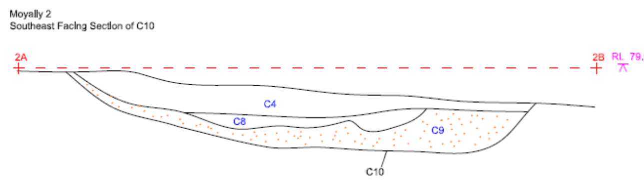


Figure 4.12 Section of C10 (Bayley 2009).

4.1.3. Temporal Patterns

The smelting and smithing features outlined above are distributed fairly evenly across the EIA and DIA, with an increase in total features during the DIA and possibly later (Figure 4.13 and Figure 4.14). Figure 4.14 shows the distribution of ^{14}C dates taken from furnaces or hearths. This demonstrates the unfortunate aspect of using radiocarbon dates to develop a chronology of specific technology; the resolution, especially when using 2 sigma dates, is not very fine. Within this sample, more features used in iron production were found at sites dated to the DIA than from the EIA, although more smithing hearths were associated with EIA sites. Some of the sites identified in this project skew or possibly confuse the strict application of chronological periods. One site, Hardwood 3, is noted for the extreme range of ^{14}C dates recovered from its archaeological features - one feature produced a date of 380 – 60 cal. BCE, while another produced a date of 1440-1640 cal. CE (Murphy 2004a). This specific site demonstrates an important problem with many of these sites and the way each feature is dated. Since only a portion of the actual ironworking features could be dated, the remaining features are dated by association with other dated features. If, as in the case of Hardwood 3, these sites were utilized over a long period of time, the exact dating of the ironworking technology is difficult. While this is not the case at most sites, the possibility for attributing dates incorrectly is there. Another factor that may skew the temporal attribution of ironworking features is the large number of furnaces present at the site of Derrinsallagh 4. There are a total of 44 smelting furnaces recorded at that site, which have been dated to the DIA/LIA (Lennon and Kane 2009a). This is by far the most furnaces found at any one site and makes up 80% of the ironworking features at sites that date to the DIA/LIA. Without the inclusion of Derrinsallagh 4, the increase in ironworking features over time would not appear as drastic.

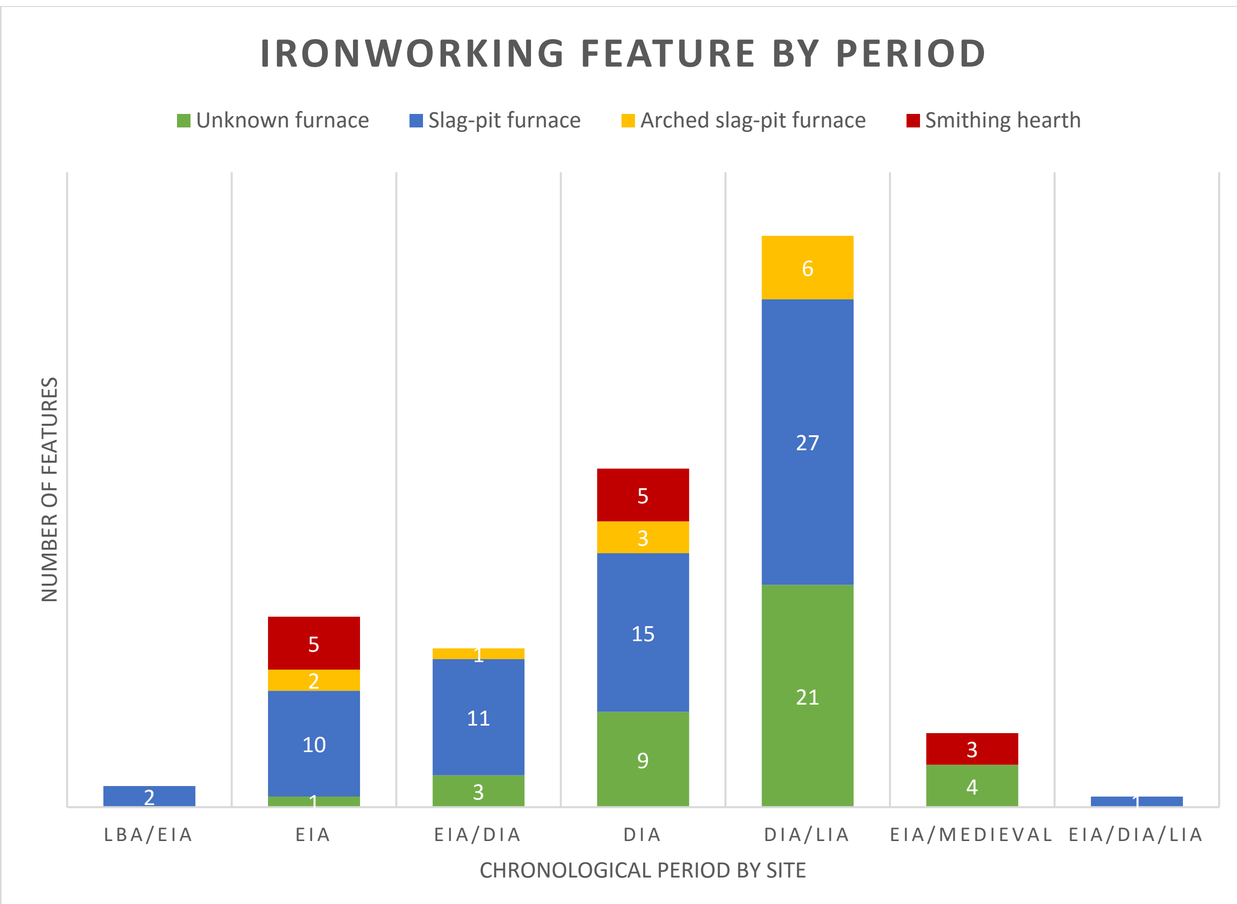


Figure 4.13 The number of ironworking features across chronological periods.

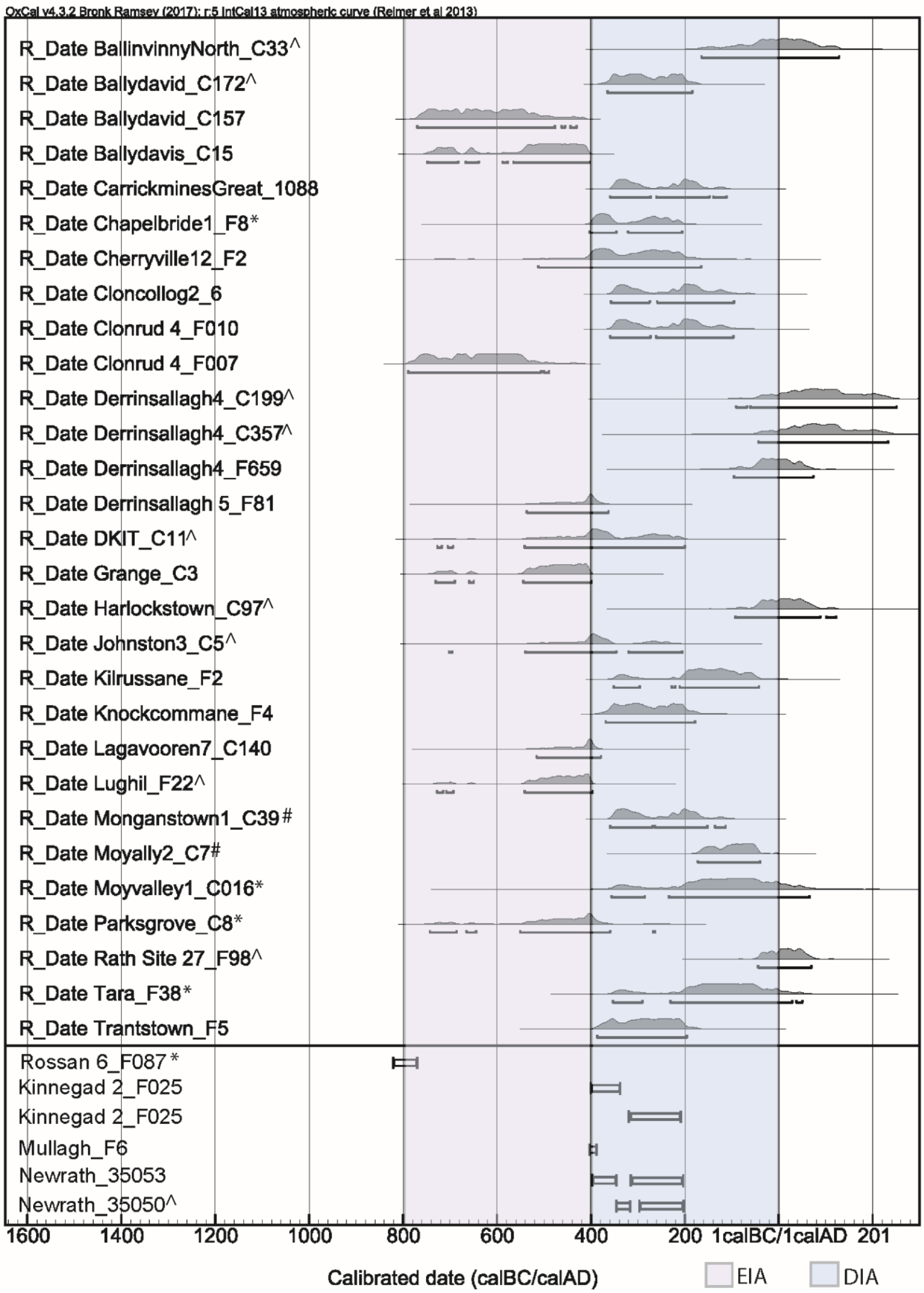


Figure 4.14 Sites that provided Iron Age ^{14}C ($2\ \sigma$) dates from a smelting furnace or smithing hearth context. Context number listed in ( ); * = smithing hearth; ^ = unknown furnace type; # = arched slag-pit furnace; no symbol = slag-pit furnace. The separated contexts on the bottom of the figure were not calibrated by the author and the calibration curve is unknown.

A noticeable shift in technology through time is seen in the increase of arched slag-pit furnaces. The first three arched non-slag tapping slag-pit furnaces are recorded at sites that date to the EIA and the EIA/DIA, two at Kinnegad 2 and one at Lughil. The numbers then increase in the DIA. It should be noted, however, that only two of the identified arched slag-pit furnaces produced ^{14}C dates (see Table 4.3), one from Monganstown 1 and another from Moyally 2. These dates place the usage of these features definitively in the DIA. The remaining arched slag-pit furnaces were dated by association at their respective sites, meaning that the "early" examples of this technology could also represent re-used locations of earlier activity.

The temporal distribution of the sites as a whole also produced an interesting pattern. The study conducted by Becker and others indicated that there is no significant patterning on the landscape of sites that date to the EIA (Becker et al. 2008)[6]. Figure 4.15 shows the distribution of all types of sites that produced EIA dates as part of that project. In contrast to all of the dated EIA sites recovered as part of the *Iron Age Ireland* project, the EIA sites within my project display a different pattern. Every site with evidence for ironworking features that produced ^{14}C dates for the EIA or DIA was included in this project. In addition to EIA dates, some sites also produced dates that extended from the EIA into the DIA. When these data are displayed, it appears that sites utilized for iron production during the early part of the Iron Age cluster towards the middle and eastern part of the island, through the midlands and down into the modern-day M7 to M8 roadway (Figure 4.16). This figure shows a definite concentration in this area with sites that

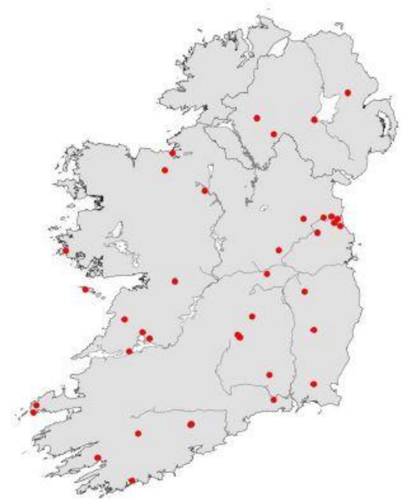


Figure 4.15 Map showing EIA sites in red (Becker et al. 2008).

[6] See also Section 2.1.3 of this dissertation.

have produced ^{14}C dates during the EIA or across the EIA to the DIA. EIA sites have been discovered throughout the island, as Figure 4.15 shows, which suggests that the concentration seen in Figure 4.16 is not only based on an excavation bias of the motorway but there are potentially other social explanations for this distribution[7].

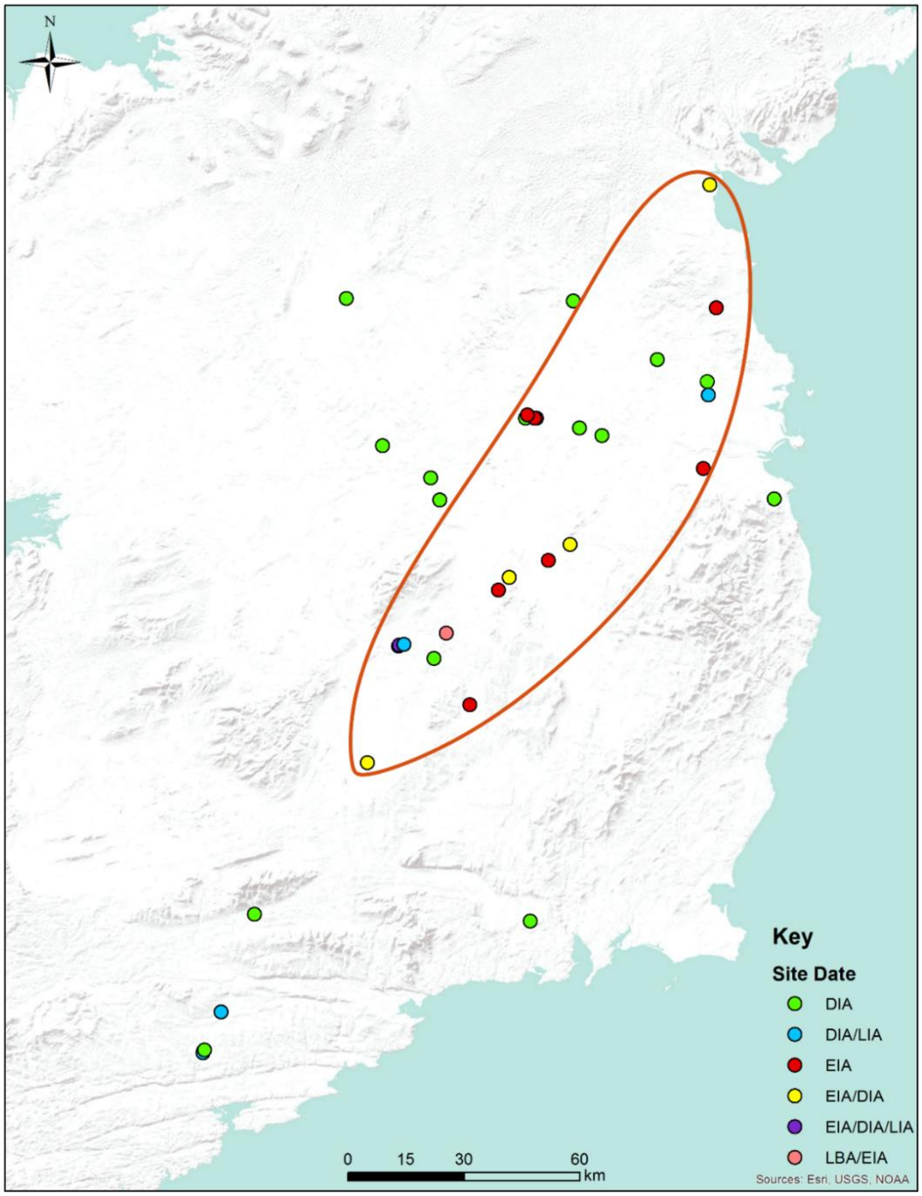


Figure 4.16 Distribution map of ironworking sites by chronological period. Cluster of early sites indicated by the line.

[7] It should be restated that the excavation bias does have a role in the spatial patterning of these sites. However, it should also be possible to work with the existing data to identify patterns.

4.1.4. Spatial Patterns

The inter-site distribution of smelting furnace types (Section 4.1.1) maintains a fairly regular pattern throughout the island (Figure 4.17). Slag-pit furnaces are found in the center-east of the island, down along the modern M7 to M8 towards the southwest. The distribution of unknown type of furnaces mostly follows this pattern as well, which is to be expected considering many of these features may actually be slag-pit furnaces (see discussion in 4.1.1.3). The most notable distribution pattern is the location of arched slag-pit furnaces, which occur solely in the midlands. Figure 4.18 shows the isolated distribution of this furnace type, and highlights the central placement of these features. The clustering of these furnace types in a relatively small region, as compared to the distribution of the total number of smelting furnaces, may be significant. The sites demonstrating this specific technology exhibit two smaller clusters, one group made up of Derrinsallagh 4 and Derryvorrigan 1, and one

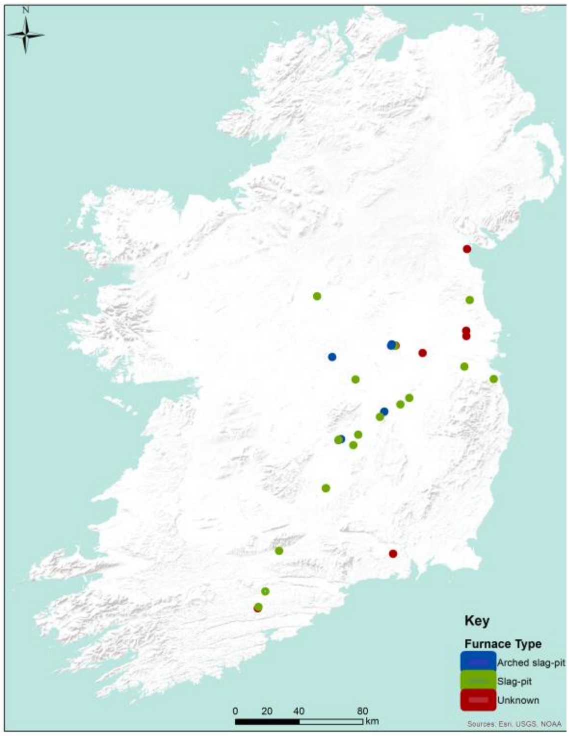


Figure 4.17 Distribution of smelting furnace types.

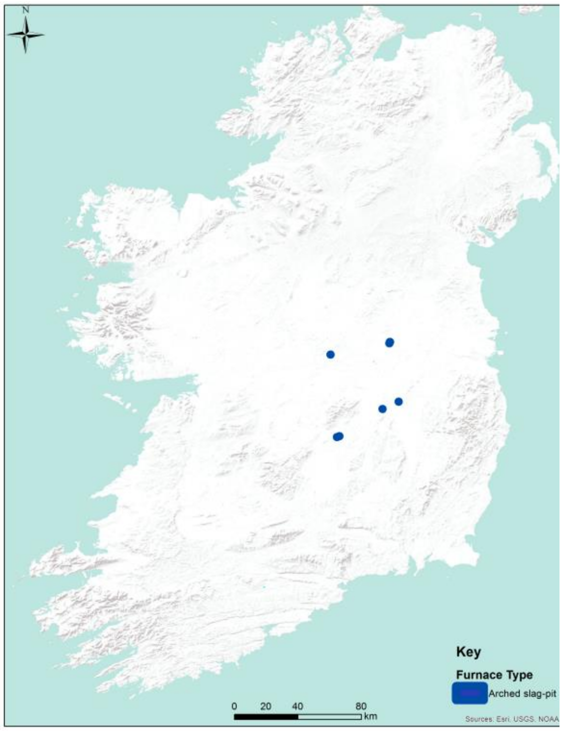


Figure 4.18 Distribution of arched slag-pit furnaces.

group consisting of Monganstown 1 and Kinnegad 2 (the northern and southern groups shown in Figure 4.18, respectively). In contrast to the distribution of slag-pit and unknown furnaces, arched slag-pit furnaces have not been found in the south, or mid-upper east of the island.

Moving from the distribution of furnaces between sites to the relationship of different furnace types within sites, a few different trends emerge. Specifically, I examined the spatial relationships between non-slag tapping slag-pit furnaces and arched non-slag tapping slag-pit furnaces. These two feature types represent different techniques for smelting iron, and their relationships within a single site could have implications for how they were used in association or through time. At sites with both types of furnaces, some fall into the category of closely associated features (top in Figure 4.19; bottom in Figure 4.20; right in Figure 4.21), while others do not appear to illustrate a close relationship between different furnace types (bottom in Figure 4.19; top in Figure 4.20; left in Figure 4.21). The first group of sites shows that arched slag-pit furnaces have been found within a meter of slag-pit furnaces. The close proximity of these features may indicate contemporaneous use, which if true would need further evaluation regarding why different techniques were used at the same time. The sites which show furnace types at a distance from each other may suggest that these different technologies were in use at different times of the site's use. Unfortunately, none of these sites produced ^{14}C dates for both arched slag-pit and slag-pit furnaces, so a more nuanced temporal explanation for their distribution cannot be proposed. Interestingly, the site of Derrinsallagh 4 included examples of both of these patterns, with the top image in Figure 4.19 showing an arched slag-pit furnace (C397) found immediately next to slag-pit and unknown smelting furnaces, while the bottom image in Figure 4.19 shows an arched slag-pit furnace (C005/057) c. 10 meters from other furnaces. This suggests that a single explanation for the distribution of furnace types within each site is unlikely.

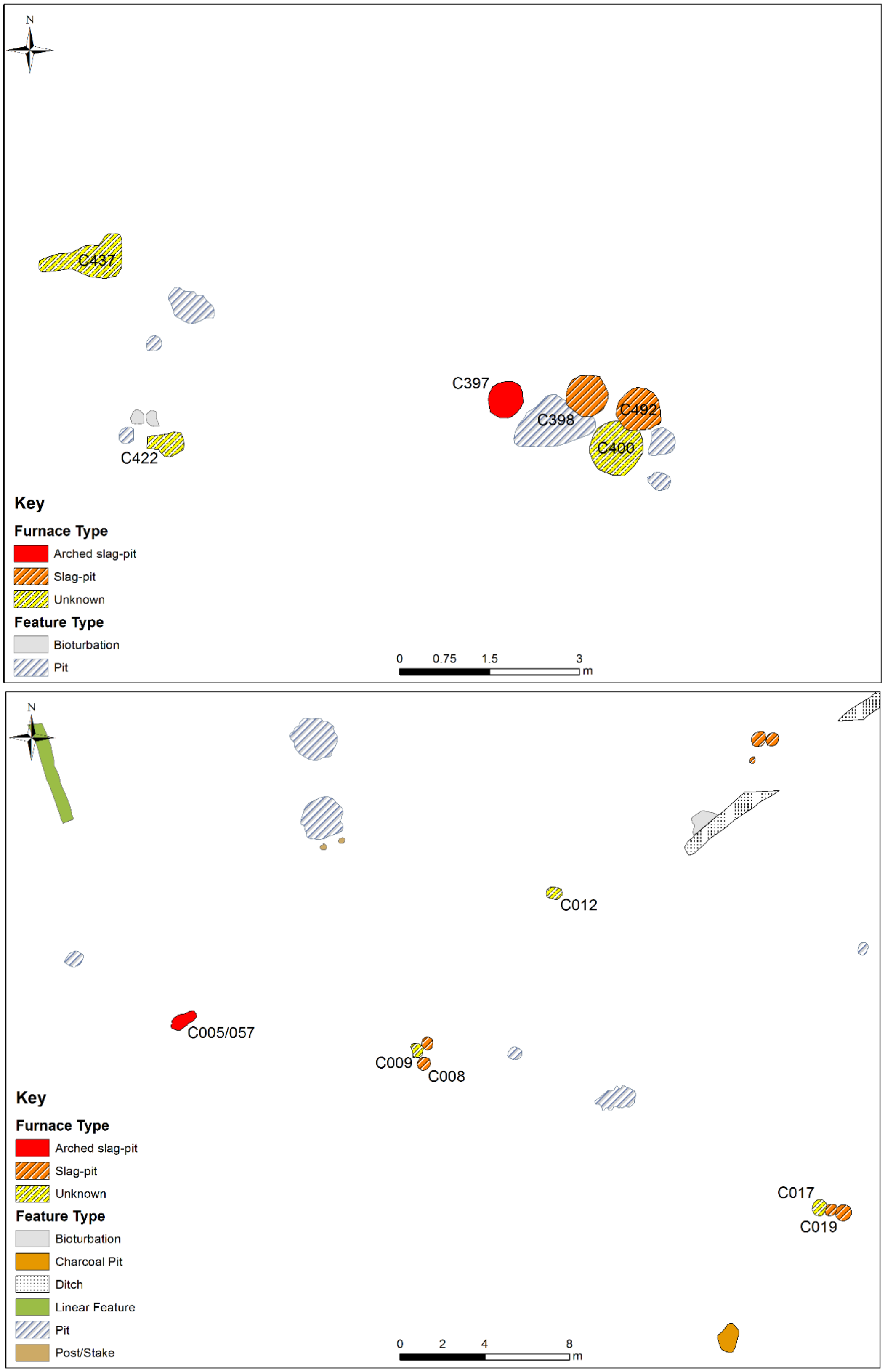
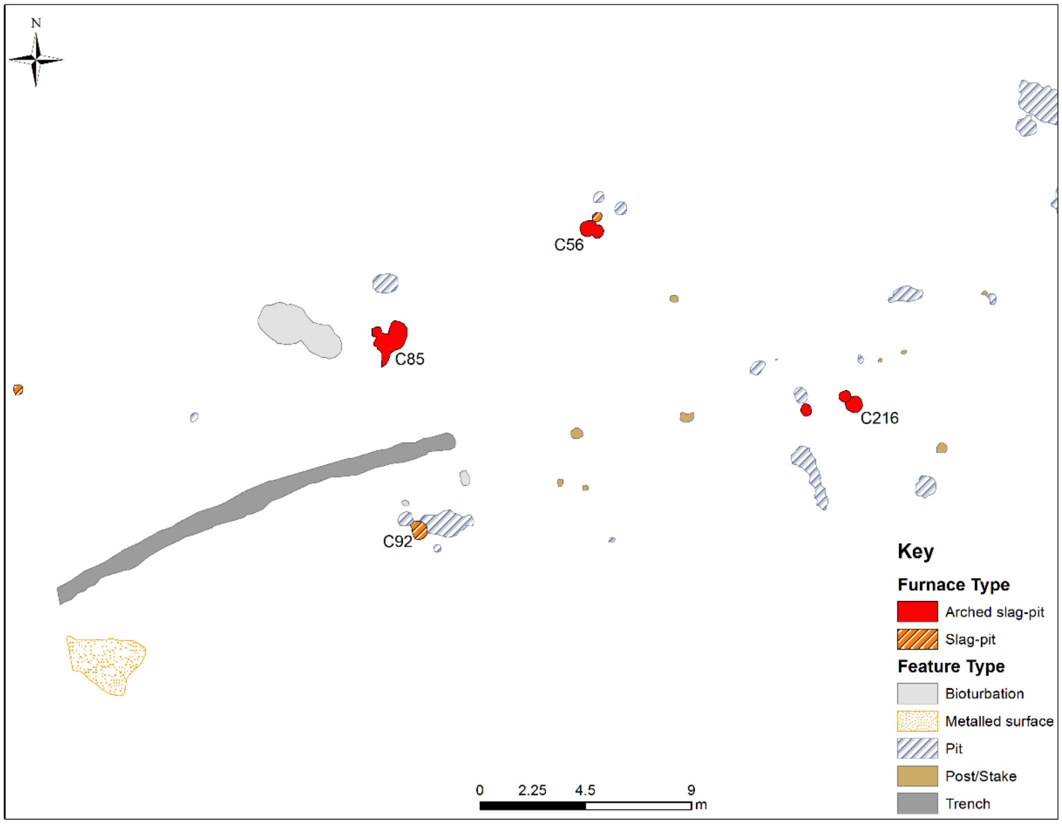


Figure 4.19 Relationships between different furnace types within Derrinsallagh 4. Top and bottom show different areas of the site.



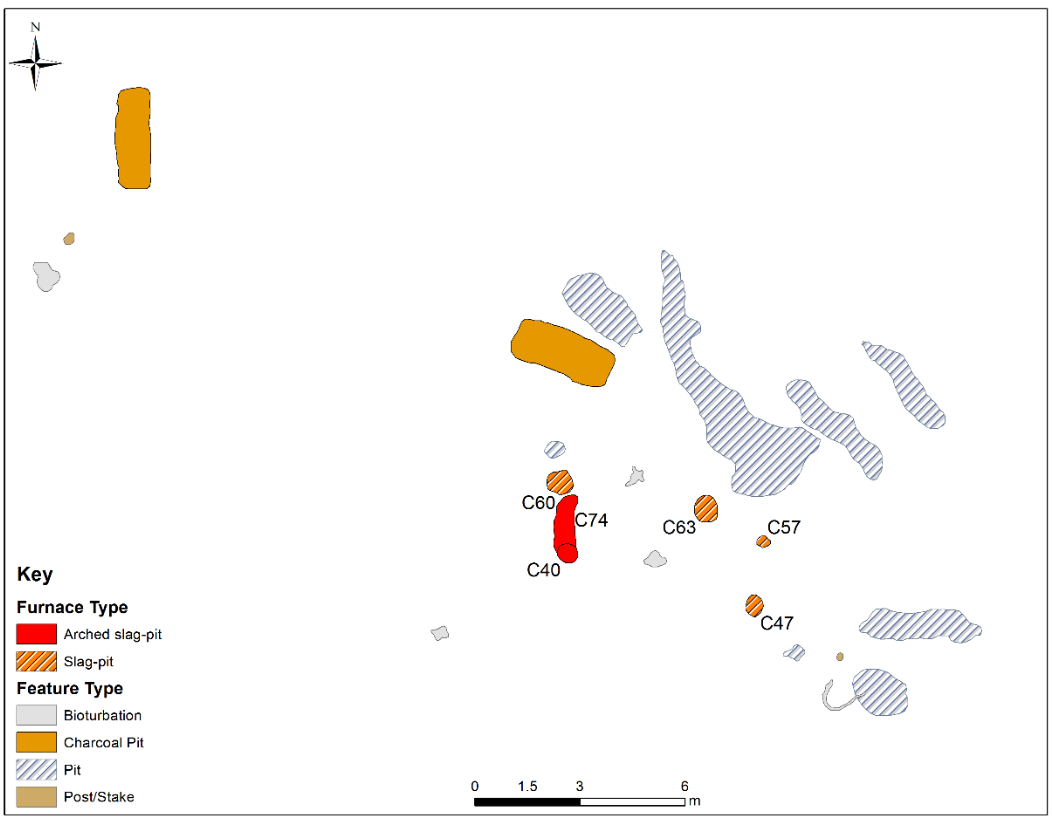


Figure 4.20 Relationships between different furnace types within sites. Top: Derryvorigan 1. Bottom: Monganstown 1.

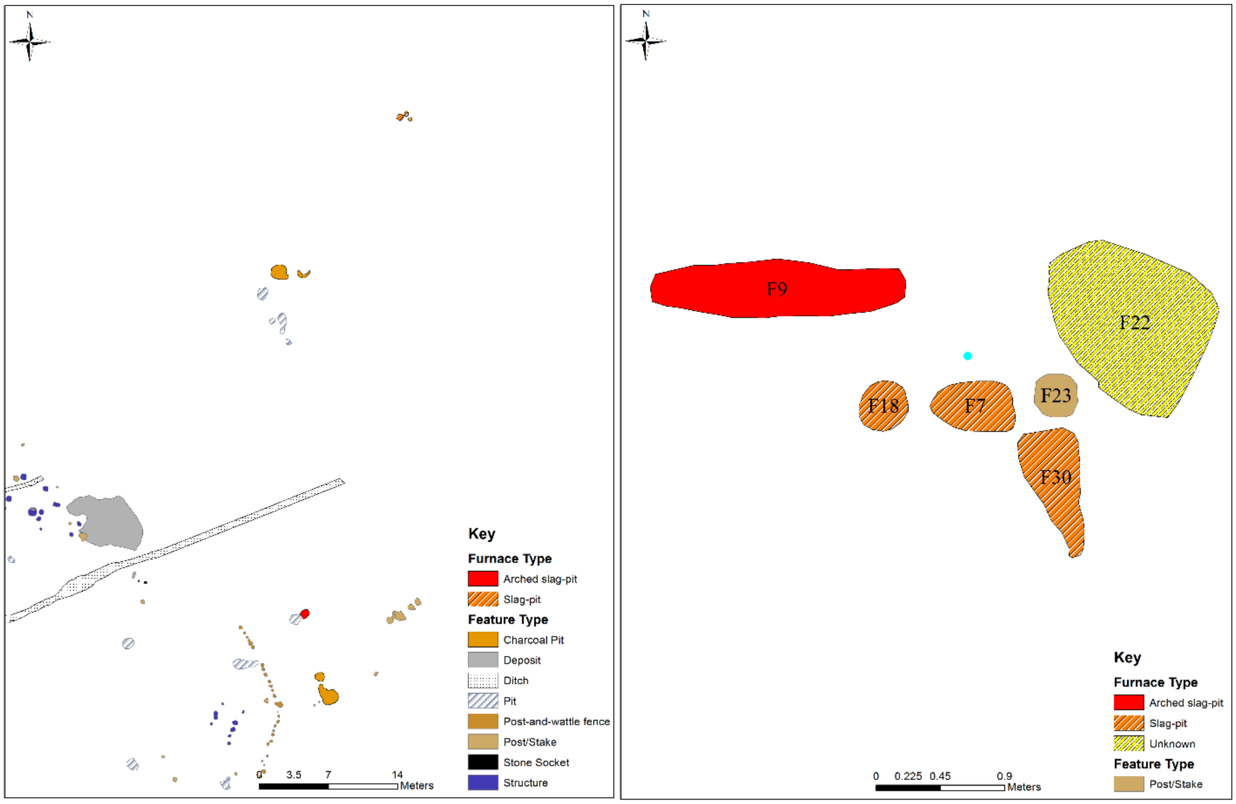


Figure 4.21 Relationships between different furnace types within sites. Left: Morett. Right: Lughil.

The distribution of smithing hearths found at EIA and DIA sites can also be approached from an inter- and intra-site perspective. At the regional scale, smithing hearths can be seen to cluster in the midlands, with one exception to the south (Figure 4.22). The one outlier from this cluster is the site of Parksgrove 1, which provided evidence for a single smithing hearth surrounded by a burned spread (Stevens 2005). The cluster consists of nine sites, with evidence for 12 features involved in smithing activity[8]. This regional distribution, with a very notable clustering through the midlands, does parallel some of the other spatial patterning observed in other aspects of early Irish iron production. As noted above, arched non-slag tapping slag-pit furnaces are also largely restricted to the midlands. Additionally, ironworking sites that have produced evidence for EIA or

[8] Hardwood 3 contained three smithing features, and Rossan 6 contained two.

EIA/DIA dates are found within this same area. The possible explanations and interpretations of these patterns are discussed in Chapter 5 of this dissertation.

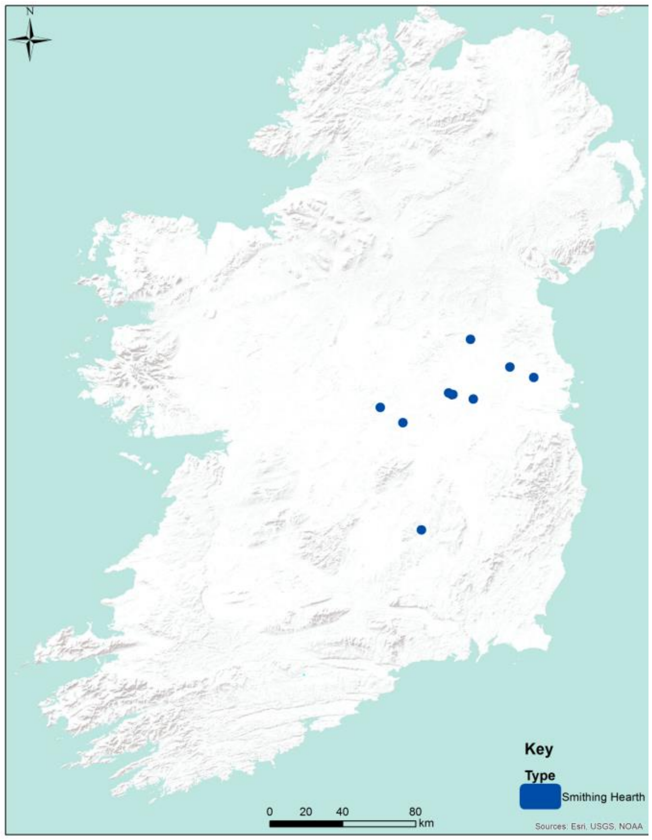


Figure 4.22 Distribution of smithing hearths.

At those sites which provided evidence for both smithing and smelting features, the intra-site relationships between smithing hearths and smelting furnaces could indicate how these features were being used by individuals. The hypothesis is that these smithing hearths represent the primary smithing activities which happen directly after an iron bloom is produced, in which the bloom is heated and hammered to continue to remove excess material and create a workable piece of iron. If this is the case, one could expect that a smithing hearth would be used contemporaneously (or at least within a few days) of the initial smelt. Five sites included both types of ironworking structures, and mostly shared the expected spatial relationship[9] between the two features. The location of the smithing hearths in relation to smelting furnaces indicates that most of them were used at the same time. Figures 4.23 – 4.25 illustrate the spatial relationships between these various ironworking features. Figures 4.23, 4.25, and the bottom of Figure 4.24 show smithing hearths were placed approximately two to four meters from a smelting furnace. The only site that demonstrates a different pattern is the site of Hardwood 3 (top of Figure 4.24). At this site, three smithing hearths were distributed across the site, with only one being in close proximity to the smelting furnaces, which are all clustered. Interestingly, one smithing feature (C044) found to the southeast of the furnaces provided the late date for the site (1440-1640 cal. CE). In contrast, the smelting furnace C052 produced a ^{14}C date of 380 - 60 cal. BCE. It could be that the cluster of smelting furnaces and the single smithing hearth found at the center of Figure 4.24 were from an earlier occupation of the site, while the smithing hearths to the northwest and southeast are from a later period of activity.

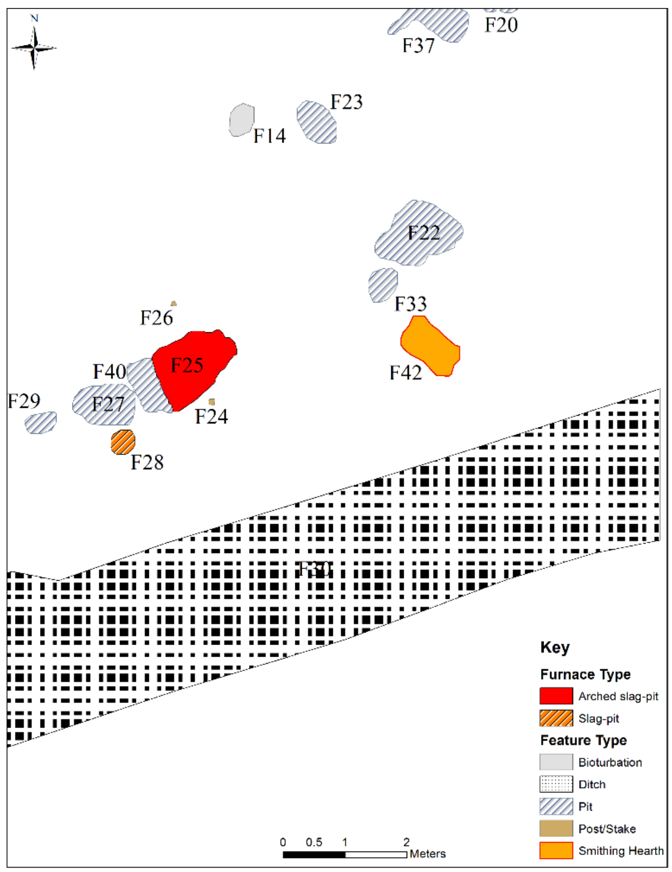
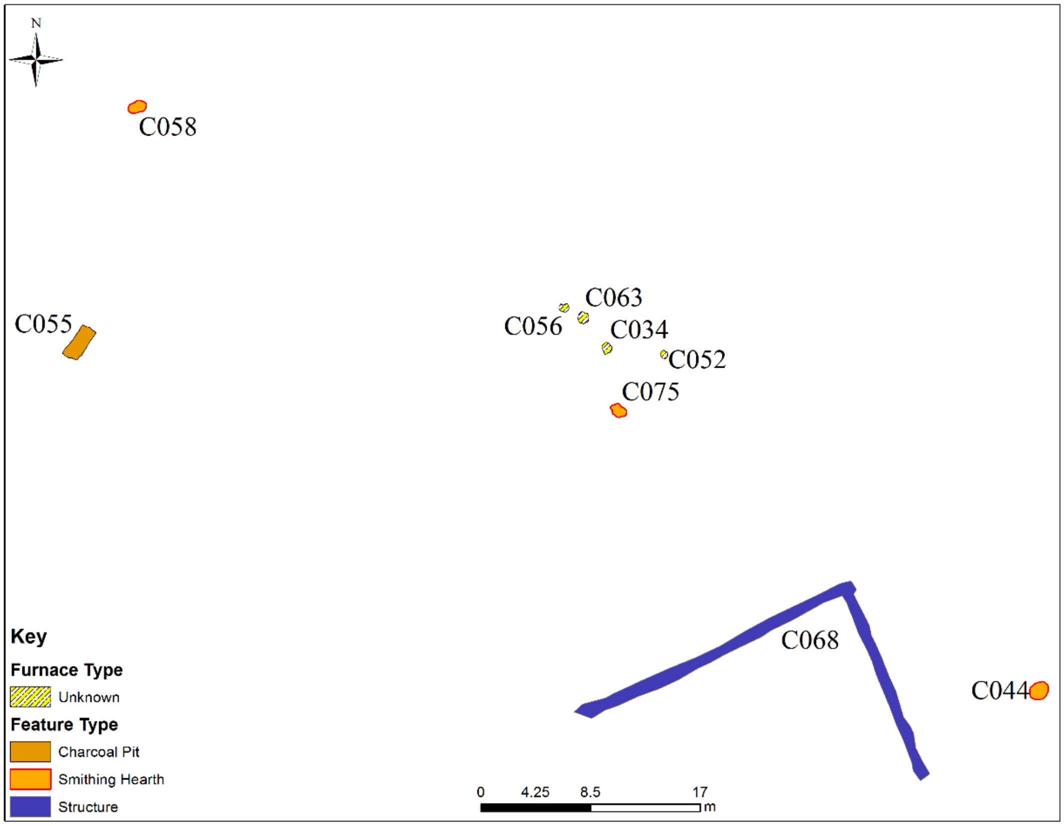


Figure 4.23 Relationship between smithing hearth and smelting furnaces within Kinnegad 2.

[9] That smithing hearths are found nearby smelting furnaces.



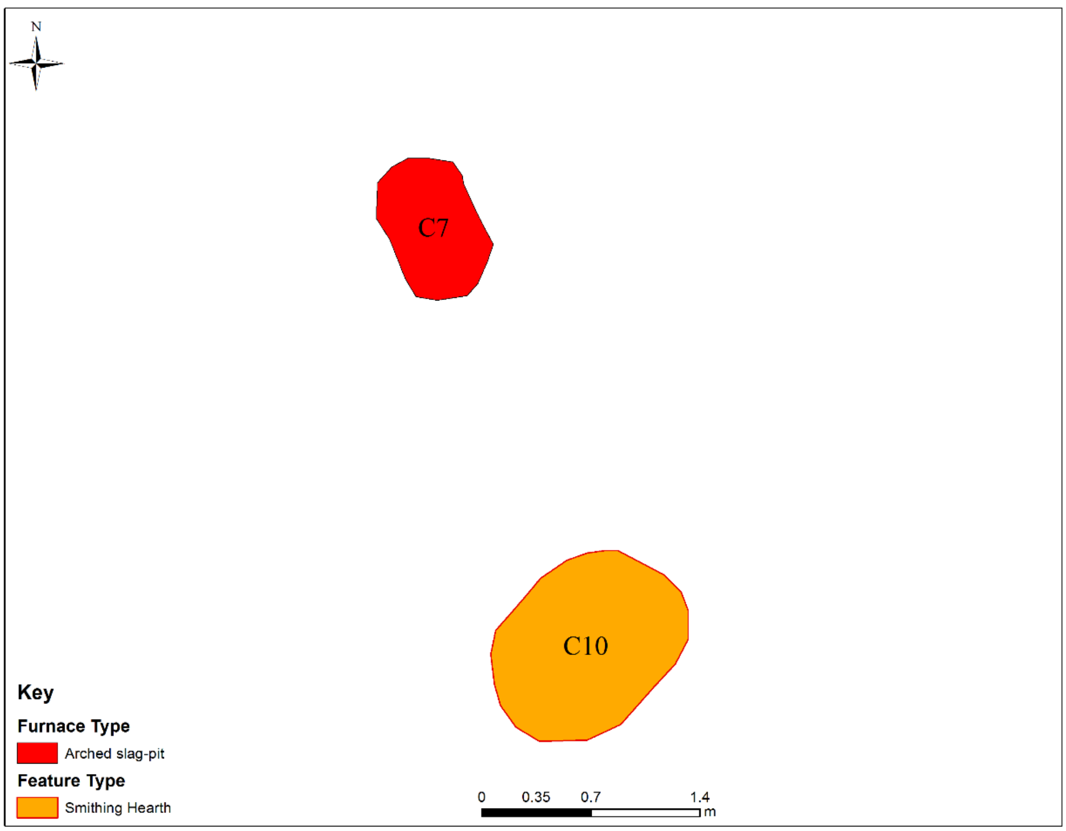


Figure 4.24 Relationships between smithing hearths and smelting furnaces within different sites. Top: Hardwood 3. Bottom: Moyally 2.

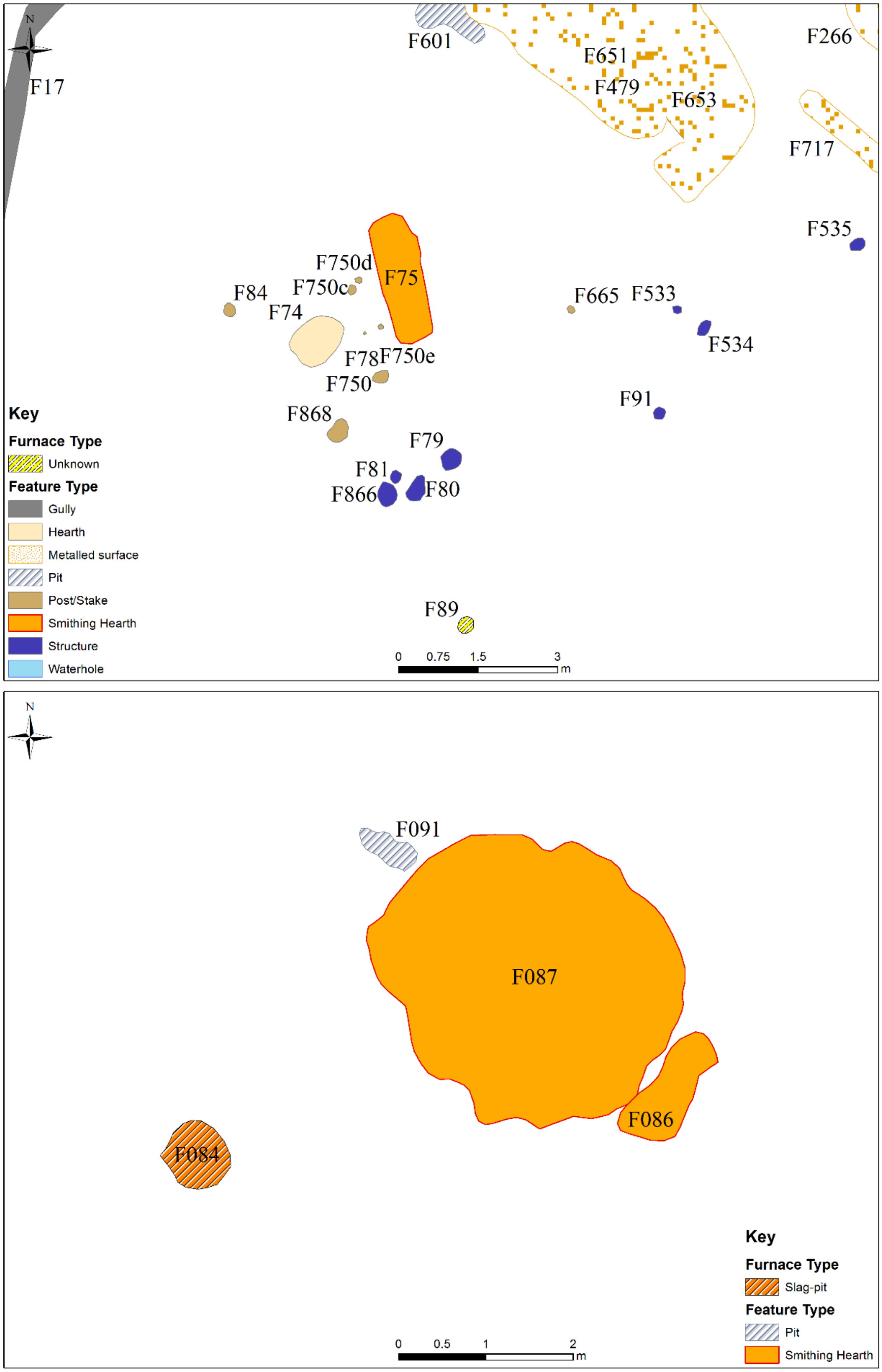


Figure 4.25 Relationships between smithing hearths and smelting furnaces within different sites. Top: Rossan 6. Bottom: Rath Site 27.

4.1.5. Smelting vs. Smithing

The archaeological data recovered from the EIA and DIA sites for this project have produced evidence of both iron smelting and smithing, although these activities do not always occur at the same site. Five sites have produced evidence for both smelting furnaces and smithing hearths, and the possible relationship between the two ironworking features was discussed above (Section 4.1.4). Furthermore, an additional five sites produced only evidence for smithing hearths. However, what has not yet been discussed in this chapter is that another four sites produced evidence for iron smithing activities without the presence of an actual smithing hearth. At Cherryville Site 12, a smithing hearth cake (also called a plano-convex bottom [PCB]) was recovered from a refuse pit, which is a strong piece of evidence that smithing was occurring on site (Young 2005). Similarly, a PCB was also recovered from the site of Lisnagar Demesne 1 (Fairburn 2005) and Monganstown 1 (Fairburn 2006), while additional smithing slag was identified at Harlockstown 19 (Photos-Jones 2007b). These residues suggest that either the remains of a smithing hearth were misidentified during excavation and analysis, or that the hearth lay outside the excavation boundaries.

In addition to sites that have produced slag evidence of iron smithing, the site of Knocknaulin in County Kildare must be mentioned. A brief background on this ritual center was provided in Chapter 2 (Section 2.4.2.5), but some amount of slag was recovered from excavations at Knocknaulin between 1968 and 1975 (Johnston and Wailes 2007). Because no ironworking features were identified at the site, it was not included in the larger dissertation database for this project. However, the slag recovered from across this site does indicate smithing was occurring there, possibly in the EIA and DIA. For this reason, this site is included in Figure 4.26, which shows the distribution of smelting and smithing across the island.

4.1.5.1. Temporal and Spatial Differences

The spatial patterning of sites with smelting furnaces and those with smithing hearths has been discussed above (Section 4.1.4). It was noted that a clustering of smithing hearths is found in the midlands, with one outlier slightly to the south (Parksgrove 1). This pattern continues when sites which have provided evidence for smithing, in the form of slag, are added. Figure 4.26 shows the distribution of sites that have produced evidence for smelting, smithing, or both. The concentration of smithing-only sites (shown in blue) lay almost exclusively in the center-east of the island. In addition, mixed smithing and smelting sites (shown in green) are also predominantly found in the same region. An exception to this pattern is the site of Lisnagar Demesne 1 (number 13 in Figure 4.26), which produced a PCB – an indication of smithing. This site is found in the southern part of the island, in County Cork. In contrast to the smithing activities, sites which only produced evidence for iron smelting are found throughout the study area, without exhibiting any significant trends.

The temporal patterning of smelting furnaces was also discussed above (Section 4.1.3), and demonstrated that earlier ironworking sites were largely located in the midlands and down through the M7 to M8 corridor. There do not seem to be any additional temporal patterns within smithing sites as compared to smelting sites. Sites with smithing hearths, as well as sites that have produced only slag evidence of smithing, are evenly distributed across the EIA and DIA. Five smithing hearths were found at sites dating to the EIA, while five hearths were found at sites dating to the DIA (Figure 4.13). This type of pattern demonstrates relative continuity of smithing activities through time.

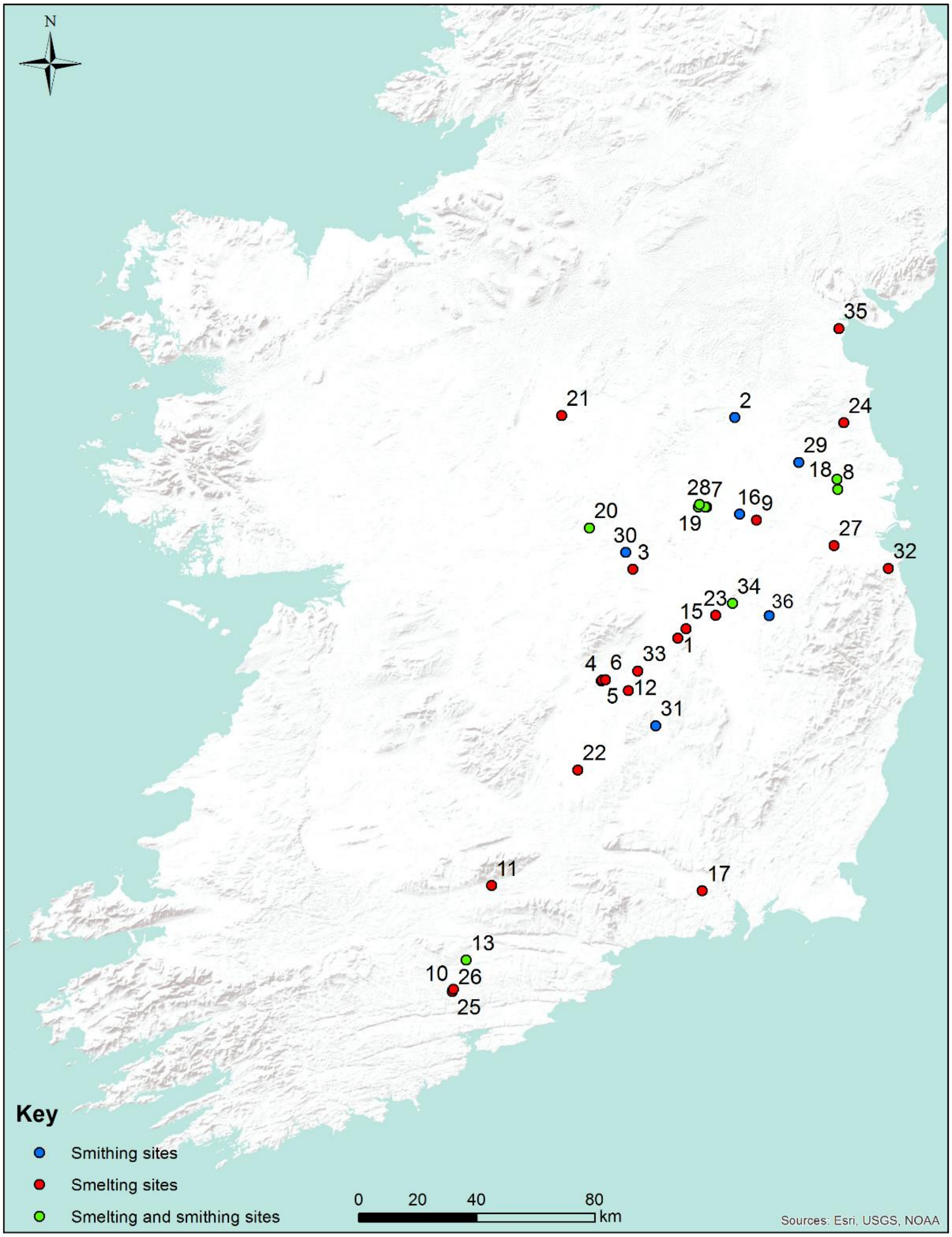


Figure 4.26 Sites with evidence for smithing and/or smelting. *1:Ballydavid; 2:Chapelbride 1; 3:Cloncollog 2; 4:Derrinsallagh 4; 5:Derrinsallagh 5; 6:Derryvorrigan 1; 7:Hardwood 3; 8:Harlockstown 19; 9:Johnstown 3; 10:Kilrussane; 11:Knockcommane; 12:Leap 1; 13:Lisnagar Demesne 1; 14:Monganstown 1; 15:Morett; 16:Moyvalley 1; 17:Newrath 35; 18:Rath Site 27; 19:Rossan 6; 20:Moyally 2; 21:Mullagh Site 1; 22:Ballydavid; 23:Lughil; 24:Lagavooren 7; 25:Ballinvinny North; 26:Trantstown; 27:Grange; 28:Kinnegad 2; 29: Ráith na Ríg; 30:Gormagh 1; 31:Parksgrove 1; 32:Carrickmines Great; 33:Clonrud 4; 34:Cherryville Site 12; 35:DKIT; 36:Knocknaulin.*

4.1.5.2. Association With Features/Site Types

By far the most common site type in this project sample fall into what I have called the Isolated Metalworking site category. These sites consist solely of features used for some level of ironworking, along with some associated pits or undiagnostic features, but no clear stuctures; 26 sites in the database were given this designation (Table 4.7). Eleven of the sites with evidence for smithing, either in the form of slag or a smithing hearth, were categorized as isolated metalworking sites. Smithing sites that are not listed as isolated metalworking sites include Ráith na Ríg, Tara, Harlockstown 19, and Rath Site 27. The most unique of the sites was at Ráith na Ríg, Tara, which was utilized much more extensively in the LIA. The metalworking activity at Tara occurred prior to the creation of the bank of the Ráith na Ríg, the largest hilltop enclosure at the site (Roche 2002). The nature of the site during this period is still largely unknown, as it predates most of the monuments that make up the Tara sites complex. The presence of post and stake-holes surrounding the smithing hearth suggests that there may have been some small structure surrounding the production activities (Roche 2002:73). Possibly the most important aspect of the ironworking activity at the site is that it does not seem to have been the only industrial processing occurring there. The hearth used for iron smithing may have also been used for bronze-smithing and glass-working, based on the residues for both activities, as well as molds for bronze casting (Crew and Rehren 2002). These associations distinguish this ironworking feature from any other example in this study sample.

Table 4.7 List of site types with evidence of smelting and/or smithing. Asterisk indicates that only bloomery furnaces or smithing hearths were found on site, no associated pits, postholes, or hearths.

Site Name	Type of Site	Date	Smelting	Smithing
Morett	Burial	EIA/DIA	X	
Site AR 26, Ballydavid	Enclosure	EIA/DIA	X	
Cherryville Site 12	Isolated Metalworking	EIA/DIA	X	X
Moyally 2	Isolated Metalworking*	DIA	X	X

Mullagh	Isolated Metalworking*	DIA	X	
Gormagh 1	Isolated Metalworking*	DIA		X
Grange	Isolated Metalworking	EIA	X	
Derrinsallagh 5	Isolated Metalworking	EIA/DIA/LIA	X	
Site L, Lughil	Isolated Metalworking	EIA	X	
Cloncollog 2	Isolated Metalworking*	DIA	X	
Leap 1	Isolated Metalworking	DIA	X	
Kinnegad 2	Isolated Metalworking	EIA	X	X
Chapelbride 1	Isolated Metalworking	DIA		X
Ballinvinny North AR26	Isolated Metalworking*	DIA/LIA	X	
Clonrud 4	Isolated Metalworking*	LBA/EIA	X	
Kilrussane AR 27	Isolated Metalworking	DIA	X	
Newrath Site 35	Isolated Metalworking	DIA	X	
DKIT	Isolated Metalworking*	EIA/DIA	X	
Hardwood 3	Isolated Metalworking	EIA/Medieval	X	X
Moyvalley 1	Isolated Metalworking*	DIA		X
Johnstown 3	Isolated Metalworking*	DIA	X	
Lisnagar Demesne 1	Isolated Metalworking	DIA/LIA	X	X
Monganstown 1	Isolated Metalworking	DIA	X	X
Parksgrove 1	Isolated Metalworking	EIA		X
Rossan 6	Isolated Metalworking	EIA	X	X
Trantstown AR 29	Isolated Metalworking	DIA	X	
Site B, Ballydavis	Isolated Metalworking	EIA	X	
Lagavooren 7	Isolated Metalworking	EIA	X	
Ráith na Ríg, Tara	Other	DIA		X

Knockcommane 4700.1b	Structure	DIA	X	
Carrickmines Great	Structure	DIA	X	
Derrinsallagh 4	Structure	DIA/LIA	X	
Derryvorrigan 1	Structure	DIA/LIA	X	
Harlockstown 19	Structure/Burial	DIA/LIA	X	X
Site 27, Rath	Structure/Burial	DIA	X	X

Three sites in this sample produced evidence for human remains in association with ironworking activities: Morett, Rath Site 27, and Harlockstown 19. The site of Morett contained a cluster of smelting furnaces, as well as an arched slag-pit furnace on one side of the site. Roughly 45m to the northeast of the site were two Iron Age ring-ditches dated to 400 – 200 cal. BCE and 370 – 110 cal. BCE (Cotter 2011) (Figure 4.27). While none of the furnaces produced a direct ^{14}C date, associated features date the furnaces as contemporary or slightly later than the ring-ditches. It is very likely that the ring-ditches were still visible at the time of iron smelting took place there.

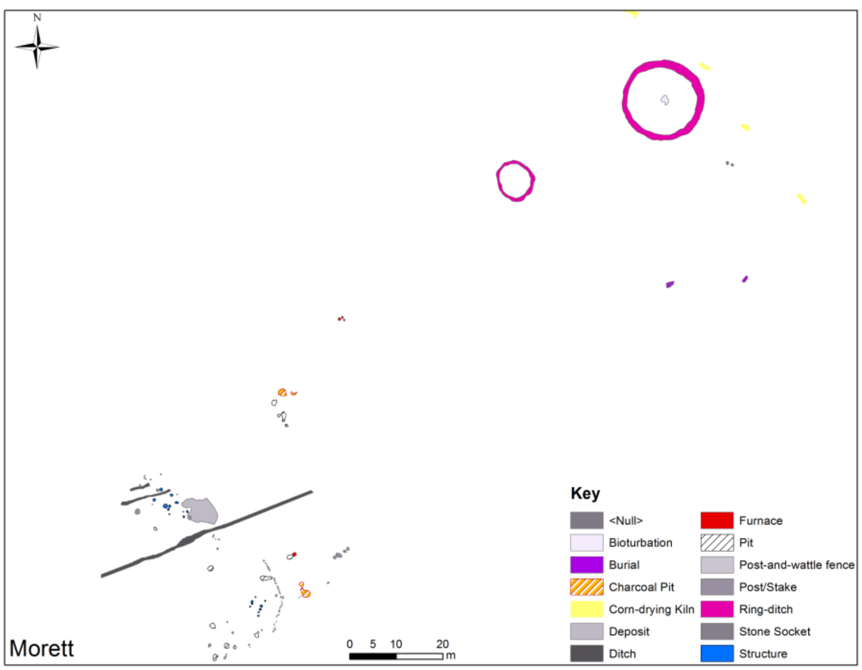


Figure 4.27 Plan map of the site of Morett.

The site of Rath Site 27 consisted of a large number of features that represented a continuation from the Bronze Age into the Iron Age. There were four ring-ditches at this site, with at least one, if not all four, dating to the DIA (Schweitzer and O'Carroll 2009). Additionally, and more uniquely, a feature was uncovered that was termed a "sweat lodge" dating to this period, as well as two waterholes with wooden superstructures. The bloomery furnace and smithing hearth were in the center of the site, between the ring-ditches and other features (Figure 4.28). In association with these ironworking features was what appeared to be a small, 2m^2 post-structure.

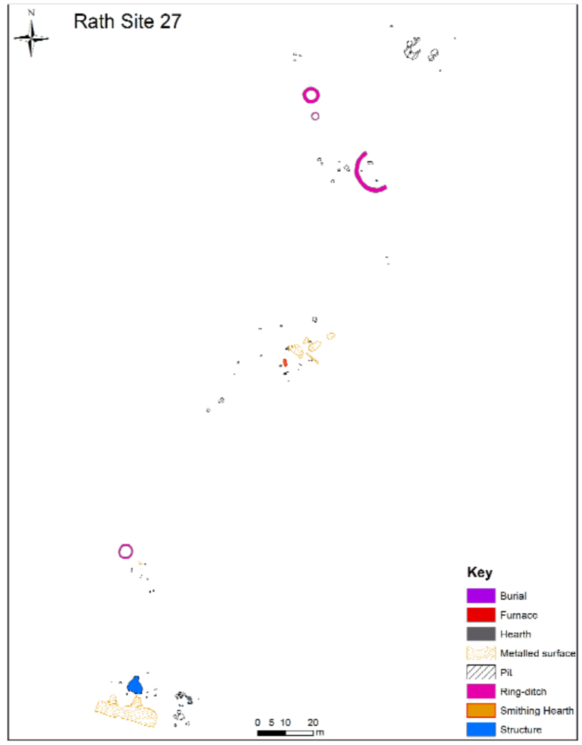


Figure 4.28 Plan map of the site of Rath Site 27.

The final site associated with mortuary activities is Harlockstown 19 (Figure 4.29), which was established immediately on top of an Early Bronze Age ditched enclosure containing cremations and inhumations. The Iron Age occupation at the site included a single bloomery furnace in the center of the site (F96), as well as large burnt spreads, possible work floors, and a sunken-floor feature. F3, a circular ditched feature almost 8m in diameter at the north end of the site, is contemporaneous with the ironworking at the site. Although it was interpreted as a house structure (O'Connor 2008), there is no indication of habitation, nor is there any entrance into the ditched features. I argue that the shape of the feature is much more reminiscent of a ring-ditch[10].

[10] In O'Connor (2008; Figure 40), burnt or cremated bone is identified as being recovered from F3, but this is not described anywhere else in the report.

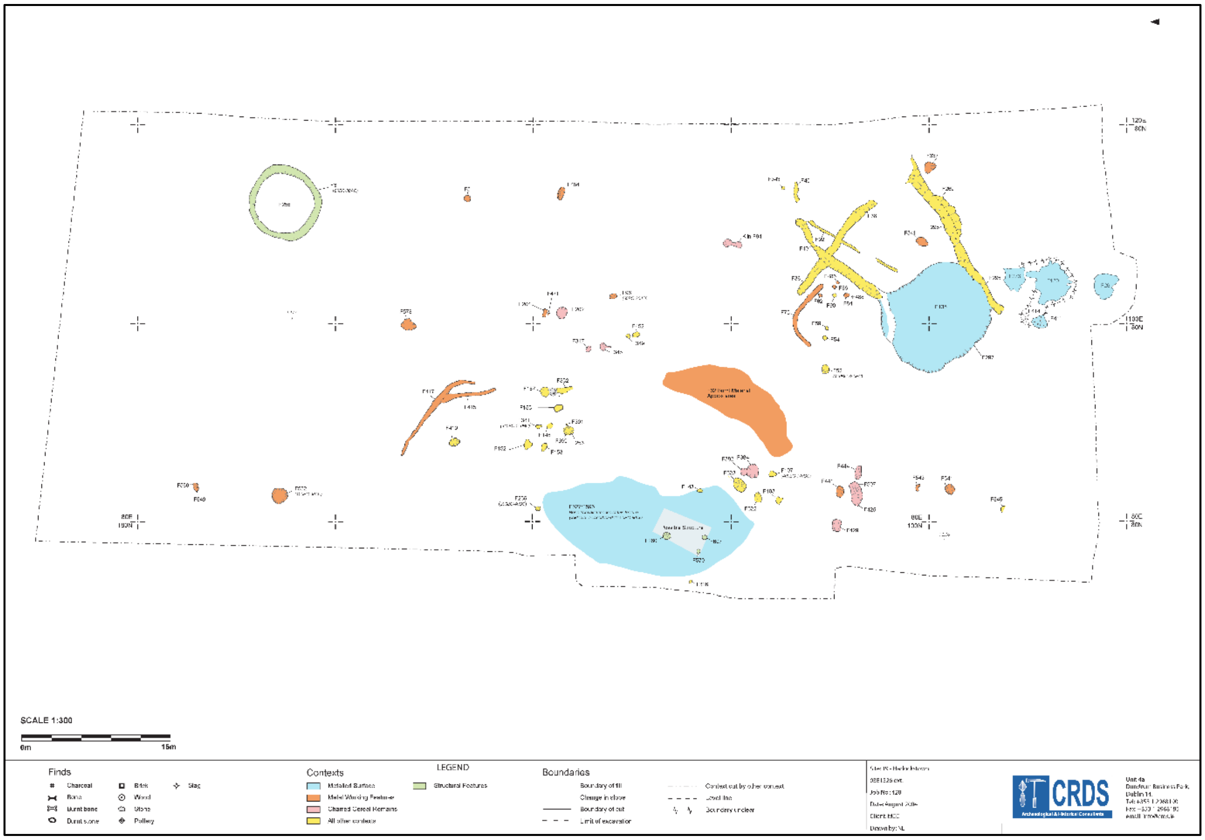


Figure 4.29 Plan map of the Iron Age features at Harlockstown 19 (O'Connor 2008).

Four sites in this sample produced evidence for some type of structure in association with the iron production features. However, the nature and use of these structures varied across sites. The bloomery furnace at Carrickmines Great is one of the few, possibly the only, examples of iron smelting occurring in a domestic context. The furnace was found approximately 12m northwest of the two structures (Figure 4.32). One structure is a c. 5m^2 post-structure, while the other is a smaller 2m^2 post and trench structure. The distance away from the habitation structures is likely relevant to the questions of how this pyrotechnic activity was integrated into everyday life.

At the site of Derrinsallagh 4, a sub-circular trench structure was found dating to the DIA, just north of much of the ironworking activity. It dates to just before most of the ironworking activity but could have still been in use during the industrial activity at the site (Lennon and Kane 2009a). Pits associated with the features suggest that it may have been used for domestic purposes.

The smelting and smithing features are dotted throughout the site, with none being closer than 10m from the structure (Figure 4.30). Just east of Derrinsallagh 4 is the site of Derryvorrigan 1, which also produced evidence of a structure associated with ironworking activities. The rectangular post-structure measured 6.5 x 5m, and was found at the northeast part of the site, roughly 40m from the ironworking activity (top images in Figure 4.31). The structure dates to the DIA/LIA transition but may have been in use at the same time as the iron production (Lennon and Kane 2009b).

The only site that produced evidence for an ironworking feature located within a structure was Knockcommane. The site consisted of a singular circular structure (8.5m in diameter) made up of a slot trench and a series of posts, surrounded by a circle of gullies (Molloy 2007). Within the structure was a single slag-pit furnace (bottom image in Figure 4.31). This site may represent the only known smelting structure found in Ireland.

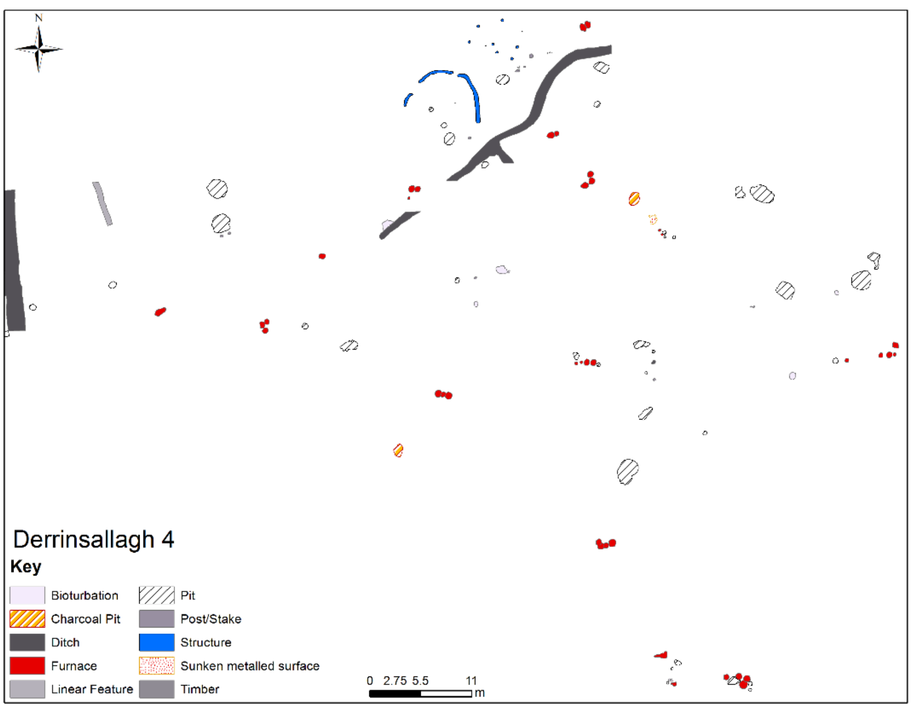


Figure 4.30 Plan map showing spatial relationship between structure and furnaces at Derrinsallagh 4.

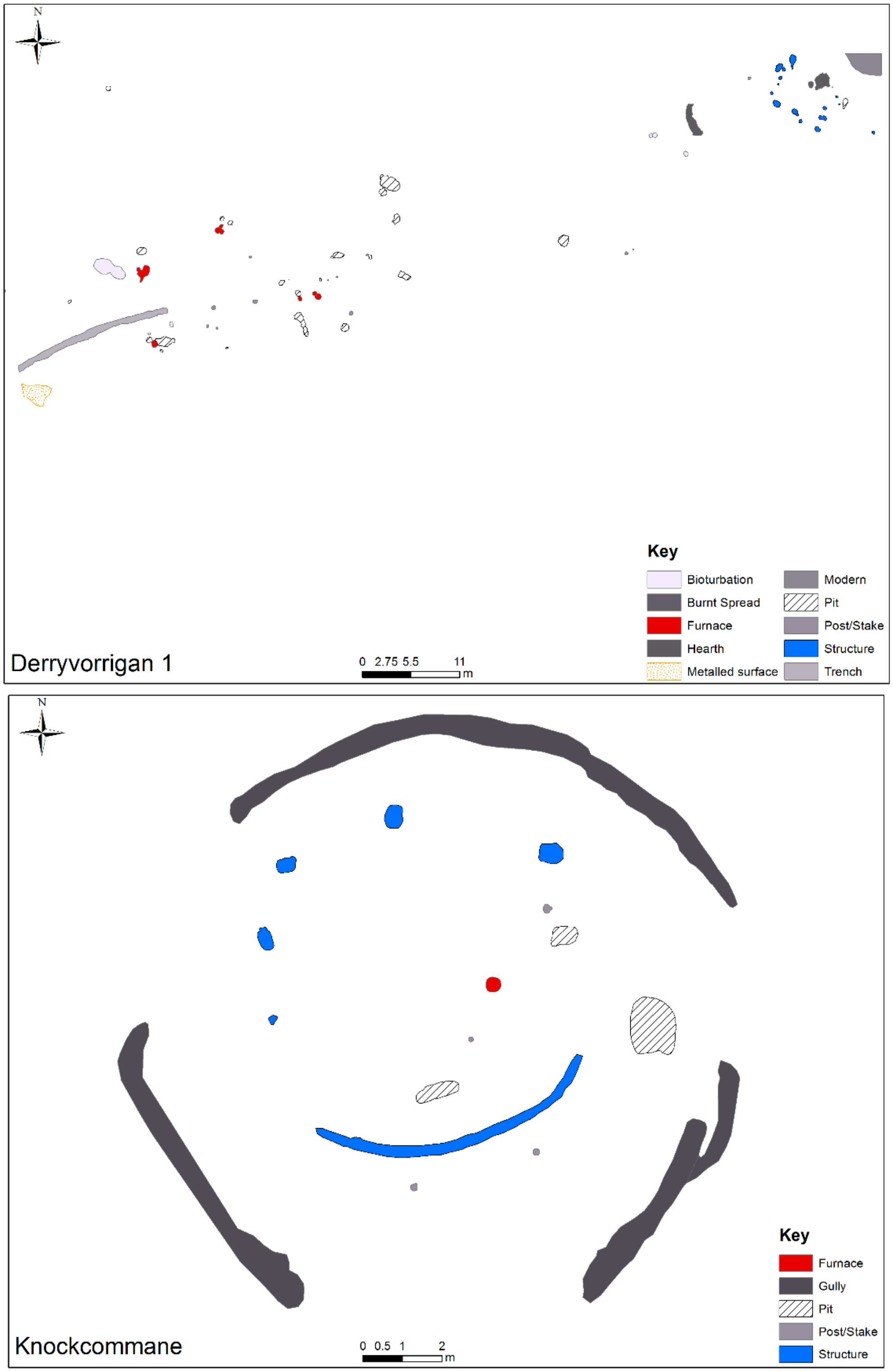


Figure 4.31 Plan map showing spatial relationship between structure and furnaces at Derryvorrigan 1 (Top) and Knockcommane (Bottom).

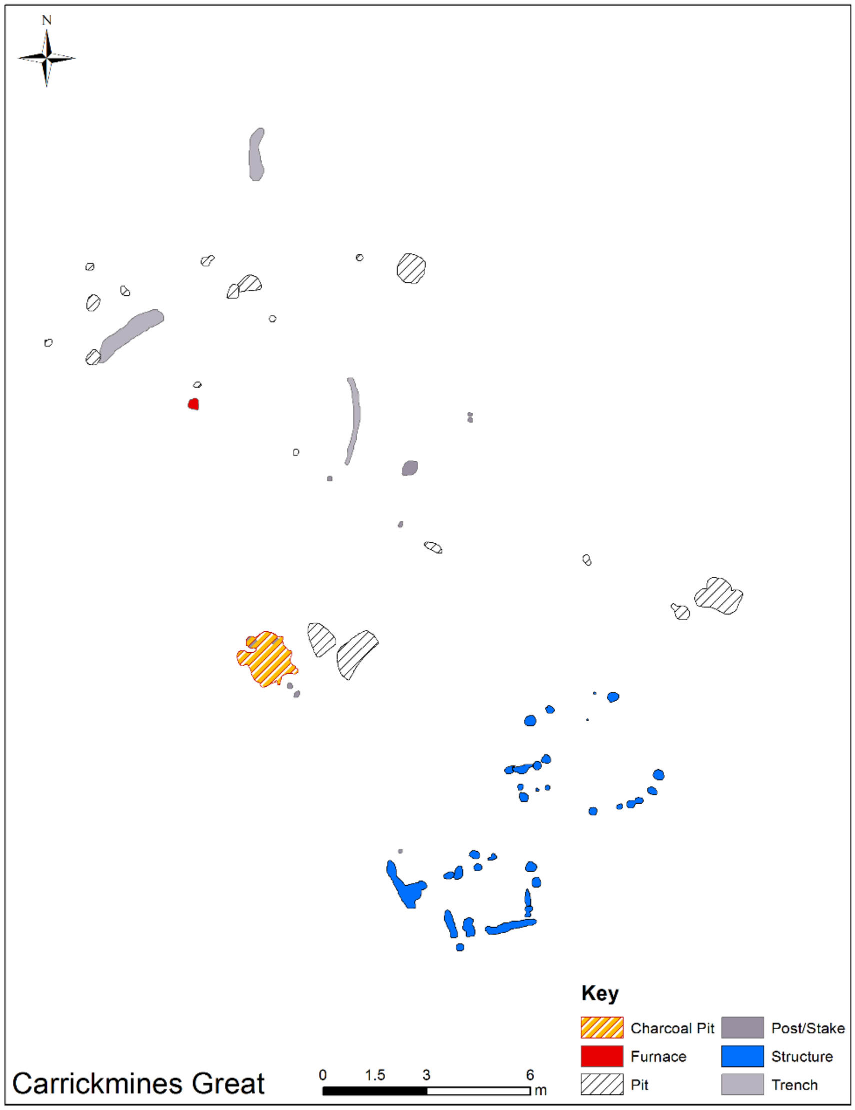


Figure 4.32 Plan map showing spatial relationship between structure and furnace at Carrickmines Great.

The remaining site type associated with ironworking not discussed so far is the occupation at the site of Ballydavid. A large, 125m diameter enclosure was uncovered at the top of a hill, with occupation from the Middle and Late Bronze Age, and possibly into the Iron Age (Hardy et al. 2010). Surprisingly, there is no evidence for any structures within the enclosure (Figure 4.33). Only a series of pits and fill in the enclosure ditch indicate occupation through these periods. All of the bloomery furnaces were found outside the enclosure, sometimes immediately outside it, while others were over 50m away to the northeast. If the enclosure was indeed used for habitation during the Iron Age, the placement of the ironworking features outside the enclosure suggests that there was a preferred distance between industrial activity and settlements in this period.

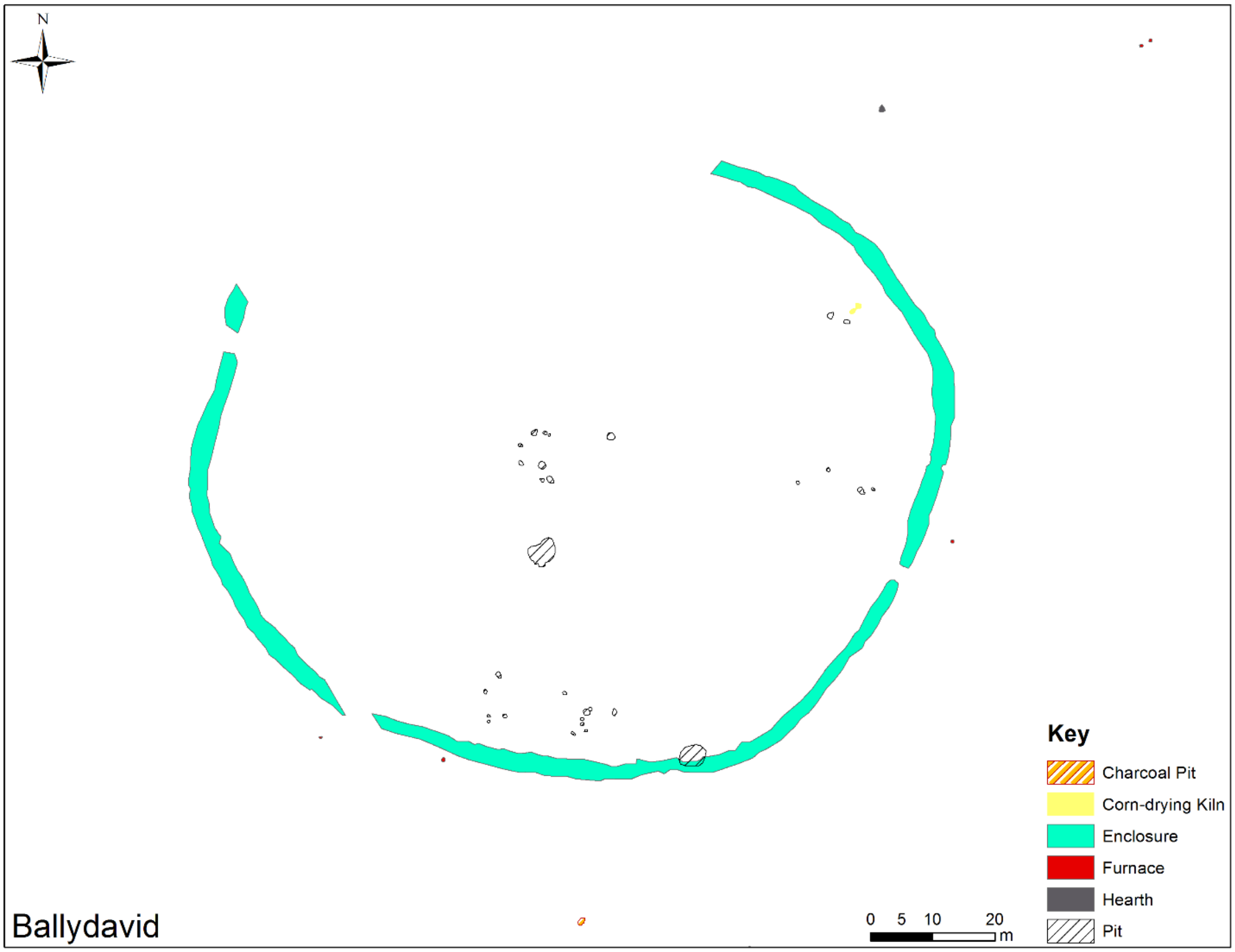


Figure 4.33 Plan map of Ballydavid.

4.1.5.3. Elevation

In his 2012 unpublished dissertation, Dolan suggested that smithing was a restricted activity that occurred at more important, communal hilltop sites (2012:155-157). This argument was based in part on the evidence from Tara and Knocknaulin for smithing activities. He also states in a 2014 article that, “smelting and smithing were physically separated in the landscape, with smelting undertaken in isolation from other sites and smithing often taking place in hilltop sites associated with burial and ritual" (Dolan 2014: 365). To test whether the new data from ironworking sites continue to support this theory, I utilized the elevation data retrieved from DEM files made available by NASA. The elevation for each site was linked to the site record, and I was able to gain a picture of the distribution of sites on the landscape. Figure 4.34 illustrates the elevation of each site in the study sample, organized by the type of ironworking activity that was occurring at the site. In this case, elevation was taken as a partial proxy for hilltops, which is where most of the 'high status' or more communal sites are found. While two of the most important sites from the Iron Age, Tara and Knocknaulin, are the sites with evidence for ironworking that are at the highest elevation, the overall pattern does not seem to fully support Dolan's assertion. Figure 4.24 shows that many sites with evidence of smithing alone, or of both smelting and smithing, are found at lower elevations.

In turn, a number of non-ritual sites with only evidence for smelting were also found on hilltop sites. The site of Ballydavid, for example, produced evidence for iron smelting alone, but was located atop a hill in association with an enclosure. Other sites that produced only isolated ironworking evidence, such as Kilrussane, or more complex association with burials, as at Morett, were also found on hills. These data demonstrate that different aspects of iron production were conducted on a wide range of landscapes at various elevations. To be sure, the examples of smithing at Tara and Knocknaulin are important and likely indicate something more than typical iron production, especially considering the range of pyrotechnic activities occurring at the Ráith na Ríg. However, smithing was occurring on other locations on the landscape, in both seemingly isolated sites and in association with smelting activities.

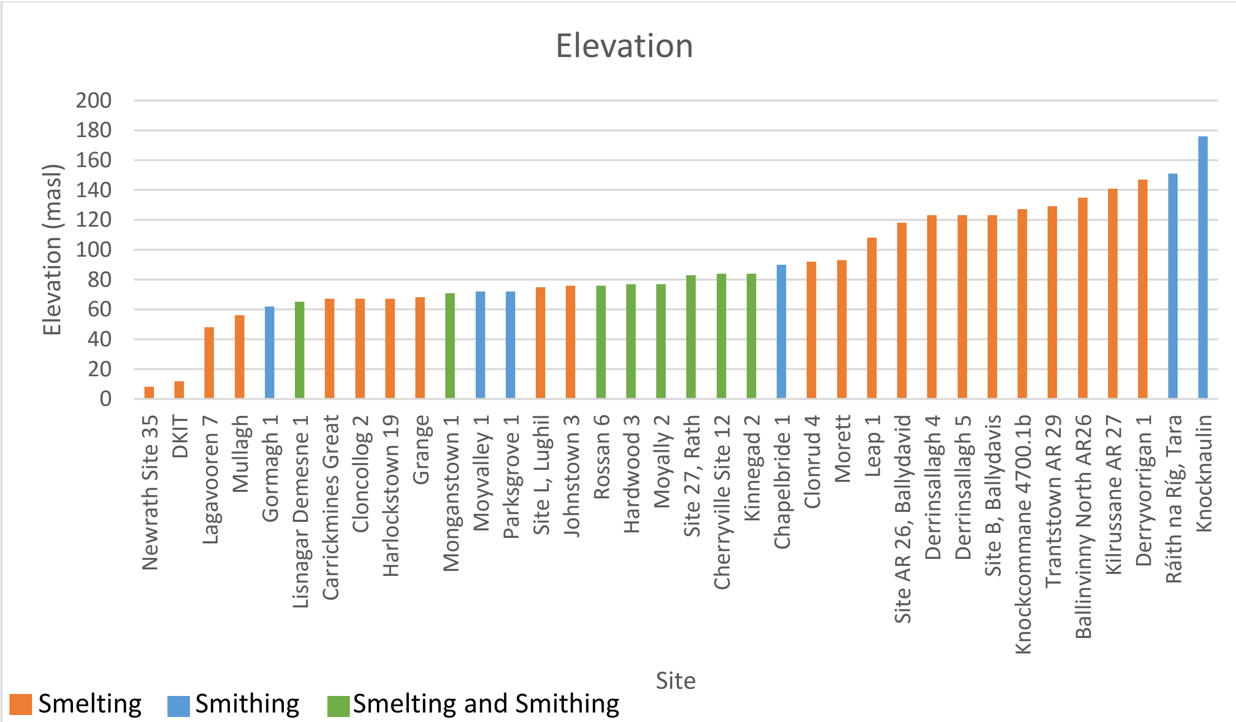


Figure 4.34 Site elevations by type of activity.

4.2. Slag

Bloomery furnaces more generally, but slag-pit furnaces specifically, produce a variable assemblage of slag and other residues. At the basal level of the slag-pit, sinter-like pieces may be made up of fine ore particles that fell through the charge too quickly to react. These pieces would mix with charcoal, ash, and other fragments and accumulate at the bottom of the furnace (Young 2008b:2). Around the blowhole is where the hottest zone occurs within the furnace and as a result generates the most fluid slag. On this wall, descending vertical prills may form, and they may flow down across the bottom of the pit (Young 2008b:2). These flow-like slags may at times be confused with tap-slag, since they also have a fluid look to them[11]. Additional slags form as they drip from the bloom, in smaller coffee bean-like structures.

Following the smelt, the pit would have been cleaned out, removing the bloom but also as

[11] See Fairburn (2005, 2006) for examples of possible mistakes in the use of "tap-slag" terminology.

much of the excess slag as could be reached so that the furnace could be used again. During this time, it seems possible that some of the basal layer of slag (fines) would be left (Young 2008b). After a furnace went out of use, it is likely that excess slag was dumped back into the pit as layers of refuse, meaning that not all of the slag found within a slag-pit necessarily indicates the final use of the furnace. With that said, it is likely that the slag found within each furnace was made either in that specific furnace or in a contemporaneous furnace nearby, and therefore can act as an important piece of evidence for reconstructing the process of the smelt.

4.2.1. Synthesis of Existing Sources

Due to the reburial of much of the slag from the sites in this analysis (see Section 3.1), no morphological or compositional analysis could be conducted on the documented ironworking residues for this dissertation. Instead, I had to rely on the analyses of previous specialists' reports on the slag and other metallurgical residues. It is worth noting that there is still a lack of significant agreement about terms used by the analysts describing slag types, specifically the sites that are part of this dissertation. The results of some of the analyses have even been questioned (see Rondelez [2014a:12-13] discussion of Photos-Jones). Unfortunately, the often brief descriptions and analyses provided are the only evidence remaining from these furnaces.

In all, I was able to access archaeometallurgical reports for 28 of the 35 sites used in this dissertation. Most of the analysis was conducted by two people, either Dr. Tim Young of GeoArch[12] or Dr. Effie Photos-Jones of Scottish Analytical Services for Art and Archaeology[13]. Additional work was conducted by Neil Fairburn, Ray Chadburn, and Paul Rondelez. These reports always contained a brief morphological description and interpretation, and sometimes

[12] 11 sites (39.3% of analyzed sites).
[13] 12 sites (42.9% of analyzed sites).

contained SEM-EDAX analysis carried out on samples of slag[14]. In two examples, XRF was used for bulk compositional analysis on the slag (Young 2005, 2011a).

All samples collected and analyzed by specialists were compiled in the database for use in helping to identify each furnace (Appendix B). Overall, the slag assemblages across sites are mostly uniform. These mainly include the variety mentioned at the beginning of Section 4.2, although the range of terms used by different analysts to morphologically describe the same types of slag makes recognizing patterns across sites difficult. Additionally, the analysis of slag was limited to the samples collected during excavations, which did not represent 100% coverage of all of the slag or furnaces. Unfortunately, due to the variability of specialist reporting not many inter-site patterns could be identified using the slag database. Blooms were identified at three sites, Harlockstown 19, Knockcommane, and possibly at Cloncollog 2 (Figure 4.35). Each of these blooms come from sites dating to the DIA, later in the project chronology. However, it is likely these later dates do not correspond to any behavioral patterns, only a lack of *in situ* preservation of the bloom in earlier smelting sites.

Additionally, the appearance of some type of clay furnace lining or possible superstructure was seen at 18 of the sites in this database (Figure 4.36). This represents any clay furnace lining that was collected in the field and identified in an archaeometallurgical report. The use of a clay lining may not have been limited to the sites from which samples were recovered and was almost certainly present in all of the slag-pit furnaces to create the low-shaft superstructure. It is also possible that clay was only used to create a superstructure and not for the lining of the basal pit of the furnace.

[14] This typically occurred with analysis from SASAA.

Figure 4.35 Distribution of iron blooms.

Figure 4.36 Distribution of clay furnace lining fragments.

4.2.2. Ore Types

Table 4.8 List of ore types identified at ironworking sites.

Site	Ore Type
Ballinvinny North	Bog ore
Cherryville 12	Bog ore
Clonrud 4	Bog ore
Derrinsallagh 4	Bog ore
Derryvorrigan 1	Bog ore
Kinnegad 2	Bog ore
Knockcommane	Bog ore
Lagavooren 7	Goethite?
Monganstown 1	Bog ore
Moyally 2	Bog ore
Rath Site 27	Bog ore
Trantstown	Bog ore

Analysis of the slag recovered as samples from the various ironworking sites included in this project provided additional information on the type of iron ore that was being used in these furnaces. Bog ore has long been considered to have been used widely in early iron production, due in large part to its ubiquity. Until recently there has been a substantial lack of ore found in ironworking contexts to support this claim. Table 4.8 shows a list of sites that have produced some evidence for the type of ore, usually based on compositional analysis of the slag. Moyally 2, Kinnegad 2, Derrinsallagh 4, Cherryville 12, Trantstown, Ballinvinny North, and Knockcommane all produced evidence for bog ore in the compositional analysis of the slag recovered from each site. The report from Moyally 2 notes that,

> although there is no physical evidence of ore in the shape of a hand specimen, there is plenty of evidence in small particles thereof trapped within the slag. These particles have partly reacted with fuel/fuel ash. The result is an intermediate noncrystalline phase, alumino-silicates of iron with a high phosphorus content and varying manganese presence. (Photos-Jones 2008: xvi)

In most of these sites, the high level of manganese and/or phosphorous pointed to the use of bog ores. Additionally, at the site of Derrinsallagh 4, a nearby iron seepage was sampled to test it as a possible ore source (Photos-Jones and Hall 2011; Photos-Jones and Wilson 2007). The sites of Clonrud 4 (Young 2008c), Derryvorrigan 1 (Young 2008e), Monganstown 1 (Fairburn 2006), and Rath Site 27 (Photos-Jones 2009) produced samples of actual ore that could be identified as bog ore. At the site of Rath it was noted that in addition to the non-crystalline structure, the ore contained plant material and high amounts of manganese, which all suggest that it was bog ore

(Photos-Jones 2009:401). The use of bog ore seems to be evenly distributed throughout the study area, without any significant patterning (Figure 4.37). The discussion of bog ore use should be approached carefully, as a recent PhD dissertation challenged many of the sites which were argued to have yielded bog ore inclusions in slag (Rondelez 2014b:91)[15].

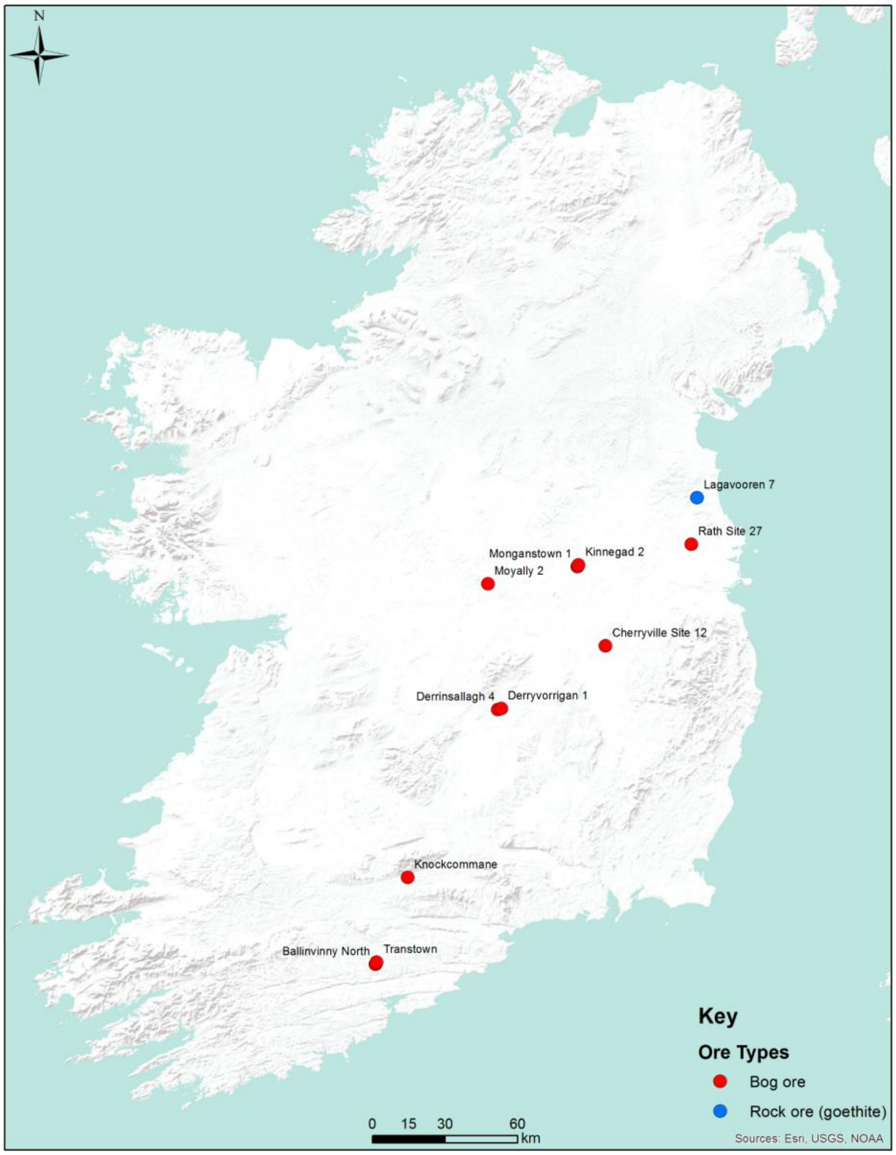


Figure 4.37 Distribution of ore types from ironworking sites.

[15] The author also noted that residual bog ore fragments were found at the site of Nangor (Grange), Co. Dublin.

The site of Lagavooren 7 is the one site that has provided evidence suggesting that more than just bog ore may have been utilized during this period. In the slags recovered from this site, there were unusually high levels of molybdenum and uranium. These high levels have not been seen in Irish bog ore samples, but have been seen on goethite iron ores from outside Ireland, specifically in Wales (Young 2011a:cccvi-cccvii). Iron ores of the proper type (oxidized sulphide minerals) were also found just over 1.5km to the northwest at the site of Sheephouse 2 and 3, suggesting that similar ores could have been found nearby or within the bedrock of the region (Young 2011a:ccvii).

4.2.3. Ternary Diagrams

Bulk compositional testing was conducted on samples from two of the sites in this dataset using XRF: Cherryville 12 and Lagavooren 7. Major elements were determined in these contexts by analyzing fused beads with a WD-XRF system (Young 2005; 2011a). These examples were used to provide data for the efficiency of production strategies in the creation of an iron bloom in these smelting furnaces. Utilizing the methods described in section 3.6.4, some indication of the production strategy may be indicated by plotting the percentages of FeO, SiO_2 and Al_2O_3.

Two features from Cherryville 12 produced slag that was tested, F7 and F6, both of which were identified as slag-pit furnaces. Figure 4.38 shows the samples' position within the ternary diagram, and their location clustered near the Optimum 2 described by Charlton et al. (2010). The sample from F7 and one sample from F6 appear to have been formed within the boundary between the fayalite and wüstite phases, while the other sample from F6 was within the wüstite phase. What this diagram illustrates is that these two furnaces were fairly efficient at reaching the temperature required to achieve fluid fayalitic slag, which is the main purpose of a smelting furnace. Their proximity to Optimum 2 suggests that they were using a low iron ore to fuel ratio, meaning that less charcoal fuel was necessary for the smelt but that the furnace would have produced a smaller quality of iron bloom (Charlton et al. 2010).

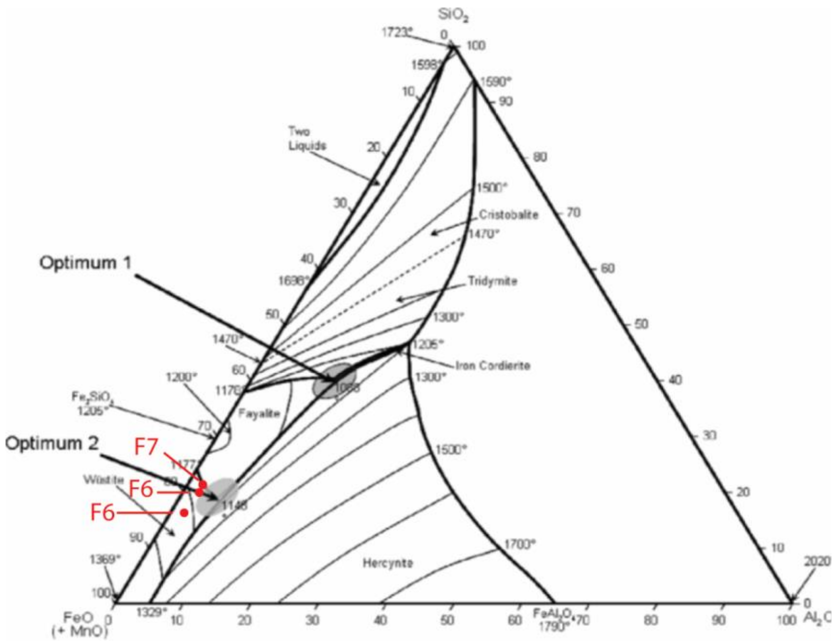


Figure 4.38 FeO - SiO2 - Al2O3 ternary diagram of samples from Cherryville 12 (after Charlton et al. 2010)

Two additional features from the site of Lagavooren 7 were also analyzed using the WD-XRF (Young 2011a). Features C141 and C164 were both identified as slag-pit furnaces, the former producing a ^{14}C date of 520-380 cal. BCE. These samples are much more dispersed when plotted on the ternary diagram (Figure 4.39). Two samples from C140 cluster around Optimum 2, while another sample from C140 was in the middle between the two optima. The fourth sample was from C164 and contained a much higher proportion of FeO. The high amount of wüstite and the morphology of the sample may point to it being a sinter, formed when multiple melted and unmelted pieces coalesce at the basal level of the furnace (Young 2011a:cccv). The variability between these samples, however, does not discount the possibility that they were produced in the same type of furnace. Due to the hot and cool zones found within a slag-pit furnace, there is often a high degree of heterogeneity exhibited by the slag assemblages due to the way the slag forms differently within the furnace (Young 2011a).

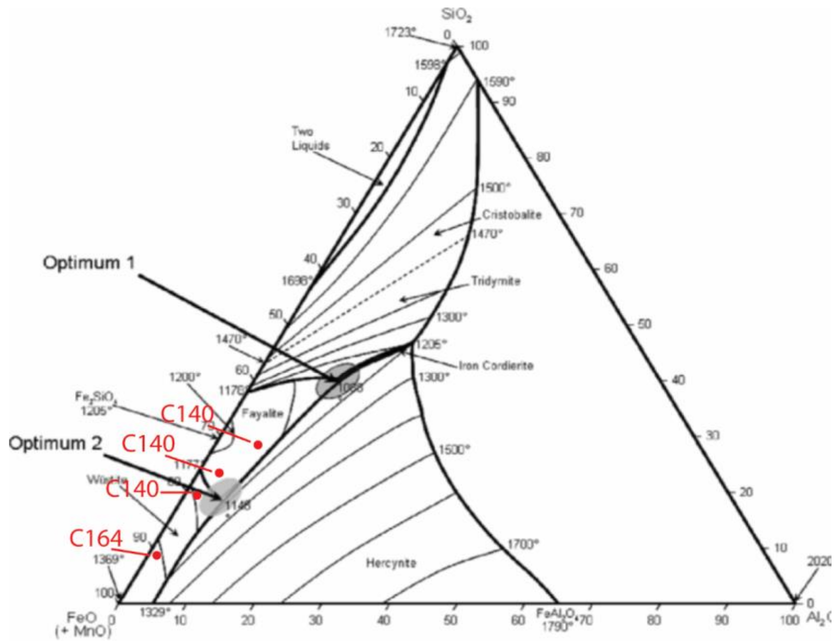


Figure 4.39 FeO - SiO2 - Al2O3 ternary diagram of samples from Lagavooren 7 (after Charlton et al. 2010).

Although limited, these two examples demonstrate that the furnaces in use during this period in Irish prehistory were not necessarily "better at making slag than iron," as one researcher has suggested (Photos-Jones and Wilson 2007a)[16]. To the contrary, these limited examples, in addition to the increasing amount of archaeometallurgical analyses conducted by others, suggest that slag-pit furnaces were quite efficient at smelting the bog ore most often in use at these sites. Unfortunately, for most of the sites analyzed earlier in the 2000s, the unpublished reports on the slag are the only evidence available for the slag recovered from these sites.

[16] At the site of Derrinsallagh 4, a project was undertaken to use magnetic susceptibility on the soils within the furnaces to determine the temperature at which these furnaces were heated (Photos-Jones and Wilson 2007). The results suggested that *none* of the furnaces were heated to higher than 600°C, which would make smelting iron essentially impossible. I argue against the accuracy of these findings on the grounds that the methods for which the *K* value was translated into temperature was very unconvincing, and that the exact locations where readings were taken were never outlined. It is possible that even if the technique is sound, the samples were taken from soil that was not actually burnt *in-situ* but was a post-occupation mix of *in-situ* fill and later soil accumulation. These data will need to be revisited in the future to determine their accuracy.

4.3. Site Types

The individuals involved in the production of iron in prehistoric Ireland did not work in isolation. That is, their lives did not solely consist of iron smelting and smithing, and as such, other types of archaeological features can provide a glimpse of the relationships between iron technology and other aspects of Iron Age life.

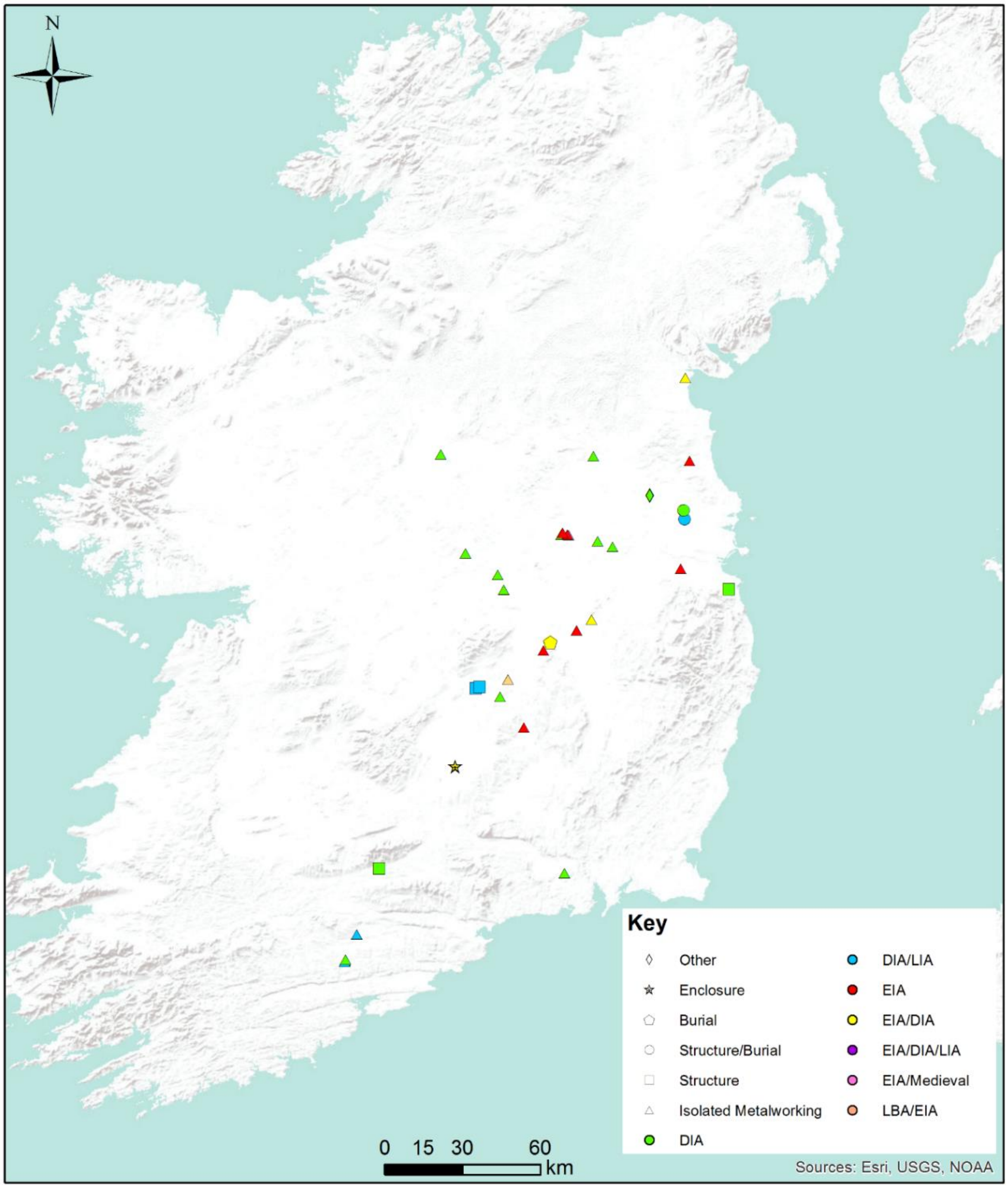


Figure 4.40 Map showing ironworking site types by date.

4.3.1. Production Site Types

The relationships between ironworking features and other types of occupation have been discussed in part above (4.1.5.2). The overwhelming trend in early iron production is toward isolated sites, with no evidence of associated settlements (or even simple structures). Of the 35 sites identified in this project, 26 can be categorized as isolated ironworking sites (Table 4.7). This group of isolated sites can be further subdivided based on other associated features (17 sites), such as pits, hearths, or postholes which may have been used alongside the iron producing activities, and those with no associated features (nine sites). The remaining sites in this sample consist of iron production associated with one or more structures (four sites), with some mortuary features (one site), with both structures and mortuary features (two sites), with a large enclosure (one site), and with ritual/mortuary/high status activities (one site). No identifiable inter-site spatial pattern is visible, and the locations of the different types of sites are spread across the entire study area (Figure 4.40). Furthermore, these isolated sites are seen in both the EIA and the DIA. The other site types also do not immediately demonstrate any inter-site spatial or temporal patterning, in part because there are not enough of each type to show any significant trends. One possible trend among those sites that have produced evidence for some type of structure in association with ironworking is that they mostly occur in the DIA[17]. All six sites that produced evidence for a structure yielded ^{14}C dates suggesting they were in use during the DIA or DIA/LIA. Two of these sites are categorized as "structure/burial": Harlockstown 19 and Rath Site 27. While this pattern may be interesting to elaborate on, it should be noted that the structure types associated with ironworking varies between sites. As such, the structures may have served very different purposes and therefore their association with iron production may have meant drastically different things. The patterning,

[17] See circle and square shapes in Figure 4.30.

or lack thereof, present between sites of different "types" suggests that the reason for the association of ironworking with some additional features may not have been tied to regional differences or changes through time.

4.3.2. Multi-Period Sites

Much of Irish prehistory and early history is characterized by its palimpsest nature. Many major sites appear to have been either continuously used through many periods, or to have seen intermittent use from one period to the next. The so-called royal sites demonstrate this point quite well (Section 2.4.2.5). The landscape of Tara, for example, was occupied as far back as the mid-fourth millennium BCE. The Mound of the Hostages found within the Ráith na Ríg began its long occupation during the Neolithic, and the nearby palisades have been dated to the Neolithic-Bronze Age transition (Bayliss and O'Sullivan 2013). Following this trend, a number of iron production sites also seem to have been utilized either sporadically or continuously before and after the Iron Age. A total of 15 sites from this sample were utilized, in some form, either before or after the Iron Age ironworking activities took place (Table 4.9). As Table 4.9 shows, seven sites included in this study have produced evidence of Neolithic occupation, four of Early Bronze Age occupation, eleven of Middle or Late Bronze Age activity, and six of Medieval activity. Three sites also appear to have been utilized from the Neolithic all the way through to the Iron Age[18].

Table 4.9 Table of ironworking sites occupied in periods before or after the Iron Age.

Site Name	Neolithic Occupation	EBA Occupation	MBA/LBA Occupation	Medieval Occupation
Ballinvinny North AR26	No	No	No	No
Carrickmines Great	Yes	Yes	Yes	No
Chapelbride 1	No	No	No	No
Cherryville Site 12	No	No	No	No
Cloncollog 2	No	No	No	No
Clonrud 4	No	No	No	No
Derrinsallagh 4	Yes	No	Yes	No
Derrinsallagh 5	No	No	No	No

[18] However, the occupation was almost certainly not continuous but at sporadic periods throughout prehistory.

Derryvorrigan 1	No	No	Yes	No
Gormagh 1	No	No	No	No
Grange	No	No	No	Yes
Hardwood 3	No	No	No	Yes
Harlockstown 19	Yes	Yes	Yes	Yes
Johnstown 3	No	No	No	No
Kilrussane AR 27	No	No	No	No
Kinnegad 2	No	Yes	Yes	No
Knockcommane	No	No	No	No
Lagavooren 7	Yes	No	Yes	No
Leap 1	No	No	No	No
Lisnagar Demesne 1	No	No	Yes	No
Marshes Upper Area 16	No	No	Yes	No
Monganstown 1	No	No	No	No
Morett	Yes	No	No	Yes
Moyally 2	No	No	No	No
Moyvalley 1	No	No	No	No
Mullagh	No	No	No	No
Newrath Site 35	Yes	No	No	No
Parksgrove 1	No	No	No	No
Ráith na Ríg, Tara	Yes	Yes	Yes	Yes
Rossan 6	No	No	No	No
Site 27, Rath	No	No	Yes	No
Site AR 26, Ballydavid	No	No	Yes	Yes
Site B, Ballydavis	No	No	No	No
Site L, Lughil	No	No	No	No
Trantstown AR 29	No	No	No	No

When iron production took place on these sites, in some cases they had already been in use for hundreds of years. This re-use, or continuity, poses some interesting questions about the changing landscape over time. For example, Harlockstown 19 contained a Late Neolithic/Early Bronze Age enclosure with a number of burials. Although there are no associated features, the presence of LBA vessels suggests use during that period as well. Additionally, an enclosure and trench system was constructed in the Early Medieval period, likely representing field systems for a farmstead (O'Connor 2008). While the burials and enclosure may not have been clearly visible at the time of the iron production on site, the proximity to these features, and sometimes the re-use of the features, suggests a knowledge and relationship with past occupations.

The site of Lagavooren 7 also produced evidence for multiple periods of occupation, the first of which was an Early Neolithic cluster of pits, followed by a Late Neolithic timber post circle. There was also a circular slot-trench structure that dated to the Middle Bronze Age (1540 – 1380 cal. BCE) (Stafford 2012). The architectural feature of timber post circles was a new phenomenon c. 2900 BCE; these have been identified as having had both domestic and ritual purposes (Stafford 2012:61). The circle consisted of 23 posts, with larger internal posts. A polished stone axe recovered from one of the internal post-pits suggests ritual deposition may have been part of the activities at this site (Stafford 2012:68). The Early/Middle Bronze Age circular structure was on the large end for typical roundhouses in the MBA, and seems to have been occupied over a long period of time. The position of the Iron Age furnaces away from these earlier features (see Figure 4.41) at Lagavooren may suggest that the activities are unrelated – that those individuals involved with iron smelting were unaware of the previous occupation of the area.

The occupation at the site of Morett dated back to the Late Neolithic, which included a four-post structure and fence line. Additionally, there is evidence for some Early Medieval occupation in the form of corn-drying kilns and four burials. The Neolithic occupation is rather ambiguous, since the exact function of the four-post structure remains unknown. Too small for a domestic structure, one explanation may be a platform. The Early Medieval occupation includes a mixture of domestic and mortuary activities. The corn-drying kilns appear to match the same time period as the four burials found on site. Interestingly, the association of the Iron Age features is variable with respect to the Neolithic and Medieval occupation. The iron production was occurring much closer to the Neolithic occupation, which can be assumed to not have been visible during the period of Iron Age use. In turn, the Medieval burials are within 30m of the Iron Age ring ditches (see Figure 4.19).

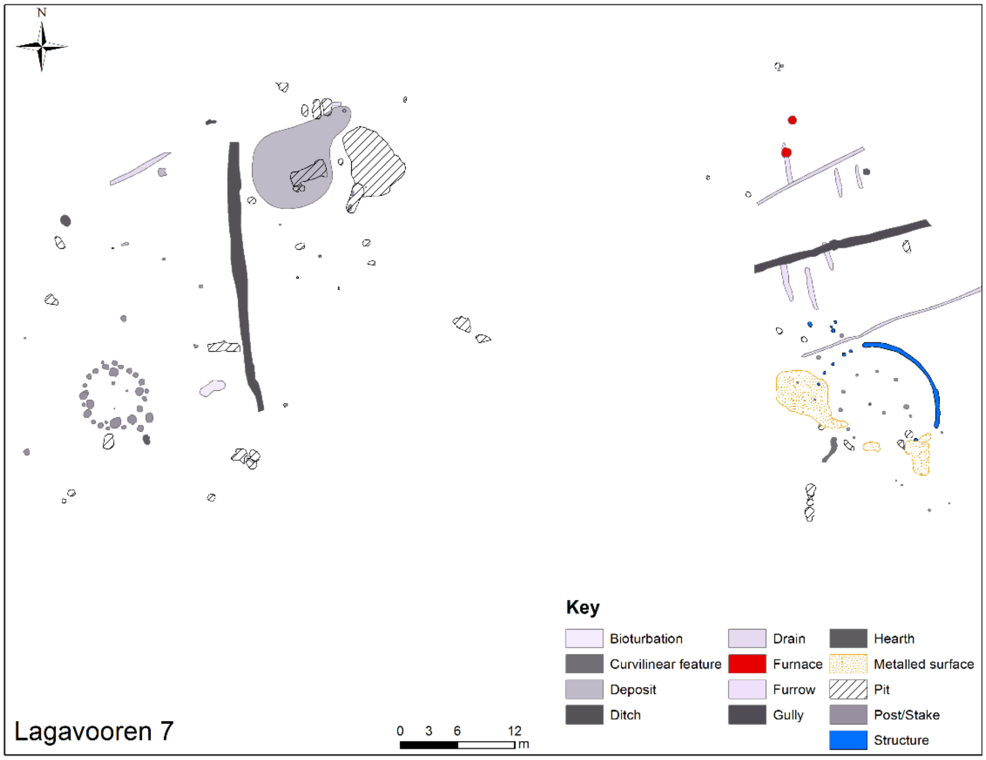


Figure 4.41 Plan map of Lagavooreen 7.

At Newrath Site 35, the Early Neolithic phase of the site was represented by a series of pits containing significant lithic and ceramic material. The Middle Neolithic phase of the site contained a semicircular ring gully[19], which may have acted as a habitation structure (Wilkins 2006). The ironworking area at Newrath was only c. 10m from the Neolithic structure, yet once again, it seems unlikely that this earlier occupation would have been known to the iron producers.

4.3.3. Complexes

The nature of many of the national road projects, or other larger infrastructure projects, means that each immediate group of archaeological features discovered during monitoring was provided with an individual site name and licence number by the National Monuments Service. As such, each individual "site" many not represent the full extent of the occupation of the

[19] This feature may have been a fully circular ring-ditch that eroded away

immediate landscape. During the course of this project, a number of larger groups of sites were identified that should at the very least be considered in association with each other, and at the most indicate a single period of use - I term these groups of sites complexes. The identification of "complex" is based largely on temporal and spatial proximity. I did not use a single metric to determine different complexes, using them more as a way to think through production at a scale that was larger than the site licence number. Therefore, the categorization of these areas of activity should be considered as fluid and subject to change with additional data.

Figure 4.42 All complexes identified in this study.

4.3.3.1. Ballinvinny North Complex

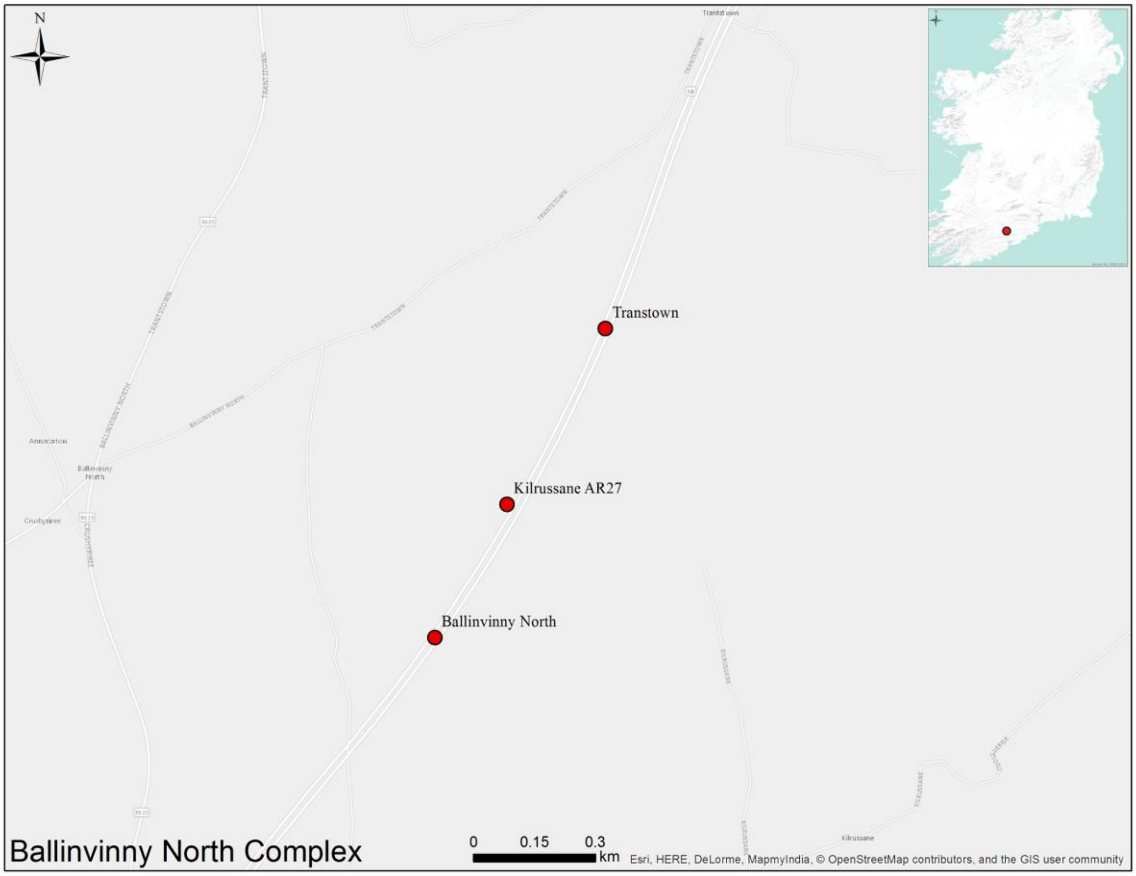


Figure 4.43 Map of the Ballinvinny North Complex. Inset showing general location in Ireland.

One example of the differing methods of applying site licence numbers is exemplified by the Ballinvinny North complex. The two sites, Ballinvinny North and Trantstown, were excavated under the same licence number, 01E0501. However, the site of Kilrussane, which lay between the two, was given a separate number: 01E0701. These three sites should be considered in association with one another, as the farthest two sites are only .87km away (Figure 4.42). All of these sites were considered isolated ironworking sites, with a total of seven bloomery furnaces between them. These sites all produced evidence for DIA occupation, with Ballinvinny North producing ^{14}C dates more towards the end of that period, but otherwise mostly overlapping. Trantstown and Kilrussane each contained paired groups of slag-pit furnaces (Table 4.5). While these sites may not have been in use at exactly the same time, they were likely used by the same group of people over a short period.

4.3.3.2. Derrinsallagh Complex

Four sites can be placed into the Derrinsallagh Complex, named for the largest Iron Age ironworking site in Ireland (Figure 4.43). The primary site, Derrinsallagh 4, contained 44 bloomery furnaces, with dates placing the use of these furnaces firmly at the end of the DIA. About 350m to the northeast was the site of Derrinsallagh 5, which produced a number of pit features that included one slag-pit furnace. The date from the furnace places it earlier[20] than the furnaces nearby, although only three of the Derrinsallagh 4 furnaces produced ^{14}C dates. It is possible that some of the Derrinsallagh 4 furnaces were used contemporaneously with Derrinsallagh 5.

The site of Derryvorrigan 1 was slightly farther afield from Derrinsallagh 5, but should also be thought of in conjunction with the two Derrinsallagh sites. As at Derrinsallagh 4, Derryvorrigan produced evidence for arched slag-pit furnaces, an apparent later technological development. It seems probable that these sites were in use at the same time, as their ^{14}C dates suggest, possibly by the same people. Lastly, about one km from Derryvorrigan 1 was the site of Barnasallagh 1, which provided evidence for a charcoal production pit dated to 110 cal. BCE – 80 cal. CE, and could have been used to support the iron production at Derryvorrigan (Lennon 2008). I would argue that if there any region in Ireland is to be considered a center of iron production during the DIA, the Derrinsallagh Complex is it. The scale of production occurring in this region is much larger than anything else during this period that has been discovered thus far.

[20] 520 - 230 cal BCE.

Figure 4.44 Map of the Derrinsallagh Complex. Inset showing general location in Ireland.

4.3.3.3. Ashbourne Complex

This group of two sites, Rath Site 27 and Harlockstown 19, is named for the nearest town to the two of them. The distance between these two sites places them on the edge of what may be considered a complex (Figure 4.44). However, even if the same people were not occupying both locales, their proximity to one another likely means that they were strongly connected. These two sites present some interesting similarities, starting with their use through time and the presence of associated structures and mortuary activities. The ring-ditches found at Rath were likely used earlier in the Iron Age than the production of iron at the site, and they also yielded a wider array of grave goods (O'Carroll et al. 2012) than the possible ring-ditch at Harlockstown. Both sites produced non-typical structures; Harlockstown contained a sunken floor feature that is not seen elsewhere, as well as a smaller rectangular structure, while Rath contained what was deemed a "sweat lodge" (O'Connor 2008; Schweitzer and O'Carroll 2009).

Figure 4.45 Map of the Ashbourne Complex. Inset showing general location in Ireland.

4.3.3.4. Ballydavis Complex

The Ballydavis complex consists of Ballydavis Site B, taken from the sites identified in this dissertation, and a site within .5km of that site also named Ballydavis (95E0111). Also, the site of Morett lay about 4km to the northeast, and may be considered as part of iron production in this region (Figure 4.45). At the site of Ballydavis, four ring-ditches were uncovered that have produced some of the most impressive suite of grave goods dating to the Iron Age (Keeley 1999)[21]. Additional pits were found in association with the mortuary activities, eight of which were deemed furnaces (Keeley 1999:29). Unfortunately, I was not able to gain access to the actual excavation

[21] From the largest ring-ditch, a bronze box was found in association with the cremated bone, as well as a safety-pin brooch, and 86 beads.

report for this site, which is why it was not included in this study. Furthermore, Keeley notes that some crucible fragments were found in association with the furnaces, which is evidence against them being used as bloomery furnaces (1999:31)[22]. It does seem clear that at least some ironworking was occurring at Ballydavis Site B, very near the Iron Age burials at the other Ballydavis site. The site of Morett may be slightly too far away to belong to the same complex as Ballydavis, although the dates do overlap at the beginning of the Iron Age and both sites produced evidence for slag-pit furnaces.

Figure 4.46 Map of the Ballydavis Complex. Inset showing general location in Ireland.

4.3.3.5. Kinnegad Complex

This is a large grouping of sites, both from within my sample of sites and from a group of

[22] Cast iron was not created during this period in Ireland, meaning there would have been no use for crucibles. It rather points to copper smelting at the site.

secondary sites that seem to be associated with these sites but did not produce evidence of ironworking. In the grouping to the southwest, Rossan 6 produced EIA evidence for iron smithing and smelting. Within 370 m, 240m, and 460m lay the sites of Rossan 1, Rossan 3, and Hardwood 3, respectively (Figure 4.46). Rossan 1 contains a series of pits and charcoal-rich deposits that date to the LBA-IA transition. Rossan 3 contained pits dated to the medieval period, as well as the Middle – Late Bronze Age. In addition, Rossan 3 produced three linear features that contained a fair amount of slag. Hardwood 3 contained a number furnaces and smithing hearths dated from the EIA to the Late Medieval period. Slightly further afield, two to three km to the west, lay three other sites with evidence for Iron Age iron production: Kinnegad 2, Griffinstown 3, Monganstown 1. Kinnegad and Monganstown produced radiocarbon dates spanning the EIA into the DIA. No ^{14}C dates were recovered from Griffinstown 3, however the furnace types match those in the surrounding area.

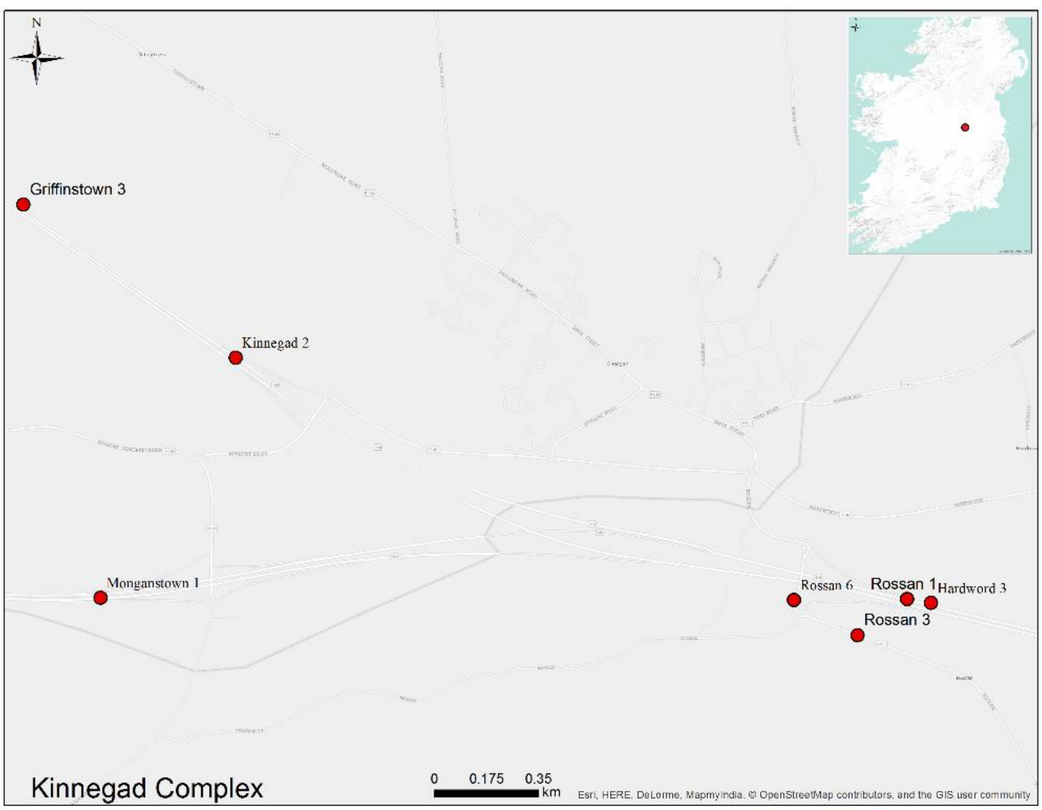


Figure 4.47 Map of the Kinnegad Complex. Inset showing general location in Ireland.

Rossan 6, Hardwood 3, Kinnegad 2, and Monganstown 1 all produced evidence of iron smithing, with the former three containing at least one smithing hearth each. Furthermore, two of the sites in the more western grouping displayed evidence of arched slag-pit furnaces. Based on the earlier dates from the eastern grouping of sites within this complex, it is possible that they represent an earlier ironworking occupation of the landscape, while those to the west were in use later.

4.3.3.6. Lagavooren Complex

Although it is the only iron production site in the area dating to this period, the site of Lagavooren falls in the center of a larger Iron Age landscape, and a landscape of iron production (Figure 4.47). Occupation at the site dates back to the Neolithic, but the features associated with the Iron Age were limited to ironworking, and date from the Early into the Developed Iron Age (485 – 385 cal. BCE). Under four km to the northwest was the site of Tullyallen 6 (00E0944), which produced a single bloomery furnace with evidence of a smelting furnace bottom (Young 2003b). However, the furnace did not produce a ^{14}C date and was associated with a Bronze Age enclosure, which is why this site was not included in this dissertation (Campbell 2003). Shallon 1 was also an isolated ironworking site, but is associated with a LIA/Early Medieval date. Slightly farther afield were the sites of Colp West (99E0472) and Claristown 2 (01E0039) and 4 (01E0382). Claristown 2 and 4 may be considered together, as the later only consisted of a single EIA pit, while the former was an Iron Age re-used ring-ditch and possible structure (Russell 2012). Colp West was a small DIA/LIA hut site that was later partially destroyed by an Early Medieval enclosure (Ó Drisceoil and Devine 2012).

While these sites may not have been in direct use at the same time as Lagavooren 7, they serve as important reminders that the landscape of Iron Age occupation represented a larger context than the sites that have been recorded. Unfortunately, the nature of archaeological recovery bias does not allow for full coverage of landscapes. If excavations had not been limited to road corridors, we would likely see more similarities between complexes with even more robust use of the landscape for industrial activity, habitation, and mortuary practices.

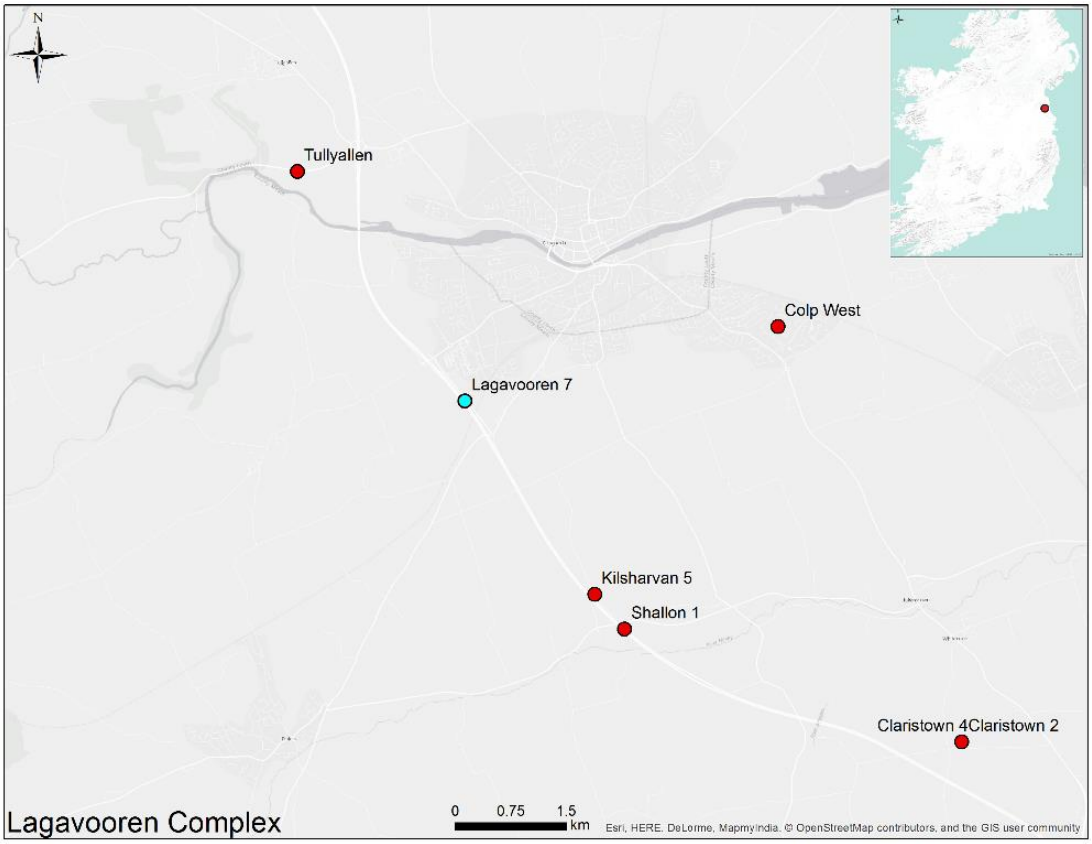


Figure 4.48 Map of the Lagavooren Complex. Inset showing general location in Ireland.

4.4. Charcoal/Fuel

4.4.1. Charcoal Production Associated with Iron Production

The production of iron requires significant amounts of fuel to reach the temperatures necessary to smelt the iron. Wood charcoal was the most obvious and useful fuel source for reaching these temperatures during the Iron Age. The process of transforming wood into charcoal can vary significantly (see Section 2.3.2), and because of this identifying the remains of this process archaeologically is often difficult. Only the charcoal production process known as a charcoal pit has been identified in this sample, largely for reasons of preservation. Charcoal was also produced in various periods in Europe by piling up wood on the ground surface and sealing it, much as one would do with a pit (Pleiner 2000:119). However, the only trace this process leaves behind is a spread of charcoal-stained soil, which is an extremely ambiguous piece of archaeological evidence that might not be recorded in the field.

The evidence for charcoal production discussed here does not constitute all instances of known charcoal production that have produced EIA and DIA dates, but only those instances been associated with an iron production site dating to that period. For one, the compilation of all of such sites was outside the immediate scope of this dissertation. More importantly, however, is the fact that not all charcoal was necessarily used for iron production. Charcoal could have been utilized in other pyrotechnic activities, so the actions associated with producing it cannot in and of themselves be assumed to be part of iron production. On the other hand, the charcoal that was used in iron smelting furnaces and smithing hearths was an extremely important part of the production process, and understanding the production of charcoal in association with ironworking provides a more complete understanding of the processes of iron production.

Nine of the 34 sites in this database provided evidence for charcoal production in association with iron production (Table 4.10). There may be some issue with including the charcoal pit found at the site of Hardwood 3 in this sample due to the date recovered from the charcoal pit itself (720 – 970 cal. CE). What has made this site difficult to interpret is the

Table 4.10 Sites with evidence for charcoal production

Site Name	Licence_Num	Date
Kinnegad 2	02E0926	EIA
Grange	13E0435	EIA
Hardwood 3	02E1141	EIA
Rossan 6	02E1068	EIA
Morett	03E0461	EIA/DIA
Site AR 26, Ballydavid	E2370	EIA/DIA
Monganstown 1	E2771	DIA
Carrickmines Great	02E0272	DIA
Derrinsallagh 4	E2180	DIA/LIA
Derryvorrigan 1/Barnasallagh 1	E2193/E2205	DIA/LIA

varied dates produced by the small number of iron production features, ranging from the DIA to the Medieval period. Additionally, the charcoal pit found at the Grange site also produced a Medieval date (671 - 867 CE). These two examples demonstrate the difficulties encountered when dealing with such site palimpsests. While iron smelting may have been occurring at these sites during the Iron Age, the charcoal production may have been an unrelated event hundreds of years later. One site that could be added to this list is Derryvorrigan 1 (indicated in Table 4.10 with an asterisk). This site was within one km of Barnasallagh 1, which produced evidence for a charcoal production pit that was ^{14}C dated to 110 cal. BCE – 80 cal. CE (Lennon 2008). This date corresponds with the date the smelting furnaces were in use at Derryvorrigan. These sites were likely part of a complex of activity during this period (see Section 4.3.3), and thus can be considered part of the same period of occupation. The site of Griffinstown 3 may also be brought into this discussion of charcoal production in association with iron production, as it is c. 0.8km from Kinnegad 2 and 1.3km from Monganstown 1. Griffinstown produced a rectangular charcoal production pit, in addition to two furnaces, but no radiocarbon dates were recovered from the site.

Table 4.11 illustrates all of the recorded charcoal production pits within the sample of sites included in this dissertation. In total, 16 features were recorded as being used for the production of charcoal, either in the field or in the analysis phase. One of these features, F087 at the site of Rossan 6, was interpreted as being used initially as a charcoal production pit and later as a smithing hearth (Photos-Jones 2003). Five of the features recorded were directly dated by ^{14}C samples, including the pits from Hardwood 3 and Grange mentioned above that were dated to the Medieval period. These two features are separated at the bottom of Table 4.12, as well as the additional charcoal production feature that was identified at Barnasallagh 1. That feature (C001) was dated to 110 cal. BCE – 80 cal. CE, and could be associated with the smelting furnaces at Derryvorrigan

1. The remaining charcoal production features can only be secondarily dated by their association with other features.

Table 4.11 Each feature identified as a charcoal production pit in the project sites by feature morphology. * Small circular or oval; ° Large rectangular; ` Large sub-circular; ^ Irregular.

Site Name	Context Number	Description	14C Dates	Site Date
Kinnegad 2	F43*	1.3m diameter circular feature, 0.22m in depth. Bowl-shaped.		EIA
Rossan 6	F087`	3.54 x 3.22 x 0.44m, sub-circular pit. Gradual sloping slides with a flat base.	820-780 BCE	EIA
Morett	C46*	Severely truncated during test trenching.		EIA/DIA
Morett	C37*	~1.6m x 1.9m 'circular' feature, 0.45m in depth.	170 BCE - 30 CE	EIA/DIA
Morett	C128*	~1m in diameter circular feature	770 - 410 BCE	EIA/DIA
Morett	C126*	1.8 x 1.6m. 0.5m in depth		EIA/DIA
Site AR 26, Ballydavid	C179*	1.27m x 0.9m x 0.2m. Gradual sloping sides and a flat base.		EIA/DIA
Monganstown 1	C21°	Sub-rectangular pit, 2.85 x 0.85 x 0.26m. Vertical sides, flat base.		DIA
Monganstown 1	C24°	Sub-rectangular pit, 2.8 x 1.2 x 0.2m. Vertical sides, flat base.		DIA
Carrickmines Great	1240^	Irregularly shaped, 1.3 x 1.2m. Multiple postholes and pits at the bottom of this pit.		DIA
Derrinsallagh 4	C426*	1.24 x 1.1 x 0.36m oval pit. Vertical sides, flat base.		DIA/LIA
Derrinsallagh 4	C424`	2.6 x 2.2 x 0.3m sub-circular. Sloping sides and a rounded base		DIA/LIA
Derrinsallagh 4	C419*	1.2 x 0.9 x 0.3m oval-shaped pit. Sloping sides and a flat base.		DIA/LIA
Derrinsallagh 4	C123*	1.3 x 1m oval pit. 0.3m in depth. Sloping sides and a flat base.		DIA/LIA
Grange	C10*	0.97 x 0.69m pit. Upper fill included partly baked clay, representing clamp superstructure.	671 - 867 CE	EIA
Hardwood 3	C055*	2.8 x 1.15m rectangular pit. Called 'charcoaling platform'	720 - 960 CE	EIA/ Medieval
Barnasallgh 1	C001*	0.9 x 0.88 x 0.1m. Slightly sloping sides and mostly flat base.	110 BCE – 80 CE	DIA/LIA

4.4.1.1. Charcoal Pit Morphology

Based on the data provided by the excavation reports for these sites, a few different methods were used for creating a pit to be used as a charcoal production kiln. Unfortunately, with only a few of the features providing primary ^{14}C dates, no trends can be identified through time at this stage.

4.4.1.1.1. Small Circular or Oval

This type of charcoal pit includes ten features from the above sample. They largely consisted of a circular or oval-shaped pit ranging in diameter from 0.9m to 1.9m. However, there is also quite a lot of variability within this grouping as well. The depths of the furnace are clustered together, with one group (F43, C46, C179, C426, C419, C123, C001) being below 0.36m, and the other group (C37, C126) being over 0.45m in depth. As one would expect, sites with multiple charcoal production pits are more similar to one another. The three small circular or oval charcoal pits identified at Derrinsallagh 4 parallel one another quite closely, although C426 contained vertical sides while the others did not. Also, two of the pits from Morett have very similar proportions.

4.4.1.1.2. Large Rectangular

Two features make up a category of large rectangular charcoal production pits, both from the site of Monganstown 1. Both demonstrate a low length to width ratio and are much larger than the small circular or oval charcoal pits. Additionally, the vertical sides of the pit differed from many of the other charcoal pits.

4.4.1.1.3. Large Sub-Circular

These two charcoal production pits were near-circular in shape and larger than two meters in diameter, although F087 was a meter larger than C424.

4.4.1.1.4. Irregular

The final pit type listed here is dubbed irregular, due to its lack of noticeable shape. It is unique among the other charcoal production pits identified in this study in that additional postholes or pits were found at the base of the charcoal pit. This may have been due to reuse of the feature for multiple charcoal production events, or they were used for some built timber structure within the pit that helped facilitate the low burn necessary to create the charcoal.

4.4.1.2. Distribution within sites

When looking at the spatial relationship between charcoal production and iron smelting or smithing on a site, no definitive pattern emerges. Some of the charcoal pits can be found at a significant distance (30-40m) from the iron production, as at Ballydavid and Kinnegad 2 (Figure 4.48). Others, such as Morett, Derrinsallagh 4, and Carrickmines Great, are about 5-10m from the smelting furnaces (Figure 4.49). At Monganstown 1, one of the charcoal pits is within a few meters of a smelting furnace (Figure 4.50). There does not seem to be a pattern, temporally or otherwise, to account for the differences in charcoal pit placement. Nor does there seem to be a relationship between the number of charcoal pits and the number of furnaces or smithing hearths, i.e. more charcoal for more furnaces.

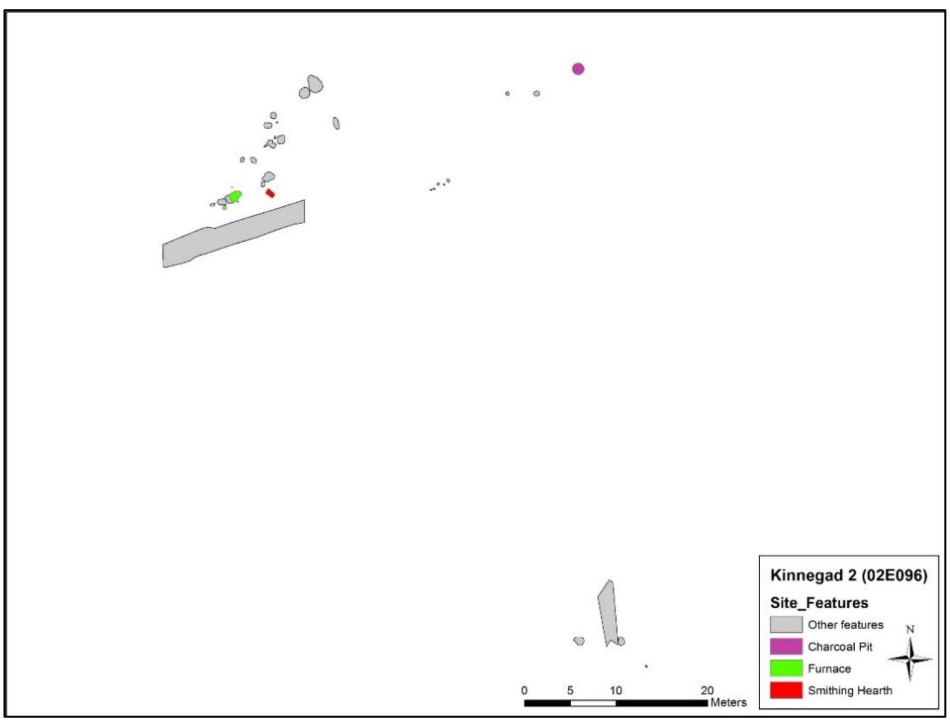


Figure 4.49 Example of long distance between iron and charcoal production.

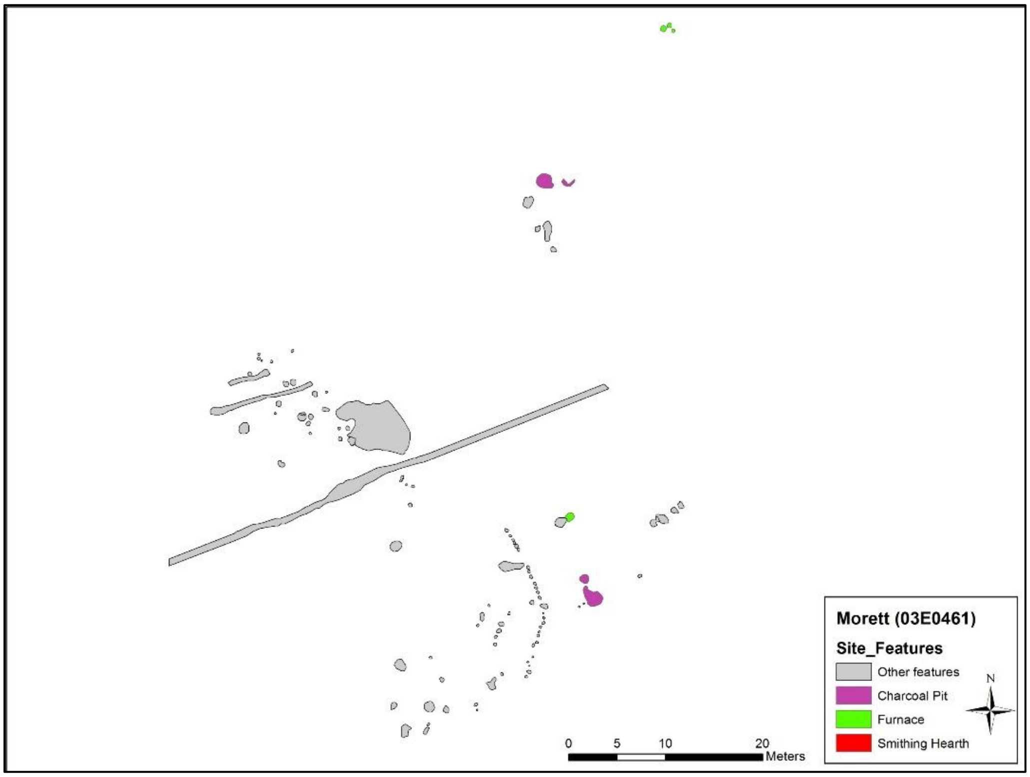


Figure 4.50 Example of medium distance.

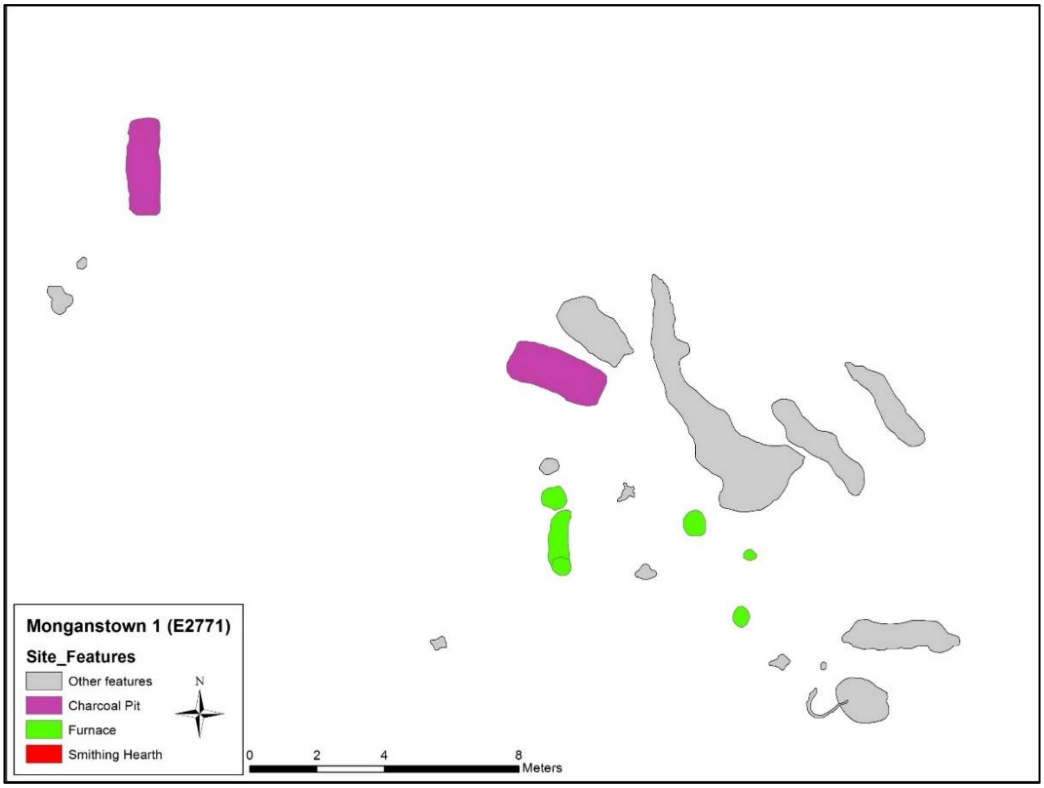


Figure 4.51 Example of short distance.

4.4.1.3. Wood used for charcoal

Of the recorded charcoal production pits from the sample of EIA and DIA iron production sites, seven[23] produced charcoal samples that were analyzed by a specialist (Table 4.12). The overall trend visible in these features is the use of oak (*Quercus*) in the charcoal production pits. Two species of oak, sessile oak (*Quercus petraea*) and pedunculated oak (*Quercus robur*), are both native to Ireland. *Q. petraea* is normally found on poor, acidic soils, as well as well-drained soils and areas of flooding (O'Carroll 2006). *Q. robur* is characteristic of more fertile parts of the island (Dillon 2009). However, these two species cannot be differentiated microscopically, which is why the more general term "oak" is used to identify the charcoal remains (O'Carroll 2006). Both of these species of oak can grow to large heights, upwards of 40m, and live as long as 400 years. This type of wood is often used in the structural elements of the built environment, often found in postholes of settlements. Additionally, it appears to be the most commonly utilized wood for charcoal production (also see Section 4.4.1.4). The density of the wood makes it ideal for use as charcoal (O'Carroll 2008a). Small amounts of ash (*Fraxinus excelsior*) and willow/poplar (*Salix/Populus*) were also found in association with the oak charcoal in two of the features. These species were likely used as kindling for the charcoal fire; ash is especially good fuel, both green and dead, and willow/poplar is much less dense than oak. It could have also acted as the support for a clay or wattle and daub structure to cover the wood to contain the slow burn and create the charcoal; it could have burned along with the oak wood, and been mixed with the charcoal.

Table 4.12 Charcoal production pits with analyzed wood.

Site Name	Context Num	Wood used in charcoal pit
Morett	C37	Mostly hazel, some oak
Morett	C128	Oak
Monganstown 1	C21	Oak, small amount of ash and willow/poplar

[23] Barnasallgh 1 was not part of the sample sites because it lacks any direct evidence of iron production, but it was found within one km of the iron production site of Derryvorrigan 1.

Monganstown 1	C24	Oak, small amount of ash and willow/poplar
Grange	C10	Oak
Hardwood 3	C055	Alder
*Barnasallgh 1	C001	Hazel

The only non-oak dominant outliers from this sample were features at Morett (C37), Barnasallagh 1 (C001), and Hardwood 3 (C055). The feature from Morett produced hazel rods that represent the remains of small brushwood, possibly selected from coppiced woodland (O'Carroll 2006). Hazel (*Corylus avellana*) is a species native to Ireland, and was once extremely widespread. The wood makes good fuel and was used as a main source of charcoal during the industrial revolution (O'Carroll 2006, 2008a)[24]. At Barnasallagh 1, the charcoal recovered from the pit was all from hazel rods that were six years old and were also likely chosen from coppiced hazel woods (O'Carroll 2008c). The charcoal production pit at Hardwood 3[25] produced evidence that the wood being used for charcoal was alder. Alder (*Alnus glutinosa*) is a widespread tree native to Ireland that is largely found in wet habitats along stream and river banks (O'Carroll 2008a). This wood is very good for charcoal.

4.4.1.4. Wood from Ironworking Features

In total, there were 34 ironworking features (smelting furnaces or smithing hearths) from which charcoal samples were recovered and analyzed (Table 4.13). The general trend for the wood used for heat in smelting and smithing activities was to use oak charcoal – 25 of the 35 features (76.5%) produced only or mostly oak charcoal (Figure 4.51). Ellen O'Carroll (2008b) demonstrated this same trend for a higher use of oak for fuel in iron production. In this same project, in which all of the wood recovered from Contract 2 of the M7 Portlaoise to Castletown/M8

[24] It has also been argued elsewhere that hazel does not make good charcoal (Dillon 2009:64).
[25] It should again be noted that this feature was dated to the Medieval period, not the Iron Age.

Portlaoise to Cullahill Motorway Scheme, oak was not actually recorded as the most prevalent wood in use (O'Carroll 2008c:36)[26]. Based on the data from Contract 2, the prevalence of oak does seem to increase during the Iron Age, up to 53% of the assemblages (O'Carroll 2008b:38), although this may be biased by the presence of a larger number of iron production sites. It appears that a number of different types of wood were available to individuals producing iron, and that they were using these different types of trees for different activities. They were specifically choosing oak more often for their charcoal, likely due to its properties for burning long and at a high heat.

Alder is the next most prevalent wood used for charcoal in this sample; it was the main wood identified in four of the 34 features (11.8%). This wood also acts as a very good source of charcoal, and appears to have been chosen specifically for this purpose. It is likely that this was the tree that was most accessible for the production of charcoal, as compared to oak. Many of the sites[27] that produced features with alder charcoal were near streams or rivers, the ideal environment for alder to grow. Hazel was the third most common wood used as the primary fuel for ironworking, found in three of the 37 features. One of the samples recovered from C135 from Derrinsallagh 4 was found to be a piece of hazel, with a chisel point (O'Carroll 2008a:147). A chisel point occurs on a piece of wood that is cut to a point on one single face. This may be an indication of the felling of a branch or coppiced stool from the tree trunk, although it does indicate a lower degree of efficiency as compared to cutting on two sides (wedge points) (O'Carroll 2008a:150). The additional wood recovered from these features seems to play a minor role: blackthorn (*Prunus spinose*), hawthorn (*Crataegus*), willow (*Salix*), ash (*Fraxinus excelsior*). It is

[26] The sites in this Contract were dated to a number of different periods, not only the Iron Age.
[27] E.g. Cherryville Site 12, Harlockstown 19, Leap 1.

likely that these pieces of wood were gathered unintentionally while collecting the main charcoal wood, or the smaller branches were used as kindling in the furnace or hearth.

One other pattern identified here is that there appears to be continuity within each site with regards to the type of wood used for fuel. For example, sites that produced oak charcoal were mutually exclusive from sites that had features with hazel charcoal. Aside from this pattern, no temporal pattern of wood use was visible in the sample. Furthermore, there was no pattern of wood used for charcoal based on the type of ironworking feature; smelting furnaces and smithing hearths presented a similar distribution of wood charcoal types.

Table 4.13 Ironworking features with analyzed wood.

Site Name	Site Licence Number	Context Number	Feature Type	C14 Date	Site Date	Charcoal wood
Clonrud 4	E2167	F005	Furnace	790 - 500 BCE	LBA/EIA	Oak
Site AR 26, Ballydavid	E2370	C157	Furnace	765 - 416 BCE	EIA/DIA	Oak
Site L, Lughil	03E0602	F22	Furnace	730 - 390 BCE	EIA	Oak
Lagavooren 7	00E0914	C141	Furnace	520 - 380 BCE	EIA	Hazel, small amount of blackthorn
Derrinsallagh 5	E2181	C070	Furnace	520 - 350 BCE	EIA/DIA/LIA	Oak
Cherryville Site 12	01E0955	F2	Furnace	520 - 150 BCE	EIA/DIA	Alder
DKIT	02E0201	C11	Furnace	420 - 200 BCE	EIA/DIA	Hazel
Johnstown 3	02E1094	C5	Furnace	420-230 BCE	DIA	Oak
Mullagh	09E0311	F6	Furnace	409 - 386 BCE	DIA	Oak, small amount of hazel and hawthorn
Chapelbride 1	E3172	F7/8	Smithing Hearth	401 - 206 BCE	DIA	Oak
Trantstown AR 29	01E0501 AR29	F5	Furnace	387 - 197 BCE	DIA	Oak
Hardwood 3	02E1141	C052	Furnace	380 - 60 BCE	EIA/Medieval	Oak
Knockcommane 4700.1b	E2342	F3	Furnace	375 - 182 BCE	DIA	Oak, small amount of hazel
Site AR 26, Ballydavid	E2370	C172	Furnace	374 - 191 BCE	EIA/DIA	Oak

Monganstown 1	E2771	C40	Furnace	361 - 113 BCE	DIA	Diffuse porous wood charcoal
Clonrud 4	E2167	F003	Furnace	360 - 90 BCE	LBA/EIA	Oak, small amount of willow
Moyvalley 1	02E1088	C016	Smithing Hearth	360 BCE - 70 CE	DIA	Alder
Kilrussane AR 27	01E0701	F2	Furnace	352 - 42 BCE	DIA	Oak
Carrickmines Great	02E0272	1195	Furnace	320 BCE - 70 CE	DIA	Oak
Cloncollog 2	E2850	C007	Furnace	261 - 94 BCE	DIA	Oak
Ráith na Ríg, Tara	97E300	38	Smithing Hearth	200 BCE - 16 CE	DIA	Oak
Moyally 2	E2672	C7	Furnace	173 - 5 BCE	DIA	Oak
Ballinvinny North AR26	01E0501 AR26	C3	Furnace	165 - 123 BCE	DIA/LIA	Oak
Harlockstown 19	03E1526	F96	Furnace	100 BC - 130 CE	DIA/LIA	Alder
Site 27, Rath	03E1214	F89	Furnace	50 BC - 80 CE	DIA	Alder
Kilrussane AR 27	01E0701	F3	Furnace		DIA	Oak
Moyally 2	E2672	C10	Smithing Hearth		DIA	Oak, small amount of ash
Monganstown 1	E2771	C60	Furnace		DIA	Oak
Monganstown 1	E2771	C63	Furnace		DIA	Oak
Monganstown 1	E2771	C57	Furnace		DIA	Oak
Derrinsallagh 4	E2180	C135	Furnace		DIA/LIA	Hazel, 7years, chisel pointed post
Derryvorrigan 1	E2193	C92	Furnace		DIA/LIA	Oak
Lisnagar Demesne 1	03E1510	C41	Furnace		DIA/LIA	Oak
Hardwood 3	02E1141	C044	Smithing Hearth	1440-1640 CE	EIA/Medieval	Oak

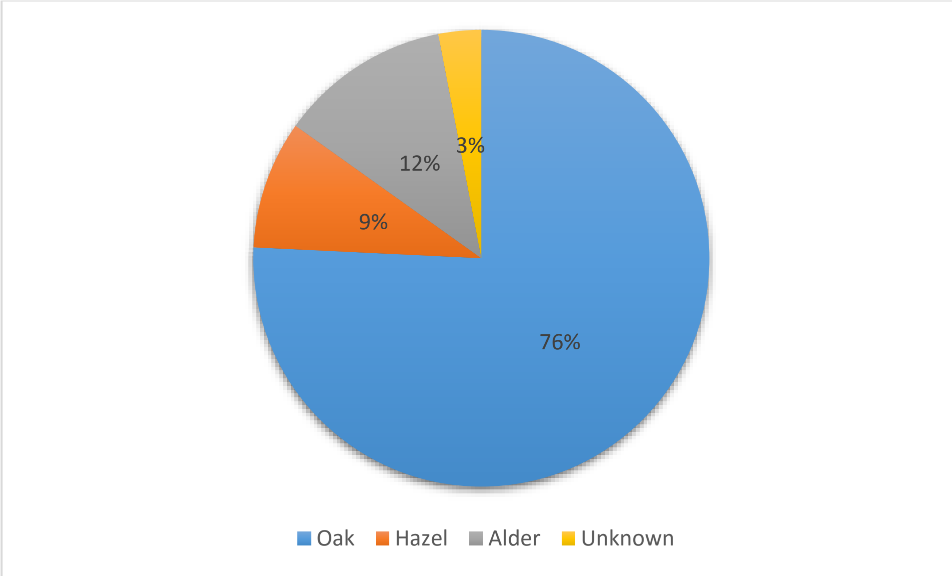


Figure 4.52 Percentage of wood used for charcoal in ironworking features, excluding wood making up minor percentages.

Chapter 5: Interpretation

5.1. Introduction

The early production of iron, whether in Ireland or in Britain[1], is still not very clearly understood. This is in part due to the fact that focused, analysis-based studies of the residues of iron production have been conducted only recently. Yet the largest difficulty to understand ironworking is that, like any other technology, it is so socially entangled that to not understand one facet of the process is to miss significant portions of it. In the first place, the knowledge of iron as a workable material needed to be transferred to LBA and IA people in Ireland[2]. This involved not only the knowledge that iron *can* be worked, but *how* to process, smelt, and create iron objects. This knowledge transfer was built upon networks of relationships with outsiders. These networks may have taken the form of purely political or economic relationships, or the permanent or temporary movement of individuals from the outside, or likely a more complicated, multi-stage process.

Once the knowledge of iron production existed within a community of practice (Wegner 1998) and could be performed and replicated, innumerable inputs then affected how that knowledge was enacted: the type of ore that was procured, the type of wood used for charcoal and the way the charcoal was created, the form chosen for a bloomery furnace and the techniques employed during a smelt, the way the furnace was cleaned out (of slag and bloom), if a bloom was processed on the smelting site or taken away to be processed elsewhere, and all of the technological

[1] Much more is known regarding ironworking in Britain compared to Ireland.
[2] Photos-Jones and Wilson (2007) suggest that ironworking was an *in situ* development in Ireland, but I find the premise for that idea very implausible.

inputs necessary for creating a finished iron product from an ingot or bar. Furthermore, the individuals involved in these technological practices did not act in isolation, nor was their entire life devoted to the utilitarian act of creating an iron bloom from a furnace. Iron technologies were thus social practices, intertwined with the rest of Iron Age life. This means that the context, both spatially and socially, in which smelting and smithing occurred had an influence on the meaning that was derived from the process as well as the final product. The locations at which this technology was being enacted depended on economic factors such as sources of ore, fuel, proximity to settlements and the economic requirement of iron, but also was impacted, and was governed by, the social conventions and ritualized practices of Irish society at the time.

To attempt to reconstruct the complexity of this social technology in this project, it was necessary to analyze the remains of production at multiple scales and with multiple foci. The data in Chapter 4 were presented in such a way as to address as many aspects of this network as possible. In the following chapter the research questions that were posed at the onset of this project are revisited in order to extrapolate and interpret the many different facets of the organization of iron technologies during this period.

5.2. What level of skill is demonstrated by the remains of iron smelting and smithing?

Skill can be a tricky term to use when evaluating prehistoric technologies. The presumption inherent in an argument for skill is that there is a higher or lower level of skill – this judgment in part obscures processes which may not be strictly utilitarian in motivation but nevertheless impact technological practice. We may look to other contexts to remind us that technologies which on the surface suggest a low level of skill or expertise can in fact be the result of much more complex social and environmental factors. For example, Frink and Harry (2008) address the conception that cooking pots made by people of the Thule culture in Alaska are lacking in technological skill, and could even be thought of as “ugly”. The shapes and textures of the pots appear not well suited for the task of cooking. However, due to the challenging environment conditions the pottery required this otherwise “ugly” manufacture process, and the pots seemed well suited to the cooking required by the Thule people. This example demonstrated that the characterization of skill and expertise cannot solely rely on the empirical classification of an individual object or process, but requires a view of the entire system within which the technological process is occurring.

With this caveat in mind, the nature of archaeological data, as addressed in this dissertation, necessitates the use of a largely utilitarian lens to begin to address skill in iron production; that is, I have focused on how successful EIA and DIA individuals were in producing fluid fayalitic slag that was removed from the metallic iron, forming a Fe-dominant bloom, and being able to work that bloom into a useable piece of iron. While this approach is limited to a more economic understanding of practice, it is necessary to first understand how the process occurred before we attempt to contend with the myriad reasons the process may have diverged from expectations based purely on economic production. By this I mean that in a purely economic model of production of bloomery iron, the construction of the furnace and techniques employed by the smelters would maximize the bloom output versus the amount of ore, fuel, and time consumed in the process. When these are not maximized the question can be asked, what actions were performed that modified the ideal conditions of production and why was this done?

As the amount of archaeological evidence for the Iron Age expanded rapidly in Ireland during the beginning of the 2000s, the remains of early iron production began to be examined in more detail (see section 2.2). One interpretation of the archaeological data was that the features being identified during excavation of ironworking sites were bowl furnaces, a tradition long suggested to have existed in Europe (Pleiner 2000) as well as Ireland (Scott 1990). In a bowl furnace the slag and iron bloom would have had to have been removed as a conglomerate, and would have required processing to isolate the metallic iron, resulting in a significant loss of iron. Additionally, the lack of a cover would have resulted in a rapid loss of heat, requiring constant re-fueling. Based mainly on this early, and largely unsubstantiated, claim for the use of bowl furnaces, a number of specialists' reports proposed that all of the bloomery furnaces identified during the NRA infrastructure projects were bowl furnaces (e.g., Photos-Jones 2003a, 2003b, 2003d, 2003e). It was therefore concluded that, "the technology is primitive, limited not by the skill of the smith but by the primitive design of the furnace which does not allow for long residence time i.e., long exposure to carbon monoxide, or enough space for a bloom to form and grow" (Photos-Jones 2003e:82). While the basis for this statement, the evolutionary assignment of primitive[3] skill, is flawed, the biggest problem with this argument is the assessment of the technological structures in use.

If bowl furnaces were indeed the technique of choice for Irish iron smelters, there would have been significant limitations placed on iron output. However, based on the analysis and review of the expanded dataset of ironworking sites throughout the island presented here, bowl furnaces do not seem to have been used in any significant way during the Iron Age in Ireland. As more features were uncovered during the NRA road schemes that appeared to have involved iron production, similarities began to be noted by some of the specialists responsible for the archaeometallurgical analysis of the projects. Building on the work of Crew and Rehren (2002), Tim Young (2003a) was one of the first to challenge the assumption that bowl furnaces were used in early iron smelting in Ireland at all. Young noted correctly that classifying bloomery furnaces as bowl furnaces was almost entirely based on the lack of an archaeologically-identified

[3] And by extension, the claim that Irish smelters and smiths were unaware of or chose not to use "civilized" technology.

superstructure (2003a:3). However, the absence of a superstructure is expected, as it would have been made mostly out of clay and would have been destroyed to remove the bloom or degraded over time after use. Analysis of the slag samples recovered from the 35 sites analyzed in this dissertation has produced at least 18 examples of some type of fired clay or furnace lining recovered from furnaces. Combined with the many other sites that noted the presence of a clay lining during excavation that were never formally recorded, it seems evident that clay superstructures were present at most, if not all, of these smelting furnaces. This further undermines the claim that bowl furnaces were in use for iron smelting during this period, and indicates that Irish smelters in fact were making use of "state of the art" technology, like their counterparts elsewhere in Europe.

Further evidence supporting the use of slag-pit furnaces is the morphology of the features uncovered during these excavations and the lack of a tuyére or visible blow-hole near or beneath the surface. All of the 28 sites where slag samples were analyzed[4] produced slag[5] that indicated the slag flowed away from the iron bloom within the furnace. This means that although rarely recovered from *in situ* furnaces, the bloom must have formed higher up than the slag in these furnaces, since once the furnace temperature was hot enough the fluid fayalitic slag would have seeped down through the bloom. During the setup of a smelting furnace, layers of charcoal and iron ore were piled up within a shaft higher than the blowhole (Figure 5.1). Since blooms form around the hottest zone in the furnace, around and beneath the blow-hole, the absence of a below-ground blowhole indicates that the bloom and the blowhole were above ground. This also means that there was a superstructure in which the initial charcoal and ore were piled up, and in which the bloom was eventually created. Furthermore, a pit with steep-sided walls and vertical base

[4] That I was able to access for this dissertation.
[5] See section 4.2 for a description of the type of slag that would indicate this.

matches morphologically all of the known comparable furnaces on the continent and in Britain (Crew 1991; Pleiner 2000; Tylecote 1987). This furnace shape is seen in almost all of the 66 furnaces identified in this dissertation as slag-pit furnaces, as well as the 11 arched slag-pit furnaces included in this study.

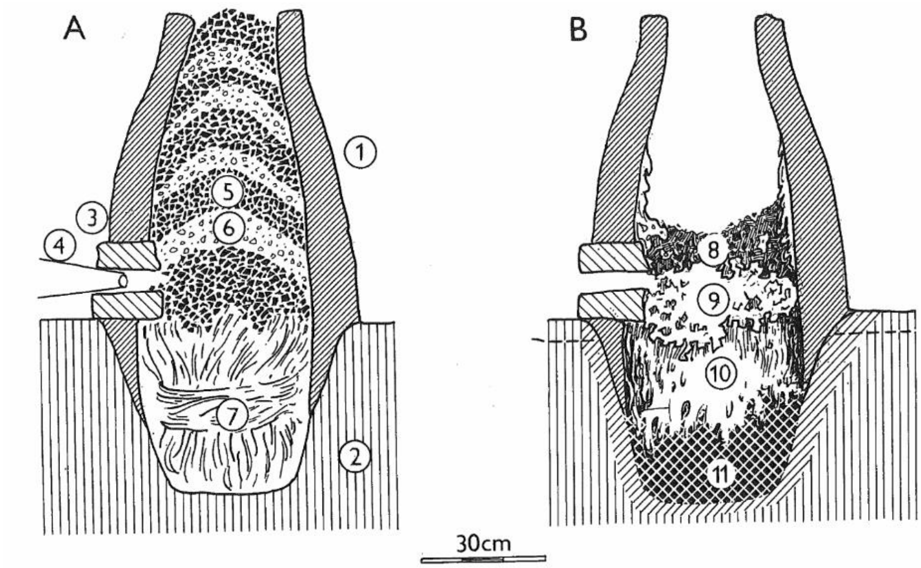


Figure 5.1 Schematic of slag pit furnace before a smelt (A) and after a smelt (B). 1–Shaft; 2-Virgin Soil; 3-Tuyére blocks; 4-Bellows; 5-Charcoal; 6-Iron ore; 7-Straw or brush wood; 8-Furnace slag; 9-Iron bloom; 10-Slag bloc in the pit; 11-Charcoal with ash (Pleiner 2000:150).

So while bowl furnaces would have indeed been inefficient in terms of the loss of iron and the large amounts of fuel required to maintain a high enough heat, the data from this project do not support the use of such a smelting technique in Ireland at this time. Instead, the slag-pit low shaft furnace was the most common type used to smelt iron during the EIA and DIA. De-slagging the iron bloom by using a slag-pit mitigated the significant loss of iron that would have occurred in a bowl furnace. This innovation in iron production has been called a "great achievement" and the "first technological revolution in metallurgical development" (Bielenin 2011:38). Indeed, the extension of a furnace above the surface of the ground allowed for a higher heat to be sustained and provided room for the slag to flow away from the consolidating bloom. The use of this type of furnace has been identified as far back as 1000 BCE in Anatolia and throughout Europe (Tylecote 1987:154). The slag-pit furnace was also used during the Iron Age in Wales, Yorkshire, and elsewhere in Britain, until it was replaced in some regions by the slag-tapping furnace during the Roman period (Crew 1984, 1989, 1998; Halkon 2011; Paynter 2007; Pleiner 2000; Tylecote 1987). It is therefore likely that this technology was introduced into Ireland rather than developing independently from earlier furnace types.

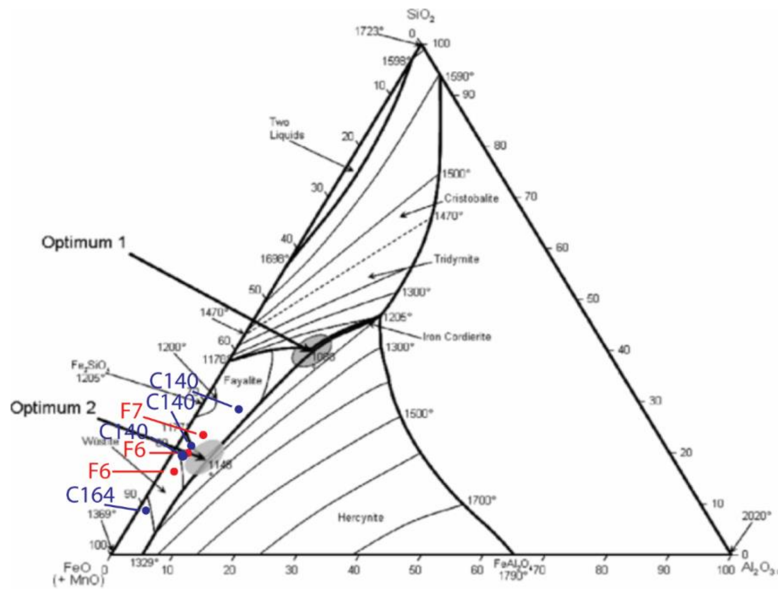


Figure 5.2 FeO - SiO2 - Al2O3 ternary diagram of samples from Lagavooren 7 (blue) and Cherryville 12 (red) (after Charlton et al. 2010).

A slag-pit low shaft furnace produced temperatures hot enough to effectively create a fluid slag that could separate from the iron ore. Analysis of the composition of some of the slag samples from the sites of Cherryville 12 and Lagavooren 7 indicate that temperatures between 1100° and 1200° C were achieved, allowing the slag to reach the fluid fayalitic phase (Figure 5.2). Each of the samples in Figure 5.2 was recovered from slag-pit furnaces and although limited, they point to a smelting technology that was quite capable of producing useable iron blooms. For example, the XRF analysis of one sample from the site of Cherryville 12 showed relatively low iron content, high silica, high manganese and high phosphorous[6] (Young 2005). This suggests a high yield of metallic iron was produced by that smelt.

I would go further and argue that in fact the slag-pit furnace technology was particularly well suited to Ireland and the types of ores that were being exploited there. In alloying with iron, manganese encourages the uptake of carbon and nitrogen, and removes sulphur (Crew et al. 2011). This increases the hardness of the iron while also changing the fluid state of the furnace ore. If the fluid state is reached earlier, less fuel and time are required for a smelt to succeed. As such, bog ore is extremely well suited for use in slag-pit furnaces because of the ease with which it can be smelted, due in large part to its relatively high manganese content (Fairburn 2006). High manganese levels were noted in many of the samples recovered from the dissertation sites[7] (e.g., Martinón-Torres 2006; Photos-Jones 2003b, 2003d, 2003e). Furthermore, at least 11 sites analyzed in this dissertation have provided evidence for the use of bog ore (see section 4.2.2).

Building on the results from the compositional analysis of the slag samples recovered from particular sites, the residues suggest a clustering around what Charlton et al. (2010) have called Optimum 2. Based on evidence from experimental archaeometallurgy (Crew 2004; Tylecote et al. 1971), it has been suggested that recipes closer to this optimum required lower fuel to ore ratios (closer to 1:1) and occurred in less reducing environments (Charlton et al. 2010:357). However, the result of these environments is that slag can incorporate more free iron oxides, lowering the metallic yield. These chemical processes impacted the economic net yield of the smelt: lower fuel amounts were needed to reach sufficient temperatures, but there would be a lower iron yield. Therefore, from a purely economic point of view, Irish smelters during this period appear to have

[6] These samples were, however, extremely heterogeneous.
[7] Rondelez (2014:91-92) has brought up methodological issues with the microscopic characterization of bog ores in slag conducted by Photos-Jones.

been quite efficient. It has been suggested that the largest “expense” or “investment” in iron smelting was the fuel (Rostoker and Bronson 1990). Indeed, the time expended on creating charcoal significantly impacts the amount of time spent on other necessary activities. This economic net yield could also be increased based on the apparently greater availability of bog ore.

Viewed through this evidentiary lens, the individuals taking part in smelting iron during the EIA and DIA were quite skilled at producing workable iron blooms that were largely free of excess slag. They were able to do so at a lower fuel cost by sacrificing the gross yield. This means that in any given smelt, the amounts of metallic iron being produced were limited. Coupled with the small amounts of slag recovered from each site, as compared with contemporary activities occurring in Britain (Crew 1998)[8], there was not very much total iron being produced by any group of Irish smelters. However, the low amounts of iron produced do not necessarily reflect on the skill of the smelters, but could indicate a low economic need for the iron being used at the time. I will return to this point later in the chapter, but it is important to consider that one impetus to innovation is economic pressure. Without significant pressure from the market, innovations for increased yield may not be developed or adopted.

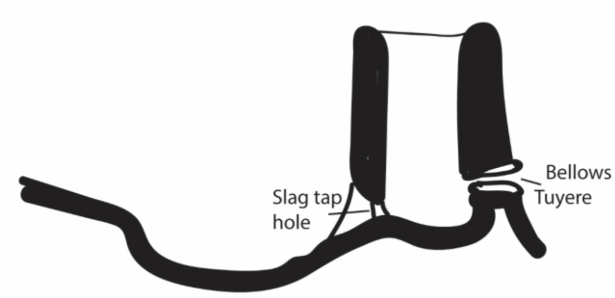


Figure 5.3 Schematic of slag tapping furnace.

One innovation that was not seen in Ireland during this period was the slag-tapping furnace. Tapping furnaces typically had a ground-level base with an aperture in the wall through which slag flowed out or was removed while in its liquid form (Figure 5.3). Through the Late Iron Age and Romano-British period, the slag-tapping furnace began to be utilized in Britain, partially

[8] The ironworking site of Crawcwellt West produced 1350kg of slag, for example.

supplanting the slag-pit[9] furnace (Paynter 2007). One argument for the choice of a tapping furnace over a non-tapping furnace is quantity of yield. As demand for iron increased during the Romano-British period, tapping furnaces were likely preferred because they could be easily reused without significant cleaning (Paynter 2007:209). Additionally, they were easier to use with a variety of ore types and qualities, allowing for exploitation of many possible ore sources. While this type of furnace came into prominence in Britain largely after the chronological periods involved in this dissertation, there was no trend towards this technique during the DIA in Ireland, nor have any tapping furnaces been identified that date to later periods[10]. The driving factor behind the avoidance of the tapping furnace in Ireland may have been the limited demand and market for iron. If the settlement record is any indication, the population was very dispersed across the landscape. With higher demand not driving the need for adoption of an additional production technique, there was little impetus to change existing furnace design. In addition, the slag-pit furnace was so well suited for the high-manganese bog ore that conservatism was economically beneficial.

One variant of a normal slag-pit furnace that appears to have been utilized beginning in the DIA[11] was a type I have termed the arched slag-pit furnace. One of the drawbacks of a low shaft slag-pit furnace is the difficulty of cleaning it out for multiple uses. The shaft can only be as deep as an arm's length to be cleaned out and the excess slag removed; reaching the bloom through the top of the furnace to avoid removing the clay superstructure was another limitation. To avoid having to remove the superstructure after every use or abandon the furnace after the pit has filled up, there is evidence from across the Irish Sea in Wales of another furnace type that utilized an arched opening in the side of the furnace to clean out the slag. The slag and bloom could be mostly

[9] Also known as the sunken hearth furnace.
[10] Cuffsborough, Co. Laois, Johnstown 1, Co. Meath, and Shallon, Co. Meath are all LIA or later ironworking sites that do not have evidence for tapping furnaces.
[11] Perhaps in the EIA, at Kinnegad 2 and Lughil.

cleaned out through this archway and brought into an adjoining pit or shallow ditch where the bloom could be worked. Peter Crew has noted this type of furnace technology during excavations at Bryn y Castell and Crawcwellt in Wales (1991). During the Derrinsallagh 4, Co. Laois excavations, one definite example of this type of arched slag-pit furnace was identified (Young 2008a). This remarkably intact furnace still contained the arch leading to a working hollow, as well as the evidence for the placement of the tuyère and blowhole (Figure 5.4). The arch was 16cm above the base of the slag-pit, meaning that the opening could not have been used to tap the furnace. The preservation and method of excavation have allowed us to reconstruct a most of the techniques involved in the use of this furnace. The original blow-hole for the forced draught of a bellows was placed at 90° from the arched opening. In addition to this type of placement being attested in examples outside Ireland (Crew 1991), it is an ideal position to minimize blocking the arched opening. Descending prill slag normally accumulates along the blowing wall as well as opposite the blowhole at some of the hottest zones in the furnace. Therefore, with the original placement of the blow-hole at 90° from the arched opening, significant slag would not have accumulated over the opening, allowing access into the furnace.

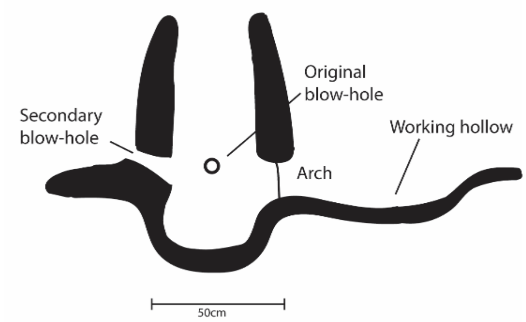


Figure 5.4 Schematic of arched slag-pit furnace.

However, over time it is possible that a slag hood can form over a blowhole as the cool air coming from the outside chills the slag on the blowing wall as it runs over the hole (Young 2008a:211). Once this happens, the furnace quickly cools down, halting the smelting reactions. This apparently occurred in the Derrinsallagh 4 example, and as a result the smelters made a choice to continue using the furnace by changing the orientation of the blowhole to a position directly across from the arched opening. This type of ad hoc improvisation demonstrates a significant knowledge of the smelting process, and how to adjust techniques to continue to use the furnace. As the function of the furnace began to falter due to the blockage of the blowhole, three options were available to the smelters. The first was to clean the slag accumulation from over and around the blowhole; however, this does not seem to have been worth taking on. The furnace could have also been abandoned and smelting could have moved to other areas of the site, since there were at least 43 other furnaces used at this site. The final option was to move the location of the blowhole, allowing continued use of the furnace. The choice to move the blowhole indicates the ability to diagnose the problem with the furnace and why it was no longer reaching the necessary temperatures for separating the slag from the iron. This example demonstrates an intimate knowledge of the technology; not only *how* to smelt iron but *why* certain aspects of the furnace did or did not work.

Although furnace C397 is the most completely preserved furnace recovered in Ireland for this period thus far, and the only example of an intact arch, I suggest there are ten additional features that also utilized this sort of furnace technology. This number is still tentative since 38 bloomery furnaces were categorized as unknown due to the lack of evidence for features indicating a more specific type which could have originally contained an arched opening (Table 4.4). The only two directly dated samples from arched slag-pit furnaces were 361 – 113 BCE from a Monganstown 1 furnace and 173 – 5 BCE for a Moyally 2 furnace (Table 4.3). In general these types of furnace come from sites dating to the DIA or DIA/LIA. It thus appears that the technological innovation of an arched opening was a later development in the production of iron in Ireland. Furthermore, this furnace type is concentrated in the midlands, in the center of the island (Figure 4.18).

Through these patterns, a picture begins to emerge of the way iron technologies were used and developed. The location of the arched slag-pit furnaces mirrors the location of the earliest dated ironworking sites in this dissertation sample. I would argue that this area of the island acted as a focal point for the early adoption of the technology and its subsequent development. Furthermore, these patterns also point to a fairly conservative approach to production. The limited variability across slag-pit furnaces in general suggests that there was little deviation from prescribed knowledge bases, i.e., how to smelt iron. As discussed above, the slag-pit furnace was very well suited to smelting bog iron ore, prompting the question: what was the impetus to change or innovate? Whether it was due to the small group of individuals that had access to the knowledge of how to smelt iron, or if there was a widespread conservative tradition of iron smelting, the techniques used for smelting seem to have been fairly static. It should be noted that normal slag-pit furnaces were still in use at the same time or even after arched slag-pit furnaces were adopted. The data support the idea of a wider community of smelting knowledge but with smaller groups that maintained more constant interaction. This would account for the centralized location of certain types of furnaces. I will return to these overlapping communities of practice later in this chapter.

The example of the arched slag-pit furnaces in Ireland may also help address the *process* of technological innovation. Slag-pit furnaces with arched openings to clean out the furnace were used contemporaneously in Wales (Crew 1989, 1991). Discounting independent development in two areas so near one another[12], the question that arises from this shared technology is where was

[12] 100 – 200 km away.

it first in use? I would argue for the westward movement of this particular aspect of iron smelting furnaces and iron technology more generally. The movement from the east of iron technology is suggested by Tylecote (1987), Scott (1990), and Pleiner (2000:30), among others[13]. Furthermore, what appears to be an example of a slag-pit furnace with an opening (non-slag tapping) was identified by Pleiner (2000:151, citing Dušek 1967) in Germany. The existence of this phenomenon on the Continent also supports the proposal that the innovation of the arched opening came from outside Ireland.

The concentration of the earliest dated ironworking sites in Ireland and the technological innovation of the arched furnace opening in the lower midlands suggests that there was a strong outside connection with this region of Ireland to the outside, potentially to Wales. The way these production ideas were moving is still unknown, whether it was through physical re-location of smelters from the outside, or by other interaction that facilitated the movement of ideas related to technology. The evidence available does not seem to suggest significant movement of peoples from the outside into this region. It is therefore more likely that the knowledge of how to smelt iron, and the subsequent development of the arched opening to clean out the furnace, arrived through the ideas introduced from small-scale movement from abroad or based on limited visits, rather than large scale migration and relocation of peoples.

The production of charcoal in association with ironworking has also provided some insight into possible networks of knowledge and the transfer of ideas. As outlined in section 4.4.1, there were a number of different techniques available for producing charcoal for use in iron production. This ranged from small circular or oval pits to large rectangular pits. People could have also been utilizing a technique involving charcoal piles, which would have left very little archaeological

[13] However, the suggestion for the expansion of iron into Britain and Ireland is often tied to the movement of "Celtic Peoples."

evidence. In contrast to the relative continuity in the way in which iron ore was smelted, the lack of standardization of charcoal production suggests different techniques and approaches to this initial process in iron production. The charcoal pit morphology does not correlate in any way to the type of wood chosen for the charcoal, suggesting that the technique of charcoal production was not dependent on the fuel available. The discernable patterns support the idea that charcoal production was a more local process, the knowledge for which was possibly passed on through generations or small communities. Since charcoal was not solely a fuel used in ironworking but was used in other pyrotechnic activities as well, the communities of practice for how to produce charcoal did not have to necessarily overlap with the communities of practice for iron production. Traditions of producing charcoal likely developed in different regions throughout Ireland prior to the beginning of ironworking, utilizing large or small pits, or creating charcoal piles that left little archaeological trace. These techniques continued to be used as iron production began, mixing new technologies with existing production methods.

The wood used for the production of charcoal appears to have followed specific local traditions, while at the same time allowing for the most efficient use of resources. The three main types of wood that were used to produce charcoal during this period were oak, hazel, and alder (Table 4.12; Table 4.13). Each of these types of wood is very good for charcoal production, so a significant difference in the quality of charcoal and function within a furnace would not have been noticed[14]. I argue that Irish smelters utilized the wood nearest to the production site for charcoal. Both oak and hazel were extremely widespread during this period (O'Carroll 2006, 2008a), while alder would have been found near wet environments like river and stream banks. The location of an easily accessible source of fuel cut down time expenditure and reduced the overall labor

[14] However, during experimental work, oak was found to be the least useful for smelting of the main charcoal types (Crew 2013:31).

involved in iron production, regardless if the spot for ironworking was chosen based on its proximity to the wood or vice versa.

Although the way in which iron was smelted seems to have been relatively consistent across Ireland during the EIA and DIA, the size of furnaces varied significantly. While many of the furnaces cluster in the 35 – 60 cm in diameter range, there is another smaller cluster between 60-80cm or larger (Figure 4.4 and Figure 4.9). I argue that this disparity in furnace sizes can be explained in a number of ways. First, the variation may be due in part to archaeological recording. As different excavators recorded the dimensions of each furnace at different sites, the boundary for what constituted the beginning and ends of a feature likely varied. Some excavators may have included the burnt soil that extended out from the furnace that was created during use, while others may not have. Unfortunately, because only some of the furnaces were sectioned, the discrepancy between what was recorded and what was actually preserved in the field may never be known. The size of the slag-pit, and by extension the furnace, could have been a specific choice by the smelter depending on the amount of iron needed or the amount of ore collected. This could account for the different furnace sizes found at some sites, such as at Derrinsallagh 4. The variations in size could also be an unintentional consequence of many different people involved in smelting. If the knowledge of production was only fairly standardized, an individual might only have "known" that a furnace was supposed to be about 45cm in diameter, but in actual practice it may have been between 60cm and 30cm in diameter. This demonstrates an inherent dialogue between prescribed structure and individual action during technological production. If the intention is to create a useable piece of iron bloom after a smelt, the knowledge base prescribes certain techniques to complete this task (i.e., dig a pit under the furnace, create a clay superstructure, place bellows in a certain position, etc.). Yet within this formal structure there are avenues for variation in the way the structure is enacted, in this case the size of the furnace. Other than changing the requirements of ore and fuel, there is no significant functional difference between a furnace of 35cm and 60cm. Since to this point a temporal or geographical explanation for these variations in size does not fit the existing data[15], other options seem more likely.

A phenomenon noted in this analysis was that pairs or groupings of furnaces can be found together on a single site (Section 4.1.1.4). Twenty such groups were identified in this project at ten sites. This type of patterning on ironworking sites with slag-pit furnaces has been noted elsewhere in Europe (Bielenin 1974; Tylecote 1987). The interpretation was that after a slag-pit was full, the clay superstructure of the furnace was moved directly next to it, over a newly dug slag pit (Tylecote 1987:154). The site eventually becomes a field of used slag-pits in large clusters. The differences between these continental examples and those in Ireland is one of scale. The clusters of Irish furnaces are fewer in number[16], and the slag-pits are not often completely filled with slag blocks. One explanation for this clustering in Ireland is the removal of the superstructure for reuse immediately next to it. An additional explanation is that these pairs of furnaces were used simultaneously and that their proximity allowed for one person to man two bellows at the same time. Although this theory cannot be verified based on the existing evidence, the lack of two ^{14}C dates from paired furnaces and the lack of tuyère remains *in situ*, it would be quite efficient to man two furnaces at once if the demand for iron yield exceeded the capabilities of a single furnace. Instead of expending the time cost of one smelt followed by another, using the same amount of labor to fire two furnaces at once reduces the total cost in person hours.

An unfortunate gap in the reconstruction of the skill of the individuals involved in iron production is the evidence for primary or secondary smithing. As noted in section 4.1.2, the

[15] Young (2011a) has noted that size of furnace does not always correlate to chronological date.
[16] Eleven groups of two furnaces, four groups of three furnaces, and five groups of four furnaces.

identification of a smithing hearth can be difficult. Those that have been identified in this sample demonstrate quite a bit of variability in size and shape, but the majority are closer to rectangular in shape. Thirteen features were identified as smithing hearths, at ten different sites. An additional four sites in the study sample, as well as one site not utilized in this study, provided some secondary evidence for smithing in the form of slag. It is likely that these different forms of evidence are indications of different types of production. Five of the ten sites that contained an identifiable smithing hearth also produced evidence for smelting. Added to the four sites with smithing slag, nine of the dissertation sites therefore produced evidence for both smelting and smithing. It seems likely that these sites illustrate what would be a logical practice, to smelt the iron ore and immediately process the resulting bloom on site. When the fuel for a hearth was already produced for the smelting furnace, the more economic practice would be to consolidate the bloom right after smelting. The remaining five sites with evidence for smithing were isolated metalworking sites, further confusing the narrative. These hearths could indicate either primary or secondary smithing, but based on the lack of evidence for associated smelting, I would argue for secondary smithing. However, secondary smithing sites could also have been distinct from one another depending on context. Some sites, such as Tara, could have been used for more elaborate or “high status” metalworking, while others could have been used to make more utilitarian iron objects. Unfortunately, the resulting residues and hearth structure alone cannot provide significant detail as to the capabilities of those working these features. The known smithing hearths do cluster around the midlands, in much the same way as the arched slag-pit furnaces and some of the earliest dated sites. Since the function appears to have been different, this pattern may not have any significance.

Iron artifacts that have more secure provenance and dates can also enlighten us regarding the skill exhibited by those producing iron objects. One unlooped socketed axe was recovered from the pre-bank phase of the Ráith na Ríg, Tara, dating to the DIA (Roche 2002). The axe is very similar to one found at Feerwore, Co. Galway (Becker 2012b; Scott 1974, 1990). Scott notes in his reconstruction of the Feerwore axe that the right-angle bend and open socket demonstrate "a competent craftsman used to making artifacts in fairly large numbers" (1974:12). Since this form matches the Tara socketed axe very closely (Figure 5.5), the same could be said for the smith creating it. The location of the find in a context that overlaps with the smithing occurring at that site suggests that it was produced there.

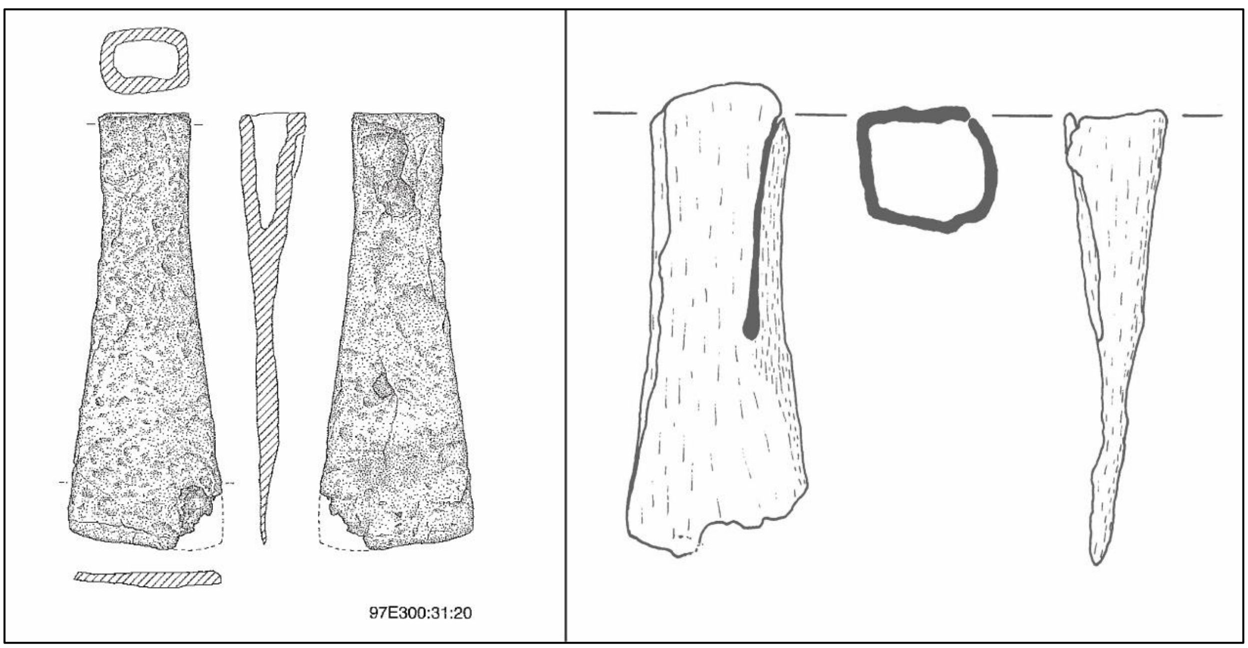


Figure 5.5 *Left*: unlooped socketed axe from Tara (Roche 2002); *right*: unlooped socketed axe from Feerwore, Co. Galway (Scott 1974).

Scott's 1990 metallographic examination of a handful of iron objects dating to the EIA suggested that there was a combination of skills at play in the production of these pieces. He argues that smelting likely produced blooms with uneven primary carburization and uneven success in removing slag within the iron (1990:58). Additionally, an unlooped socketed axe from Lough

Mourne, Co. Antrim[17] exhibited an unclosed weld in the socket, suggesting that the process of hammer welding was not fully understood or mastered by the smith (Scott 1990:58). However, techniques such as secondary carburization (to a limited degree) and quenching were in use by these smiths, which are fairly high level technical innovations.

An interesting technological development that has been noted for the Lough Mourne axe is the presence of secondary carburization on the cutting edge of the blade, the process of adding carbon to the iron after smelting. As carbon diffuses into the iron's chemical structure the hardness increases. In the production of the Lough Mourne axe the smith carburized the initial edge of the axe, and then folded it back onto itself, creating a steel center between two low carbon content areas of the edge (Scott 1990:49). It is possible that this technique was applied by accident, although it is a practice that became more common in later periods.

The individuals involved in iron technologies during the EIA and DIA in Ireland made use of techniques that were well suited for the quantity of iron used on the island as well as the type of ore being exploited. What may be viewed by some as the primitive employment of iron technologies actually appears quite appropriate when social and environmental factors are taken into account, following Frink and Harry's (2008) analysis of "ugly" Thule cooking pots. The smelting practices employed limited the resources required to produce liquid fayalitic slag and an iron bloom successfully. This intimate knowledge of production translated to the people creating the metal objects, who were using this knowledge to manipulate the iron in ways that would be utilized for hundreds of years.

5.3. How do patterns of production change through time, from the EIA (800-400 BCE) to the DIA (400-1 BCE)?

[17] This find was not directly dated, but is believed to be from the EIA.

The earliest dated ironworking sites cluster towards the middle-east of the island, through the midlands and down into the modern day M7 to M8 roadway (Figure 4.16). The interpretation of this pattern falls into two categories. One explanation is that the pattern was caused by an archaeological bias, following major road scheme implementation. However, there were roadway projects elsewhere in Ireland (Figure 2.1), as demonstrated by the ironworking sites found in those regions. Figure 4.15, illustrating the EIA sites identified by Becker et al. (2008), demonstrates that early sites with Iron Age occupation have been discovered throughout Ireland and exhibit a different distribution from the early ironworking sites. Another interpretation of this pattern is that people in the midlands were the first to utilize iron production technologies. The reasons why people in this area were the first to engage in iron production is likely a complex entanglement of social and environmental reasons. It was mentioned above that this region of Ireland may demonstrate a stronger connection abroad, possibly to Wales, which would account for the earliest uses of the technology. This theory is still speculative, since no additional lines of evidence such as settlement or mortuary patterns demonstrate a link to other regions.

The early production of iron in this region may have also been due to readily available ore sources. The region is largely covered with raised bog, a potential source of iron ore (Figure 5.6). Rondelez (2014a:68-86) has also identified known locations of bog ore throughout Ireland. The density of these find spots can be seen in Figure 5.6. This is not to say that bog ore could not have been found elsewhere in smaller patches of bogs, but the density of bogs in this region may have facilitated a higher density of iron smelting sites. As the technology was transferred through connections abroad, one region or community must have been the first to engage with the technology and use it on a regular basis. Whether due to the specific connections abroad, the movement of peoples from Britain, or the environmental conditions being well suited to providing the resources for production, the concentration of earlier ironworking sites in this region indicates that this is where ironworking was initially conducted in Ireland.

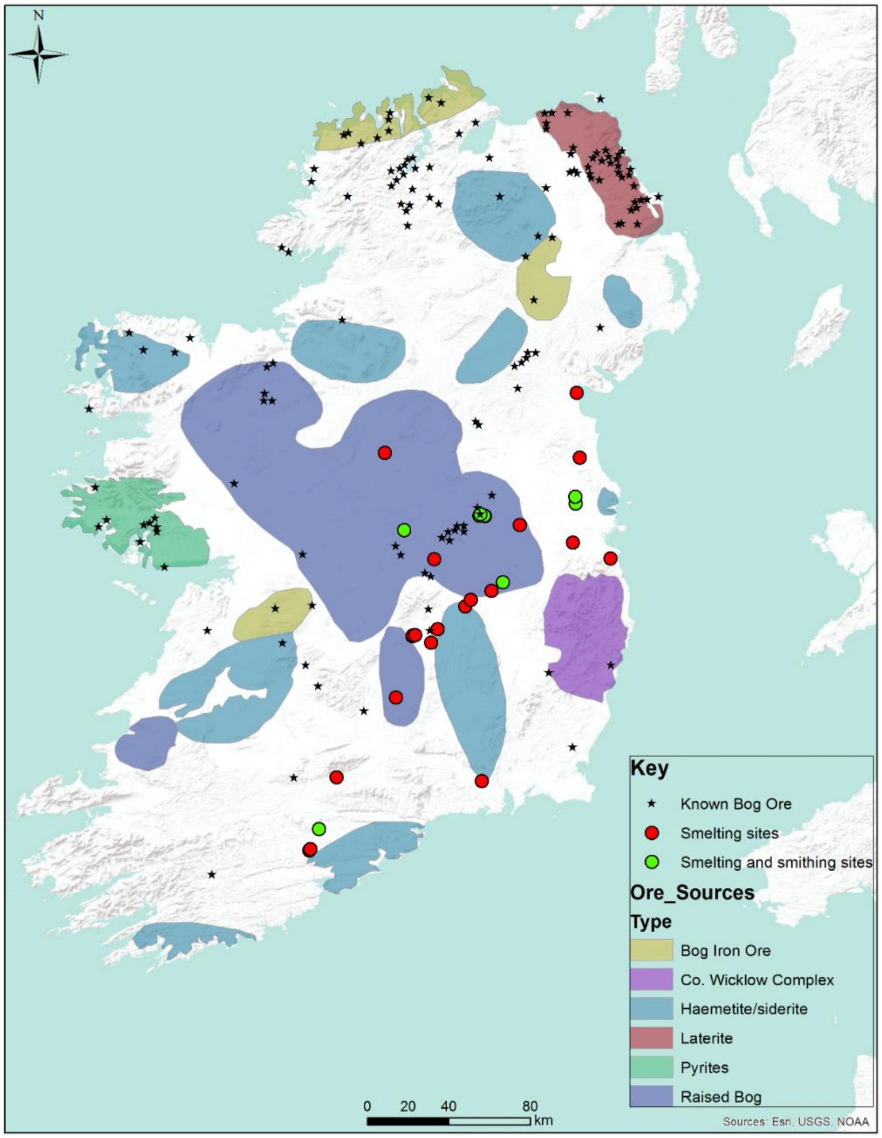


Figure 5.6 Iron ore sources in Ireland (after O'Sullivan et al. 2014). Known bog ore distribution after Rondelez (2014a). Smelting and smithing sites used in this dissertation.

In general, the technology employed for smelting, and the limited evidence we have for smithing, suggest a relatively static pattern through time. The one possible technological shift over time identified in the dataset was the use of slag-pit furnaces with an arched opening that could be used to remove slag and the bloom after use. As noted above, most of these furnaces either have direct dates placing them in the DIA or are found on sites with DIA dates (Table 4.3). There are a few earlier examples, but no ^{14}C dates were taken from these furnaces directly. This potentially later technological development is centered in the same region as the earliest evidence for iron production (Figure 4.18). Although it is difficult to say how or why the shift from regular slag-pit furnaces to arched slag-pit furnaces occurred, the similarities with developments in Britain and on the Continent suggest this was not just an insular phenomenon. The technical benefits have been outlined above, and the knowledge base for the use of an arched opening would not have been very different than for a regular slag-pit furnace.

As has been discussed at length, these periods suffer from a paucity of properly dated iron artifacts, making a discussion of change over time in iron objects difficult. In Scott's (1990) iron-centric chronology, he notes the differences between his Earlier Iron Age A (7th-3rd centuries BCE) and Earlier Iron Age B (3rd century BCE – 5th century CE). In his view, the period I refer to as the EIA is one of experimentation, yet continuity as well; experimentation in the form of the new metal technology, but continuity with some of the ideas and forms utilized in Dowris phase bronzework (Scott 1974, 1990:45). Scott (1990:45-46) identified iron skeuomorphs that maintained the style and structure of bronze objects, but were produced in iron, suggesting that these represented the tradition of Dowris bronzeworking utilized by early smiths, possibly created by the same people. The discovery of the smithing activity at Tara, which also produced evidence for bronze and glass-working, points to the idea that bronze smiths and iron smiths could have been the same people (Crew and Rehren 2002)[18].

One specific example of this skeuomorphism is an iron looped socketed axe from Lough Mourne, Co. Antrim (Figure 5.7b). Discovered late in the 19th century at the crannog site of Lough

[18] This may have also been the case at Ballydavis Site 1 (Keeley 1999).

Mourne, this looped socketed axe has been dated to the first half of the Iron Age based on parallels in Britain and on the Continent (Scott 1990). The form of this axe is extremely close to the classic looped socketed bronze axes that are a type-fossil for the Late Bronze Age in Ireland (Figure 5.7a). The looped socketed axes were first produced during the Bishopsland phase in the 13th to 12th century BCE, and became quite popular in the Roscommon and Dowris phases from the 11th to the 9th centuries BCE. At present about 2,100 bronze socketed axes have been recovered in Ireland (Eogan 2000). The similarity of form is apparent. This is not to say that differences do not exist in their forms, such as the almost concave non-looped side of the Lough Mourne axe, but the iron axe can easily fit into the larger corpus of bronze socketed axes. It may be suggested that the iron piece is a copy of the bronze one, a smith trying to reproduce a bronze artifact in a different medium, or that in the collective minds of EIA peoples, that is what an axe was *supposed* to look like.

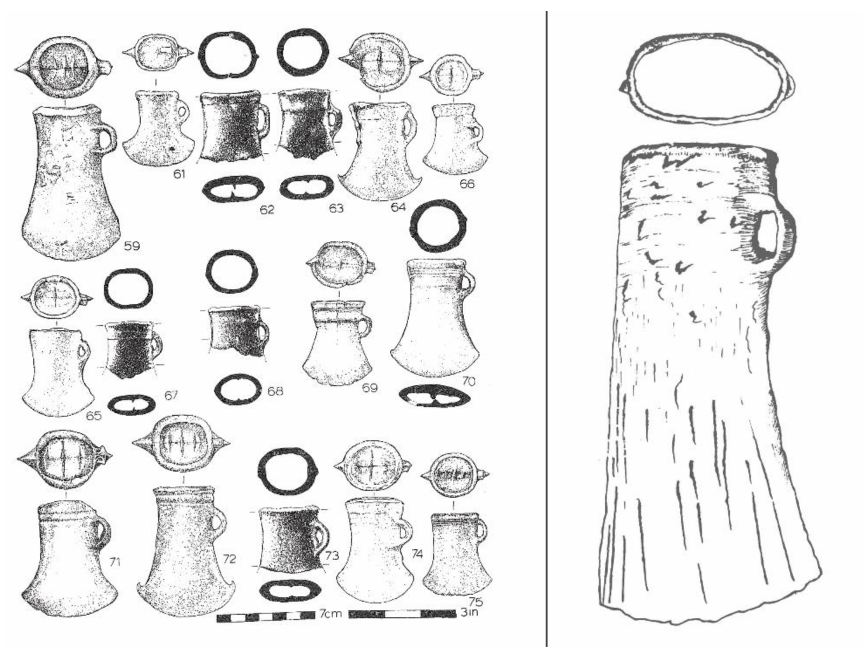


Figure 5.7 a) *left*: Bronze looped socketed axes from Ireland (Eogan 2000);
b) *right*: Iron looped socketed axe from Lough Mourne, Co. Antrim (Scott 1974).

The process of creating this axe out of iron began in the intersection between mental template and physical properties. Scott's (1990:49-52) detailed work on this piece has allowed precise reconstruction of the steps involved in the production of the socketed axe from Lough Mourne (Figure 5.8). A smith used a single piece of iron that had been forged into a flat plate. This flat piece was then folded into a cylinder, with one side again beaten out flat and the two halves welded together to form the blade. The loop was formed by pinching out a round, flat piece on the seam side of the axe and using a rectangular punch to create a hole in the iron. The technical practices involved in the production of the iron looped socketed axe are quite different from those involved in the bronze looped socketed axes from the preceding period. All bronze socketed axes were created with the use of casting technology (Eogan 2000). Following the smelting of the copper and tin, molten bronze was poured into an upright mold that had the form of the axe. In these contrasting materials we can see the influence of the physical affordances (*sensu* Gibson 1979) of each metal on technical practice. Though the conception of what an axe should be was maintained, an entirely separate suite of activities was developed to materialize this mental template, activities that were dependent upon the material itself.

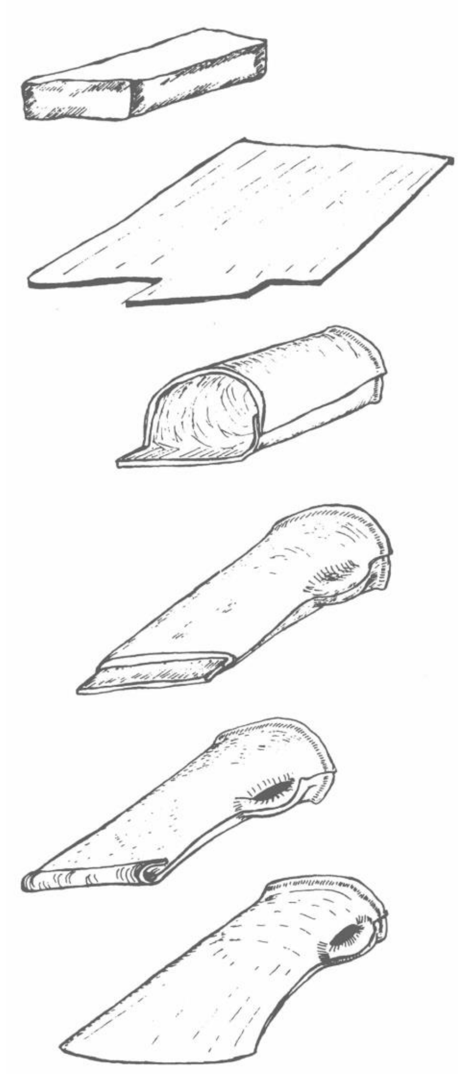


Figure 5.8 Process of forming the Lough Mourne axe, Co. Antrim (Scott 1974: fig. 2).

The DIA surely saw a significant increase in iron production, as this is what corresponds with the La Tène artifacts identified by Raftery (1984). Essentially, all of the known types of iron weapons, horse-trappings, and adornment in Ireland have been dated to the DIA and later (Raftery 1983). However, the number of properly provenanced and dated iron artifacts makes identifying technological change difficult. The iron objects from this period do incorporate many of the stylistic elements from Britain and the Continent, but the smiths retained some insular features as well. For example, the Irish iron swords and their Lisnacrogher scabbards, although very similar in style, are smaller than their British and European counterparts (Scott 1990:61). This supports a view of Ireland as part of a wider Western European network, where techniques and stylistic motifs were shared, influencing changes in technological practice over time at least to some extent.

5.4. What was the spatial relationship between iron production sites as well as with other types of sites during this period?

I have discussed in section 4.1 the lack of overall patterning between sites in this sample. The distribution of site types (Figure 4.40) did not show significant clustering or regional variation. As noted above, the concentration of early sites centered around the midlands (Figure 4.16) suggests a likely beginning point for iron production in Ireland. In section 4.1.5.2, I outlined the associations of iron production with other types of features in the sites included in this analysis. Seven sites, including the enclosure at Ballydavid, produced evidence for structures associated with iron production activity. The structures found at Rath Site 27 and Harlockstown 19 proved more unusual than any of the other structures identified in this project, and will be discussed below in conjunction with possible ritualized practices or ceremonial associations of ironworking. Ballydavid is the only site in this dataset with a large enclosure in association with iron production in the EIA and DIA (Figure 4.33). Of course, the smithing hearth uncovered at Tara predates the constructions of the Ráith na Ríg. The Ballydavid enclosure exhibits continuous use from the Bronze Age, although its exact function remains unknown, since no evidence for an internal structure exists. While there were some possible cremated human bones and animal bones deposited in the enclosure fill, it is unclear whether this indicates ceremonial behavior or incidental deposition. The location of the furnaces outside the enclosure ditch does suggest that the smelting was positioned away from whatever was happening inside the enclosure. The location of the ironworking activities in comparison to enclosure does fit with the suggestion that iron production activities were preferentially located away from structures, possibly for safety reasons. The potential dangers of smelting in particular have been previously noted (Cleere 1977; Hingley 1997; Giles 2007). The intense heat of the furnace could have posed a potential fire hazard for any surrounding structures that contained large amounts of wood and thatch. However, the evidence from Knockcommane is one counter to that suggestion, since the slag-pit furnace lay in the center of a structure.

As mentioned previously, the morphology and size of the structures does indicate that their functions varied across sites. Carrickmines Great was almost certainly a settlement of some kind (Ó Drisceoil 2007). The 3.3m diameter circular structure was associated with a nearby hut and animal pen (Figure 5.9). The iron production activity at this site appears to have been directly associated with the settlement. This type of association has not yet been documented elsewhere during this period. Later in the early Medieval period, there was a move towards more smelting on settlement sites (Dolan 2012),

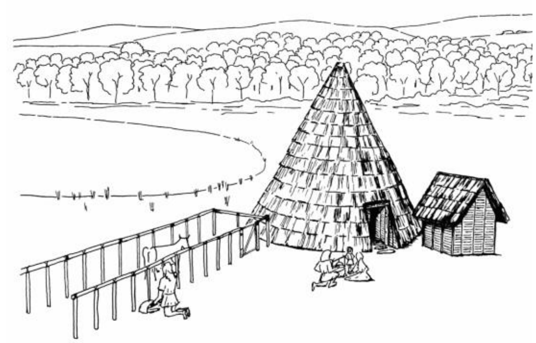


Figure 5.9 Reconstruction of Carrickmines Great settlement (Ó Drisceoil and Devine 2012: fig. 20.14).

but nothing comparable has been identified in the EIA or DIA so far. Since there was only one smelting furnace, it appears the scale of production was quite limited, perhaps only for household use. It is interesting that even if the smelting that occurred on site was for use at the homestead, there is no evidence for primary or secondary smithing. This begs the question, where was the iron bloom that was created on site being processed? It is possible that one of the pits on site was misidentified and was used for this purpose. This type of ad-hoc smithing supports Carlin's (2008) suggestion of the "farmer smith" for much of the iron production in Medieval Ireland. One other possibility is that only smelting was practiced by the inhabitants of these households, and that the bloom still needed to be taken to an expert smith to produce the final iron product.

The two structures at Knockcommane and Derrinsallagh 4 are very similar in size (8-9m in diameter) and construction, consisting of circular slot trenches and posts. The significant difference between the two structures is their associations with iron production. The structure at Derrinsallagh 4 is at the north end of the site and the nearest bloomery furnace is approximately 6m from the structure. In contrast, the structure at Knockcommane was placed around the only furnace on site, suggesting that the structure's main purpose was to protect the smelting activities from the elements. The use of this space for domestic activities seems unlikely due to the absence of typical domestic features, like a hearth, although a glass bead and copper-alloy pin were found in association with the structure (Molloy 2007). Photos-Jones (2007a) has suggested this furnace represents an example of a single experimental smelt that the smelters deemed unsuccessful since part of a bloom was discovered in the gully surrounding the structure. Since this theory was based only on the limited amount of slag recovered from this site, I disagree with this characterization. Most of the sites in this study did not produce the significant slag dumps suggestive of large scale smelting activity. However, the lack of significant slag in all of these cases is likely as much due to taphonomic processes as the lack of smelting slag. If slag is dumped in a shallow pit or simply in a pile on one side of an ironworking area, continual use of the site, in addition to environmental conditions, will disperse the slag over time. Only the slag still in the furnace after its final use or the slag that was dumped back into the furnace would remain behind. Additionally, the furnace remains, such as C397 from Derrinsallagh 4, indicate multiple uses (Young 2008a). Based on all of this, and the absence of economic reasons for constructing a structure around a single-use furnace, the interpretation of a single smelt and abandonment of this feature does not seem plausible. This structure likely stood for at least a season of smelting, although the reason for the structure is still unclear since nothing like it is seen in any other smelting location. While it is possible that a community of people was involved in the smelt, as suggested in one artist's reconstruction (Figure 5.10), the site was definitely part of a larger landscape of occupation with a ring-ditch (Knockcomanne 4700.1a) and more ephemeral settlement evidence (Brackbaun) nearby.


Figure 5.10 Artist interpretation of Knockcommane (©Dave Pollock, Hughes 2015: 47).

The final site that contained a structure associated with ironworking features was Derryvorrigan 1. The structure is a roughly 6.5 x 5m rectangular post structure, with evidence of a hearth to one side. The rectangular shape of the structure deviates from the normal circular roundhouses of the Iron Age. Typically, square or rectangular buildings are smaller and identified as sheds or huts (e.g., Ó Drisceoil 2007; Ó Drisceoil and Devine 2012). It is possible that this structure was used as a temporary residence during the production events at the nearby furnaces. Unfortunately, much of this structure was destroyed during the modern investigation of the bedrock for the proposed road development (Lennon and Kane 2009b), so the limited archaeological evidence available from the structure does not point to a specific use.

Two other sites in this study contained features that could fall into the structure category but appear to have been used for something other than short or long-term domestic occupation. The site of Harlockstown 19 contained one possible rectangular hut structure made up of corner postholes, roughly 3 x 1.5m. The small size suggests this was a temporary structure, perhaps for storage of resources. It also contained a large "sunken floor feature" (F297) whose function has yet to be identified. It had a metalled surface of pebbles and large cobbles that showed signs of repair (O'Connor 2008:41). Multiple artifacts were recovered that rested on, or were incorporated/impressed into the surface, including a copper alloy pit shaft, a bead, and a copper alloy needle. There are no post or stake-holes that would indicate the surface was covered at any point, and there were no other features within the metalled area. However, the surface did produce slag, vitrified fuel ash, and metallurgical ceramic fragments (O'Conner 2008). It is likely that this surface was related to the nearby furnace, but is unlike the working surfaces that surround two of the furnaces at Newrath Site 35.

Another unusual structure found in association with ironworking activity at Rath Site 27 was described as a "steam lodge" (Schweitzer and O'Carroll 2009). Found in direct association with the waterhole that was used from the Bronze Age occupation of the site into the Iron Age, this roughly 3 x 3.2m rectangular post structure contained an external hearth with a flue that led through the structure and to the gully that fed the waterhole (Schweitzer and O'Carroll 2009:29-30). Whether this structure was used as a steam lodge, as the excavators suggest, is still debatable.

However, it is unlike anything I have come across dating to this period[19], and the evidence from the hearth and flue suggests that they were used to heat water (Schweitzer and O'Carroll 2009:76). The radiocarbon date for this feature places it between 370 – 110 cal. BCE, although a late La Tène fibula was found on the terrace associated with the structure.

In conjunction with more unusual structures associated with ironworking, Harlockstown 19 and Rath Site 27 both produced evidence for mortuary activity as well. Harlockstown 19 included one circular ditch feature that was interpreted as a structure, but appears more likely to be a burial ring-ditch. Rath Site 27 contained four ring-dtiches, three of which were in use in the Iron Age. In all, the artifacts recovered from these burials are some of the most numerous found in an Iron Age burial (O'Carroll 2012). In addition, the site of Morett included two Iron Age ring-ditches in association with evidence for ironworking activity. The association between iron production and mortuary ritual is an interesting avenue to investigate that goes beyond the purely economic production of iron objects, and may hint at a more ceremonial or ritualized role of iron production in Iron Age society. The furnaces at each of these sites were not found immediately next to the ring-ditches but up to 60-70m away. I would suggest that the connection between the production activities and burial was not direct, but may have been referential. The smelting of iron could have been alluding to larger belief systems, with mortuary beliefs being part of these systems.

The connection between iron production and the dead was not confined to these three sites. In close proximity to the ironworking evidence at Site B, Ballydavis was the site of Ballydavis Site 1, Co. Laois (95E111), which contained four Iron Age ring-ditches in addition to some iron and bronzeworking (Keeley 1999). The ironworking site of Knockcommane 4700.1b is likewise

[19] It is similar to some Bronze Age examples at Scartbarry, Co. Cork and Rathpatrick, Co. Kilkenny (Hughes 2015).

very close to the ring-ditch at Knockcommane 4700.1a, Co. Limerick, which produced contemporary dates (McQuade and Molloy 2012). Further strengthening a possible connection between burial and iron production, Margaret Williams has noted a few sites with evidence of iron slag in barrows or associated with cremation burials (2010: 33). However, it should be said that without identifying the composition of the slag, it may have been mistaken for non-ferrous slag, specifically slag that formed as part of the cremation pyre. In later periods, the cemetery at Johnstown 1, Co. Meath produced over 400 burials dating from as early as 370 CE to 1665 CE, as well as a large amount of possibly-associated ironworking activity (Clarke 2004). However, as Dolan (2012:177) notes, the long duration of use for this site makes confirming an association between the burial activity and the industrial activity difficult.

Although the association between death and ironworking was not ubiquitous across iron production sites during this period, the connections should not be ignored as coincidental. Iron smelting is transformative; the process converts ore to a bloom. I would argue that this type of transformation is mirrored in the cremation of a human body, where one form enters the pyre and what is left is a different form entirely. Howard Williams (2004) has outlined the transformative quality of cremations, both physical and social. The physical body was altered through the intense heat into something unrecognizable as a person, while in moving through this liminal stage the person was transformed into social memory. Randi Haaland (2008) has also noticed this connection in Northern Europe, identifying iron smelting slags that have been found in several cremation burials along the west coast of Norway. The smelting occurring on these Irish sites were in full view of the ring-ditch/barrow, and if the burial activities were not being performed at the exact same time, they would have at least been known to the smelters. I prefer to think of this production in terms of transformation, as opposed to the reproductive or procreation metaphors suggested by others based on ethnographic accounts. Herbert's (1993) study of African smithing identified a number of reproductive associations with metalworking, from the physical structure of the furnace to prohibitions on the participation in the smelt. She notes the opening of a furnace represented the vulva of a woman about to give birth to the bloom (Herbert 1993:34). Furthermore, in these contexts prohibitions were placed on women attending the smelt, especially during menstruation (Herbert 1993:86). Comparing an ethnographic context in Ethiopia, Haaland (2004:5) also notes that the local terms for tuyères are the same as the male sexual organs, suggesting that the smelt represented a metaphorical sexual intercourse that resulted in the bloom (baby) and the slag (after-birth). Melanie Giles (2007) has adopted these ideas of the metaphorical connections between ironworking, procreation, and agriculture, applying them to the Iron Age British context. Based on the placement of smithing tools in an agricultural pit, Giles discusses the possible associations with various symbolic metaphors in use by the Iron Age British smith. She notes, "Iron Age people may have thought of metalworking and burial as similarly liminal practices, since both were peripheral to settlement" (Giles 2007:405). I would modify this suggestion, highlighting the fact that the liminal aspect is due to the performance of each activity. A cremation or other burial rite is the process through which a body becomes ashes or is interred. Through the process of smelting, the ore and fuel are transformed into a bloom. These processes are liminal stages between the initial input and final output. Each activity represents a period and space that is "betwixt and between" stable forms, to borrow Victor Turner's turn of phrase (1967).

A focus on the transitional aspects of both ironworking and burial can help to understand possible motivations for the proximity of one to another, with a reciprocal indexing of each. I would not argue that smelting is specifically a metaphor for death or the transformation that occurs during a burial ritual, but that the nature of smelting as a transformative process feeds into the same aspect of Iron Age ontology that occurs during cremation. I would argue that transformation played an important role in Irish Iron Age ontologies. The burial ritual can index the transformation that occurs during a smelt by filling graves with slag and resting them atop layers of ash in a barrow (Haaland 2008; Williams 2010:33). Reciprocally, the furnace can index the transformation in death by a location overlooking burial monuments, or more directly by incorporating part of the body into the furnace. Joakim Goldhahn and Terje Oestigaard have noted Iron Age contexts in Sweden where burnt human remains were found within the furnace, even cremated within the iron smelting furnace (2008:224). Through experimental work, Terje Gansum proposed the idea that human bone could have been used to carboranize iron, making steel (2004). He suggests that the smiths or smelters could have 'robbed' out barrows for bones to use in the ritual production of iron objects (Gansum 2004:45). While no pieces of burnt bone have been recovered from any of the furnaces or hearths in this study, a piece of slag recovered from Kinnegad 2 demonstrated an interesting connection to bone. Apatite or calcium phosphate was seen in the glass phase of one of the slag pieces, which led the researcher to suggest that bone could have been used as a source of phosphorous in the smelt (Photos-Jones 2003b:22). This is not to suggest that the bone was human, however, it opens the possibilities for not only a symbolic or ritual component to the smelt, but a technological reason for the association with the dead as well.

It should also be mentioned that possible ritual associations at these Irish ironworking sites are not limited to burial activities. At Rath Site 27, the very unusual "steam lodge" did not appear to have any utilitarian function. Yet in addition to this, two waterholes (F1122/F1223 and F1076) were in use during the iron production and burial phases. In addition to containing a number of well-preserved wooden objects[20] likely associated with the practical use of the waterholes, they

[20] Wooden bowl, a ladle/scoop, a bentwood box, a losset.

also contained large quantities of animal bone. The animal depositions, in addition to the wooden objects, was interpreted as "ritual behavior", to decommission the use of the waterhole (Schweitzer and O'Carroll 2009). These remains may have been connected to some kind of "ritual feasting" that has been noted for other ceremonial complexes during this period (Crabtree 2003). All of these behaviors should probably be viewed in a larger suite of symbolism that maintained the production practices and mortuary rites. And while the exact nature of the steam structure and waterhole deposits are unknown, their use was very likely part of a wider expression of ritual behavior on the landscape. These various non-economic connections to iron production reinforce the idea that what can be viewed as mundane, everyday activity is often situated within a network of symbolic, political, and cosmological behaviors and beliefs. For this reason, it is necessary to remind ourselves that the divide between ritual and non-ritual is an outgrowth of post-enlightenment thought (Bradley 2005; Brück 1999). The technological production of iron from ore may have at once been viewed as the economic manipulation of physical matter with a conception that the cause (smelt) resulted in an effect (bloom), while at the same time acting as a performance of transformation though which the progression of a liminal state indexed parallel concepts of death.

When considering how iron production was organized in Ireland during the first two periods of the Iron Age, it is important to keep in mind that the sites identified during archaeological excavation or survey do not necessarily represent the full picture of occupation of a landscape. As noted in section 4.3.3, even within individual road contracts, a number of sites within a short distance of one another may be given multiple site names and licence numbers, but beg for a broader interpretation of what a "site" means. Based on proximity and chronological contemporaneity, I have identified a group of what I have termed complexes to indicate a likely connection of site-use (section 4.3.3). It is necessary to state that the use of "complex" for these various groups of sites does not mean the same thing for each one. In some cases, complexes of ironworking sites appear to indicate a centralized location of ironworking in Ireland. I would characterize the Ballinvinny North, Derrinsallagh, and Kinnegad Complexes as examples of concentrated landscapes of iron production. The Ballinvinny North Complex (section 4.3.3.1) represents the smallest of these concentrations, containing seven bloomery furnaces over three sites. It remains unclear if these sites represent contemporaneous production within a .9km span, or if they represent the use of that location for production over a short period of time. All three sites only produced evidence for smelting, providing further questions about the activities in this area; perhaps the primary smithing for the bloom recovered from these furnaces was conducted elsewhere along the ridge where the sites are found and was never identified.

The Derrinsallagh Complex appears to have been a very concentrated iron production area, with 53 total furnaces across three sites (Section 4.3.3.2). Located within a little over one km from one another, this complex represents the highest activity of iron production in Ireland during this period. While the one furnace from Derrinsallagh 5 produced an EIA date, the remaining furnaces seem to have been in use mainly during the DIA and possibly into the LIA. Just as with Ballinvinny North, the reason for this concentration of activity is likely too complex to address with the limited information available, but could be due to the proximity to ore and fuel resources. This could also be argued for the Kinnegad Complex (Section 4.3.3.5), which appears to have been a center of iron production during the EIA- DIA transition. What these three examples demonstrate is that perhaps the site is sometimes at too small a scale of analysis to grasp the full picture of production on a landscape, especially when the temporal scale of analysis is, by necessity, measured in centuries. These complexes could be the remains of concentrated activity over a few years of work by a community, or they could represent a longer tradition of iron production in which a community always returned to a particular locale to perform the smelt. In this way the production process was tied strongly to the location, for intimate social reasons or for economic ones (i.e., proximity of resources).

The Ballydavis Complex is an example of a group of sites found in close proximity to one another that demonstrated a wider array of activities in addition to iron production. The site of Ballydavis (95E0111) is within half a kilometer of the ironworking site of Ballydavis Site B. The former was a mortuary landscape with four ring-ditches, in addition to some pyrotechnic activity (iron or bronze production). It may even be suggested that the iron smelted at Site B was then taken for secondary production at the nearby Ballydavis site. The proximity to the mortuary activity may support the interpretation of some iron production as involving more than just economic motivations and meanings.

The Lagavooren Complex (section 4.3.3.6) is a prime example of the intricacy of reconstructing the prehistoric landscape, and the need to look beyond site borders. In the surrounding area of Lagavooren 7, two additional sites with iron production evidence were uncovered[21], in addition to sites with other evidence of Iron Age occupation. This type of pattern is also visible at the sites of Chapelbride 1, Co. Meath and Knockcommane, Co. Limerick. The circular slot trench structure discovered at Chapelbride 4 lay about .5km from the iron smithing area at Chapelbride 1. The overlap of ^{14}C dates strongly suggests that the industrial activity is related to the round house. The ring-ditch at Knockcommane 4700.1a is less than a kilometer from Knockcommane 4700.1b and they overlap in date (McQuade and Molloy 2012). The reason for identifying these complexes is twofold: first, they can help in locating centers of iron production in this period and help to refine research questions to address the reasons for a florescence in a

[21] Dating evidence for these features was either indirect or became available too late for inclusion in this project dataset.

certain location. Second, these complexes reinforce the idea that while the focus may be on one aspect of life, iron production, this activity was not removed from all others, or unconnected to other social practice and networks. Instead, these individual ironworking sites were often used in association with other areas across the landscape.

The sites which have been termed Isolated Metalworking in this dataset, were likely associated with nearby areas of contemporaneous occupation that have not been found or were recorded under different licence numbers. However, the areas of iron production not associated with burials, structures, or some other type of occupation also need to be interpreted. I have argued elsewhere that these isolated sites could be explained by an itinerant group of smiths (Garstki 2016). In her larger discussion of settlements and production in Early Medieval Ireland, Michelle Comber notes that this later period has produced written evidence for the movement of smiths across the landscape and between communities:

> However, in some ways the smith was more privileged than other nobles. The metalworker was, for example, free to move between *tuatha* whereas other craftworkers were not. This may have been to facilitate the transfer of ore, stock and artifacts from one type of production site to another, or to the final consumer. No specialist traders are mentioned in the laws, suggesting the possibility that the smiths themselves undertook the relevant transactions. (Comber 2008:20)

This is not to say that the hierarchical relationships documented for the Early Medieval period were analogous to those 1500 years prior, but that there is some later evidence for the mobility of ironworkers in the region. This remains one possible explanation for a portion of these isolated sites, as is the suggestion that smelting occurred near the sources of ore and fuel and then the bloom, billet, or ingot was brought back to the settlement. How these isolated sites are interpreted is in part dependent on the way in which craft production was assumed to be organized. The idea of a restricted, guild-like access to knowledge of smelting would suggest that only a limited number of community members had the knowledge to successfully smelt, which supports a model of itineracy. In contrast, if smelting knowledge was passed down through families on a generational basis, these isolated sites could have been family or community areas where groups went to access ore and fuel and create an iron bloom. However, as will be discussed below, these two models of production may not be mutually exclusive. The isolated sites with evidence solely for smithing support more of a model of travelling smiths, since access to a source of ore would not have been a requirement for secondary smithing.

The relationship between iron technologies and other forms of social life is demonstrated by the spatial associations between and within these sites. There was only a single site that could be considered a settlement with evidence for iron production, while others contained possible limited use domestic structures. The ritualized connection with mortuary practices constructed a mutual reference system that spoke to larger ontologies present in Iron Age society. Furthermore, the multi-scale approach of this project illustrates that sites may be at times too small of a unit of analysis to fully reconstruct iron production on the landscape.

5.5. Were different aspects of iron production tied to specific topographies and/or locations?

It has been suggested that smelting and smithing were conducted away from one another, and that smithing specifically occurred on hilltop sites or locations with stronger ceremonial connections or associations with burial (Dolan 2012, 2014). As discussed above, the sites which have evidence for associations with burial only produced evidence for smelting. However, the few examples of what have traditionally been known as "high status" sites, Tara and Knocknaulin, each produced evidence for smithing[22]. Yet, overall, there is no direct association between smithing and elevation on the landscape, as seen in Figure 4.34. Many of the isolated smithing

[22] Tara with a smithing hearth, and Knocknaulin with smithing slag.

sites are found on low, flat land, except for the two hilltop sites mentioned above (Tara and Knocknaulin). Unfortunately, many of the isolated smithing sites are devoid of finished iron artifacts that might give some indication as to what was being produced there. At the Ráith na Ríg, Tara excavations, an iron socketed axe was found in the same level as the smithing hearth (Roche 2002). Additionally, the excavations at Knocknaulin uncovered an iron sword[23] dating to the Mauve phase, the last Iron Age phase at the site (Johnston and Wailes 2007). From these limited examples it may appear that smithing was occurring at high status domestic or ceremonial centers, although not exclusively so. The smelting sites were not always in low-lying areas, and were themselves sometimes located on hilltops. For example, the furnaces found surrounding the enclosure at Ballydavid are on the top of a high knoll overlooking a flat plain (Hardy et al. 2010), and the smelting evidence at Derryvorrigan 1 was located on the slope of a high hill, with far-ranging views (Lennon and Kane 2009). What these data may show is that primary smithing was happening at some sites in conjunction with smelting, to provide initial processing of the bloom before it was taken to be formed into an iron object. Most of the isolated smithing sites could have been the focus of small scale iron production, making more utilitarian goods. The smithing that was happening at the "high status" sites could have been more geared towards high-skill items, possibly in association with bronze and gold-working.

The landscapes that appear to have been most utilized for iron production, specifically smelting, were in areas with easy access to ore and fuel resources. Many of the sites in this dataset are currently, or were at the time of their use, within sight of bogs, the likely source of the iron ore being smelted. The physical environment and landscape then seem to have played some role in

[23] Raftery Type 1 (1984); Ryan Type A (1981).

structuring the multiple levels of iron technologies that were practiced during the EIA and DIA, but this relationship not as straightforward as initially thought.

5.6. Technical Practice of Iron Production

The knowledge that was required to produce iron could not have simply been “picked up” or developed by a series of trial and error experiments. At some point it had to be transferred, possibly from Britain, to people in Ireland. As discussed above, one possible explanation for this transfer is the permanent settlement of people from abroad with knowledge of iron production. This idea was prominent during much of the 20th century, tying iron production to the “coming of the Celts.” I have discussed in Chapter 2 the lack of evidence of any such large-scale population movement and replacement. However, we cannot completely discount small-scale movement of people across the Irish Sea, especially if the arguments for the constant connections with the Atlantic Zone are held to be true (c.f., Cunliffe and Koch 2010; Henderson 2007; Waddell 1991). Recent work has identified frequent small-scale movement occurring throughout the European Iron Age (Arnold 2005; Knipper et al. 2014; Scheeres et al. 2013; Scheeres et al. 2014), and to suggest that this was not also the case during the Iron Age in Ireland would be difficult to justify[24]. Another possible explanation for the movement of technological knowledge was through networks of communication, for the purposes of economic exploitation or trade, or to maintain socio-political relationships[25]. To this point, the data do not indicate precisely how the technological knowledge of iron production made its way to Ireland[26], but once the knowledge existed in the

[24] See Cahill Wilson and Standish (2016), and Cahill Wilson (2014) for recent strontium and oxygen isotope analysis of LIA Irish burials indicating movement from outside of Ireland.
[25] A reliance on long-distance exchange relationships that were cultivated by specific powerful members of society that included the exchange of elite markers such as feasting equipment, v-notched shields, and weapons (Waddell 2000).
[26] Although, as discussed earlier in this Chapter, the style of furnace does point to a connection with Britain, possibly Wales.

minds of people within Ireland, it then had to be transferred, maintained, altered, and utilized by Iron Age peoples.

Those involved in iron production, at all levels, may be thought of as participating in multiple but overlapping communities of practice. Etienne Wegner (1998) introduced the idea of communities of practice as a way to think of learning and knowledge transfer in the context of lived experience and participation in wider social networks. This idea allows us to think through how individuals learn behavior, or at least the knowledge to enact specified behaviors, and how the enactment of that knowledge (re)constructs the socio-technological communities. Keller and Keller have suggested that the basis for technical knowledge is dynamic, in that it grows and changes based on the way it is engendered through practice (1996). In other disciplines that study learning and the transfer of knowledge the learning of competence and grasp of concepts may be a major focus, but in archaeology the *practice* of the communities of practice is what is manifested in the evidence. As Dobres argues,

> even when single technicians work alone to fabricate, use, and repair material objects for some explicitly functional end, they are still part of their social community – a collectivity within which they develop their technical skills, learn to value them, and within which they display gestural competence and practical knowledge in acceptable or challenging ways. (2000:128-129)

Following this, the archaeological evidence discussed in this dissertation can point to how communities of practice were organized and overlapped as the knowledge of iron ore acquisition, charcoal production, iron smelting, and iron smithing were transferred between individuals.

The production of charcoal as an activity supporting iron technological activities can be seen as a distinct community of practice, one that would not have necessarily overlapped with those involved in iron production. The data for this project suggest that there were multiple traditions for producing charcoal in various sized and shaped pits as well as possibly in charcoal piles. Since charcoal was not solely used for iron production, the existence of different communities of practice for this activity should not be a surprise. The way to transform wood into charcoal was a practice that was likely transferred within families, so a strong regional pattern would not necessarily be visible in the archaeological distribution of different charcoal pits. Since this knowledge base was not tied directly to the knowledge of how to smelt iron, it is no surprise that the furnace types are relatively standardized across sites while the charcoal pits are not.

The separation of the other communities of practice involved in iron technologies is more difficult. I would argue that those individuals involved in the acquisition of ore were likely the same people conducting the smelt. The exploitation of bog ore, which seems to have been the main source of ore during this period, would have really only required the knowledge of where to find it or how to identify it. The knowledge of a place could have been passed down through generations as one would have to return to a set of locations in order to find iron ore. This knowledge is enacted simply enough, by travelling to the procurement site and recovering the ore. Through consistent action, the knowledge of where to collect iron ore is embodied by the Iron Age person and continues the reciprocal process of knowledge transfer and practice.

The transmission of smelting knowledge within a community of practice would also necessitate a consistent practice that simultaneously demonstrates knowledge and reconstructs the tradition of iron smelting. Practices could have been easily transferred by creating mnemonic rituals or stories to accompany the smelting process from one generation to the next. Similarly, Budd and Taylor suggested that complex metalworking procedures could have been committed to memory through a ritualized sequence, a “spell” (1995:139). These practices are the most archaeologically visible manifestation of the productive processes of iron; remains of bloomery furnaces and the residues from the smelting process provide indications as to how each smelt took place and the enaction of traditional knowledge. The relatively standard use of slag-pit furnaces across Ireland through the EIA and DIA suggests the widespread tradition of furnace construction within a community of practice. The tradition consisted of digging a circular pit in the ground of roughly 35 – 60cm in diameter. The sides of the pit were largely vertical and the bottom was mostly flat. Clay was then used to build a low shaft up from the pit. This structure was then filled with brushwood as a fire starter at the bottom of the pit, followed by layers of processed ore and charcoal fuel. This level of standardization across regions and across time suggests an initial introduction and dispersal of these activities through a single community of practice. There was a mental conception of the technological apparatus for transforming ore to a bloom, and this was transferred through consistent practice of this knowledge. However, the variability within these practices, as evidenced by the different sizes and shapes of pits (or the "unknown" furnace types), suggests that the tradition was far from rigid and that within a larger community of practice that transferred knowledge of how to smelt, there were smaller communities with "space" for improvisation and innovation through choices.

This space for innovation and change is an important aspect of the reconstruction of a technology. If a technological tradition is thought of as too rigid, a structure in which the smelter has no agency, there can be no change occurring in practice. In this hypothetical scenario, the smelter-automaton simply goes through the predetermined steps for how to accomplish this task. The archaeological manifestation of these choices is demonstrated in the variability of furnace sizes and construction. During the event of production, these choices resulted in differences in the fuel and ore that were required, the activities involved in firing a smelt, potentially the work that was required on the bellows, and on the iron yield from the furnace. On a larger scale, the decisions enacted by individual smelters led to a lack of patterning in the distribution, spatially and temporally, of furnace pit sizes.

We can also look to the well preserved furnace, C397, from Derrinsallagh 4 for the archaeological evidence of the smelters at work, and the choices made during the course of a smelt. During the use life of this furnace, the blowhole began to accumulate slag, halting the flow of air into the furnace and causing a dramatic drop in temperature. Using their knowledge of how this smelting technology worked, the smelters were able to diagnose the problem and move the blow-hole to a different part of the furnace. This activity, and innumerable others that were never preserved archaeologically, point to a few different facets of the practice of iron technology during this period. The connection to, and knowledge about, the technologies of iron production was far from simplistic. The smelt was not only a prescribed activity carried out by following a strict framework and contained by a tradition learned in a community of practice, but there was a deep conception of why the smelt worked and what was happening within the bowels of the furnace. I would argue that technologies in general, and iron production in this context particularly, are characterized by a constant dialogue between tradition and innovation. Each is enacted through technological practices, but takes a different avenue within a community of practice. Traditional practice continues the community of knowledge, maintaining the knowledge that was passed on and is enacted through these activities. Innovation alters the knowledge bases from which a technology is enacted, building a new set of knowledges from which to create an iron bloom.

Changes in a suite of technological practices can arise from internal experimentation or from external ideas. Even if the innovation is economically beneficial, the existing structures within a social system may not allow it to proliferate (Hjärthner-Holder and Risberg 2009). In the case of the use of the arched slag-pit furnace, this idea appears to have come from abroad. While the dating evidence is still somewhat ambiguous, it does appear that these furnace types were a later development in iron smelting, but limited to the central part of Ireland (Figure 4.18). The community of practice within which this knowledge was shared seems to have been more narrowly focused on the construction of furnaces within a restricted region. The change in knowledge that would have been needed to construct this different furnace seems minor, but it would have had larger implications for the practices involved in iron production. The addition of an opening at the side of the furnace from which to remove the slag and bloom helps in the re-use of a furnace, allowing for limited construction time when multiple smelts are necessary. The attached working-hollow could have also been used to work the bloom in an additional set of activities to remove slag from the metallic iron. However, it would have also created a cooler zone within the furnace immediately next to the opening, even when it was plugged up (Young 2008a). Thus, an alteration in the initial knowledge base within the community of practice for how to create a furnace ultimately affected how individual actions played out during the course of a smelt.

The production of an iron object from an iron bloom proves more difficult to reconstruct based on the available evidence. Some of the final products, especially in the DIA, demonstrate a level of skill that seems likely only for full-time smiths. If this was the case, the community of practice for smiths must have been smaller and possibly more technologically conservative. However, the part of production where metallic iron is worked into a sword or axe could provide some of the most enticing locations for innovation and improvisation. Building on a technical knowledge base to create an iron sword, the way the iron is heated, hammered, quenched, and shaped all allowed for an individual to impart their choices. These activities are the intersection between the metal conception of a form, and the embodied practices necessary to bring that form into the physical realm. Charles Keller highlights the “playing out” of the conceptions originally held in the mind of the practitioner (2001:37). He notes that through experience, the practitioner learns the physical back-and-forth between actions and the object to the point where it becomes automatic (Keller 2001:38). Yet during this process, decisions are being made to manage the push-back from the physical form and complete the desired task.

So it was not solely the mental conception of technique and the activities that were enacted by the smelters and smiths, but the physical properties of iron that impacted how these technologies developed. As Conneller (2011) so perceptively outlined, we need to collapse the constructed dichotomy of concept and object in order to identify the complexity of technological practices. There were physical properties of iron that had profound influences on the way techniques of production were performed and the way in which conceptions of form were articulated in the metal. In turn, socially constructed practices were enacted on the material properties of iron. In the case of the Lough Mourne looped socketed axe discussed above, the smith used a technique to harden the edge by carburizing one end. It was the smith's knowledge of this physical property and chemical process, as well as choosing to perform these actions, that led to carburization. Conversely, the act of hardening the cutting edge could not have occurred if iron did not possess chemical properties in which hardness increased with the addition of carbon. The smith's actions were a negotiation between the physical aspects of iron, the shared knowledge of iron production techniques, and a conception of the final form. This negotiation occurred in the event of iron production, one in which the form of a looped socketed axe came into being through embodied practice and an engagement between the smith and the material. Though carburization is possible because of the properties of iron, it only actually occurred because the smith engaged in practices that themselves afforded this property of iron to be manifested. Through the technical practice of the smith, the physical properties were at once responsible for and a product of the social embeddedness of ironworking.

In the production of iron, the material was not simply a passive recipient of the productive activities of ironworking. Nor were the smith's actions fully determined by the physical affordances of iron. It may be difficult to say archaeologically what the mental template for production of any particular object was, though it is also a mistake to think it did not influence the way production occurred. In turn, a focus on the significance of the material itself in shaping these practices should not ignore the sociality of the physical affordances involved. The interaction with the iron material during production was negotiated by a specific smith, in a specific context – at other times and during other interactions, different individual engagements led to alternative outcomes or alternative forms of iron objects.

Yet through the myriad negotiations between physical form and metal conception, and between traditional practice and innovative action, these communities of practice that shared in the central knowledge base for how to smelt or form an iron object also overlapped with shared cosmologies and systems of meaning. I discussed above the possibility that the location of smelting furnaces indexed the same liminal, transformative qualities as cremations and the mortuary performances of the time. The existence of multiple levels of meaning during iron production, outside the purely utilitarian sphere, seems clear. However, one mistake that may be made by presuming iron technological practices are metaphors for other activities (e.g., burial, agricultural plowing, reproduction) is that it places the technology outside of the social; it suggests a model where technology was "outside looking in" at the social networks and embedded meanings in other social practices, and that by referencing these ironworking gained meaning. This approach seems to run counter to the consistent theme in recent anthropological approaches to technology that insists technological practices *are* social practices (Dobres 2000; Schiffer 2011). Instead, I would suggest that the meaning and non-economic associations indexed or created during production worked within a social system that references them as much as they reference other aspects of social life. Lechtman (1977, 1993) and Dobres (2000:100-104) have highlighted how technological practices and the products created from them work to materialize and express shared ontologies. The transformative qualities of iron are not important because they are similar to cremation, but because transformation itself was a powerful concept in Iron Age ontologies. In this way, both mortuary practice and iron technologies draw meaning from larger social ontologies, rather than borrowing meaning from one other. By viewing technology in this way, the practices involved in iron production can be seen as social practice with distinct motivations towards economic goals, mediating the intersection of choice and structure, and influencing wider ontological conceptions. Individuals in Iron Age Ireland then enacted iron technologies within a series of distinct but overlapping communities of practice.

5.7. The organization of iron production during the EIA and DIA in Ireland

During the 8th or 7th century BCE, the knowledge required for iron production made its way to Ireland from abroad. This may have come in the form of people settling in Ireland from Britain, or from individuals travelling outside of Ireland learning the skills of iron smelting and returning home to share that knowledge. Dating the initial adoption of these technologies is difficult; the 2 sigma ^{14}C dates provide a wide possible range of dates, meaning that any of the EIA furnaces and hearths may have been used either at the beginning of that period or towards the end of it. Yet, as limited as the data may be, I would argue against the assertion that the EIA in Ireland was a period of "iron use" as opposed to "iron production" (Becker 2012b:9). The sites with direct ^{14}C dates taken from furnaces and smithing hearths demonstrate that at least at a small scale, the knowledge required for iron production existed in Ireland during the EIA, and people were smelting and smithing iron. Production increased over time, as evidenced by the higher numbers of furnaces dating to the DIA and into the LIA. Throughout the EIA and DIA, the main type of furnace in use was the non-slag tapping slag-pit low shaft furnace. During this period, an altered form of this furnace began to be used that featured an arched opening for cleaning out and reusing the furnace. A focal point for the technology appears to have been in the center of the island in the central-lower part of the midlands. This is likely where the knowledge for iron production first appeared in Ireland (Figure 4.16), where initial technological innovation occurred (Figure 4.18), and possibly where most of the smiths were active (as indicated by the presence of smithing hearths [Figure 4.22]).

The data point to an organization of iron production that is far from simple or straightforward. It is perhaps naïve to presume that a single model of production could account for all of the activities that constituted early iron technology in Ireland. The data from this project suggest there were multiple levels of production occurring during the Iron Age, with different groups of society involved at different stages. Based on the available data from these sites, there were at least three levels or types of iron production occurring during the EIA and DIA in Ireland. In one sphere, I see evidence of small family or community production that would likely have involved small scale smelting and simple smithing with the intention of creating iron products to be used in a domestic sphere, such as nails or simple tools. This type of activity is represented by the production at Carrickmines Great or even some of the production occurring in connection with ritualized activities like burial. These small scale production sites without evidence for primary smithing on site may have also been part of this mode of production, where family groups were only responsible for the smelting and passed the iron bloom on to a dedicated smith for further working. It is important to remember that the knowledge base for each of these stages of iron production is quite different, and it should be no surprise that individuals who had knowledge of how to create a bloom could not necessarily have shaped that bloom into a sword or agricultural tool. A reference to the possible importance of blooms prior to being shaped into their final form may be found in the 11th century Irish *Lebor na Cert* (Book of Rights), where a tribute to the Connacht dynasty included “seven times fifty blooms of iron” (Scott 1990:176).

Another type of production is represented by the unattached, more specialized smith, active at the small isolated smithing sites, and/or at the larger smelting sites. This type of organization could have revolved around itinerant smiths, or local smiths working on material for the immediate community. It is true that none of the EIA or DIA sites compare to either the contemporary concentration of production in Britain (Cleere 1984; Paynter 2006, 2007) or in Ireland during the Early Medieval period[27] (Clarke 2004; Wallace and Anguilano 2010; O’Sullivan et al. 2014). However, it can be argued that the Derrinsallagh Complex (section 4.3.3.2) or even the Kinnegad Complex (section 4.3.3.5) should be considered centers of production. If these areas were the product of itinerant workers, the sites would have been consistently revisited over time to produce the large numbers of furnaces in use at the Derrinsallgh Complex. These concentrations of ironworking activity surely speak to a more intensive scale of production than previously thought, even if the evidence is not on the scale of later production in Ireland.

A further subset of iron technologies taking place during the EIA and DIA involved more valued or prestigious goods. The smithing activity at Tara seems to have been connected not only to the ceremonial and high value aspects of the site, but was likely conducted by smiths who were also engaged in bronze-working and potentially glass-working. These activities taken together are

[27] Johnstown 1, Co. Meath produced ~2,000kg of slag and Lowpark, Co. Mayo produced ~1,365kg of slag.

highly suggestive of the presence of specialists. This association may also be indicated at Ballydavis Site 1 (95E111) and at Knocknaulin. These smiths could have been tied more directly to a high status family or individual who had the resources to provide not only the material used in these technologies, but to support the craftsperson as well, as a so-called “attached specialist.”

Through this multi-scale organization of production, many people in Iron Age Irish society would have been involved in the production of iron to some extent. We can look to later texts as a possible explanation for the different groups involved in production, as the *Blai Ord Indeoin* tract, which suggests smiths during the Medieval period were organized in a tripartite hierarchy of master-smith, smith, and apprentice (Comber 2008:122; Scott 1990). At the household level of production, which included the collection of ore, making of charcoal, and smelting small amounts of iron, the technology was deeply embedded in the social fabric of the family, similarly to the production of ceramics in many other prehistoric contexts. The next scale of organization involved larger smelting centers like the Derrinsallagh Complex or isolated smithing sites, which was likely manned by the community smith or an itinerant worker. Last, the most impressive iron pieces were produced by dedicated smiths, attached specialists who were associated with a high status individual or group, and likely were also responsible for other forms of metalworking. These communities of practice that characterize the way iron technologies were organized during this period are supported by the current evidence of iron production sites. Yet secondary evidence, such as possible patterns of deposition of the final iron objects and the spatial association of production practices and other forms of social life, provide other avenues for understanding how deeply embedded these technologies were in Iron Age society.

The non-production practices by the Iron Age Irish played a part in the lack of dateable iron artifacts; all but two iron swords (Knocknaulin and the burial at Lambay Island) were found in wet sites (Cooney and Grogan 1994:197-198; Johnstown and Wailes 2007:89). The purposeful deposition of metal objects in irretrievable wet contexts, a behavior stretching far back into the Bronze Age, is partly responsible for the poor preservation and lack of datable contexts of many of the iron swords. The lack of preservation impedes any attempt to reconstruct the impact of these technologies on Iron Age society, as it suggests that there were fewer iron products in use than there probably were. However, it also suggests that iron objects fit into the category of things that were worthy of ritual deposition, which illustrates their importance in this period, and by proxy the importance of their production. Other non-production practices also speak to the embeddedness of the iron production process. The transformative process that occurred during an iron smelt indexed the transformative elements of cremation, sometimes occurring at the same site or within view of a barrow or ring-ditch. These activities were carried out in conjunction with other ritualized behaviors, as evidenced by the presence of the 'steam lodge' and waterhole at Rath Site 27, Co. Meath.

Iron production played a complex role within Iron Age Irish society, at different scales and likely changing through time. There is no direct evidence that the emergence of iron technologies caused a drastic upheaval in the organization of Irish society. Richard Bradley suggests that because iron was so widely available, its processing and production could occur locally, and it would therefore have been difficult for regional elites to control (2007:232; see also Champion 1989; Ehrenrich 1995; Geselowitz 1988; Scott 1990; Waddell 2000). If this was the case in Ireland, the archaeological evidence has yet to demonstrate how this played out through the EIA and DIA, aside from the lack of archaeological evidence that has always plagued these periods. Becker (2012a) has suggested that there does seem to be some correlation between the development of iron use in Ireland and the change in certain LBA practices, such as the use of hillforts, metal deposition, and the use of pottery. The falling out of Ireland from the Atlantic sphere of interaction during the Iron Age, as Henderson (2007) has suggested, may have also played a role. However, the appearance of iron technology and subsequent innovations did make their way to Ireland, indicating that the posited breakdown of high status connections abroad does not seem to have stopped all interaction. Henderson does note that the symbolic relationships developed in the Bronze Age could have continued into the Iron Age through the exchange of ideas (Henderson 2007). It is interesting to note that the concentration of iron production sites identified in this project somewhat align with Henderson's different spheres of interaction between 600 – 100 BCE (Figure 5.11). Whether this map reflects the nature of Iron Age connections in the Atlantic can be seriously debated, but it is clear that in Ireland, iron technologies remained relatively static through these periods, more due to the lack of economic motivation for change than the lack of knowledge of other techniques.

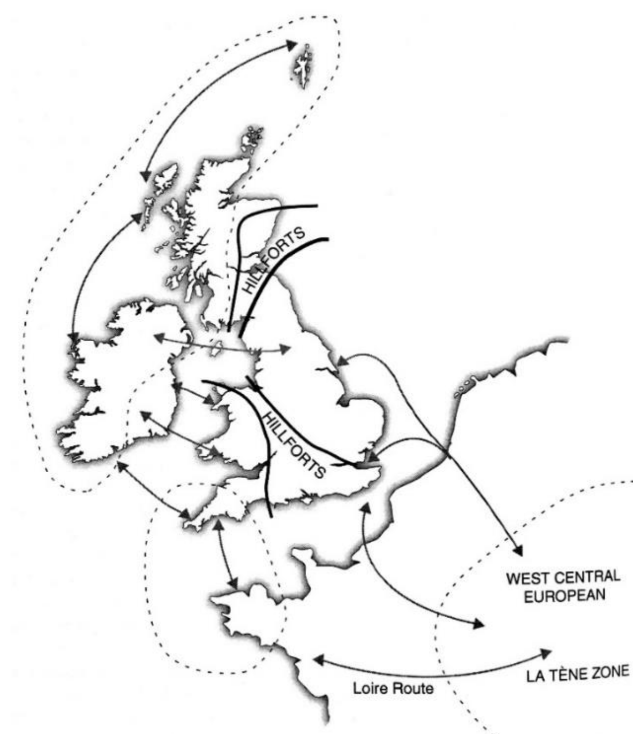


Figure 5.11 Spheres of interaction during 600-100 BC (Henderson 2007: figure 7.1).

The results of this project have provided a strong basis, both in content and methodology, on which to continue expanding our knowledge of Iron Age Ireland. The final chapter will address the impact of this project on the wider scope of Irish Iron Age archaeology and the distribution of archaeological data in the future. It will also provide suggestions for the ways to expand this project for future research in order to continue building the reconstruction of this still enigmatic period.

Chapter 6: Conclusion

6.1. The impact and significance of this data for the reconstruction of IA Ireland

It was only 20 short years ago that much of the archaeological record for the Irish Iron Age was made up of a handful of "royal sites," well preserved trackways, and largely unprovenanced La Tène style metalwork. As discussed at the onset of this dissertation, the lack of diagnostic site types, the apparent absence of pottery, and the minimal burial evidence provided archaeologists with a larger question than the evidence answered: where were the people in the Iron Age? What changed in the interim was a major influx of archaeological data bolstered by an ambitious program of radiocarbon dating which has finally shed additional light on Iron Age peoples throughout Ireland. Since this time, some research has been synthesized to use these new data to expand the knowledge of this period and further illuminate the everyday lives of the people who lived there.

When there is such a large influx of data in a short time, it is often difficult to process the more nuanced details, especially when the project focus is on large-scale survey or the compilation of data derived from rescue archaeology. Unfortunately, this can lead to a superficial understanding of the impact of certain new data due to the time constraints of dealing with such a large dataset. Previous projects that synthesized the new data on the later periods in Irish prehistory did a fine job of summarizing much of this information and provided a basis on which to build a stronger reconstruction of the period. However, when archaeologists are essentially attempting to reconstruct an entire period of prehistory in a single decade, which elsewhere in Europe was accomplished in over a century of scholarship, a nuanced approach is a challenge.

One of the main goals of this dissertation was to take one aspect of Iron Age life and approach it using a multi-scalar, in-depth analysis, where full excavation and specialist data were recorded and processed to draw broad conclusions. This approach to different aspects of Iron Age life has produced a more robust reconstruction of the period, specifically as it relates to the exploitation and production of iron. Through this approach I have identified specific patterns of production, and attempted to interpret the reasons for the absence of patterning. Building on excavation notes and specialist reports, I was able to identify the use of slag-pit furnaces across the country, further providing evidence against the proposition that bowl furnaces were used in Irish iron production. Furthermore, the identification of arched slag-pit furnaces at multiple sites, following Tim Young's (2008a) initial identification of this type, has expanded the technological repertoire for reconstructing iron production during this period.

My discussion of the various communities of practice responsible for the production of iron contributes to a larger conversation about the organization not just of ironworking but of Iron Age society in Ireland. As discussed in Section 5.7, there appears to be multiple levels of production occurring in this period, from the household level to the level of the specialized, high status smith. These different modes of production required different but intersecting knowledge, and would have relied on varying social relations for their maintenance. The various overlapping and nested communities outlined here demonstrated a more complex organization of production than expected, one that was not isolated from the rest of social life but integrated within it. This concept of multiple communities of practice could be applied to other areas of Iron Age life to identify patterns of learning and behavior. The behaviors associated with iron production occasionally included non-utilitarian practices that may have suggested a mutually referential system of meaning and symbolism linking economic production to larger ontologies. A focused study such as this thus provides evidence that speaks to larger aspects of Irish social life not otherwise considered in the realm of production; iron technologies provide a lens through which to view community networks and Iron Age ontologies.

This project also has ramifications for reconstructions of the connections across the Irish Sea. The identification of technological trends in iron production highlight the similarities with other smelters and smiths outside of Ireland. The use of slag-pit furnaces, and variations on this form, demonstrates that the knowledge of more advanced techniques existed in what was once thought a “primitive” use-zone for this technology. The suggestion that Ireland “fell out of the Atlantic Zone” presumes a relatively simple or fragile network of interaction, where changes to one aspect of social life in Ireland could cause a retraction from other economic, social or political networks. The connections throughout the Atlantic Zone appear to have been more complex than originally thought, and the evidence suggests that ideas at least were moving across the Irish Sea.

The introduction and use of iron technologies, arbitrary as it may seem to designate a chronological period based on this phenomenon, did have an impact on the societies that adopted them as well as the individuals that took part in its production and used iron products. The precise impact that the use of iron technologies had on LBA communities and on larger economic or political networks in Ireland is difficult to determine. Unfortunately, the temporal resolution in the entire Iron Age, but specifically in the EIA, is still not precise enough to identify specific changes at the beginning of the period that might indicate a disruption in previous structures. Once again, absence of evidence is not necessary an indication of what was happening at the time. When the EIA was characterized as being populated by the “invisible people” (Raftery 1994), it was suggested that people lived mobile lifestyles that left little trace. However, as more settlements were identified it seemed clear that Iron Age peoples may have just been leaving archaeological evidence that we have not been looking for. The remains of these settlements are typically beneath the topsoil, and characterized by different deposits that are often only identified after stripping of the topsoil. Therefore, unless geophysical survey data are obtained, or there is a specific reason (like a road project) to remove the topsoil, the majority of remains from this period may not be identified. This is in contrast to some of the more visible uses of the landscape in the LBA or Early Medieval period and explains the emphasis on "royal" sites before the mid-1990s, where above-ground features dominate.

The significance of this dissertation for the reconstruction of the Iron Age therefore rests on its contribution to a small but growing body of data. As the behaviors and structures of one aspect of social life are explained and expanded upon, the impacts on the larger reconstruction can be identified. Demonstrating that iron production was embedded within the rest of Iron Age life provides additional data for reconstructing aspects of mortuary behavior, settlement patterns, ceremonial practices, and other economic or political networks.

6.2. The Archaeology of Technology

As mentioned at the outset of this dissertation, because of its emphasis on a long time scale, archaeology represents an ideal juncture for investigating technological development and change over time. The material focus of the discipline reinforces the concept that all technology is social, and that what archaeologists study is the enactment of technological practice in a larger social context. Through the trajectory of this project, it has become clear that archaeological time depth can be both a benefit and a hindrance to a nuanced study of technology in a prehistoric context. Rarely do archaeological contexts that are built upon radiocarbon dates present a tight enough chronology to address technological change from smelt to smelt or year to year. In the Iron Age Irish context, we are presented with two time scales that can be reliably identified: the individual production event, and the long term measured in hundreds of years. While the middle scales of time could perhaps be demonstrated at individual sites or looking across sites, the reliability for that chronological ordering is much lower.

Yet, despite this drawback, this project was able to speak to larger issues of technological practice and the embeddedness of technology in society. Iron technology provided a set of ideas for manipulating a raw material for use in social contexts, made manifest by a set of learned behaviors. Using this approach, I was able to address the individual production methods and the choices made during the smelting process, and to a lesser extent the evidence for smithing processes. Unexpectedly, the data did not seem to reveal significant technological change over time in smelting. However, the limited change over these 800 years says just as much about the nature of these technologies and Iron Age social networks as would measureable change through the Iron Age. Stasis, like change, indicates that significant structures and connections were in place to maintain a technological conservatism. This project demonstrated that technological change does not always have to occur over a defined period of time, but it is then necessary to reframe the research questions about why it did not.

Too often a discussion of technology in an archaeological context creates an artificial divide between the material culture and the social processes surrounding technological production. Yet technology is always an active interplay between the physical and the social. The material remains found in an archaeological context reflect patterns of production and practice, but at the same time this physical material structured and informed the techniques that produced them. This dialectical relationship can be demonstrated in the production of iron in both the smelting and smithing processes. The furnaces used to smelt iron ore were constructed to utilize the material properties of the ore by heating it in a specific way. In turn, an iron axe was constructed using specific techniques that were dictated in part by the physical properties of the iron. Viewing technology in an archaeological context in this way highlights the complexity of what goes into a productive process: physical object, mental conception, social tradition, individual choice, networks of learning, economic pressure, ritual ontologies, and practice.

6.3. Open Data

Ireland, like most other parts of the world, has a data access problem. Archaeological research cannot move forward without access to archaeological data that either will never be published or have only been published in rarely accessible formats. The fast pace at which archaeological data were recovered during the last 20 years has made it very difficult to conventionally publish much of the resulting material. That, coupled with the fact that many of the sites uncovered during the NRA or other infrastructure projects were sites not well suited for individual publications[1], has led to a lack of access to much of the new archaeological evidence available. With that said, there are some excellent open access resources available for the study of Irish archaeology. Excavations.ie is a database of Irish excavation reports hosted by the National Monuments Service, Department of Arts, Heritage, Regional, Rural & Gaeltacht Affairs. It works in conjunction with the *Excavations Bulletin,* which is a compilation of every licensed excavation for the year that was published annually from 1970-2010, at which point summaries were provided only through this online interface. This database is rather unique in the discipline for its wide-ranging scope and open access, although the summaries of excavations are limited due to the timeline in which they are published; they are compiled before any major scientific analysis is carried out, meaning even ^{14}C dates are usually absent. The Mapping Death project[2] is another

[1] I.e. sites with only a few features, pits, single furnaces or hearths, etc.
[2] http://www.mappingdeathdb.ie/

excellent example of providing large amounts of synthesized data, focused on a specific topic (burial from the 1st to 8th centuries AD).

Gaining access to actual excavation reports, with detailed information on the features, specialists' reports, and artifact information, is more difficult. To access unpublished site reports in person, one must visit the Archive Unit of the NMS, and no copies can be made of the reports. The publication of findings from NRA road contracts sometimes includes supplementary files with the excavation reports, although this is not always the case. I was fortunate enough to be able to gain access to most of the excavation reports identified as early iron production sites through the TII and from contact with individual consultancy companies (see Chapter 3). However, there were still some sites that I could not fully access, mostly due to the fact that the archaeological consultancies that conducted the excavations were no longer in existence. In those cases, only minimal information was available to analyze the site, and was therefore not reliable enough to warrant use in this study. This leads directly to a discussion pertinent to archaeological research throughout the world: who should have access to archaeological data, and at what level of detail?

On one side of the discussion is the argument for relative ownership of the archaeological data that one excavates. When funding and intellectual property, in the form of archaeological interpretations, are at stake, there is a legitimate concern about making data freely available to researchers and the general public. The basis for institutional rewards rests largely on traditional publication (Fitzpatrick 2011), at the expense of other, more open access platforms for publication. Eric Kansa has noted that alternative publication models, including open access publishing services or digital data repositories, are not given substantial weight in the tenure system (2016:447). This institutional pressure hinders movement in the direction of more open data publication. On the other side of the discussion are proponents of open data, who argue that archaeological data should not be under the sole control of one group. In general, the discipline is beginning to move in more open directions, utilizing data archives, repositories, and publishing services like Open Context, tDar, or the Archaeological Data Service.

There are advantages and drawbacks to a number of the existing models and organizations that attempt to deal with open data (Kansa and Kansa 2013). In the case of the sharing model of a website, the archiving aspect of the data may be limited. As with the webGIS site created for this dissertation, the GIS data are stored through a University of Wisconsin-Milwaukee server, specifically set up for webGIS projects. The longevity of these data may be at risk once I am no longer affiliated with the University, at which point the data may have to be migrated elsewhere to still be of use to researchers. In more advanced archiving or data publishing services, there is often a problem with the interface for data usage. For example, in Open Context, GIS data need to be downloaded and used on one's own computer. This limits the usability of the data because it is still constrained by the knowledge of GIS software and datasets[3].

The Early and Developed Iron Age Ironworking in Ireland webGIS interface[4] created for this dissertation project is a small attempt to both rectify some of the data access issues, and develop one productive avenue for presenting multi-scale data. The model was borrowed from the NMS Archaeological Survey Ireland's own webGIS database produced for all of the NMS recorded sites, the Historic Environment Viewer[5]. However, the main difference between my dataset and the ASI's is a stronger focus on the spatial component of the archaeological excavations. The webGIS database designed for this dissertation works on two scales: the first is the inter-site scale, and the other is the intra-site scale. The Ironworking Sites layer contains

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[3] However, it should be noted that the goal of Open Context is to publish the data, not necessarily to make it usable on the web interface.
[4] http://webgis.uwm.edu/kgarstki/test/
[5] https://www.archaeology.ie/archaeological-survey-ireland

information on the entire site, including the presence of smelting or smithing, the ^{14}C dates, and references used for the data. Then, the individual site layers contain feature information. The intention is that this approach will expand the type of analysis that can be conducted on the data, as opposed to merely presenting the site-level data.

The platform used to create the interface produced some limitations on what I could or could not do. Ideally, the brief descriptions that were written for the Access Database in this project (also in Appendix A) would have been included in the Ironworking Site layer. Unfortunately, there is a character limit for any field entry in ArcGIS, affecting what could be included in this database. This impacted the amount of text that was included in this dataset, making it less useful in that respect as compared to the Mapping Death database. The functionality was also partially limited by my own inexperience using the WebApp Builder. With more time spent learning the intricacies of the various functions available for this interface, there is no doubt that data presented in this way could be more dynamic and substantially more useful for analysis.

The presentation of these data in an open way provides a model for one aspect of the sharing and publication of future archaeological data. One potential model for future data access is in the form of Linked Open Data, where individual aspects of the excavation data exist as discrete digital objects, which are then all relationally linked together. In the model of Wikipedia, Linked Open Data takes existing website database structures to create an archaeological-specific model of data creation and sharing (Isaksen et al. 2010; May et al. 2015). This model of open data is particularly appealing because it spreads the onus of archiving and maintenance across institutions and allows new datasets (such as this dissertation webGIS database) to be continuously integrated into the larger collection of data. The ARIADNE research infrastructure[6], of which the

[6] http://portal.ariadne-infrastructure.eu/about

Discovery Programme of Ireland is a part, is one example of this type of linked open data structure. Part of the presentation of data includes the spatial elements of archaeological sites, and this type of platform provides a useful and interactive interface for the data. In the Linked Open Data model, each individual archaeological feature contains its own data, in addition to linking it to the larger site data. In the future, it would be ideal to expand this to include links to the excavation report itself[7] or other publications of the site. It could also be further linked to individual artifact records from pieces recovered from the sites. Currently, I see the need for more detailed research on the Iron Age in Ireland linked directly to the issue of access to data. Nuanced and detailed analysis of the period cannot be conducted if there is no easy access to existing datasets.

6.4. Future Research

This project has contributed to the larger picture of the Early and Developed Iron Age in Ireland, as well as providing more substantial data for the practice of iron production during this period. However, there is still much that could expand this research that could not be done in this dissertation, either due to constraints of time or availability of data. To begin with, the somewhat arbitrary chronological distinction between the DIA and LIA was used to limit the scope of this dissertation. This project could be expanded to included LIA sites as well, in an effort to investigate more fully the concept of technological change through time. Unfortunately, the chronological scale used for this dissertation, in addition to the nature of the archaeological data, was not necessarily sufficient for identifying long-term technological change in iron production practices. Sites such as Caherweelder 7, Co. Galway (Hegarty 2010) Cuffsborough 4, Co. Laois (Murphy 2009), Knockbrack, Co. Kerry (Hull 2005), and Shallon, Co. Meath (Russell and Corcoran 2001)

[7] The TII are developing an open access database of their project excavation reports (Michael Stanely *pers. comm.*). The webGIS interface is in the beta phase, and is being undertaken in collaboration with the Digital Repository of Ireland and the Discovery Programme.

could be added to this dataset to expand the temporal scale by 50%. In addition to expanding the scale of the study to look for more expressions of production change, the inclusion of LIA sites would provide an interesting research question about any potential technological change identified: how much did connections with Roman-Britain impact the iron production methods in Ireland? Cahill Wilson (2014) has suggested that the interactions between Ireland and Roman-Britain were far from superficial or "intrusions." The model of infrequent Roman "intrusion" into Ireland no longer seems tenable. It would therefore be important to trace these connections through other areas of social life, including the production of iron.

Another obvious option for expansion of this project would be to continue to gain access to reports or minimally published sites that were not available for this dissertation. As noted in the above section, access to original excavation reports that were never published can impact the scale and scope of any Iron Age research project. Additionally, new excavations are being completed and published all the time. One sites, Moyle Big 1, Co. Carlow, where two slag-pit furnaces dating to the DIA – LIA transition were identified (Bolger et al. 2015:43-44), was only found during the final write-up of this dissertation. With the development of the open access webGIS interface by the TII, the Digital Repository of Ireland, and the Discovery Programme, access to these data will be exponentially easier. A close review of previous excavations may identify features that were misidentified in the field, or were not dated until recently. Sites that may seem small or ephemeral may actually have played a role in ironworking, making a more robust reconstruction of the period and of ironworking specifically possible.

One suggestion for future excavations is to treat the slag identified in the field with the same protocols that are applied to artifacts. Since much of the slag collected during the road scheme projects represented "samples," once analyzed they were often discarded. This negates the possibility for any future examination, such as double checking results provided by the specialist employed by the contract firm. Additionally, by collecting and curating a representative sample of slag, the entire assemblage is not always analyzed. As documented in this dissertation, as well as many of the sources cited, slag can provide significant insights into the production processes of a smelt or techniques utilized by the smith. Further data of this kind can only help in expanding the knowledge of ironworking in the Ireland.

With these different avenues for future research and expansion on this dissertation project, some specific research questions come to the fore: how were Irish iron technologies impacted by the interaction with Romano-British peoples? Did iron smelting techniques remain relatively conservative into the LIA and eventually the Early Medieval Period? What can additional analysis of the slag recovered from new Iron Age production sites tell us about the techniques employed by smelters and smiths, and what types of resources were being exploited during these periods? In addition to these areas of expansion of this project, it would be fruitful to expand the geographic range of this analysis to extend to other areas of the Atlantic Zone. Iron technology was almost certainly brought into Ireland from outside the island. I have suggested in this dissertation that there may have been a stronger connection to parts of Wales, which may have facilitated both early introduction of the technologies used as well as subsequent innovations. It may also be possible to look for similarities or differences in production techniques in Scotland, Armorica, or north-west Spain. This extended geographic comparison could provide insight into the networks of communication and technological back-and-forth occurring throughout the Iron Age along the Atlantic.

In the larger scope of Iron Age archaeology in Ireland, I have noted above that to continue to expand the knowledge of the Irish Iron Age, smaller, more nuanced studies of different aspects of social life should be conducted. As we continue to develop individual approaches to life in the Iron Age, the entangled nature of society in this period will become more clear and provide a more robust picture of the era. Following this, expanding the program of data sharing will do much to allow more detailed and data-oriented interpretations of the past. And since any future projects would likely develop discrete datasets, a model for Linked Open Data could be a powerful approach to connect these data in new ways.

This dissertation project contributes to the question of how people in the Early and Developed Iron Age organized iron production in Ireland. It provides a data-driven foundation on which to build in future years, as more data about the production of iron is uncovered. It also fills in some of the gaps in the reconstruction of Iron Age society in Ireland, beginning to make Iron Age people more visible in the archaeological record.

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2008b Evaluation of archaeometallurgical residues from Cloncollig 2, Co. Offaly NTB06, A033/E2850. *Unpublished GeoArch report 2008/09.*

2008c Evaluation of Archaeometallurgical residues from Clonrud 4, Contract 3, M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme. *Unpublished GeoArch report 2008/30*.

2008d Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derrinsallagh 4 (E2180). *Unpublished GeoArch report 2008/23.*

2008e Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1 (E2193). *Unpublished GeoArch report 2008/26.*

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2009b Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derrinsallagh 5 (E2181). *Unpublished GeoArch report 2008/24*.

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2012b Evaluation of Archaeometallurgical Residues from the N7 Heath-Mayfield Motorway Scheme: Site L (03E0602), Lughil, Co. Kildare. *Unpublished report.*

Appendix A: Site Summaries

Site Name: Ballinvinny North AR26

County: Cork

Licence Number: 01E0501 AR26

Townland: Ballinvinny North

ITM East: 574162.281

ITM North: 580161.978

Excavation conducted by

Smelting: Yes **Number of furnaces:** 1

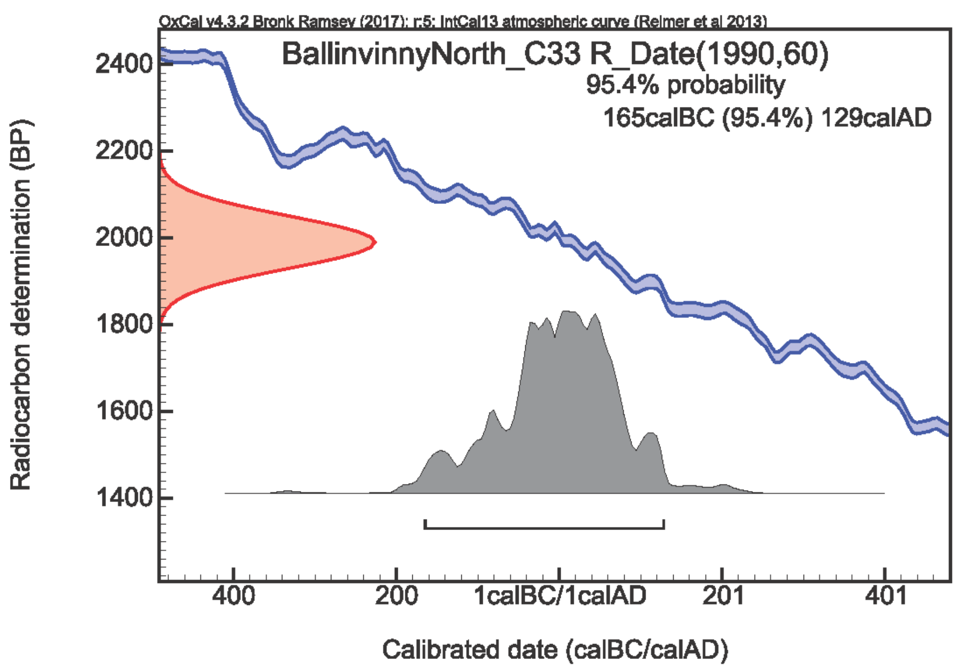
Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: DIA/LIA

C14 Dates and Context:



Description of Site: The site of Ballinvinny North AR26 was discovered during the construction of the N8 Glanmire – Watergrassh Road Scheme. It was given a joint License number with nine other sites: another produced IA smelting activity (AR 29), and one was a LBA cremation (AR 10).

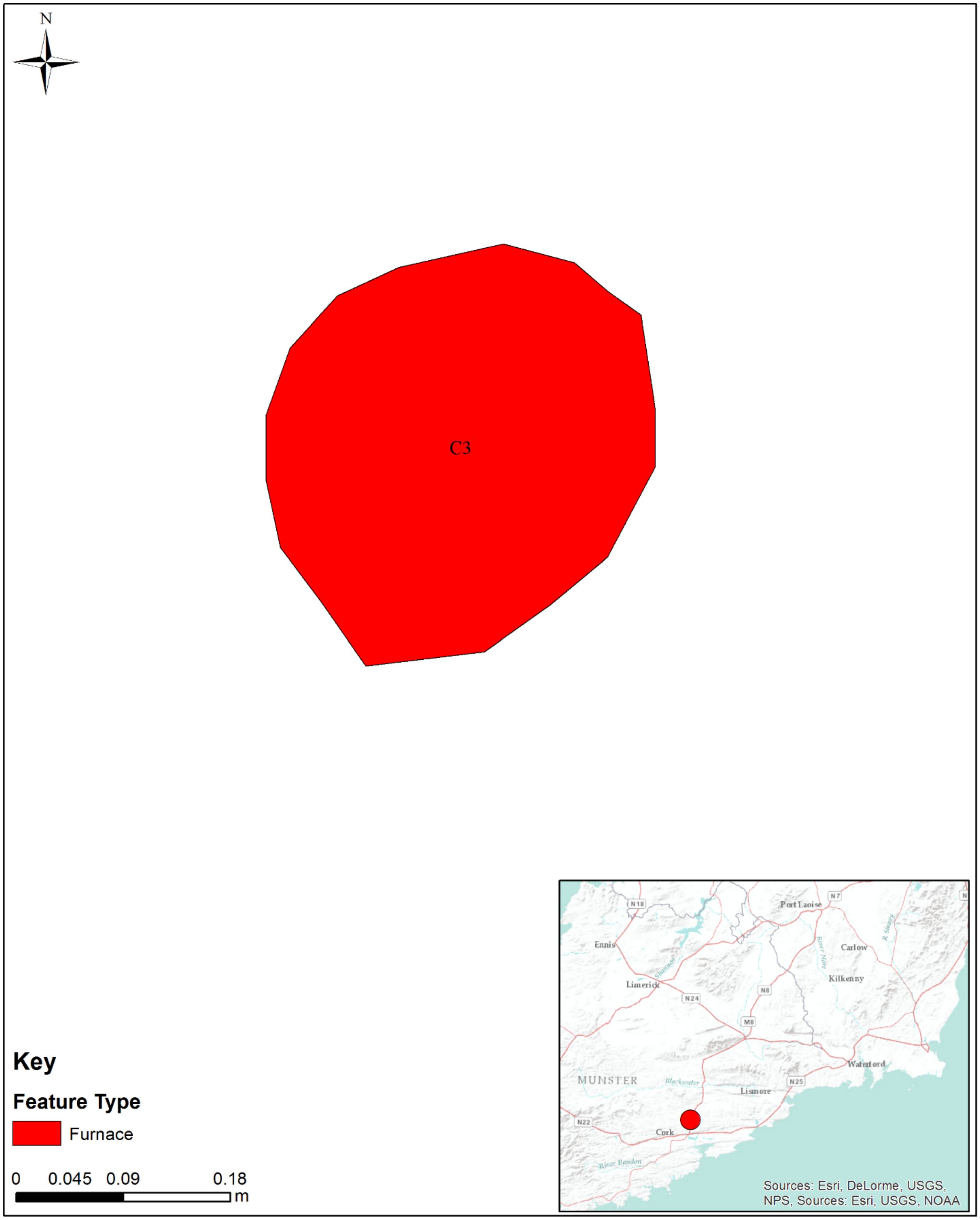
AR 26 consisted of a single feature with evidence of iron smelting, though heavily truncated. Radiocarbon dates indicate a two-sigma calibrated date of 123 BCE – 129 CE. The slag recovered from this furnace has indications that it was produced in less than ideal conditions (Photos-Jones 2003), and the high manganese content in the slag indicates a bog ore source for the iron ore. Additionally, low levels of calcium, potassium, and mangnesium are typically derived from the fuel used during the smelt. Although there is definite indications of heating and metalworking, the lack of substantial charcoal remains may indicate that this feature was never actually used as a furnace or that it was cleaned out after use. Unfortunately, the truncated nature of the feature limits the reconstruction that is possible.

Approximately 370m to the northeast lay the site of Kilrussane AR27 (01E0701), an isolated metalworking site with four furnaces that produced dates parallel with Ballinvinny North. Also, 870m to the northeast of Ballinvinny North was the site of Trantstown (01E0501 AR 29), which also provided evidence for two furnaces with DIA dates. These three sites should probably be considered as a complex of industrial production that extended larger than the site itself.

Landscape: The landscape of the area is dominated by gently sloping hills and these archaeological sites were located on the slopes and broad top of such a hill at elevations of between 83m and 88m OD. AR 26 and AR 29 were located on good quality elevated pasture between two local roads referred to as Ballinvinny Road and Trantstown Road. Both sites were situated on relatively level ground, AR 26 occupying a more exposed position than AR 29, and they were located at elevations of 135m OD and 130m OD respectively.

References:

Sherlock, R. 2005. Archaeology excavation of a Bronze Age cremation burial, a number of Iron Age smelting furnaces and other features at Killydonoghoe, Ballinvinny North & Transtown, Co. Cork. Unpublished report for the Cork County Council and the NRA. Sheila Lane & Associates.



Ballinvinny North (01E0501 AR26)

Site Name: Ballydavid, Site AR 26

County: Tipperary

Licence Number: E2370

Townland: Ballydavid

ITM East: 617747

ITM North: 654799

Excavation conducted by Valerie J. Keeley Ltd.

Smelting: Yes **Number of furnaces:** 6

Smithing: No **Number of smithing hearths:** 0

Charcoal Production: Yes

Type of Site: Enclosure

Chronology: EIA/DIA

C14 Dates and Context:

Ballydavid_C116 R_Date(2209,31)
68.2% probability
358BC (7.4%) 346BC
320BC (28.1%) 276BC
258BC (32.7%) 206BC
95.4% probability
374BC (95.4%) 197BC

Ballydavid_C129 R_Date(2038,30)
68.2% probability
92BC (14.6%) 68BC
62BC (53.6%) 4AD
95.4% probability
161BC (6.0%) 132BC
118BC (88.0%) 28AD
40AD (1.3%) 48AD

Ballydavid_C172 R_Date(2199,30)
68.2% probability
356BC (46.9%) 285BC
234BC (21.3%) 203BC
95.4% probability
366BC (95.4%) 185BC

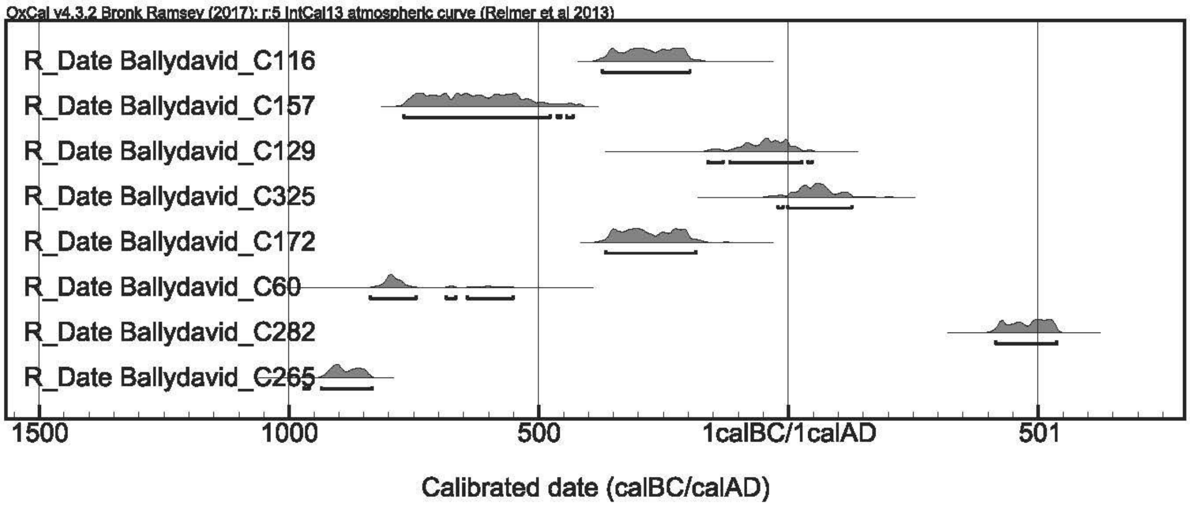
Ballydavid_C157 R_Date(2474,30)
68.2% probability
752BC (26.4%) 682BC
669BC (21.6%) 612BC
592BC (20.2%) 540BC
95.4% probability
770BC (93.5%) 477BC
462BC (0.6%) 456BC
444BC (1.4%) 431BC

Ballydavid_C325 R_Date(1946,30)
68.2% probability
18AD (68.2%) 84AD
95.4% probability
21BC (2.0%) 11BC
2BC (93.4%) 128AD

Ballydavid_C60 R_Date(2596,42)
68.2% probability
817BC (68.2%) 765BC
95.4% probability
837BC (78.4%) 745BC
686BC (4.2%) 666BC
644BC (12.8%) 552BC

Ballydavid_C282 R_Date(1587,22)
68.2% probability
422AD (9.9%) 434AD
451AD (14.6%) 470AD
487AD (43.7%) 534AD
95.4% probability
416AD (95.4%) 538AD

Ballydavid_C265 R_Date(2755,20)
68.2% probability
920BC (35.5%) 891BC
879BC (32.7%) 846BC
95.4% probability
970BC (2.9%) 960BC
936BC (92.5%) 834BC



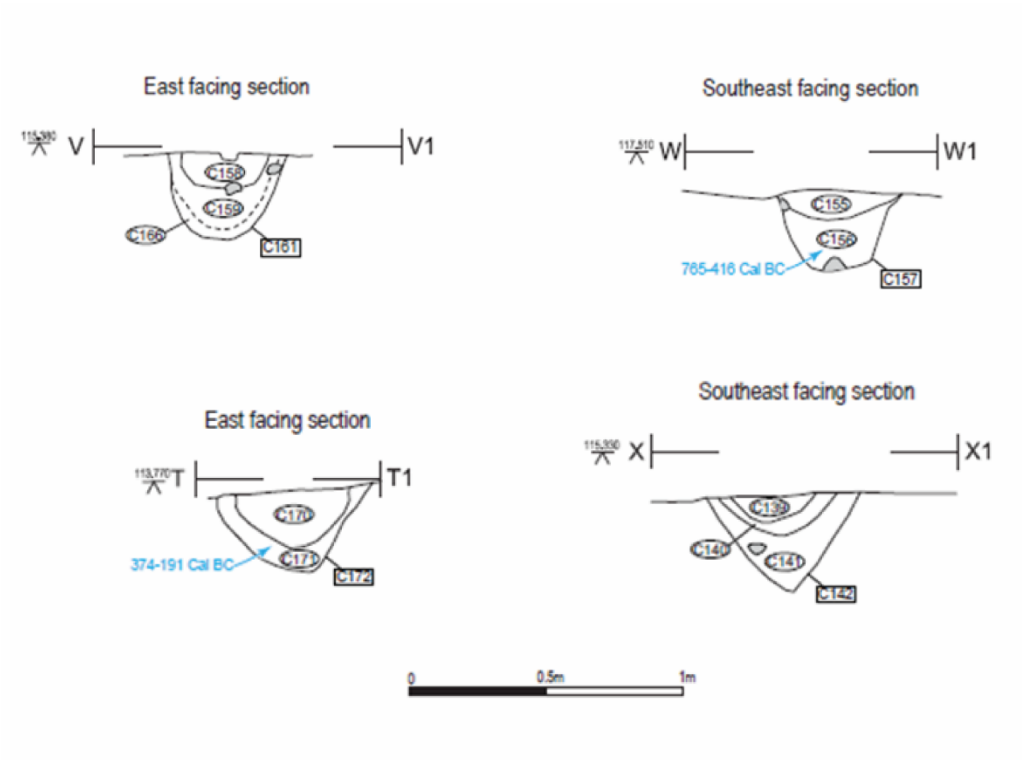
Description of Site: This site was discovered during the M8/N8 Cullahill to Cashel Road Improvement Scheme. It consists of a large sub-circular ditched enclosure ca. 125m in diameter, with an entrance in the southeast. Ceramic evidence from the enclosure suggests a MBA-LBA date, although radiocarbon dates from within the enclosure provided a date from the 6th century BCE – 2nd century CE. Radiocarbon dates from a cereal drying kiln produced dates into the early Medieval period. There appears to be multiple phases of use at the site, beginning with the digging of the enclosure ditch in the MBA, the filling in of the enclosure in the LBA (which included human and animal bones), iron-working at the site, and the processing of cereals in the early Medieval period. The purpose of the enclosure seems ambiguous, given the lack of internal structures or a hearth.

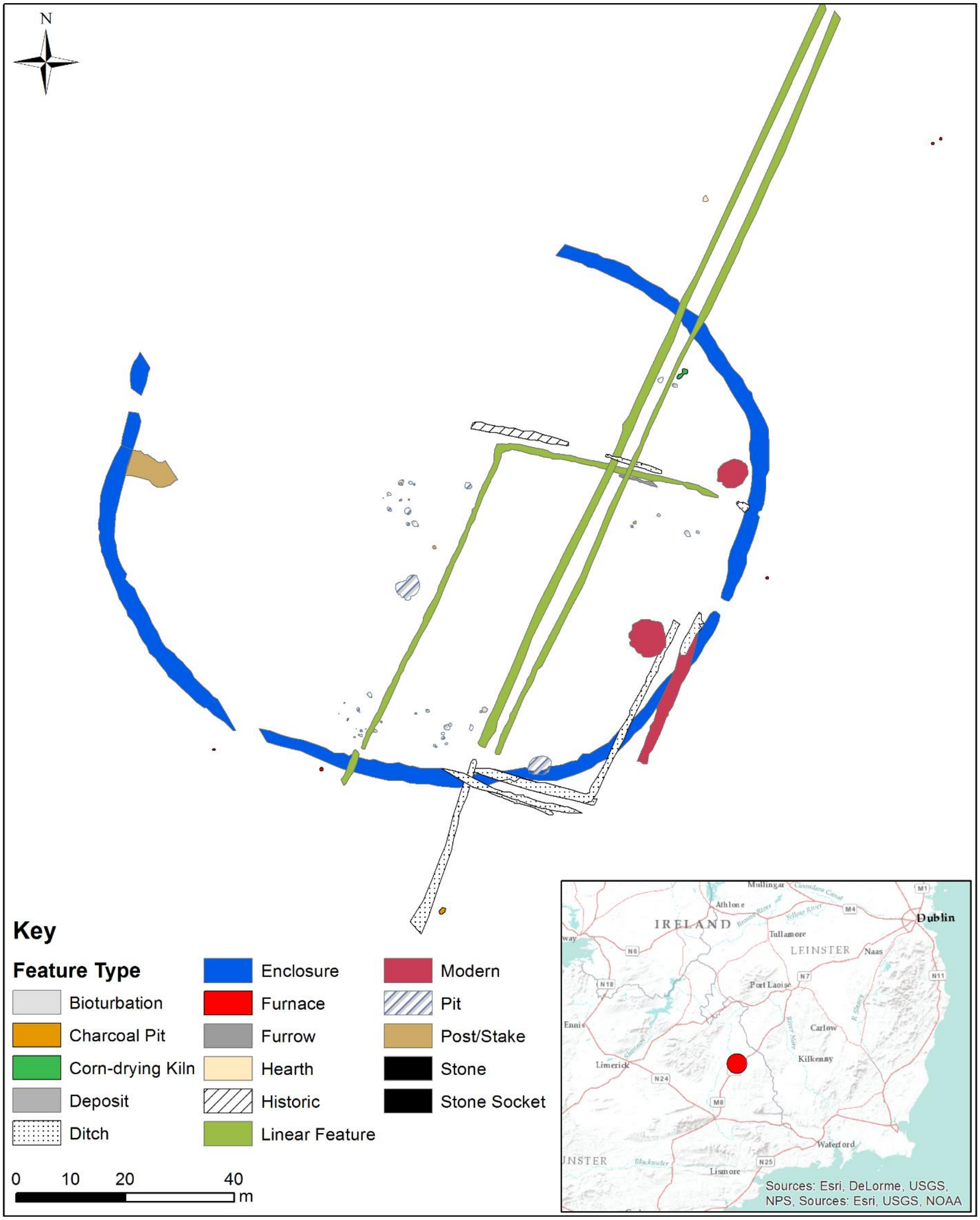
There are at least six slag-pit furnaces from this site, with an additional possible furnace whose large size and paucity of slag suggests a waste dump. These features produced 29.3kg of slag. Radiocarbon dates taken from two of these furnaces place them between 765 – 416 BCE and 374 – 191 BCE. The furnaces all appear on the exterior of the enclosure, although by the time of their use the enclosure had been filled in. There are however some pits on the interior of the enclosure that also produced DIA dates.

Landscape: “This area is set within a broad low lying 25km east – west, 40km north – south plain with a gradual northeast – southwest slope trend (falling 130-110m OD). The present undulating nature of the landscape was created during the last glacial period from morainic deposition of churned bedrock material, smoothed by passing glaciers. The plain is bounded by the Silvermine and Devil’s Bit range of hills to the west and north, the Slieveardaghs to the east and is dotted with a small number of low hills not exceeding 235m OD. From 15km north of Thurles to the south, it is effectively bisected and drained by the River Suir and its tributaries. Between the limit of useful farmland east and northwest of the Suir and the Slieveardaghs, is a network of raised bogs; Derryville Bog to the northwest and Littleton Bog to the east. The topography and geology of this section of the scheme is typical of the plain in general, with a gentle undulating northeast – southwest slope trend from (falling 120-110m OD) and occasional hillocks not exceeding 134m OD. The site is located at the western extent of a portion of landscape that is relatively dry and topographically relatively elevated. The site is located between two small hills that break the 120m contour, and you would need to travel 13km west before the topography breaks this contour again at Moyaliff Hill near Dundrum. The area is drained by the Black River and its tributaries. The majority of land use was dairy farming pasture with some tillage.”

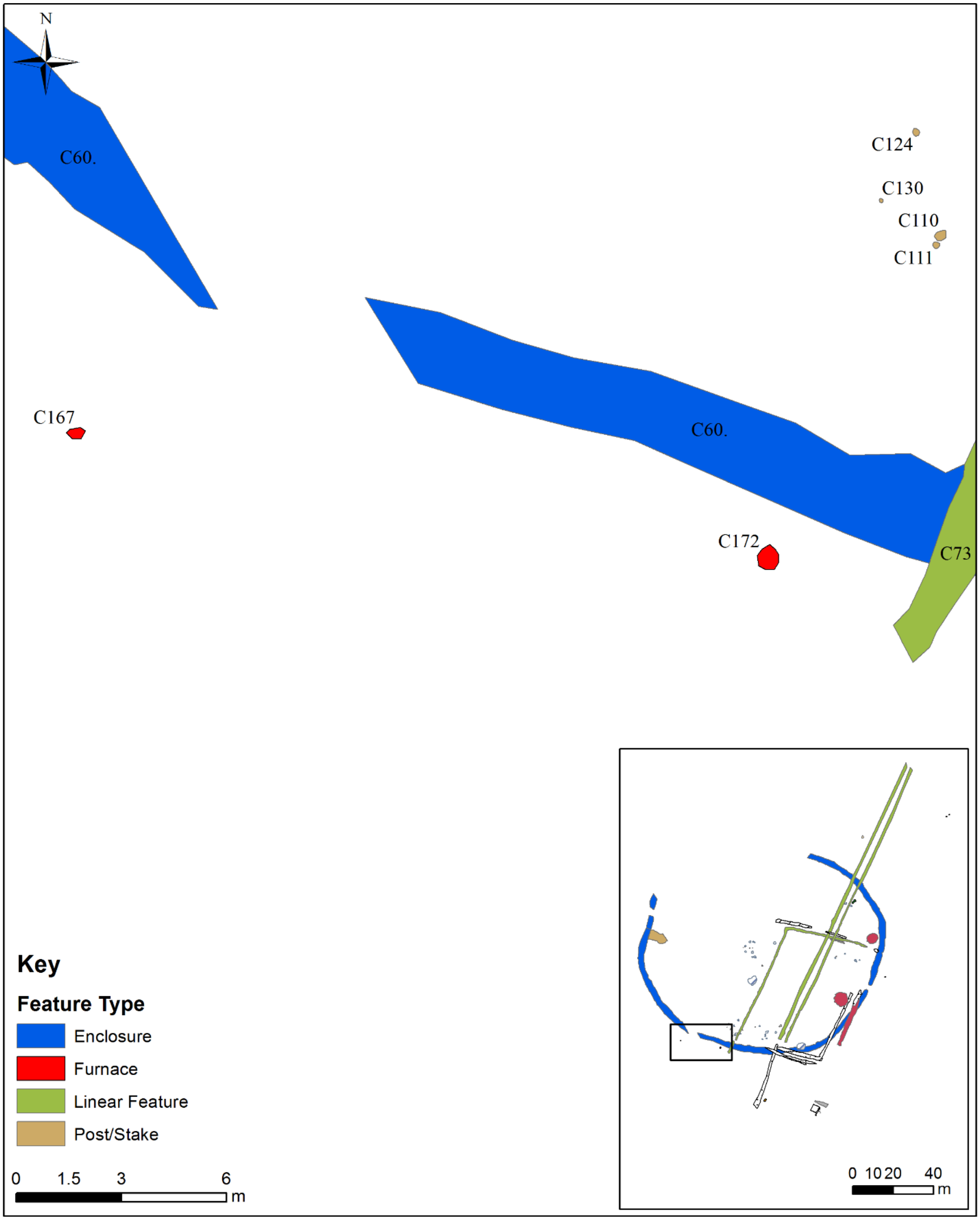
References:
Hardy, C., B. Green & P. Stevens. 2010. M8/N8 Cullahill to Cashel road improvement scheme: archaeological resolution. Final report for Site AR 26, Ballydavid Townland, Co. Tipperary. Unpublished report Valerie J. Keeley Ltd

Furnace Section:

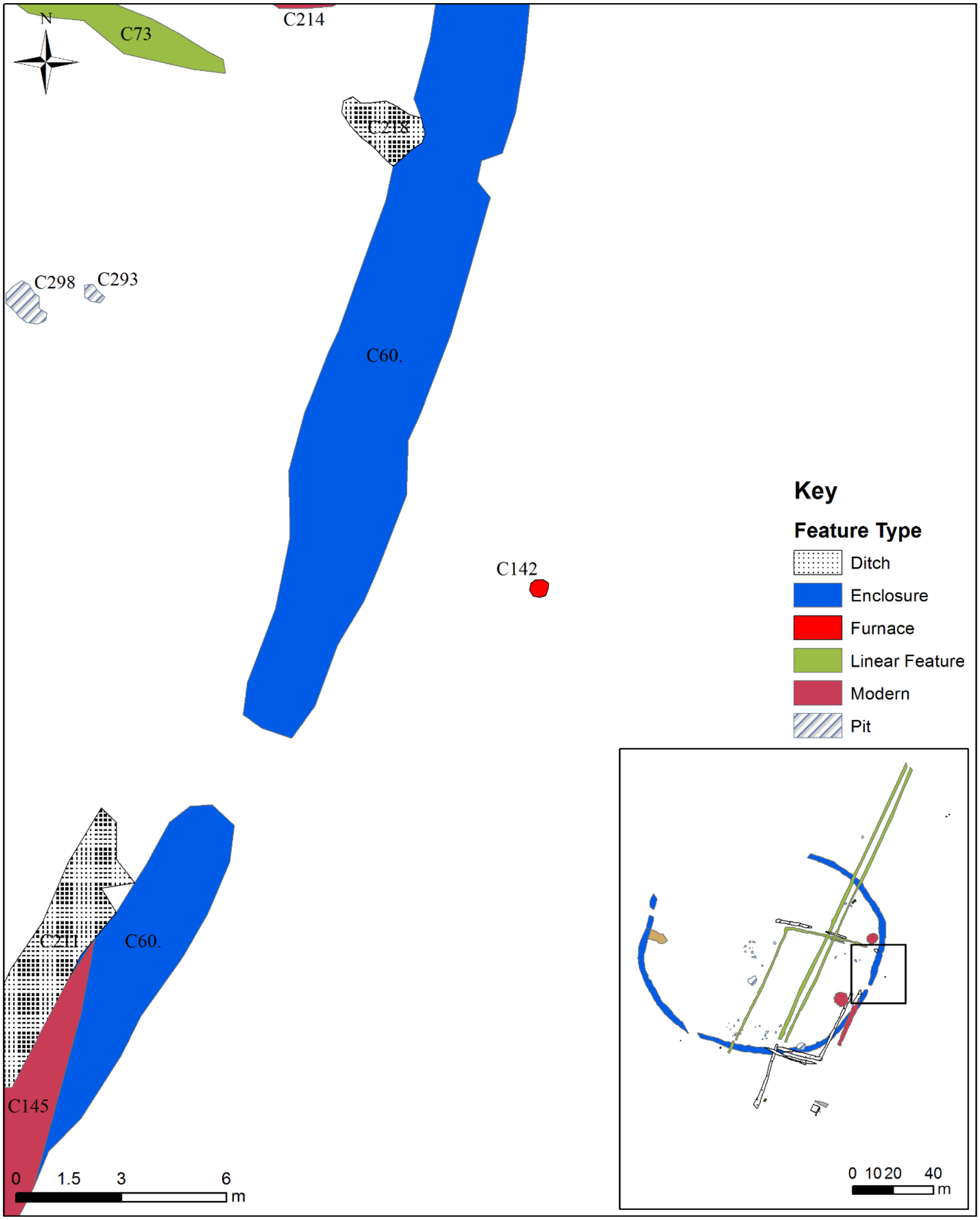




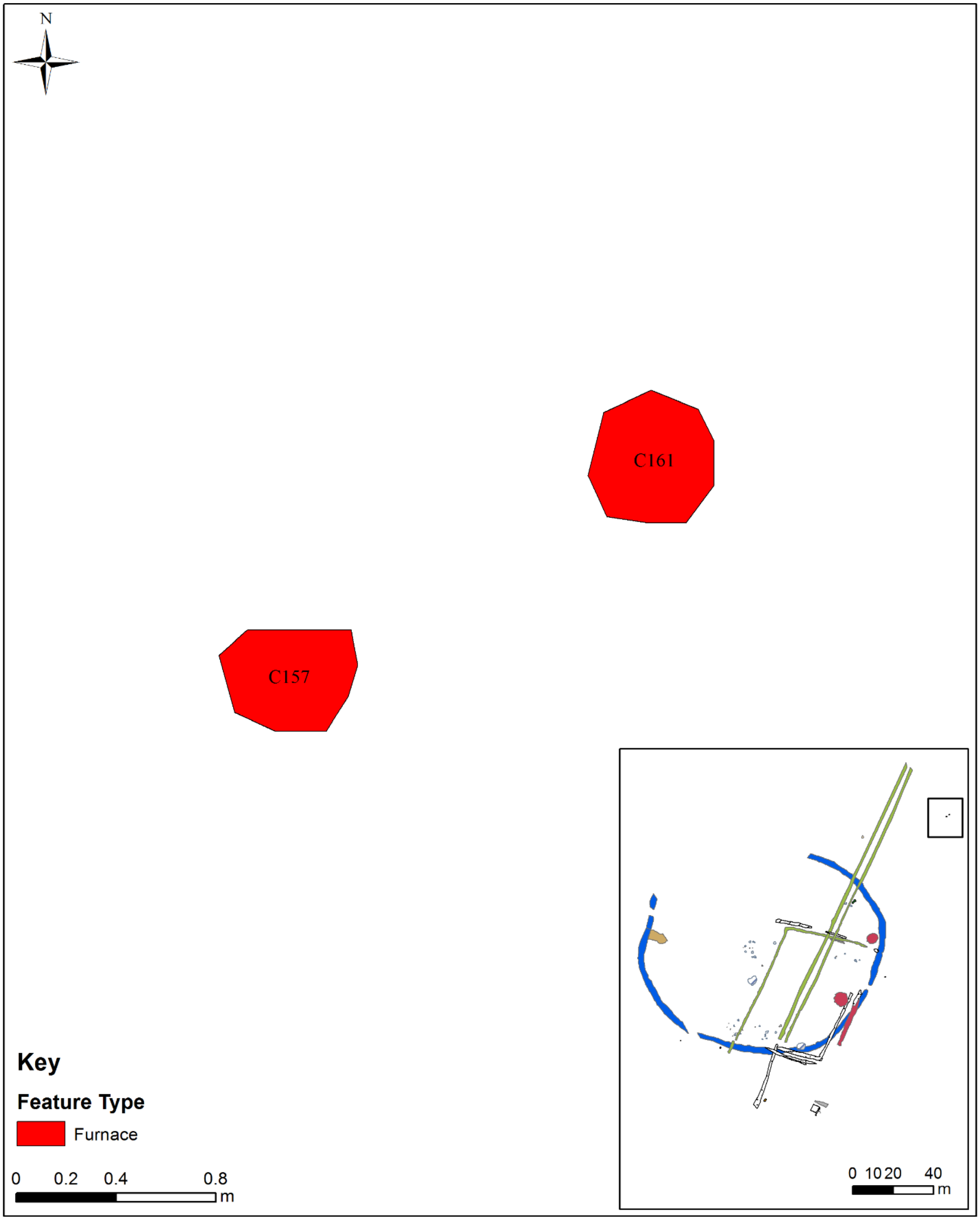
Site AR 26, Ballydavid (E2370)



Close-up of Site AR 26, Ballydavid (E2370)



Close-up of Site AR 26, Ballydavid (E2370)



Close-up of Site AR 26, Ballydavid (E2370)

Site Name: Ballydavis, Site B

County: Laois

Licence Number: 03E0966

Townland: Ballydavis

ITM East: 651900

ITM North: 699461

Excavation conducted by Valerie J. Keeley Ltd.

Smelting: Yes **Number of furnaces:** 2

Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

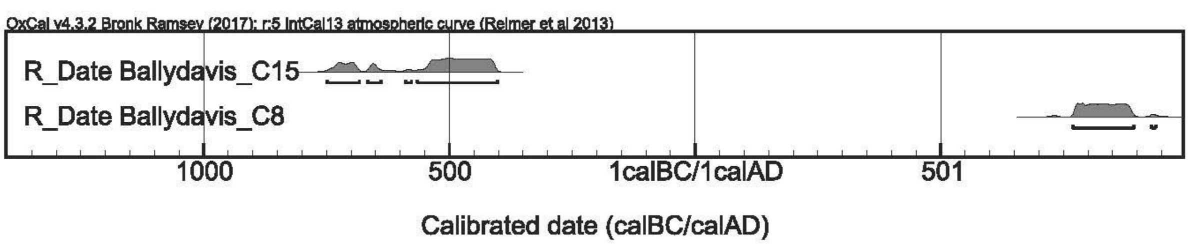
Type of Site: Isolated Metalworking

Chronology: EIA

C14 Dates and Context:

Ballydavis_C15 R_Date(2424,31)
68.2% probability
700BC (1.7%) 696BC
540BC (66.5%) 410BC
95.4% probability
749BC (17.5%) 684BC
667BC (5.6%) 640BC
589BC (1.0%) 578BC
566BC (71.2%) 402BC

Ballydavis_C8 R_Date(1188,24)
68.2% probability
778AD (12.1%) 792AD
802AD (34.7%) 844AD
854AD (21.4%) 880AD
95.4% probability
770AD (94.1%) 894AD
930AD (1.3%) 938AD



Description of Site: The site was discovered prior to construction of the N7 Heath-Mayfield Motorway Scheme. It consisted of two areas of occupation: Area 1 was a series of pits, possibly used for charcoal production, as well as a slot trench that may have formed a windbreak. An Early Medieval date was recovered from one of these pits. Area 2 contained two smelting furnaces and two additional pits. The furnaces seem to match the morphology with slag-pit furnaces, having near-vertical sides and a flat bottom. The larger of the furnaces produced a calibrated 14C date of 748 – 402 BCE.

Another site, Morett (03E0461), was also found in the vicinity of Ballydavis, Site B – over 4km to the northeast. Although the distance is too far to consider these two sites as part of the same complex of activity, they both appeared to be utilized during the same period and produced furnaces with similar morphologies. However, Morett did produce much larger evidence of occupation, from the Neolithic through the Medieval period.

Nearby Ballydavis, Site B was an Iron Age complex (95E0111), consisting of four ring-ditches, seven furnaces, and a number of pits and post-holes. The four ring-ditches uncovered produced some of the most impressive suite of grave goods dating to the Iron Age (Keeley 1999) . Additional pits were found in association with the mortuary activities, eight of which were deemed furnaces (Keeley 1999: 29). However, access to the more detailed report of the excavation was not possible, leaving open the function and type of these 'furnaces.'

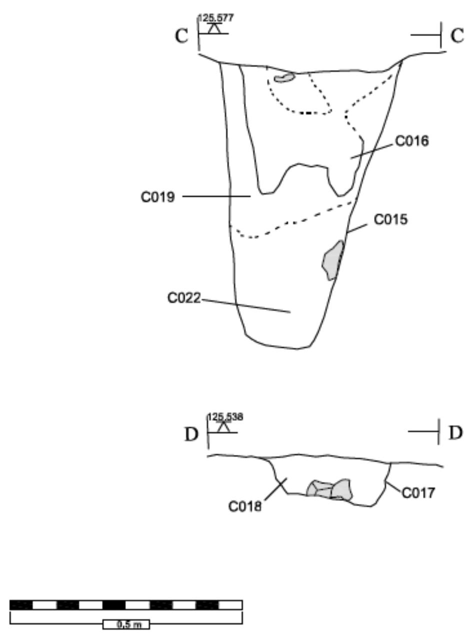
Landscape: "Ballydavis, Site B was located at chainage c.210+00 and NGR 250959E, 200133N in the townland of Ballydavis, parish of Straboe, Co. Laois. It was positioned on the southwest-facing slope of a hill. Trench extension was undertaken in order to ascertain the full extent of the archaeological site. It is not listed in 'Heath-Mayfield Scheme, Route S2 Alternative, Archaeological Assessment for EIS', Valerie J. Keeley Ltd, Archaeological Consultancy, April

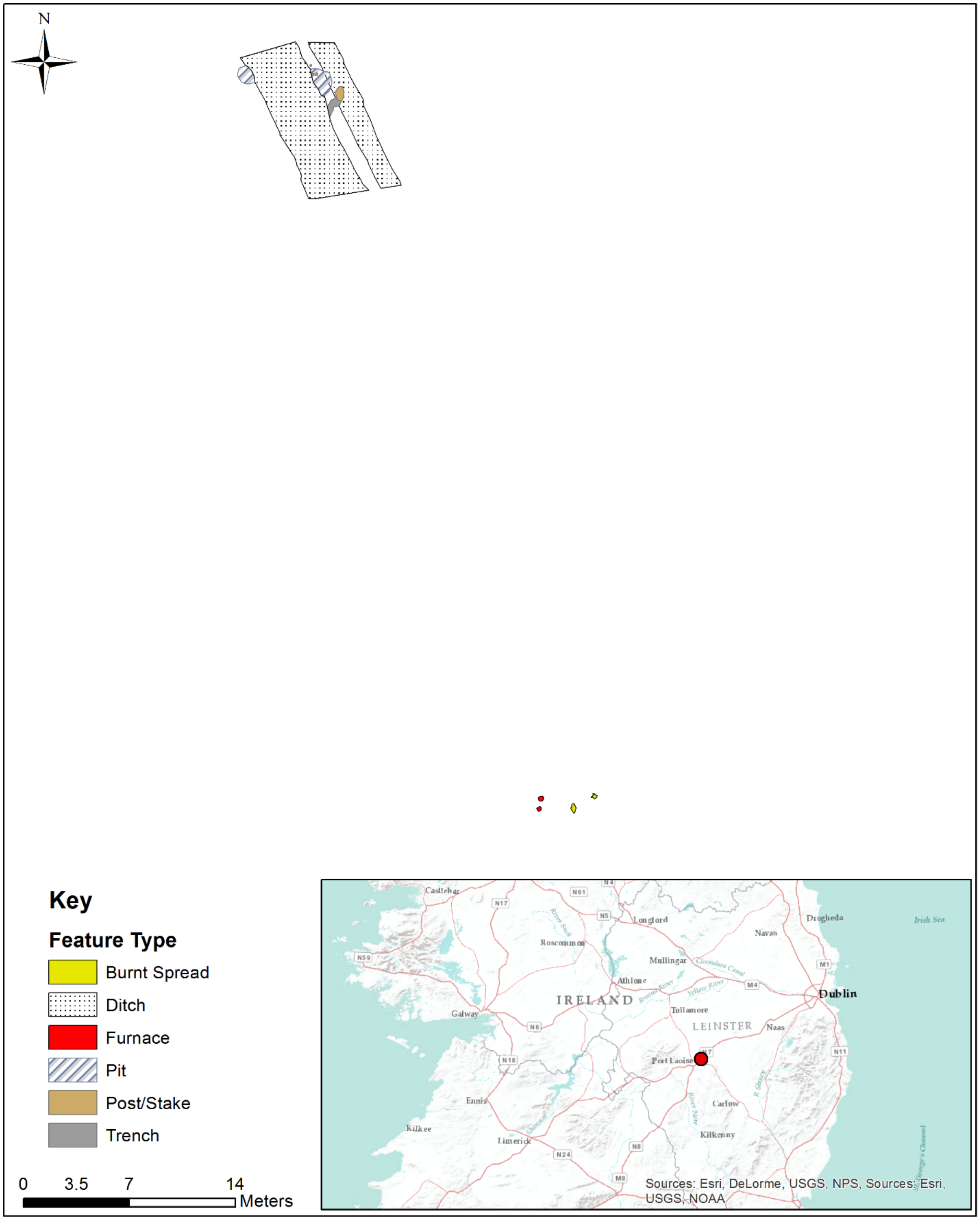
1999, as it was discovered during subsequent centreline testing. The site was adjacent to the site of an Iron Age complex, which was excavated between 1993 and 1995 (Keeley, 1999) and 130m southwest of RMP site 013:2602. Site I which was a Bronze Age complex excavated by G Fegan under the present contract, was situated north of Site B (Fegan, 2004).”

References:

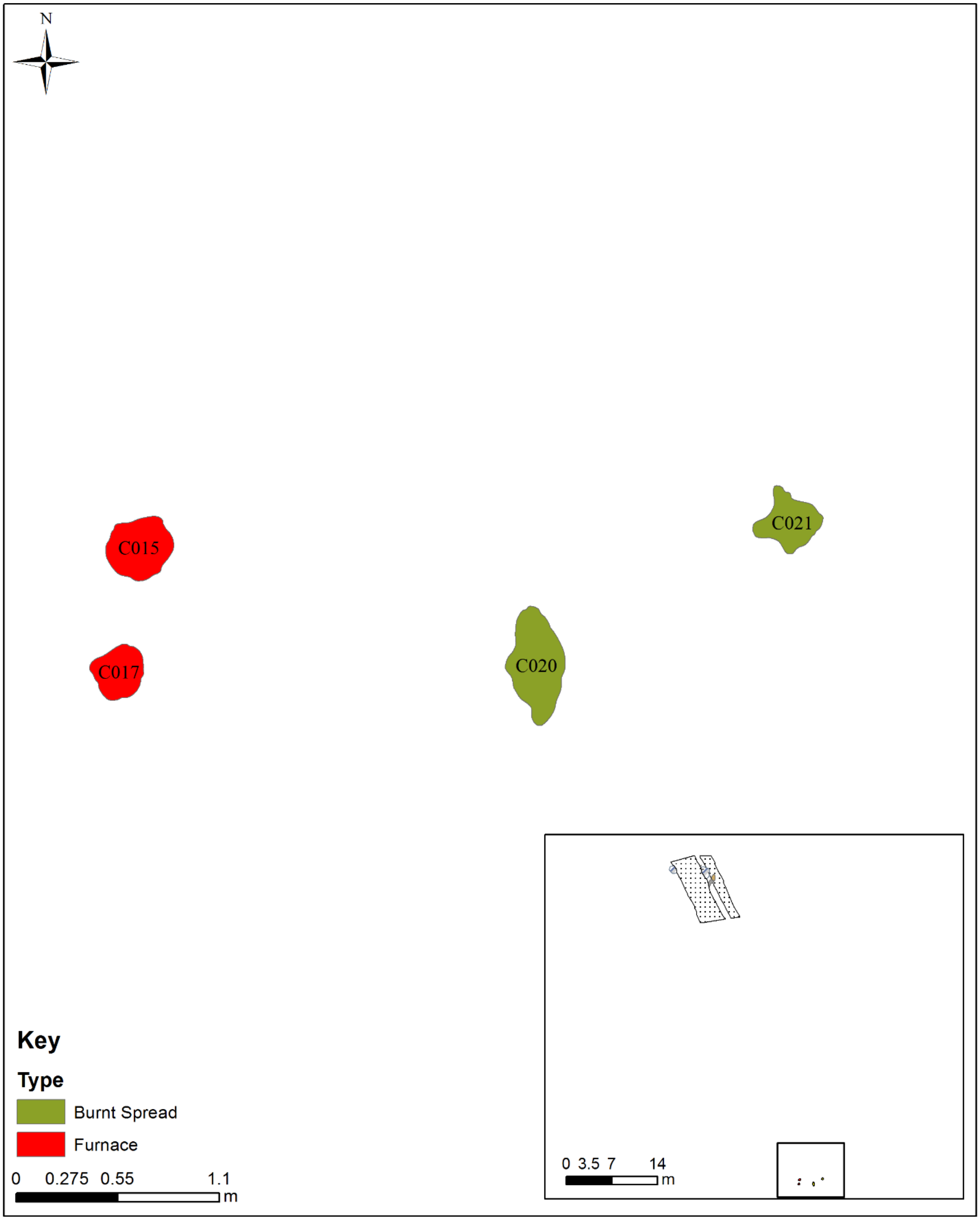
Ó’Maoldúin, R. 2012. M8/N8 Cullahill to Cashel road improvement scheme: archaeological resolution. Final report for Site B, Ballydavis Townland, Co. Laois. Unpublished report Valerie J. Keeley Ltd

Furnace Section:





Site B, Ballydavis (03E0966)



Close up of Site B, Ballydavis (03E0966)

Site Name: Carrickmines Great

County: Dublin

Licence Number: 02E0272

Townland: Carrickmines Great

ITM East: 722048.115

ITM North: 723522.871

Excavation conducted by Valerie J. Keeley Ltd.

Smelting: Yes **Number of furnaces:** 1

Smithing: No **Number of smithing hearths:** 0

Charcoal Production: Yes

Type of Site: Structure

Chronology: DIA

C14 Dates and Context:

CarrickminesGreat_1017 R_Date(2200,35)
68.2% probability
357BC (43.4%) 283BC
256BC (5.1%) 246BC
236BC (19.7%) 203BC
95.4% probability
371BC (95.4%) 179BC

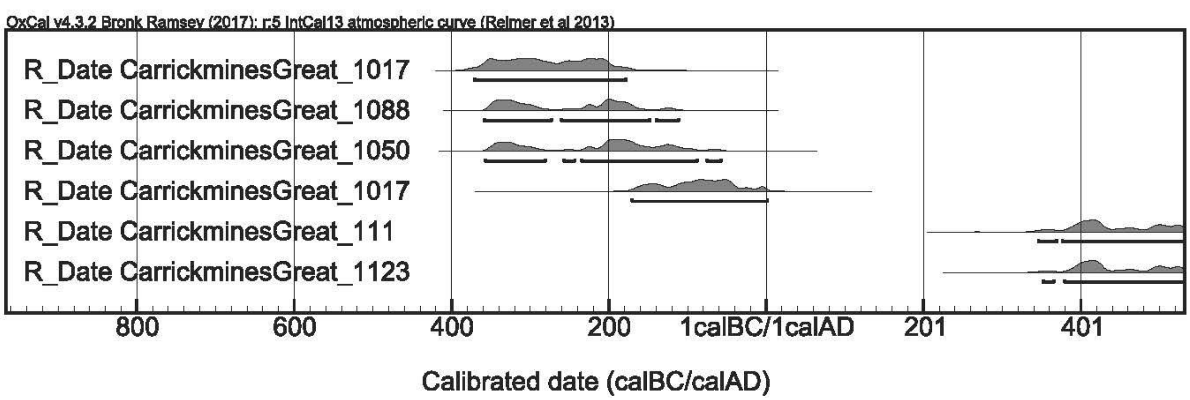
CarrickminesGreat_1088 R_Date(2165,30)
68.2% probability
352BC (36.9%) 298BC
228BC (3.0%) 222BC
211BC (28.3%) 171BC
95.4% probability
359BC (44.7%) 274BC
261BC (46.0%) 148BC
140BC (4.6%) 112BC

CarrickminesGreat_1050 R_Date(2150,35)
68.2% probability
350BC (23.8%) 303BC
210BC (35.5%) 154BC
136BC (8.9%) 114BC
95.4% probability
358BC (30.0%) 281BC
258BC (1.6%) 244BC
236BC (61.6%) 88BC
76BC (2.3%) 58BC

CarrickminesGreat_1123 R_Date(1625,30)
68.2% probability
390AD (44.5%) 430AD
492AD (23.7%) 530AD
95.4% probability
352AD (2.5%) 366AD
380AD (92.9%) 536AD

CarrickminesGreat_1017 R_Date(2065,30)
68.2% probability
156BC (11.1%) 136BC
114BC (57.1%) 42BC
95.4% probability
171BC (95.4%) 2AD

CarrickminesGreat_111 R_Date(1625,35)
68.2% probability
387AD (41.7%) 432AD
490AD (26.5%) 532AD
95.4% probability
346AD (5.1%) 370AD
377AD (90.3%) 538AD



Description of Site: The site was discovered prior to the construction of the South-Eastern Motorway. This site marks one of the few examples of Iron Age settlement. The site was an unenclosed homestead that included some industrial activity like metal-working and cereal cultivation. The site contained two structures, one "house" of c. 3.5m in diameter and one hut/shed measuring c. 2.3m x 2m. A series of posts and pits indicates some kind of fence-line through the site. Additionally, a large pit cut into the water table appears to have been a waterhole for those living at the site.

A singular slag-pit furnace was uncovered on this site, providing one of the few examples of smelting technology within a settlement. A calibrated ^{14}C date from this furnace (320 BCE – 70 CE) placed its use in the DIA. Just south of the furnace was the remains of what appeared to be a charcoal production clamp placed within a sunken pit.

Approximately 90m from this settlement, a LIA cremation burial was uncovered, making it a very later example of this burial treatment. There are also nearby (within 100m) evidence of Neolithic, Early and Late Bronze Age occupation in the form of structures and industrial activity.

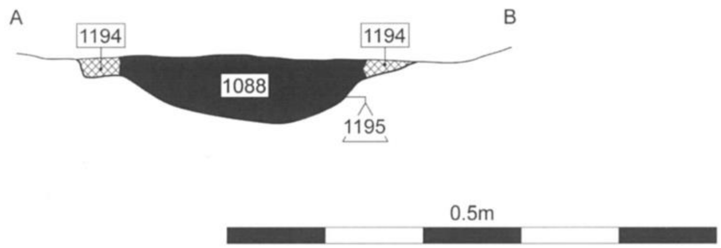
Landscape: "The excavation site is located at 100m above sea level and is directly overlooked to the southwest by the prominent peaks of the Two Rock and Three Rock mountains. To the east the land slopes gently downwards for 2.5km to the sea at Killiney Bay. Three hundred metres to the south of the excavation area is a reclaimed wetland known as "Tracy's bog.""

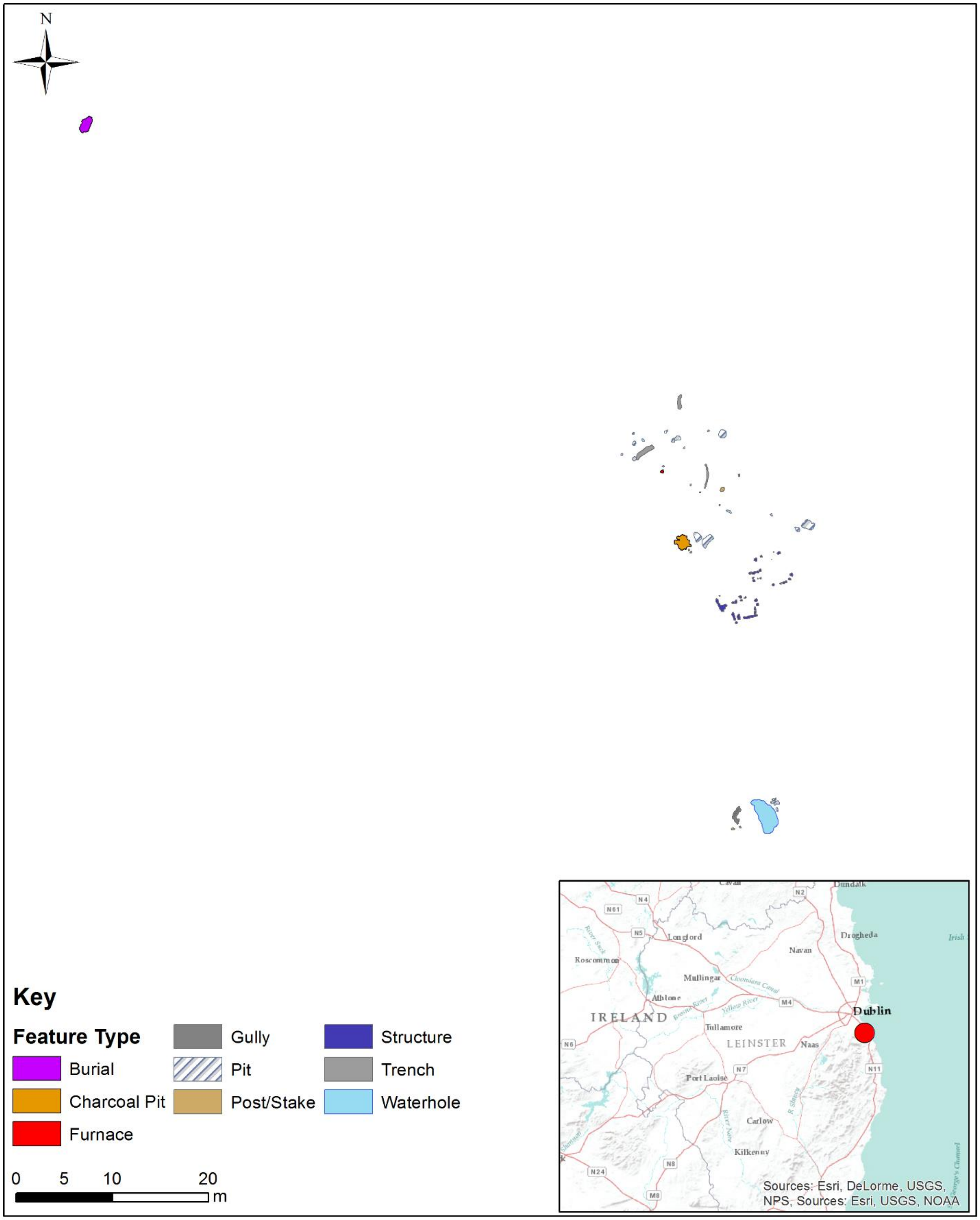
References:

Ó Drisceoil, C. 2007. Life and death in the Iron Age at Carrickmines Great, Co. Dublin. *The Journal of the Royal Society of Antiquaries of Ireland*, 137, 5-28.

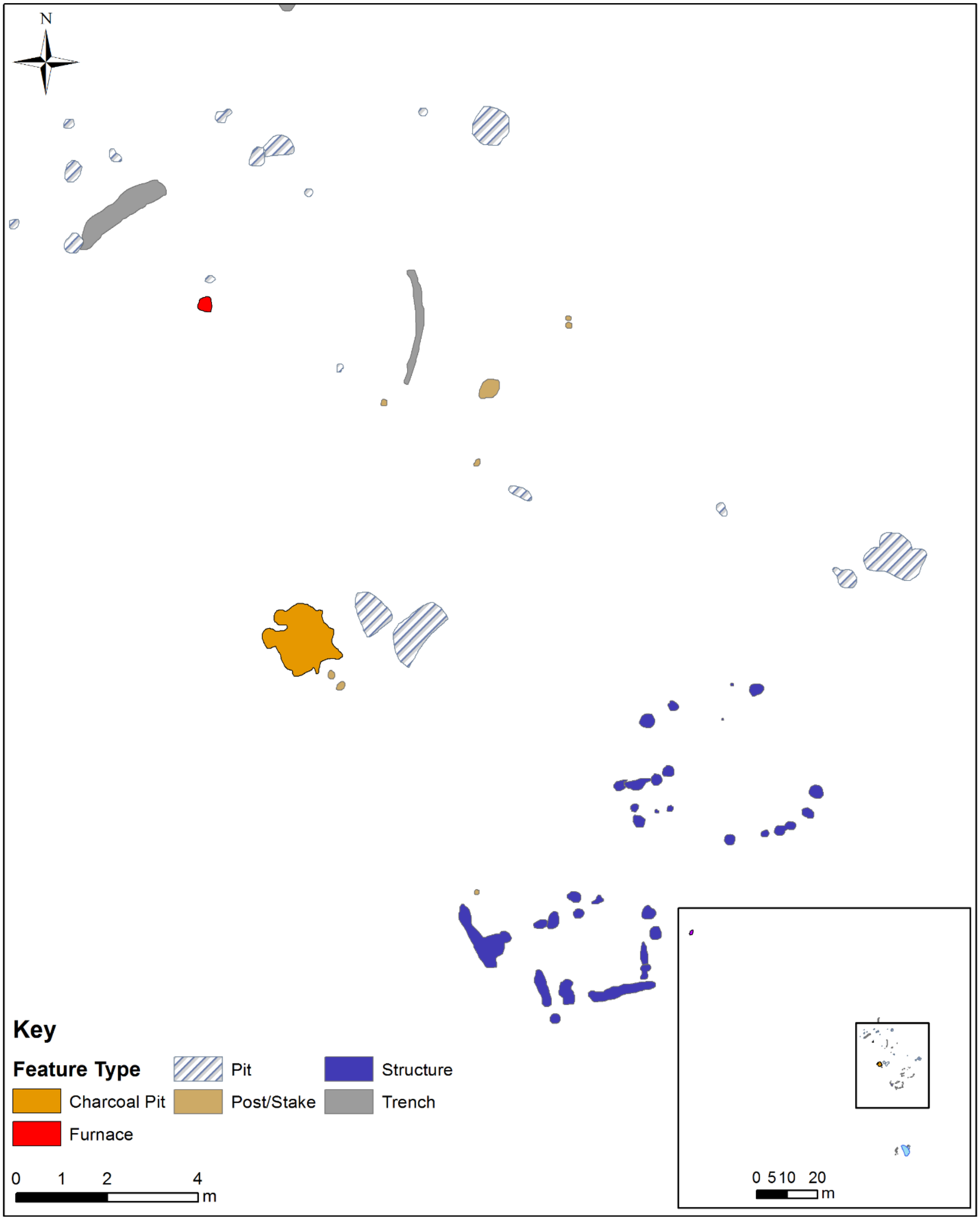
Ó Drisceoil, C. and E. Devine. 2012. Invisible people or invisible archaeology? Carrickmines Great, Co. Dublin, and the problem of Irish Iron Age settlement. In C. Corlett & M. Potterton (eds), *Life and Death in Iron Age Ireland*, 249-266. Dublin: Wordwell.

Furnace Section:

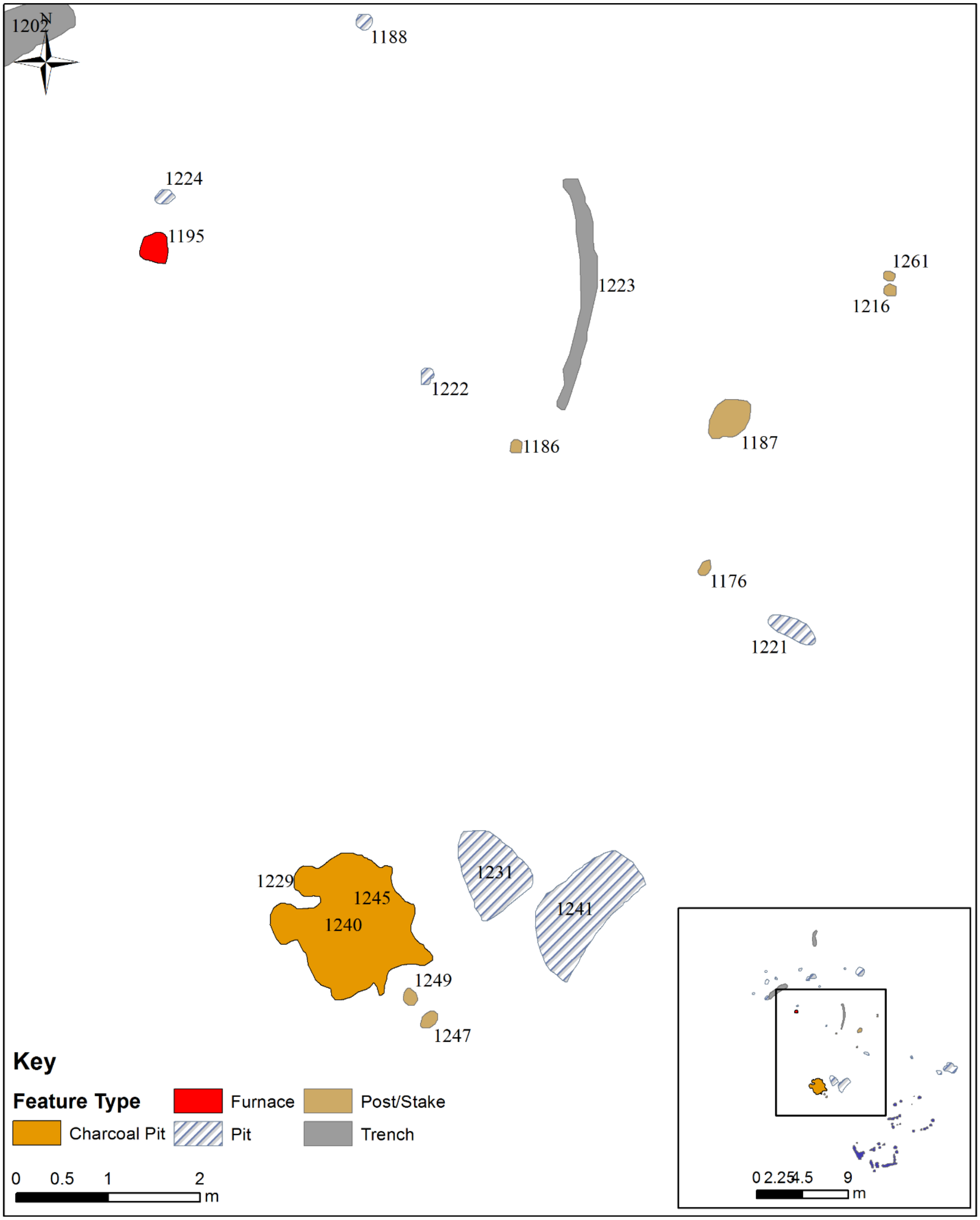




Carrickmines Great (02E0272)



Close-up of Carrickmines Great (02E0272)



Close-up of Carrickmines Great (02E0272)

Site Name: Chapelbride1 **County:** Meath

Licence Number: E3172 **Townland:** Chapelbride

ITM East: 670599.795 **ITM North:** 774701.613

Excavation conducted by Archaeological Consultancy Services Ltd.

Smelting: No **Number of furnaces:** 0

Smithing: Yes **Number of smithing hearths:** 1

Charcoal Production: No

Type of Site: Isolated Metalworking

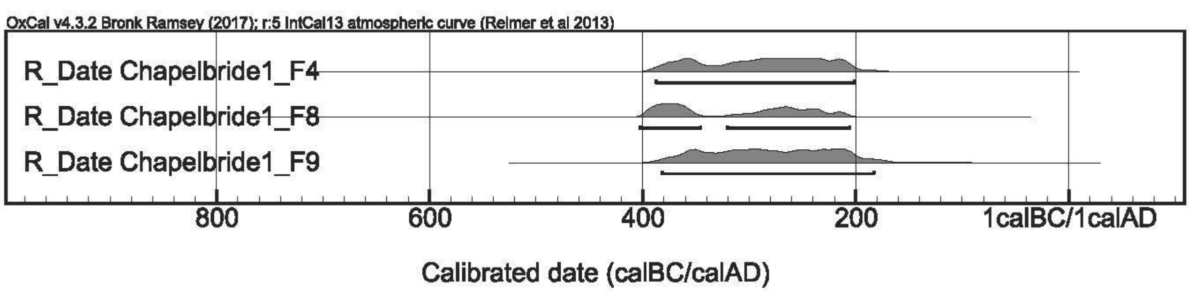
Chronology: DIA

C14 Dates and Context:

Chapelbride1_F4 R_Date(2230,40)
68.2% probability
369BC (10.8%) 350BC
304BC (57.4%) 210BC
95.4% probability
388BC (95.4%) 202BC

Chapelbride1_F8 R_Date(2270,40)
68.2% probability
396BC (35.2%) 356BC
286BC (33.0%) 234BC
95.4% probability
403BC (41.5%) 346BC
321BC (53.9%) 206BC

Chapelbride1_F9 R_Date(2210,40)
68.2% probability
359BC (7.9%) 345BC
322BC (28.3%) 272BC
261BC (32.0%) 206BC
95.4% probability
382BC (95.4%) 184BC

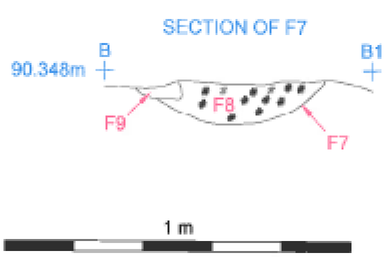


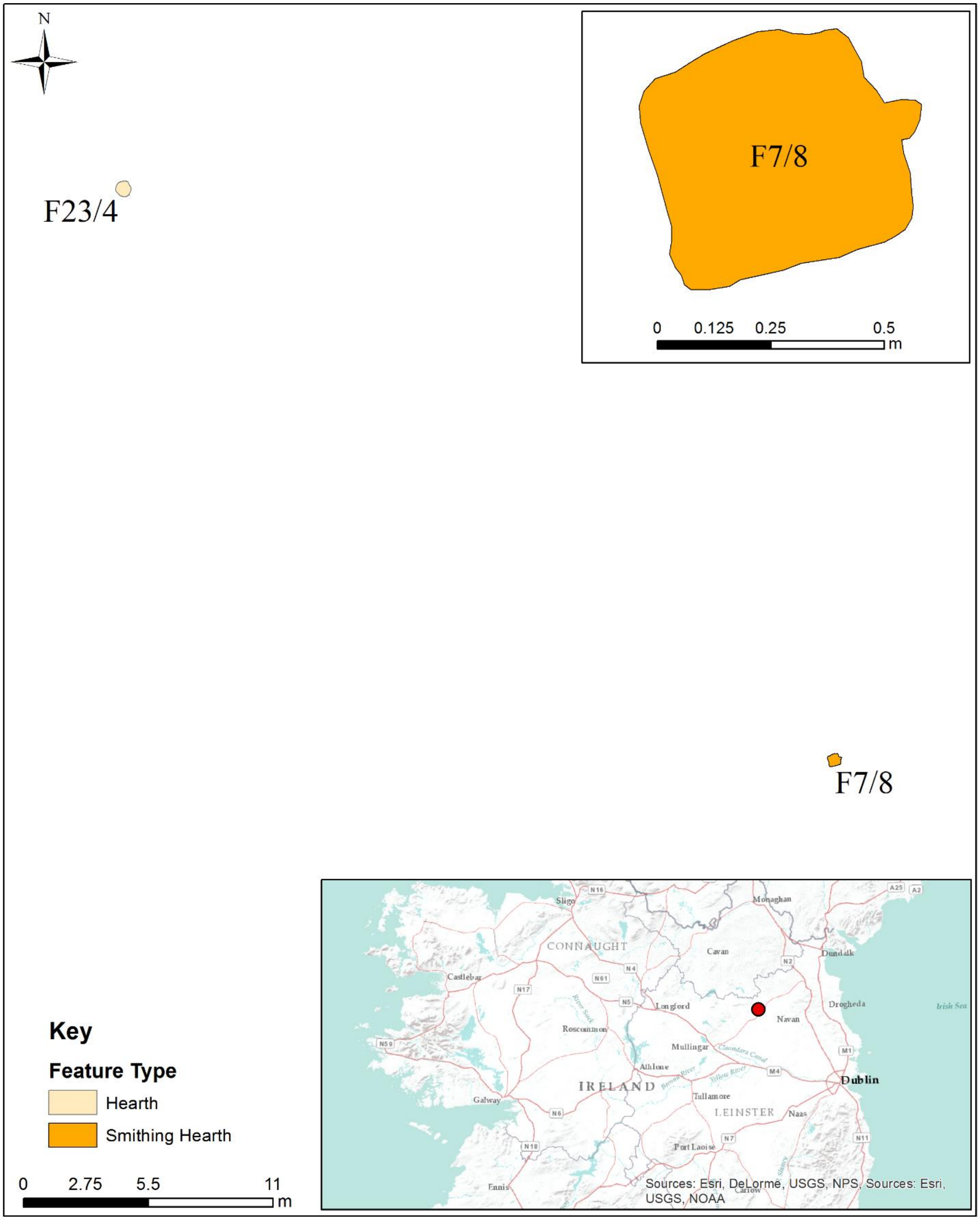
Description of Site: The site was discovered prior to the construction of the M3 Clonee-North of Kells Motorway Scheme. This site contained two small features. One pit, likely a hearth, produced a 14C date in the DIA (389-202 cal BCE). The other feature appears to have been involved in smithing, and provided two 14C dates that places its use also during the DIA. The heavy charcoal concentration, as well as the presence of slag and hammerscale, points to this second feature as being used in smithing. In turn, the lack of a definite clay lining, the small amount of slag recovered, and the shallow slope to the sides of the feature probably discounts it as being used a smelting furnace.

At about .5km from the Chapelbride 1, a possible circular slot trench structure was discovered at the site of Chapelbride 5 (E3169) that provided a 14C date of 396 - 204 BCE. These dates correspond exactly with the occupation of Chapelbride 1.

References: Danaher, D. and V. Ginn. 2008. M3 Clonee–Kells motorway. Report on the archaeological excavation of Chapelbride 1, Co. Meath. *Unpublished report for Meath County Council and the NRA.* Archaeological Consultancy Services Ltd.

Furnace Section:





Chapelbride 1 (E3172)

Site Name: Cherryville Site 12

County: Kildare

Licence Number: 01E0955

Townland: Cherryville

ITM East: 669163.991

ITM North: 711719.752

Excavation conducted by Valerie J Keeley Ltd.

Smelting: Yes **Number of furnaces:** 4

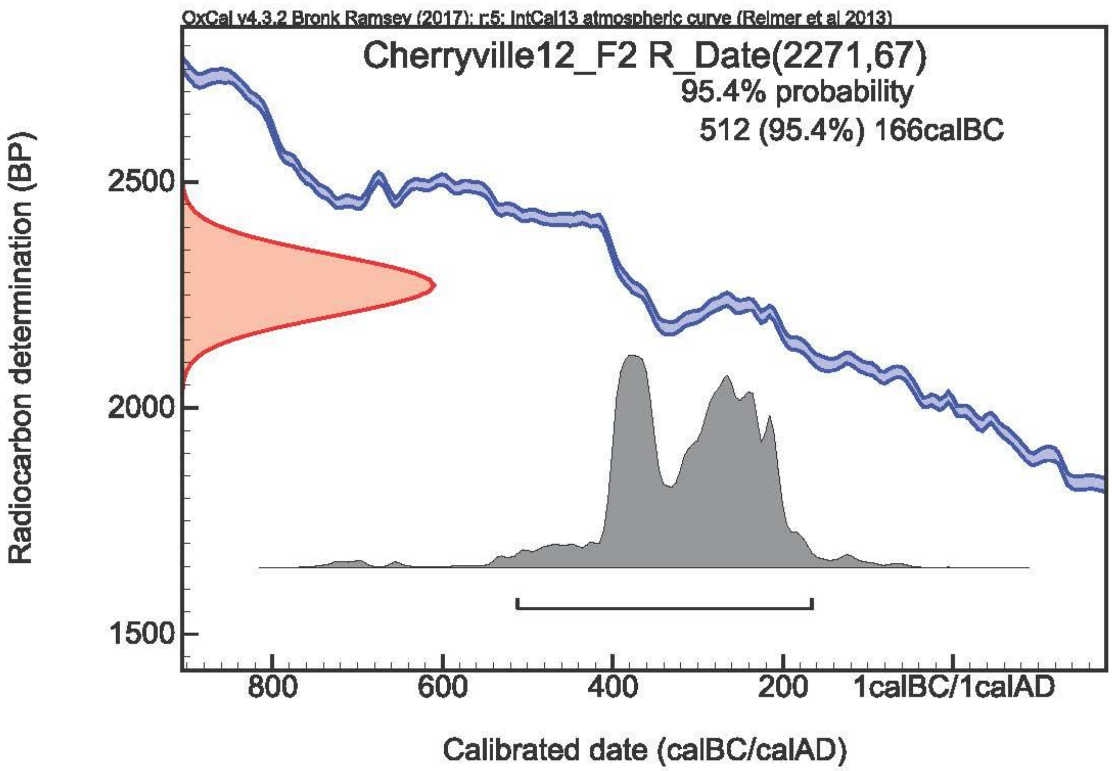
Smithing: Yes **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: EIA/DIA

C14 Dates and Context:



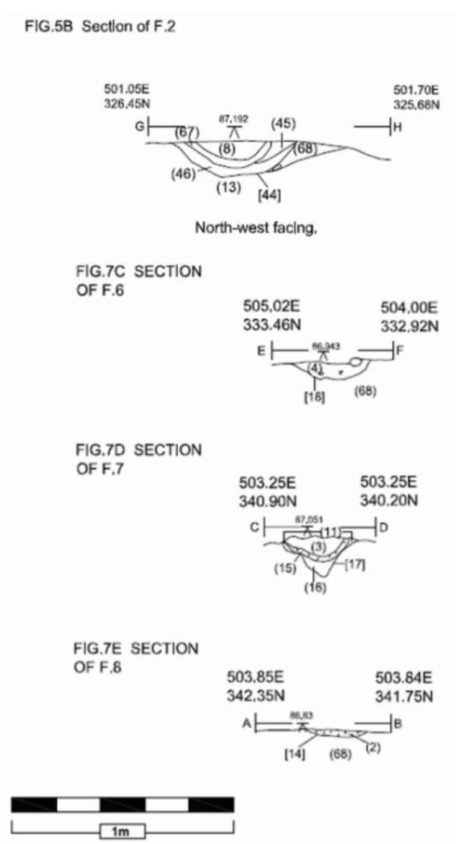
Description of Site: This site was discovered prior to construction of the Kildare Town By-Pass. The site can largely be characterized as an ironworking site, with some additional linear agricultural features that likely date to the Medieval period. A total of eight furnaces were initially identified at this site by the excavators, with somewhat varying morphologies. However, further analysis of the metallurgical residues suggests as few as four of the features were actually used as smelting furnaces. One of the features had a “figure-of-eight” shape to it, while another presented a “keyhole” shape. While there was evidence of slag and vitrified ceramic (destroyed parts of a clay superstructure) in these features, they did not appear to be in-situ. Additionally, the large size of these features likely discount them as being used for smelting. In other cases, pits of this diameter have been interpreted as smithing hearths, so this remains one possibility for their interpretation. The presence of a smithing hearth cake fragment deposited in a secondary pit context, we know that smithing was occurring in some form on this site. This two enigmatic features also resemble the morphology of corn-drying kilns, which is an additional explanation for their use.

The four features that share a similar morphology and primary deposits were likely used as slag-pit smelting furnaces. All present similar diameters and the characteristic steep sides. The additional features found in association with these furnaces were used refuse pits, of a sort, where metallurgical remains were tossed during the cleaning of the basil slag-pit or during a reconstruction of the shaft superstructure. One feature does seem to have acted as a charcoal production pit, although the typical post-features indicating a charcoal clamp are missing. The single 14C date recovered from one of the furnaces places their use in the EIA/DIA transition (520 – 150 cal. BCE). The microanalysis of some of the slag fragments indicates bog ores were a likely source of iron used in these furnaces.

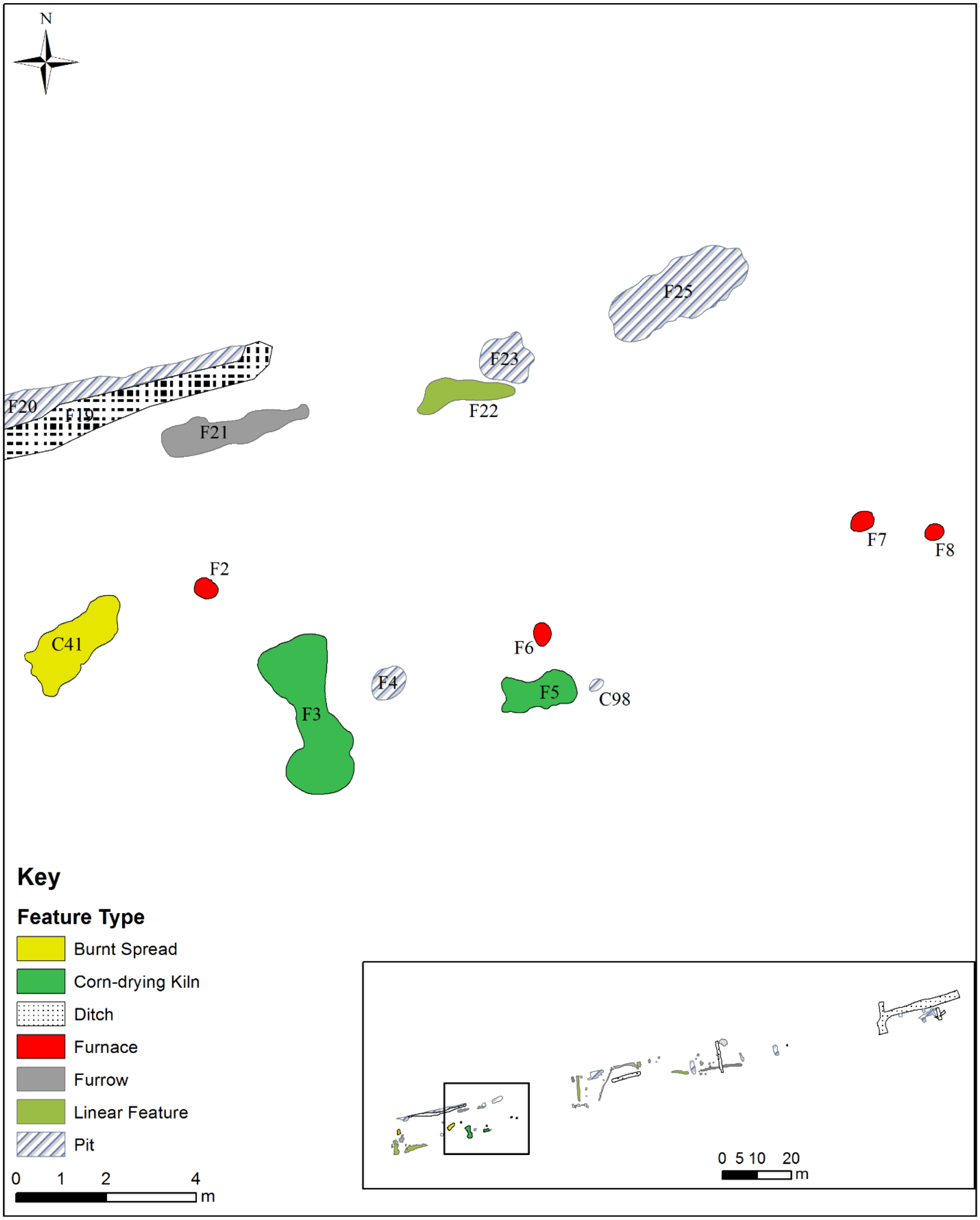
Landscape: "Site 12, in the townland of Cherryville, was 3.60km west-south-west of Kildare town, in low-lying land with frequent bogs spreading from here to the River Barrow in the west. To the north-east, beyond Kildare town, is a somewhat higher area with some low hills, and to the east is the rich grassland of the Curragh. This is all glacial till over limestone, but the Curragh consists of a build-up of sand and gravel washed out from the former ice front (Whittow 1974, 127). Close to the site itself, a stream flowed NNESSW, just 25m to the south. It is situated in an area which is generally quite level, with the land only sloping very slightly in northern direction towards the present N7, Kildare–Monasterevin road."

References: Breen. T. 2008. Kildare Town Bypass: Archaeological Resolution. Final report of Site 12, Cherryville Townland, Co. Kildare. *Unpublished report for Kildare County Council and the NRA.* Valerie J. Keeley Ltd.

Furnace Section:



Cherryville 12 (01E0955)



Close-up of Cherryville 12 (01E0955)

Site Name: Cloncollog 2

County: Offaly

Licence Number: E2850

Townland: Cloncollog

ITM East: 635437.706

ITM North: 723130.592

Excavation conducted by Headland Archaeology

Smelting: Yes **Number of furnaces:** 1

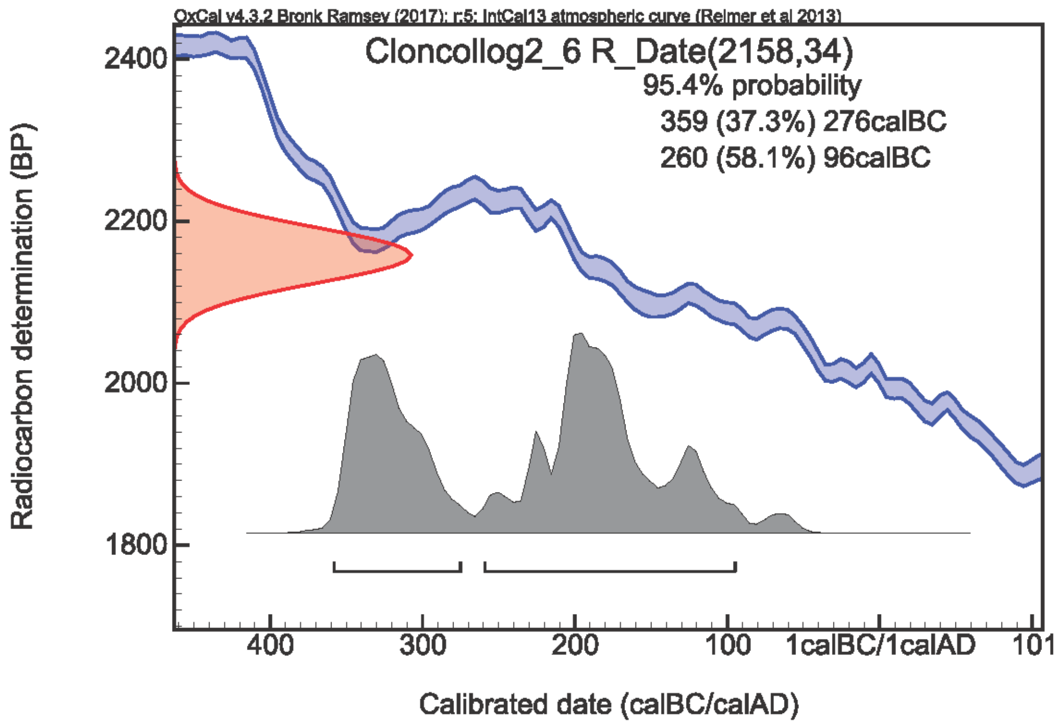
Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: DIA

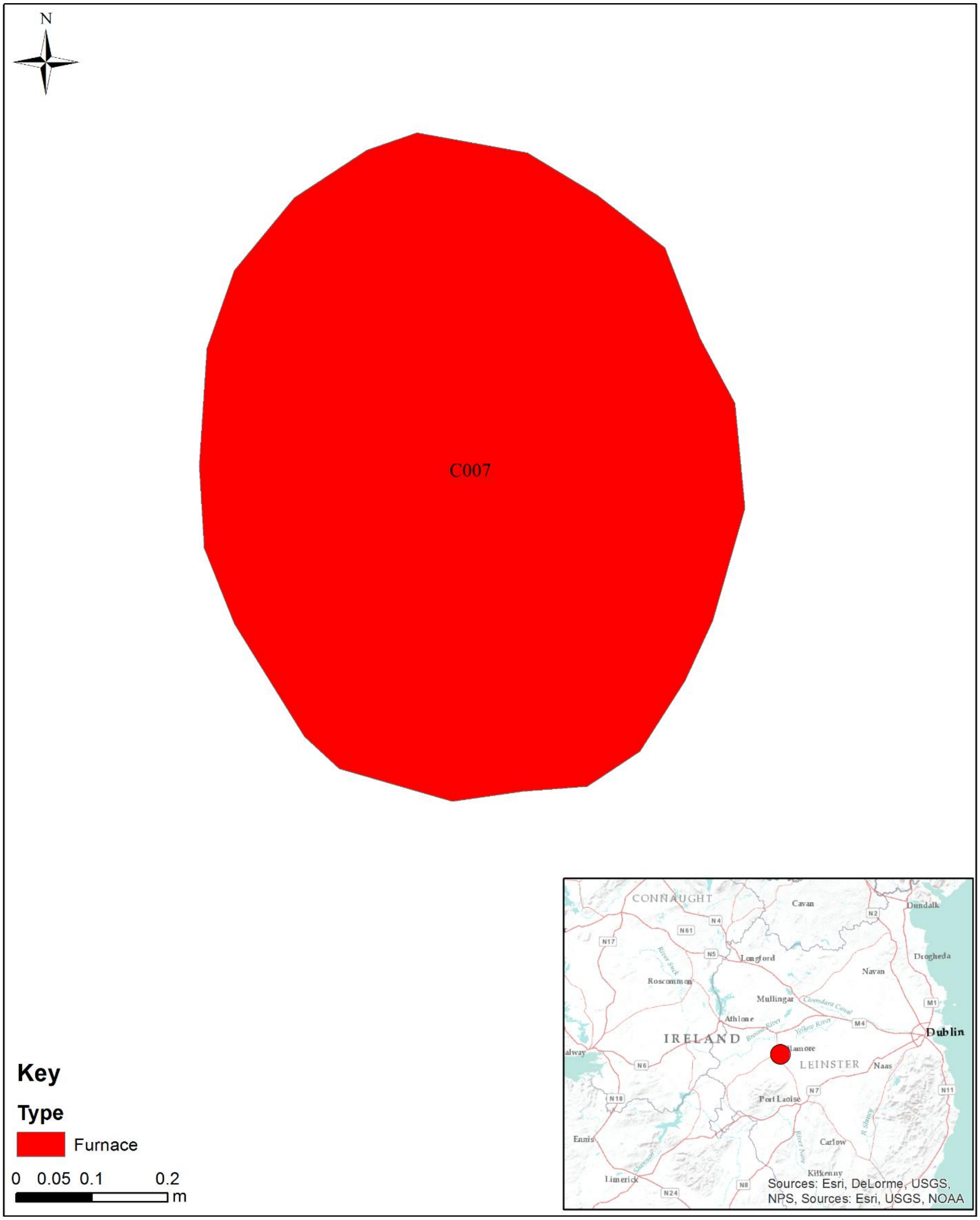
C14 Dates and Context:



Description of Site: This site was discovered as part of the archaeological works project in preparation of the N52 Tullamore Bypass. It consisted of a single pit, later identified to be a slag-pit low shaft furnace. The 14C date recovered from the feature places its use during the DIA (261 – 94 cal. BCE). No other Iron Age occupation has been recorded in the immediate area.

Landscape: **"**The field was irregular in plan and sloped gently from northeast to southwest."

References: Clark, L. N52 Tullamore Bypass: Final report on archaeological excavations at Cloncollog 2 E2850, in the townland of Cloncollog, Co. Offaly. *Unpublished report for the Offaly County Council*. Headland Archaeology Ltd.



Cloncollog 2 (E2850)

Site Name: Clonrud 4 **County:** Laois

Licence Number: E2167 **Townland:** Clonrud

ITM East: 637211.78 **ITM North:** 688627.027

Excavation conducted by Archaeological Consultancy Services Ltd

Smelting: Yes **Number of furnaces:** 2

Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

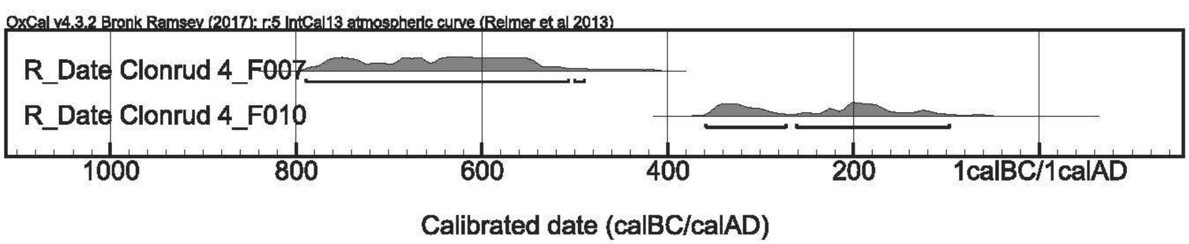
Type of Site: Isolated Metalworking

Chronology: LBA/EIA

C14 Dates and Context:

Clonrud 4_F007 R_Date(2495,35)
68.2% probability
766BC (12.9%) 735BC
688BC (11.1%) 662BC
648BC (44.2%) 546BC
95.4% probability
790BC (94.6%) 507BC
500BC (0.8%) 490BC

Clonrud 4_F010 R_Date(2160,35)
68.2% probability
352BC (33.8%) 296BC
229BC (3.7%) 220BC
212BC (30.7%) 166BC
95.4% probability
359BC (38.7%) 273BC
262BC (56.7%) 97BC

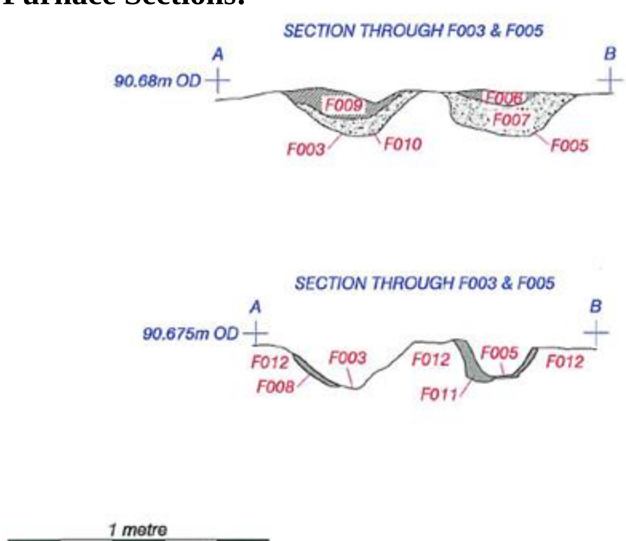


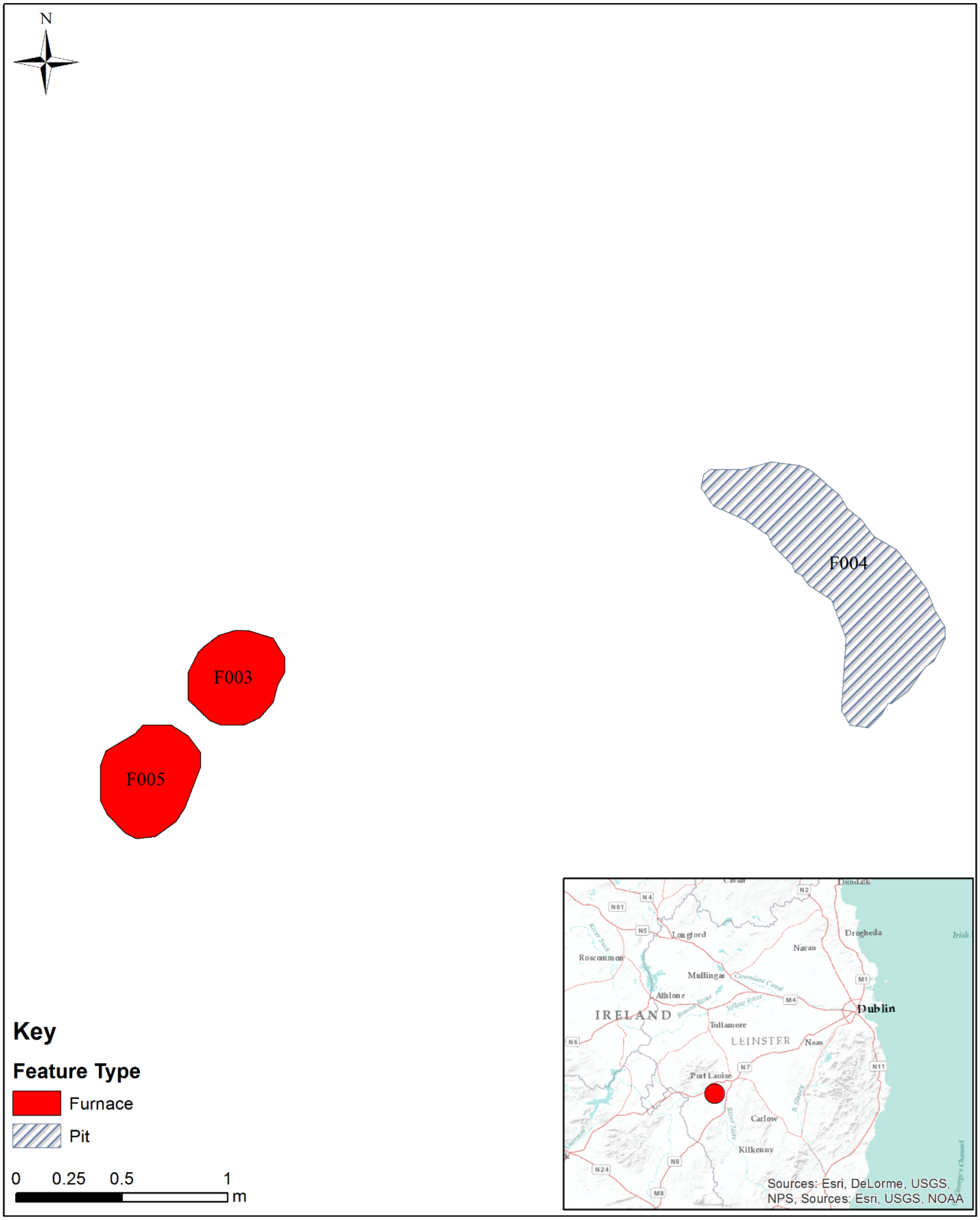
Description of Site: This site was discovered during the archaeological investigation of the M7 Portlaoise – Castletown/M8 Portlaoise-Cullahill Motorway Scheme. The site contains two smelting furnaces, likely slag-pit low shaft furnaces. The morphology of the two structures matches those found elsewhere, with steep sides and flat bottoms, though one side of each furnace appears to have been straight rather than curved, possibly representing the blowing wall. An additional feature was found at this site that represented a waste pit which also produced slag as a secondary deposit. The two furnaces provided two 14C dates, one from 790 – 500 cal. BCE and another at 360 – 90 cal. BCE. It is argued that because the early date was produced by a sample of oak, it is incorrectly 'old' and that the more recent date provides a more accurate timeline for the use of the site. A small piece of bog ore was recovered from one of the furnaces, suggesting this is the type of ore utilized at this small ironworking site.

Landscape: "Clonrud 4 was situated over 4.5km to the southeast of Castletown. The site was located along a prominent ridge bordering a large expanse of peatland to the east and undulating pasture to the north, south and west. Clonrud townland was located approximately 1km east of the River Nore and c.1km from the burnt mound activity in the townland of Cappaloughlin."

References: Kane, E. 2009a. M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill motorway scheme. Report on the archaeological excavation of Clonrud 4, Co. Laois. *Unpublished report for Laois County Council.* Archaeological Consultancy Services Ltd.

Furnace Sections:





Clonrud 4 (E2167)

Site Name: Derrinsallagh 4

County: Laois

Licence Number: E2180

Townland: Derrinsallagh

ITM East: 625144.256

ITM North: 685859.137

Excavation conducted by Archaeological Consultancy Services Ltd

Smelting: Yes **Number of furnaces:** 44

Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Structure

Chronology: DIA/LIA

C14 Dates and Context:

Derrinsallagh4_F606 R_Date(2900,35)
68.2% probability
1126BC (68.2%) 1016BC
95.4% probability
1212BC (95.4%) 996BC

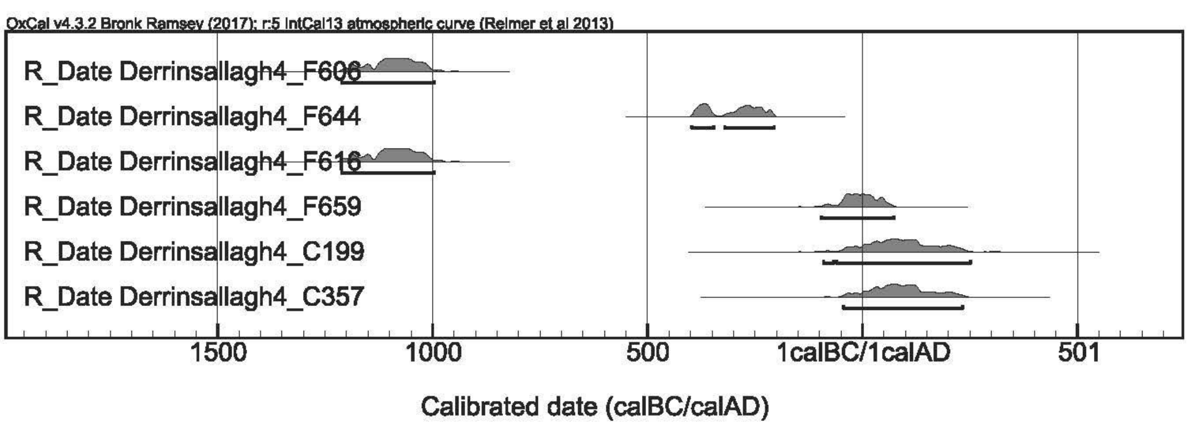
Derrinsallagh4_C199 R_Date(1920,70)
68.2% probability
2AD (64.0%) 170AD
194AD (4.2%) 210AD
95.4% probability
91BC (1.2%) 68BC
61BC (94.2%) 252AD

Derrinsallagh4_F644 R_Date(2255,35)
68.2% probability
388BC (27.4%) 354BC
290BC (40.8%) 232BC
95.4% probability
398BC (33.7%) 346BC
321BC (61.7%) 206BC

Derrinsallagh4_F616 R_Date(2900,35)
68.2% probability
1126BC (68.2%) 1016BC
95.4% probability
1212BC (95.4%) 996BC

Derrinsallagh4_C357 R_Date(1920,60)
68.2% probability
2AD (66.3%) 138AD
198AD (1.9%) 206AD
95.4% probability
44BC (95.4%) 234AD

Derrinsallagh4_F659 R_Date(2005,35)
68.2% probability
44BC (62.7%) 27AD
40AD (5.5%) 48AD
95.4% probability
96BC (95.4%) 74AD



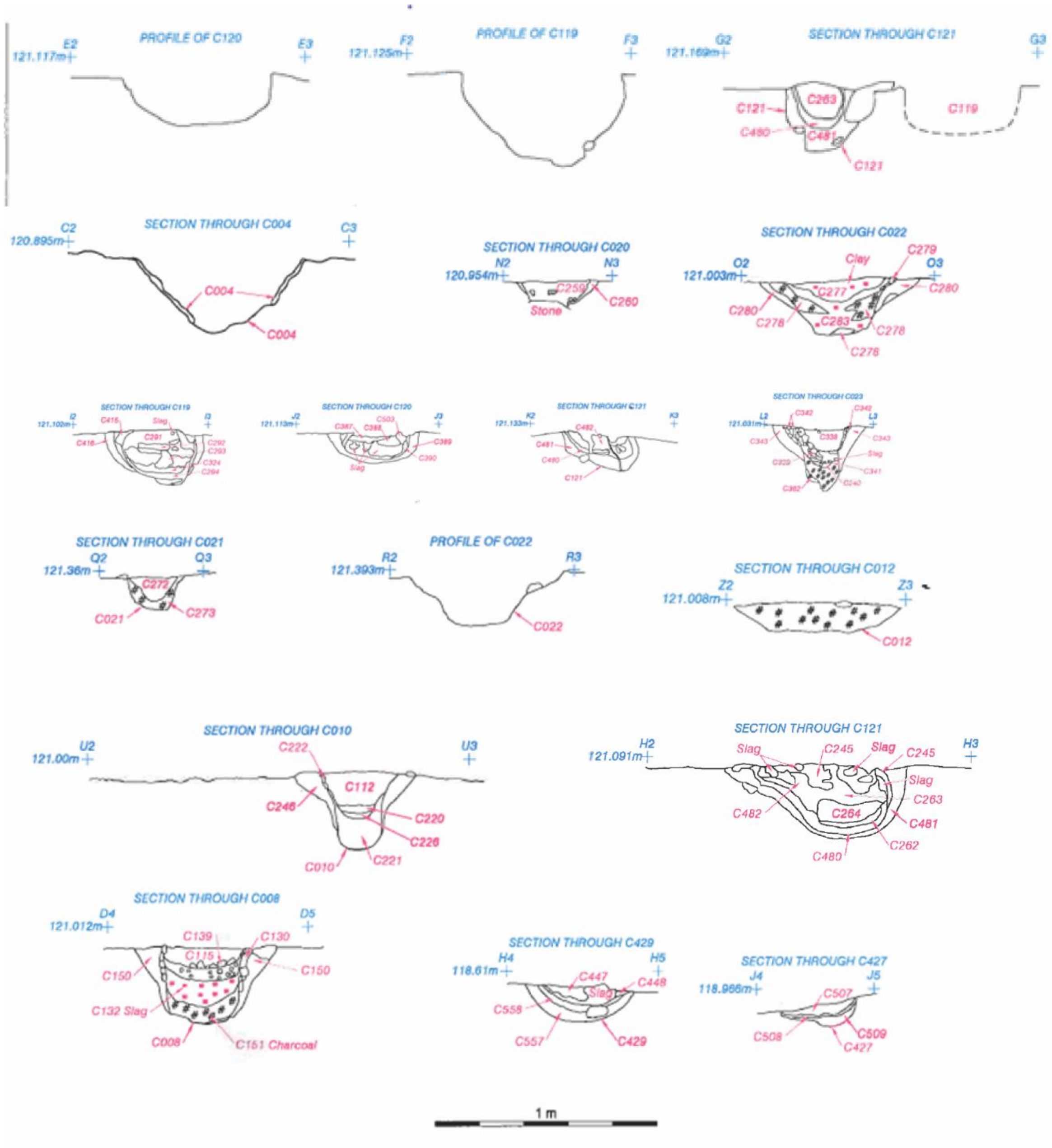
Description of Site: This site was uncovered prior to the construction of the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme. This site is arguably the most significant site for Early and Developed Iron Age iron production due to the large number of furnaces discovered at the site. While there is limited evidence for Neolithic occupation, there was a D-shaped structure and associated pits uncovered at the site that date to the LBA. The evidence for Iron Age activity at the site consisted of a sub-circular slot-trench structure, 44 furnaces, four charcoal production pits and an assortment of other features. All of the furnaces appear to date from the 1st century BCE to the 1st century CE. These furnaces often appear in clusters of two or three across the site. The morphology of each furnace varies widely; some exhibit shapes characteristic of slag-pit furnaces, while others have more rounded sides and bases. Of specific note was one furnace that was removed en bloc and excavated in lab conditions. This revealed that it was a "evolved" form of a non-tapping slag pit furnace with an arch mostly below the original surface that connected the furnace to a working hollow. Since the arch is above the bottom of the slag pit, it could not have been used to tap slag. The furnace would have been blown originally at a right angle to the arch, but in later uses the blowhole was moved across from the arch. The furnace may have had an overhanging wall, cause by a dome or bottle shaped superstructure.

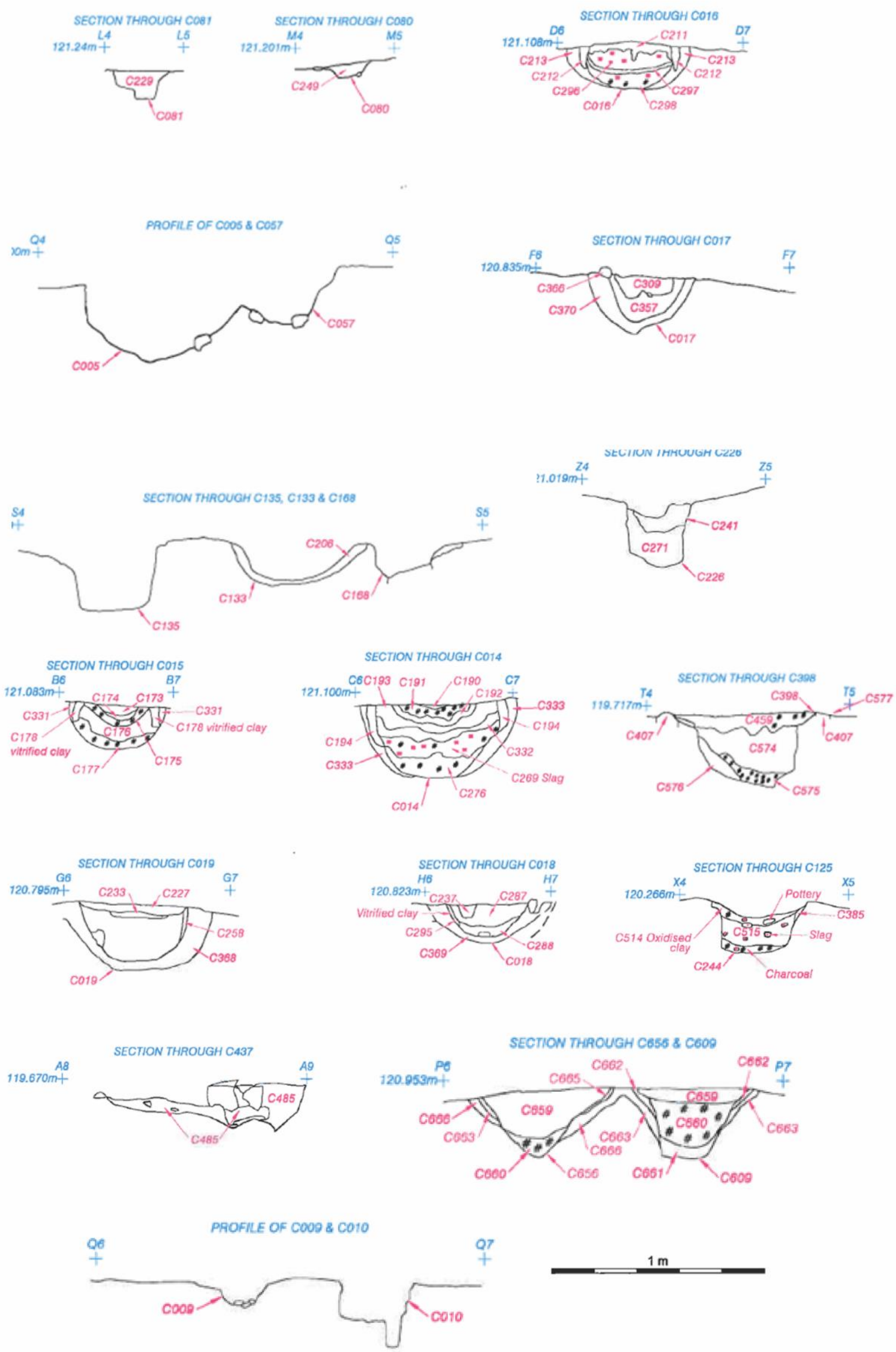
This site should be considered within a wider complex of Iron Age iron production on the landscape. C. 350m to the northeast was Derrinsallagh 5, which produced evidence of a single furnace dating the EIA/DIA. Additionally, 1.5km to the northeast was the site of Derryvorrigan 1 which produced evidence of iron production that dated to the DIA/LIA transition, and demonstrated similar furnace morphology to those found at Derrinsallgh 4. Less than 2.5km to the east lay the site of Barnasallagh 1 which provided evidence for a charcoal production pit dated to 110 cal. BCE – 80 cal. CE, which could have been used to support the iron production at Derryvorrigan.

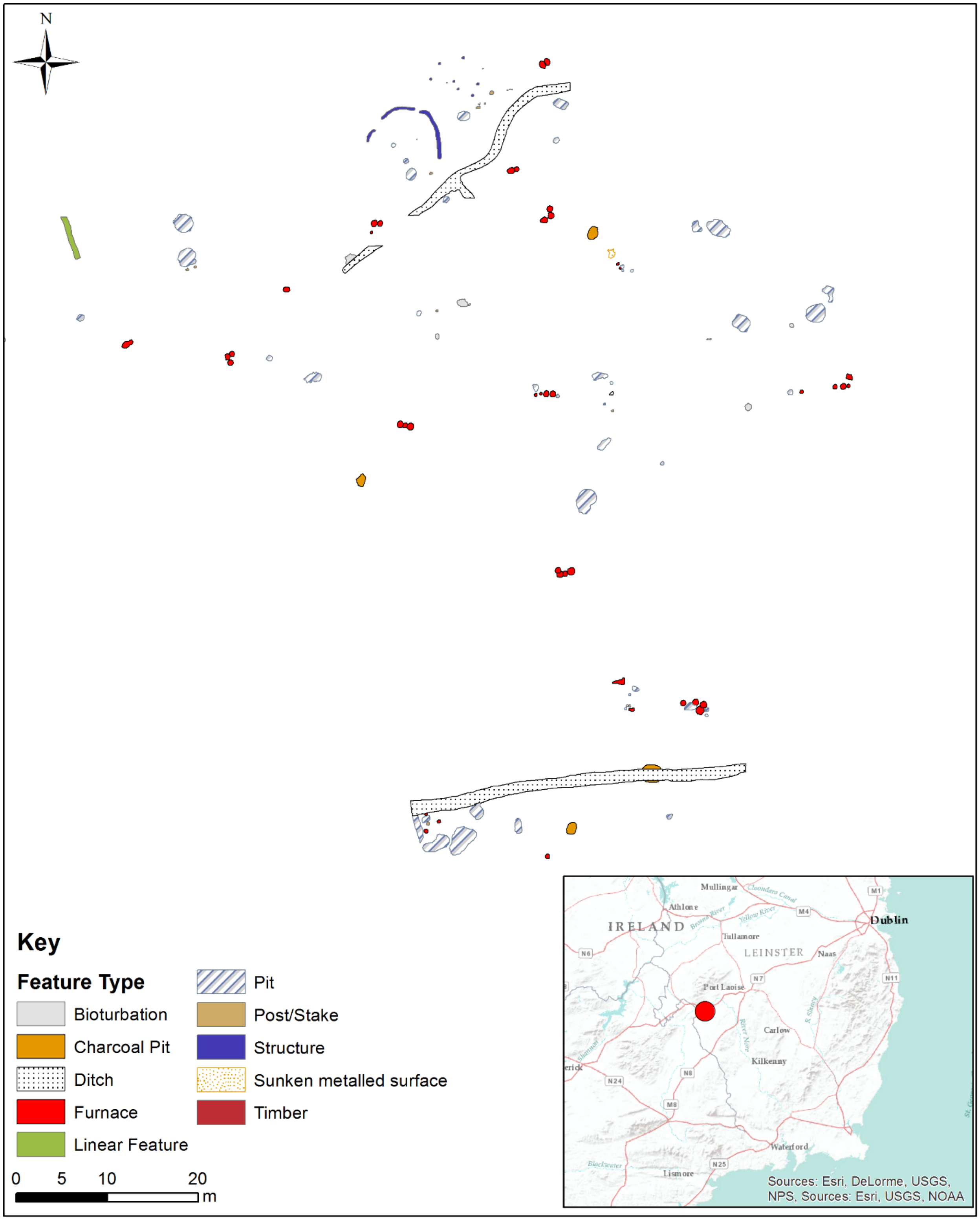
Landscape: "The location of the site of Derrinsallagh 4 in particular, but also the other recently discovered sites associated with metal-working and iron production (Derrinsallagh 1, 5 and Derryvorrigan 1 East), in close proximity to patches of bogland with free-flowing streams and oak abundant woodlands is quite significant. The integral use of oak wood in charcoal production and the important exploitation of locally available bog-iron ores will be discussed in detail later on in the report, but these factors would no doubt have had a major influence in the siting of these iron producing sites"

References: Lennon, A.M. and E. Kane. 2009a. M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill motorway scheme. Report on the archaeological excavation of Derrinsallagh 4, Co. Laois. *Unpublished report for Laois County Council.* Archaeological Consultancy Services Ltd.

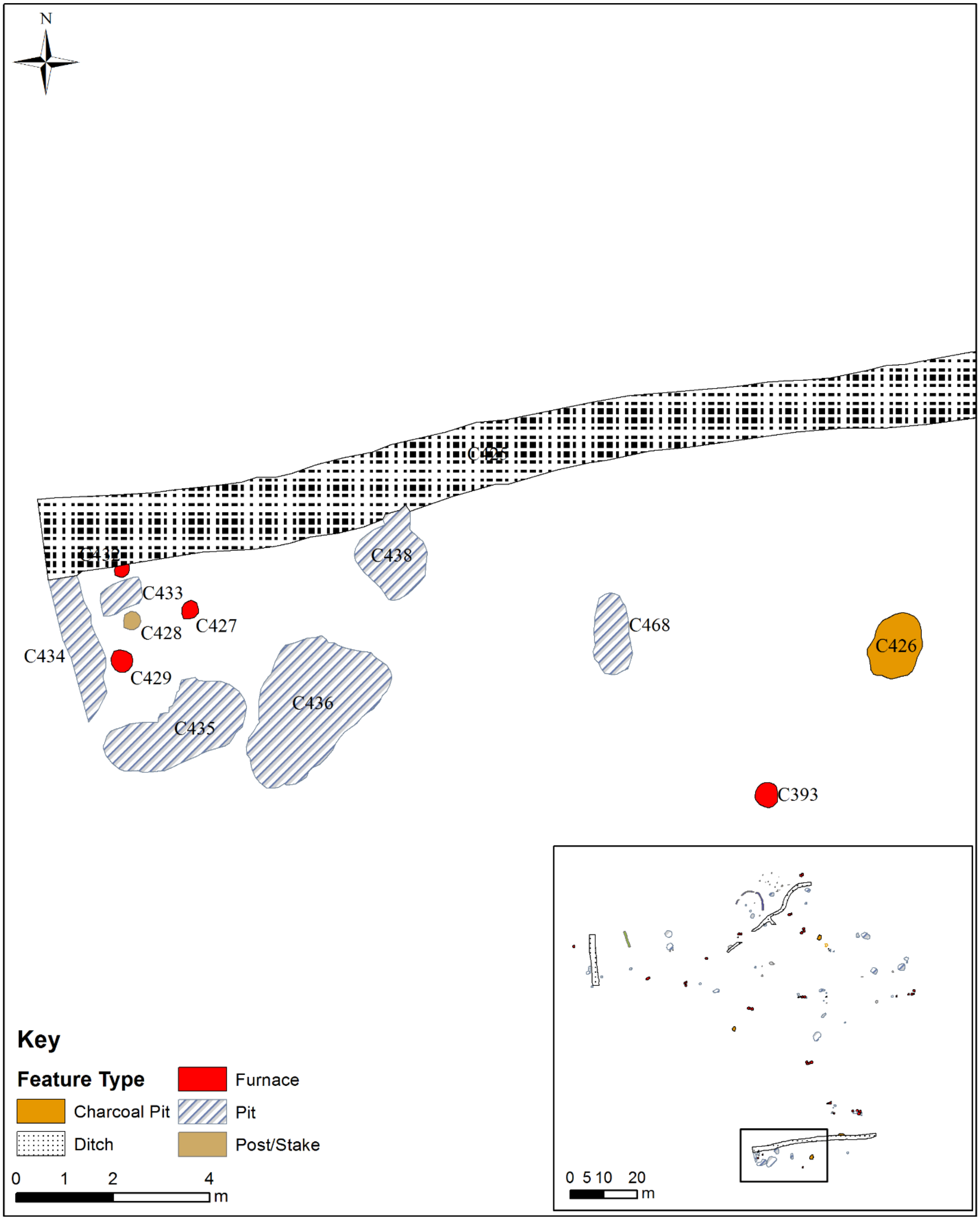
Furnace Sections:


PROFILE OF C120
E2
121.117m
E3
PROFILE OF C119
F2
121.125m
F3
SECTION THROUGH C121
G2
121.169m
G3
C263
C121
C119
C480
C481
C121
SECTION THROUGH C004
C2
120.895m
C3
C004
C004
SECTION THROUGH C020
N2
N3
120.954m
C259
Stone
C260
SECTION THROUGH C022
O2
O3
121.003m
Clay
C279
C277
C280
C280
C278
C283
C278
C278
SECTION THROUGH C021
Q2
Q3
121.36m
C272
C021
C273
PROFILE OF C022
R2
R3
121.393m
C022
SECTION THROUGH C012
Z2
Z3
121.008m
C012
SECTION THROUGH C010
U2
U3
121.00m
C222
C112
C246
C220
C226
C010
C221
SECTION THROUGH C121
H2
H3
121.091m
Slag
C245
Slag
C245
Slag
C263
C482
C264
C481
C480
C262
SECTION THROUGH C008
D4
D5
121.012m
C139
C130
C115
C150
C150
C132 Slag
C008
C151 Charcoal
SECTION THROUGH C429
H4
H5
118.61m
C447
C448
Slag
C558
C557
C429
SECTION THROUGH C427
J4
J5
118.966m
C507
C508
C509
C427
1 m

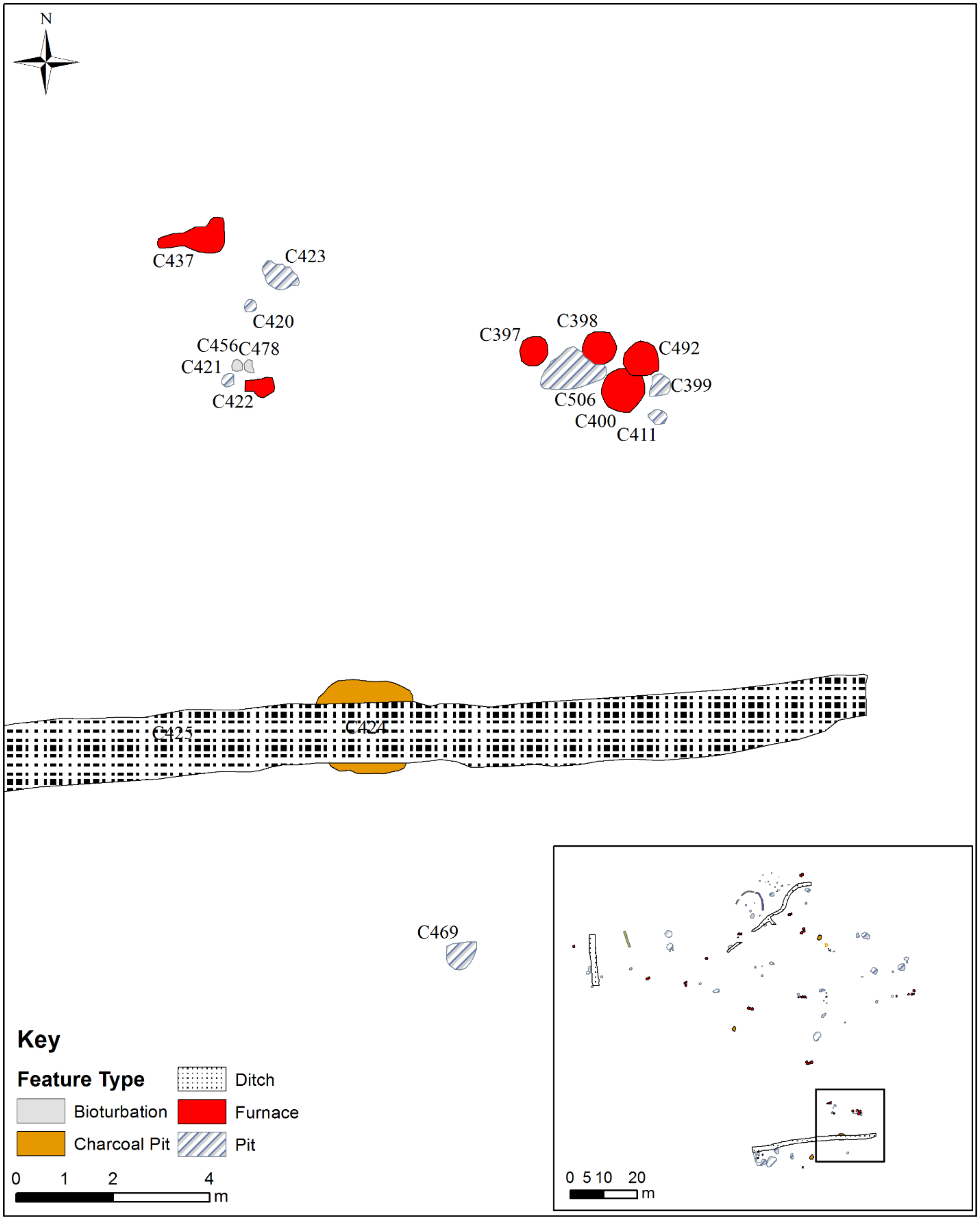

SECTION THROUGH C081
L4
L5
121.24m
C229
C081
SECTION THROUGH C080
M4
M5
121.201m
C249
C080
SECTION THROUGH C016
D6
D7
121.108m
C211
C213
C212
C296
C297
C016
C298
PROFILE OF C005 & C057
Q4
Q5
C057
C005
SECTION THROUGH C017
F6
F7
120.835m
C366
C309
C370
C357
C017
SECTION THROUGH C226
Z4
Z5
C241
C271
C226
SECTION THROUGH C135, C133 & C168
S4
S5
C206
C133
C168
C135
SECTION THROUGH C015
B6
B7
121.083m
C174
C173
C331
C176
C178 vitrified clay
C178
vitrified clay
C177
C175
SECTION THROUGH C014
C6
C7
121.100m
C193
C191
C190
C192
C333
C194
C332
C269 Slag
C276
C014
SECTION THROUGH C398
T4
T5
119.717m
C398
C577
C459
C407
C574
C576
C575
SECTION THROUGH C019
G6
G7
120.795m
C233
C227
C258
C368
C019
SECTION THROUGH C018
H6
H7
120.823m
C237
C287
Vitrified clay
C295
C288
C369
C018
SECTION THROUGH C125
X4
X5
120.266m
Pottery
C385
C514 Oxidised clay
C515
Slag
C244
Charcoal
SECTION THROUGH C437
A8
A9
119.670m
C485
SECTION THROUGH C656 & C609
P6
P7
120.953m
C665
C662
C659
C666
C653
C663
C660
C656
C661
C609
PROFILE OF C009 & C010
Q6
Q7
1 m
C009
C010



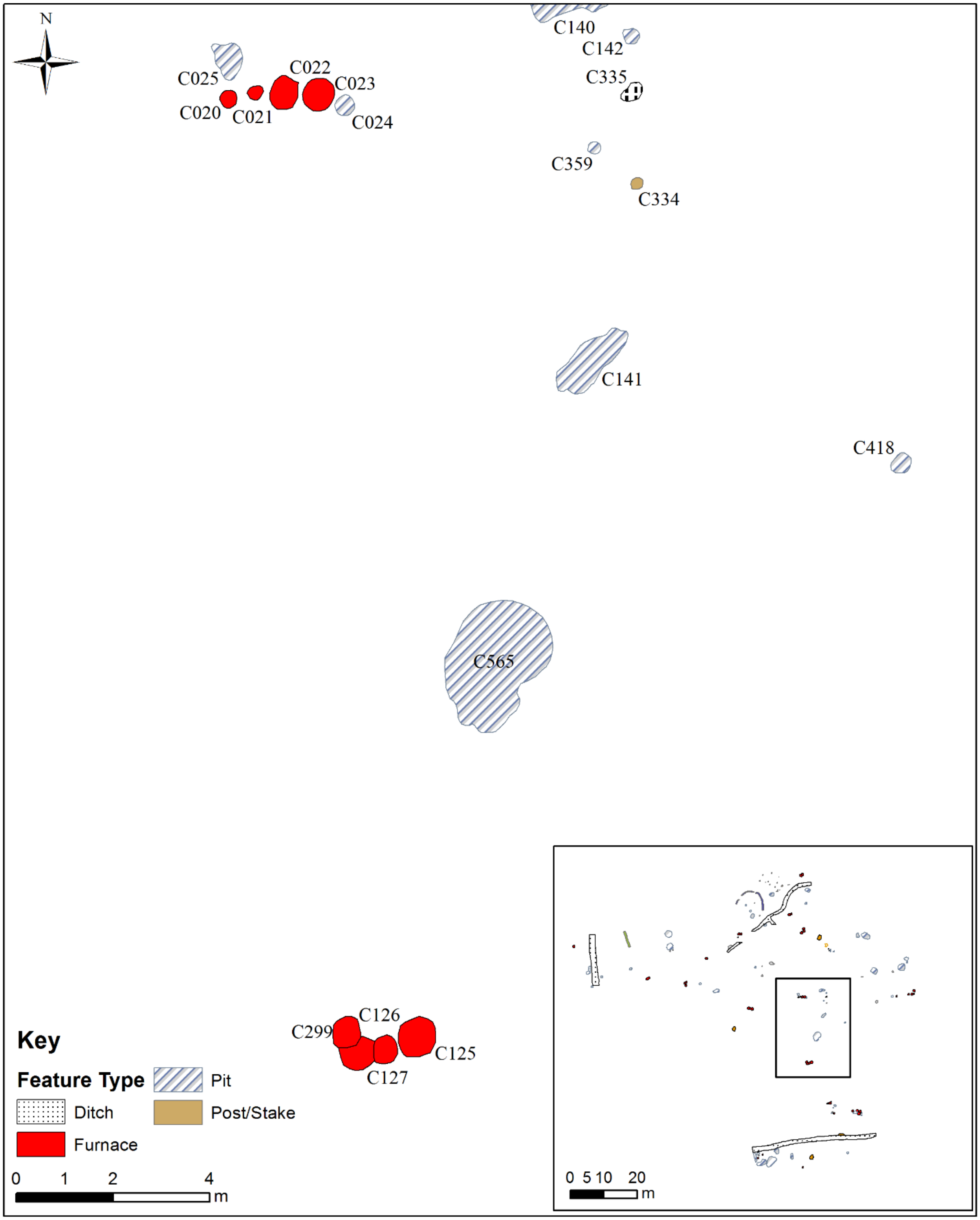
Derrinsallagh 4 (E2180)



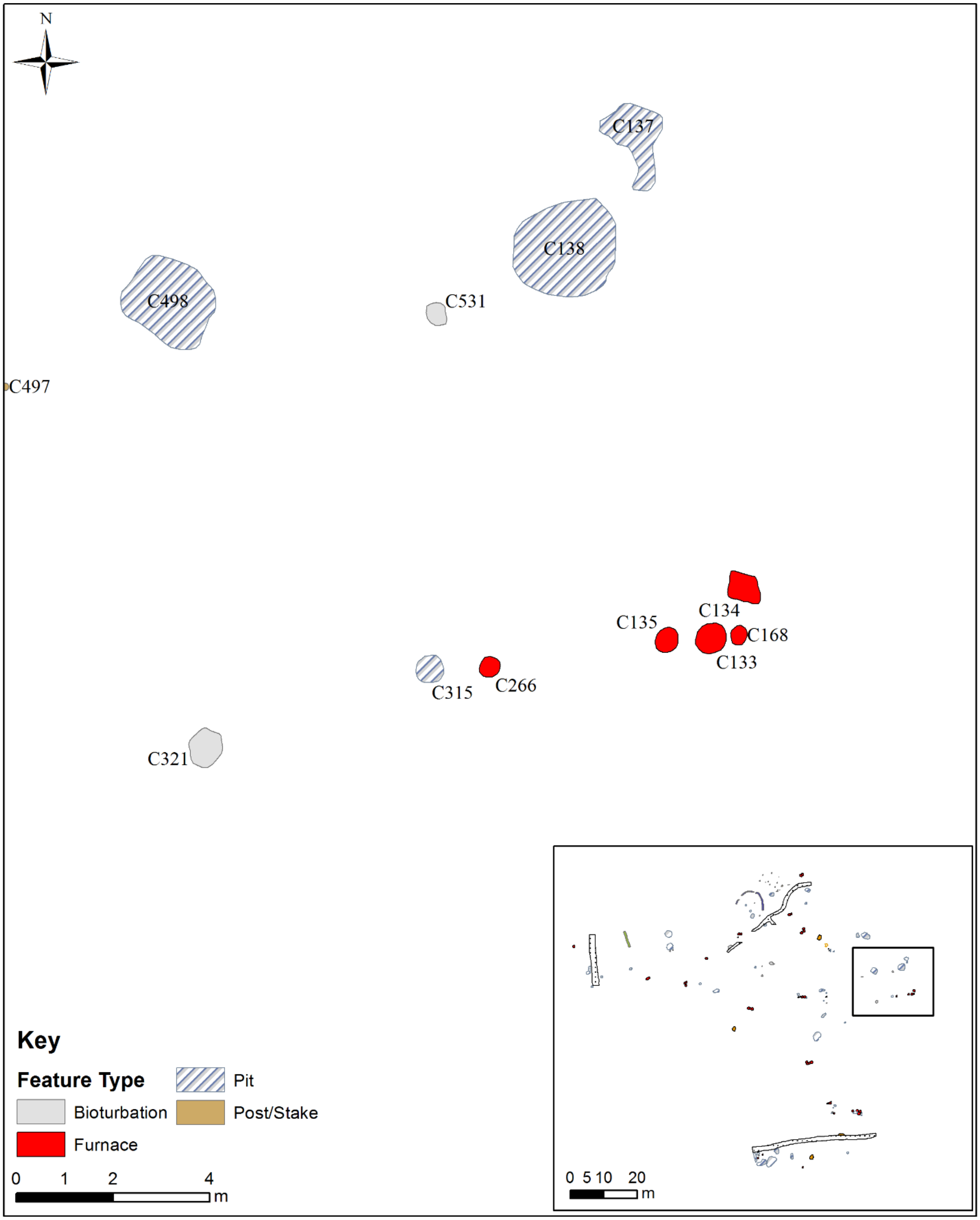
Close-up of Derrinsallagh 4 (E2180)



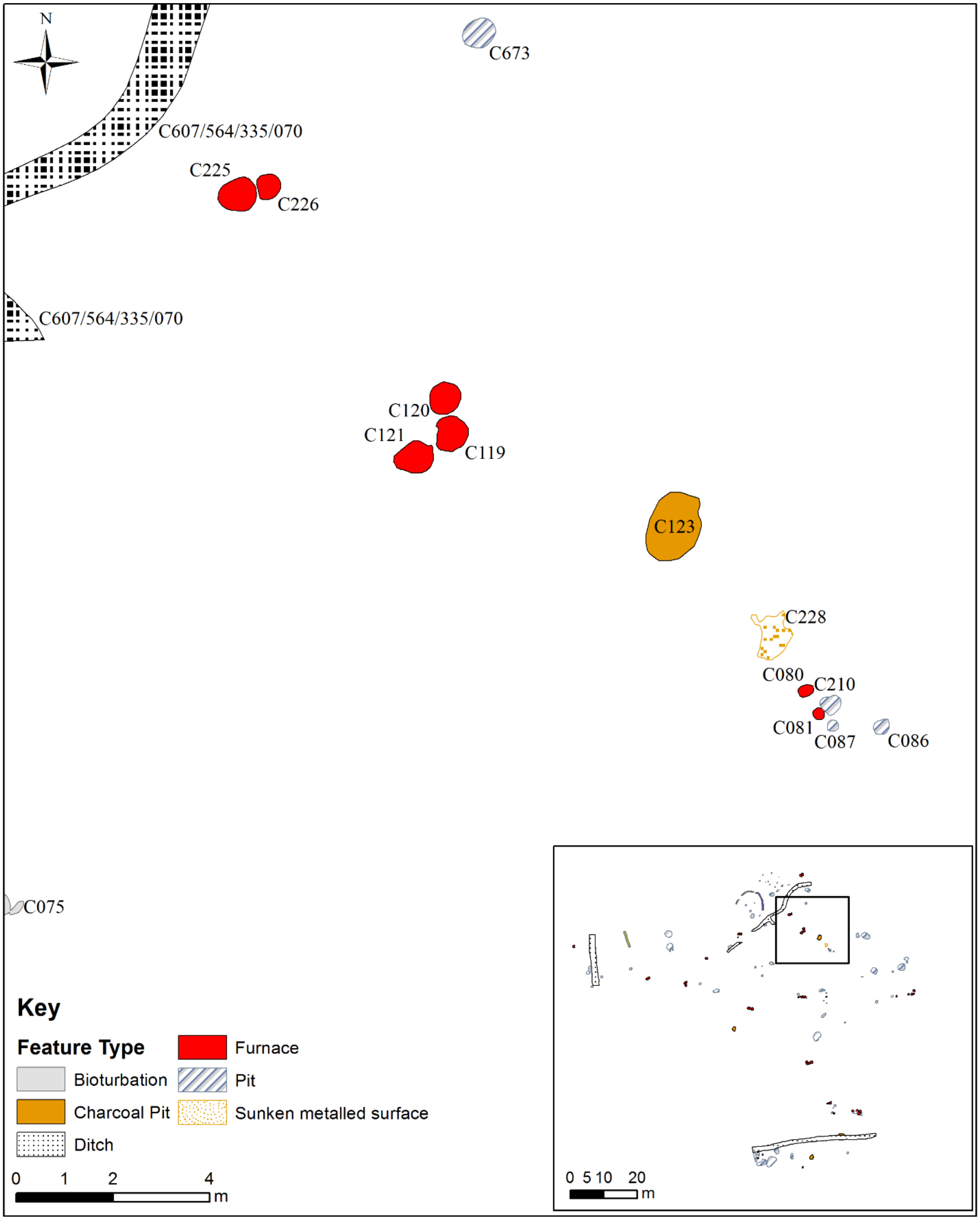
Close-up of Derrinsallagh 4 (E2180)



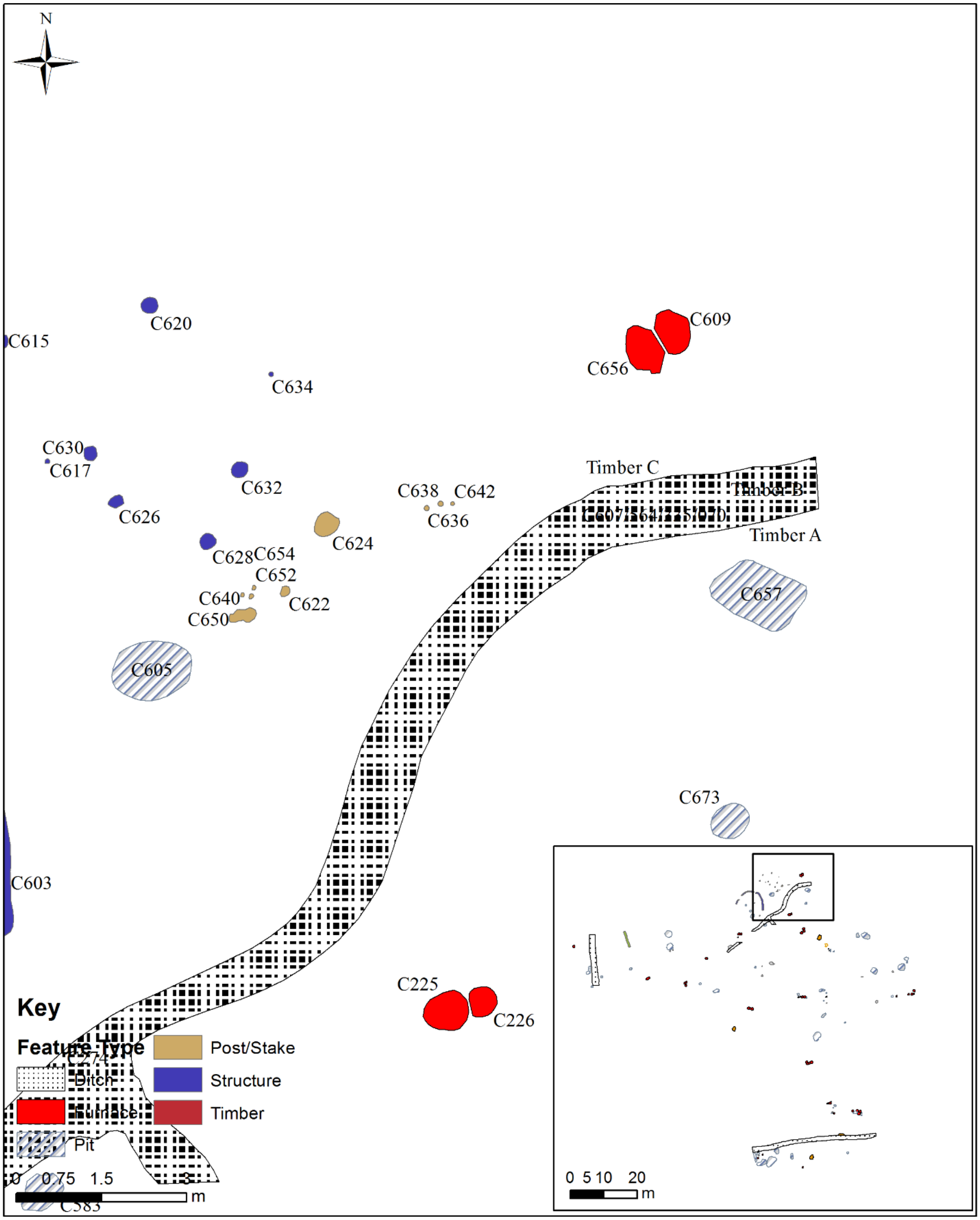
Close-up of Derrinsallagh 4 (E2180)



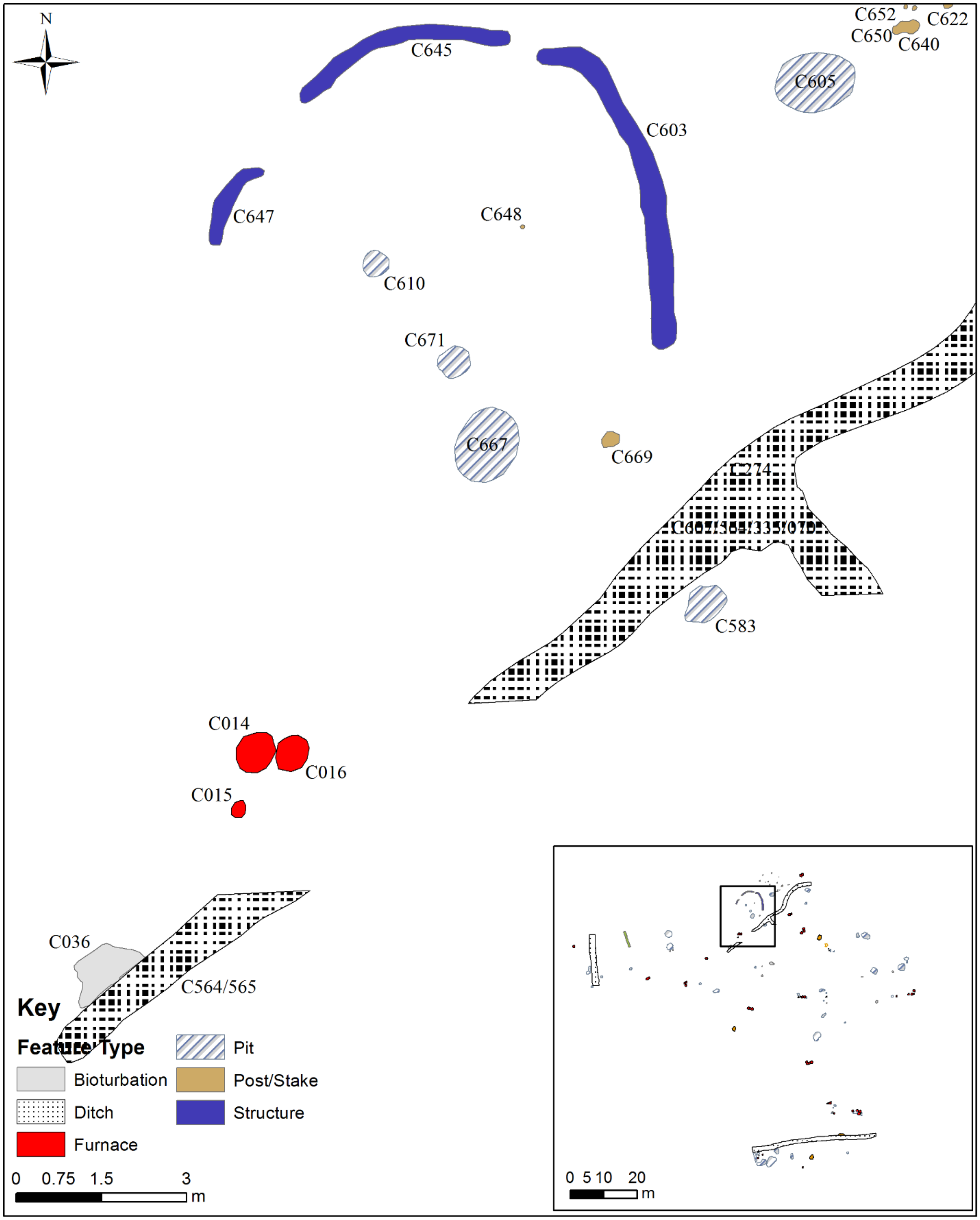
Close-up of Derrinsallagh 4 (E2180)



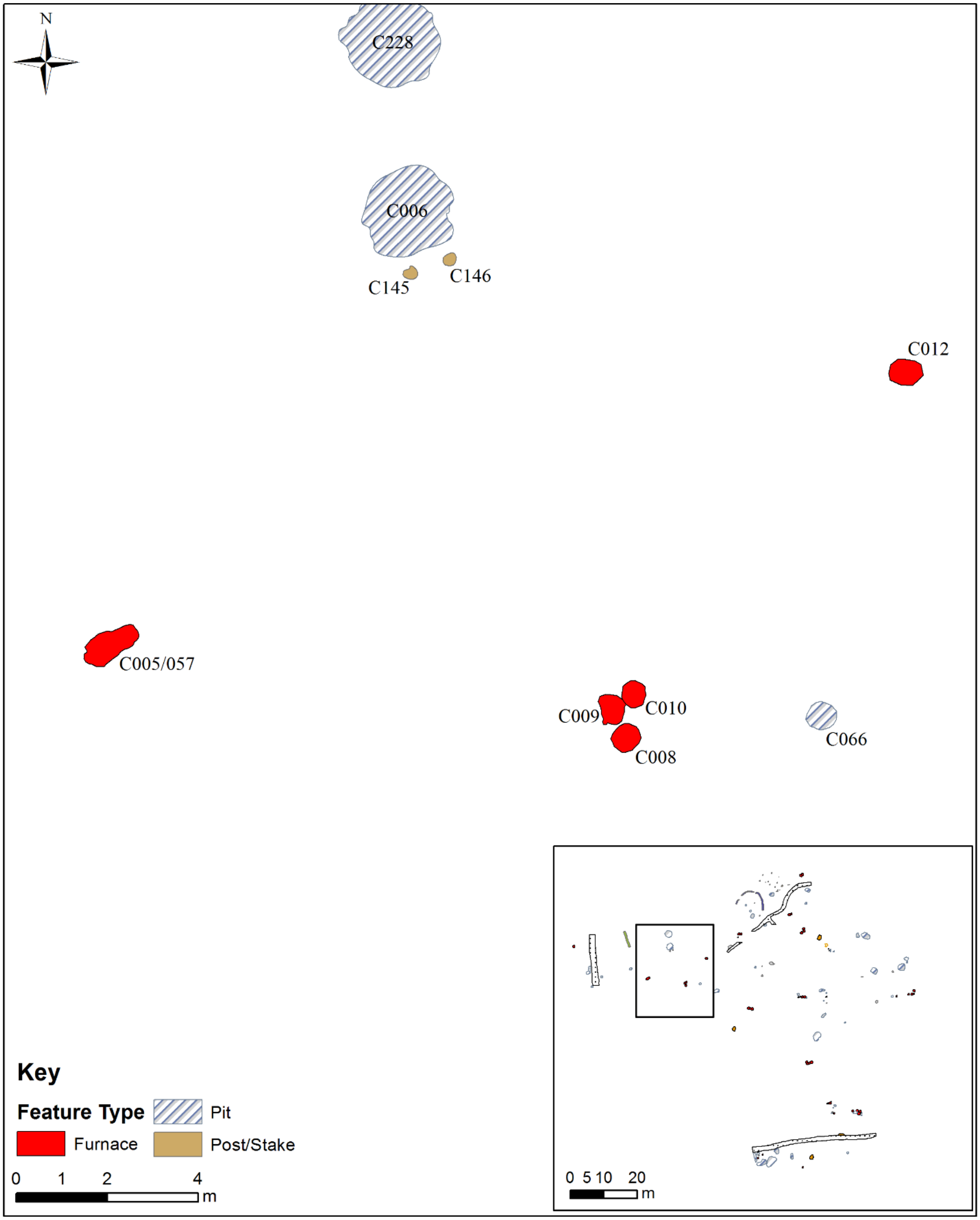
Close-up of Derrinsallagh 4 (E2180)



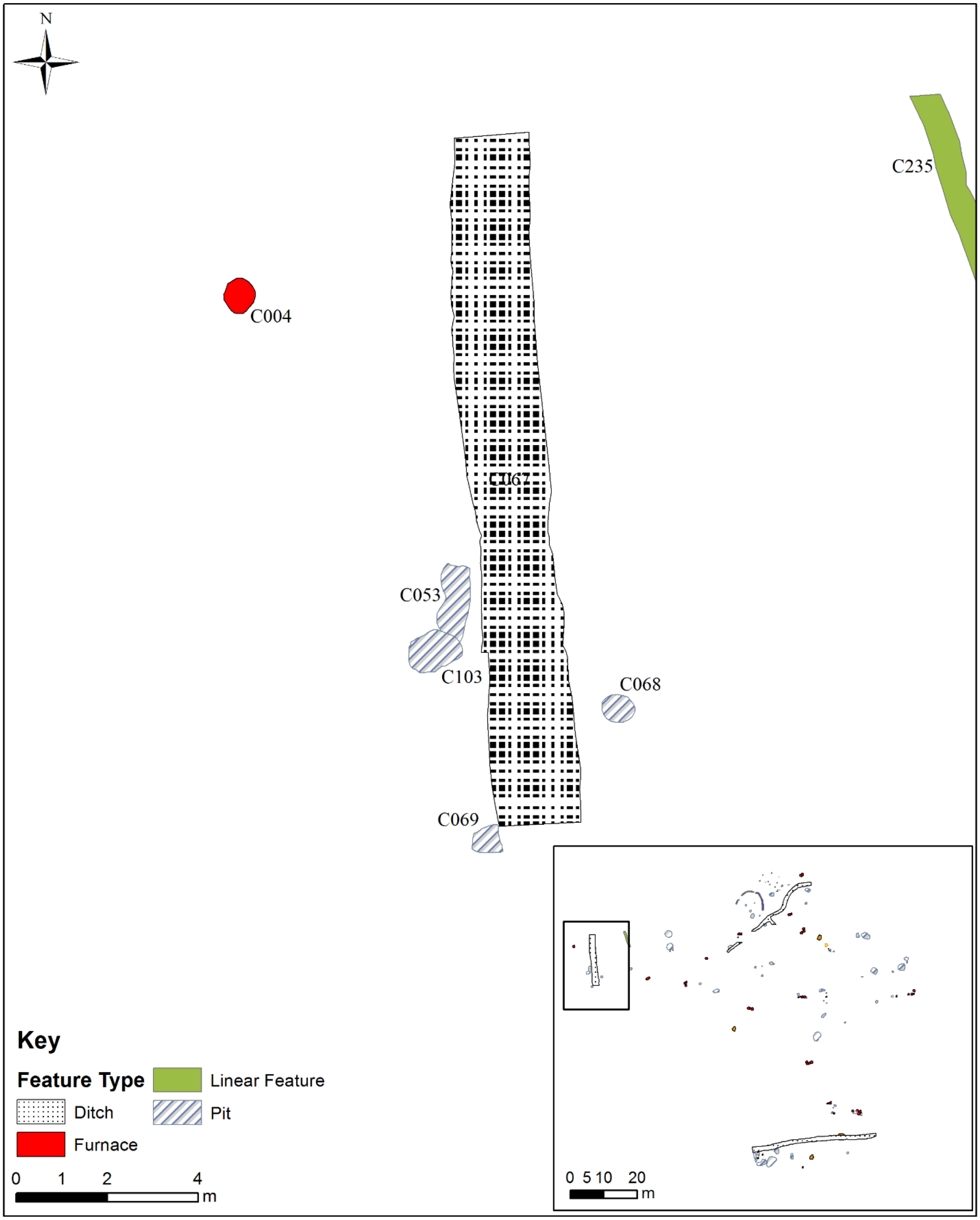
Close-up of Derrinsallagh 4 (E2180)



Close-up of Derrinsallagh 4 (E2180)



Close-up of Derrinsallagh 4 (E2180)



Close-up of Derrinsallagh 4 (E2180)

Site Name: Derrinsallagh 5

County: Laois

Licence Number: E2181

Townland: Derrinsallagh

ITM East: 625561.25

ITM North: 685789.638

Excavation conducted by Archaeological Consultancy Services Ltd

Smelting: Yes **Number of furnaces:** 1

Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

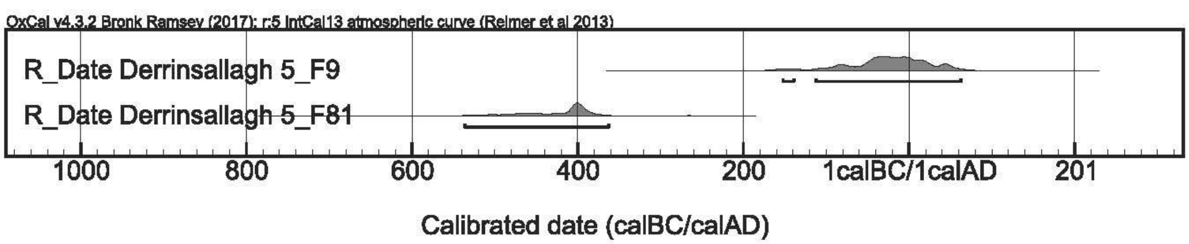
Type of Site: Isolated Metalworking

Chronology: EIA/DIA/LIA

C14 Dates and Context:

Derrinsallagh 5_F9 R_Date(2020,35)
68.2% probability
54BC (65.8%) 26AD
42AD (2.4%) 47AD
95.4% probability
152BC (1.6%) 140BC
112BC (93.8%) 63AD

Derrinsallagh 5_F81 R_Date(2345,35)
68.2% probability
474BC (10.7%) 444BC
430BC (57.5%) 380BC
95.4% probability
537BC (95.4%) 363BC

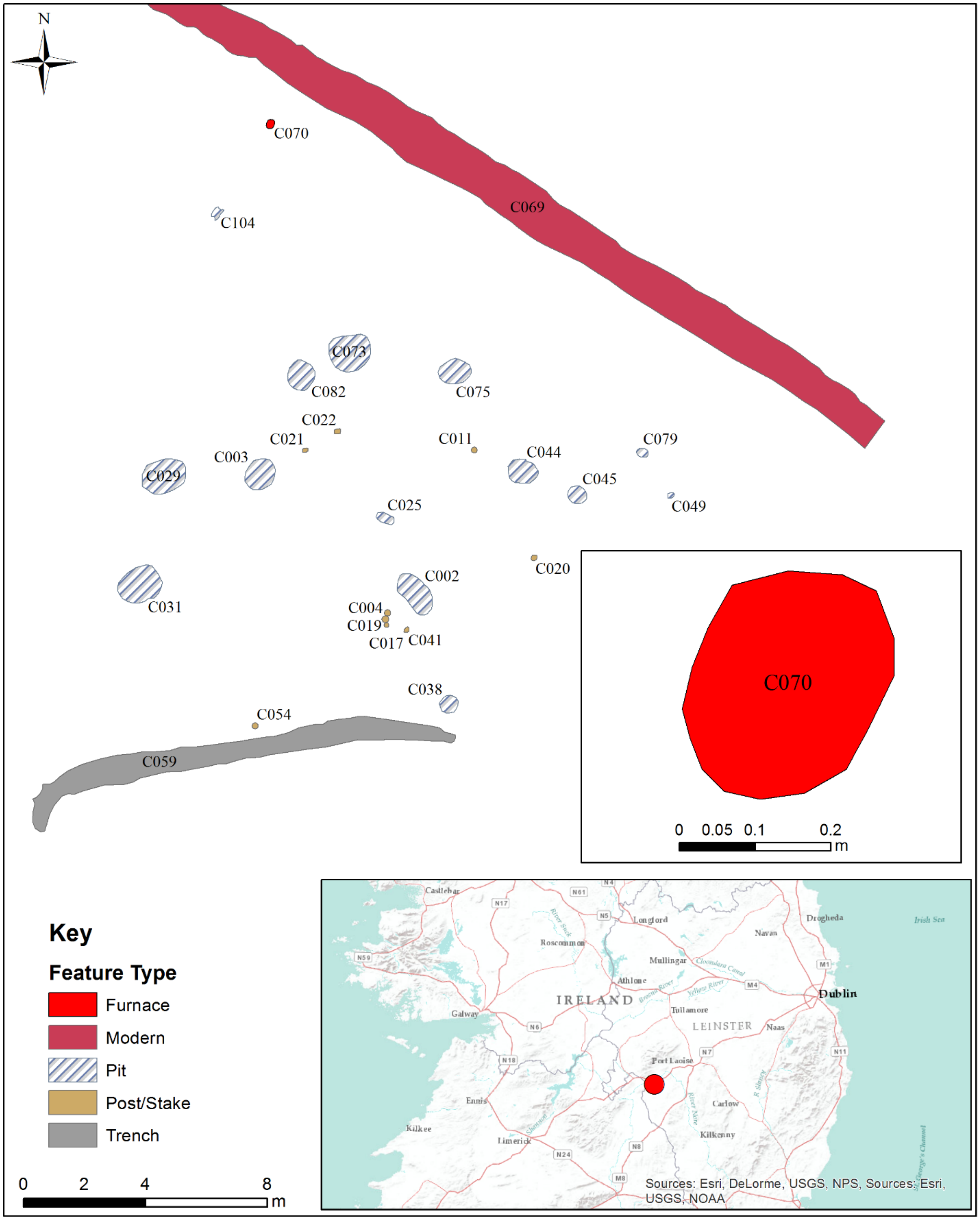


Description of Site: This site was discovered prior to the construction of the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme. It consisted of sixteen pits and various stakeholes. One of these features was interpreted as a smelting furnace, and produced a 14C date of 520 – 350 cal. BCE, although the date was taken from an oak sample, which often produces ‘old ages.’ Analysis of the slag indicates that this feature was a slag-pit furnace, even though it was quite small (0.25m in diameter) compared to contemporary furnaces.

This site should be considered within a wider complex of Iron Age iron production on the landscape. C. 350m to the southwest was Derrinsallagh 4, which produced evidence of a 44 smelting furnaces. Additionally, just over 1km to the east was the site of Derryvorrigan 1 which produced evidence of iron production that dated to the DIA/LIA transition, and demonstrated similar furnace morphology to those found at Derrinsallgh 4. Around 2km to the east lay the site of Barnasallagh 1 which provided evidence for a charcoal production pit dated to 110 cal. BCE – 80 cal. CE, which could have been used to support the iron production at Derryvorrigan.

Landscape: “The location of the site of Derrinsallagh 4 in particular, but also the other recently discovered sites associated with metal-working and iron production (Derrinsallagh 1, 5 and Derryvorrigan 1 East), in close proximity to patches of bogland with free-flowing streams and oak abundant woodlands is quite significant. The integral use of oak wood in charcoal production and the important exploitation of locally available bog-iron ores will be discussed in detail later on in the report, but these factors would no doubt have had a major influence in the siting of these ironproducing sites.”

References: Lennon, A. M. 2009. M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill motorway scheme. Final report for Derrinsallagh 5, Co. Laois. *Unpublished report for the Laois County Council*. Archaeological Consultancy Services Ltd.



Derrinsallagh 5 (E2181)

Site Name: Derryvorrigan 1

County: Laois

Licence Number: E2193

Townland: Derryvorrigan

ITM East: 626784.432

ITM North: 685817.438

Excavation conducted by Archaeological Consultancy Services Ltd

Smelting: Yes **Number of furnaces:** 8

Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Structure

Chronology: DIA/LIA

C14 Dates and Context:

Derryvorrigan1_F121 R_Date(1975,35)
68.2% probability
20BC (6.0%) 11BC
2BC (62.2%) 67AD
95.4% probability
49BC (93.6%) 86AD
106AD (1.8%) 120AD

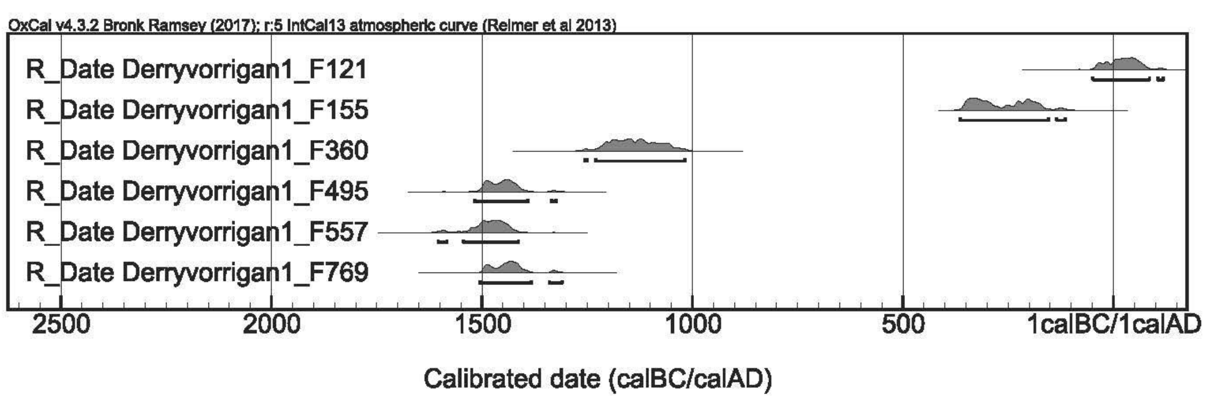
Derryvorrigan1_F155 R_Date(2175,35)
68.2% probability
354BC (39.0%) 291BC
232BC (29.2%) 176BC
95.4% probability
364BC (92.7%) 155BC
135BC (2.7%) 115BC

Derryvorrigan1_F360 R_Date(2935,35)
68.2% probability
1210BC (59.8%) 1107BC
1102BC (7.1%) 1086BC
1062BC (1.3%) 1060BC
95.4% probability
1256BC (0.7%) 1251BC
1231BC (94.7%) 1018BC

Derryvorrigan1_F495 R_Date(3175,35)
68.2% probability
1496BC (23.2%) 1474BC
1461BC (45.0%) 1420BC
95.4% probability
1518BC (94.1%) 1392BC
1335BC (1.3%) 1324BC

Derryvorrigan1_F769 R_Date(3160,35)
68.2% probability
1496BC (15.9%) 1475BC
1460BC (52.3%) 1408BC
95.4% probability
1506BC (89.4%) 1382BC
1340BC (6.0%) 1310BC

Derryvorrigan1_F557 R_Date(3210,35)
68.2% probability
1506BC (68.2%) 1438BC
95.4% probability
1604BC (3.5%) 1584BC
1544BC (91.9%) 1414BC



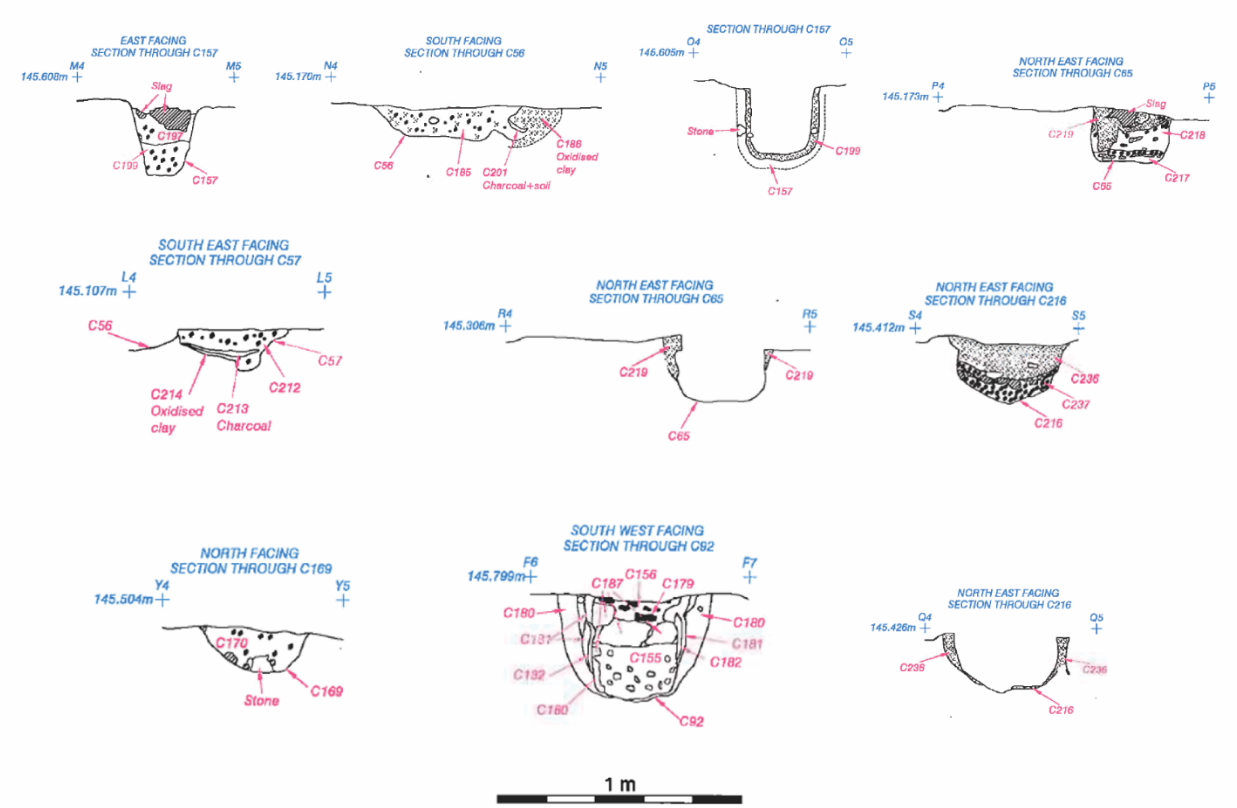
Description of Site: This site was discovered during the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme. The site contained a wide range of features that ranged from the Middle Bronze Age to the Post Medieval periods. The Bronze Age occupation consisted of a large slot-trench settlement structure, accompanied by a smaller structure possibly used as an animal pen. The Iron Age activity on the site was represented by a single structure and associated ironworking features. There were tentatively five individual smelting furnaces identified on the site, in addition to three 'figure-of-eight' shaped furnaces. The interpretation of these specific furnaces is difficult, as they could have actually been used as two individual furnaces (paired furnaces), or as one furnace pit leading to a connected working hollow in which to allow for the easy cleaning of the basal pit. There are additional closely associated pits that may have acted as working hollows to the individual furnaces, which were likely slag-pit non-tapping smelting furnaces. Unfortunately, none of the furnaces were directly radiocarbon dated so we must rely on the DIA/LIA dates from associated features. The Iron Age structure was located c. 40m to the east of the iron production and produced a 14C date of 50 cal. BCE – 120 cal. CE.

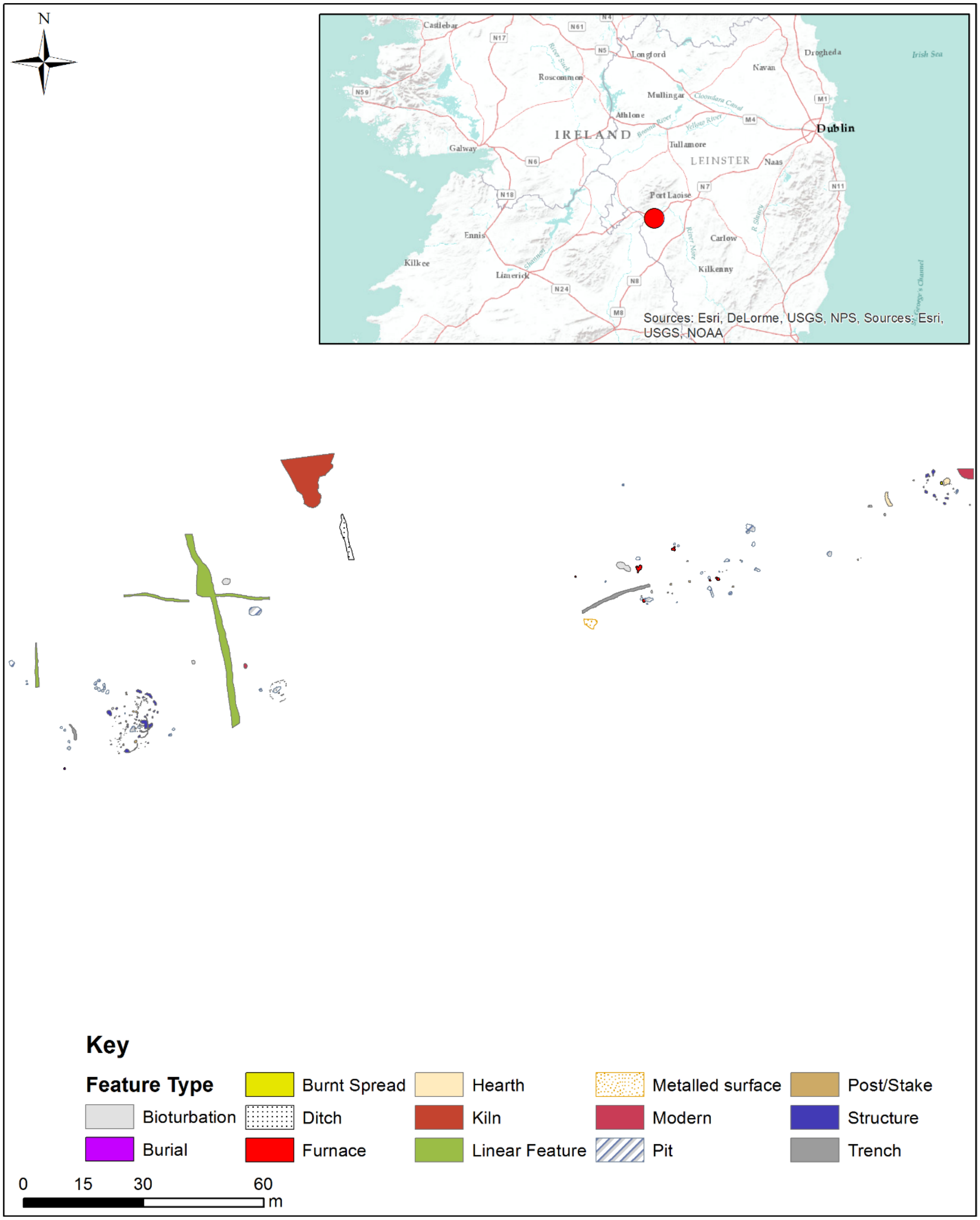
This site should be considered within a wider complex of Iron Age iron production on the landscape. Less than 1km to the east lay the site of Barnasallagh 1 which provided evidence for a charcoal production pit dated to 110 cal. BCE – 80 cal. CE, which could have been used to support the iron production at Derryvorrigan. Just over 1km to the west and slight southwest lay two additional sites with Iron Age iron production, Derrinsallagh 4 and 5, which produced evidence for 47 smelting furnaces total (46 of them at Derrinsallagh 4).

Landscape: "The sites of Derryvorrigan 1 (East and West) and 2 are situated on the lower north-western slopes of Knockseera hill. The sites, particularly Derryvorrigan 1 West, afford good views of the surrounding landscape, especially of the lower lying areas to the east, north, north-west and west. The view from the sites is restricted to the south and south-east as Knockseera hill looms in the background. Sentryhill is clearly visible in the foreground to the immediate north, while the Slieve Bloom mountain range is strikingly visible and stretches across the entire northern horizon, dominating the northern background. Derryvorrigan 1 West commands views of the entire western and north-western low-lying lands and of the plains of the river Nore and river Quinn. The sites of Derrinsallagh 1-5 in this area are also clearly visible from Derryvorrigan 1 West."

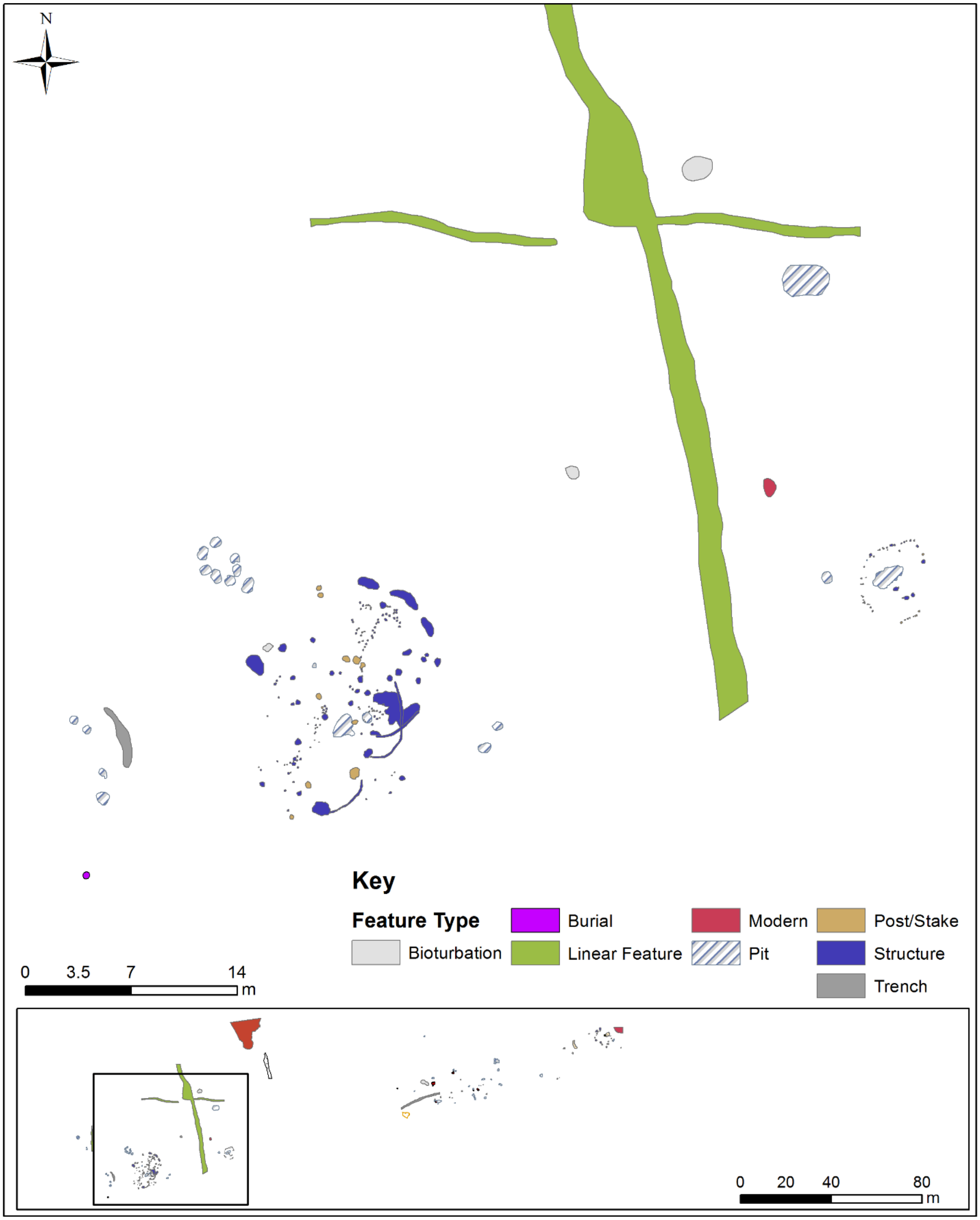
References: Lennon, A.M. and E. Kane. 2009b. M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill motorway scheme. Report on the archaeological excavation of Derryvorrigan 1, Co. Laois. *Unpublished report for Laois County Council.* Archaeological Consultancy Services Ltd.

Furnace Section

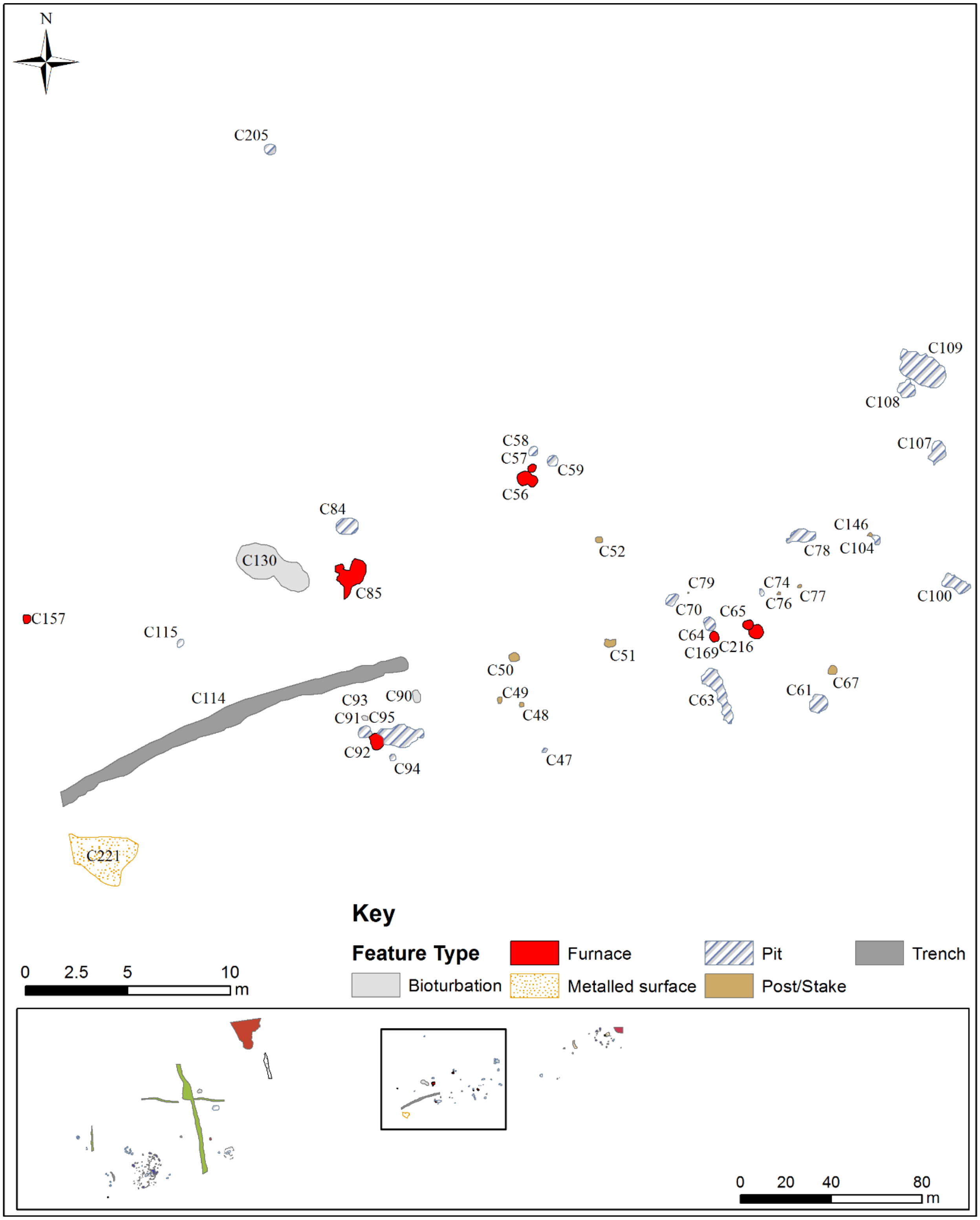




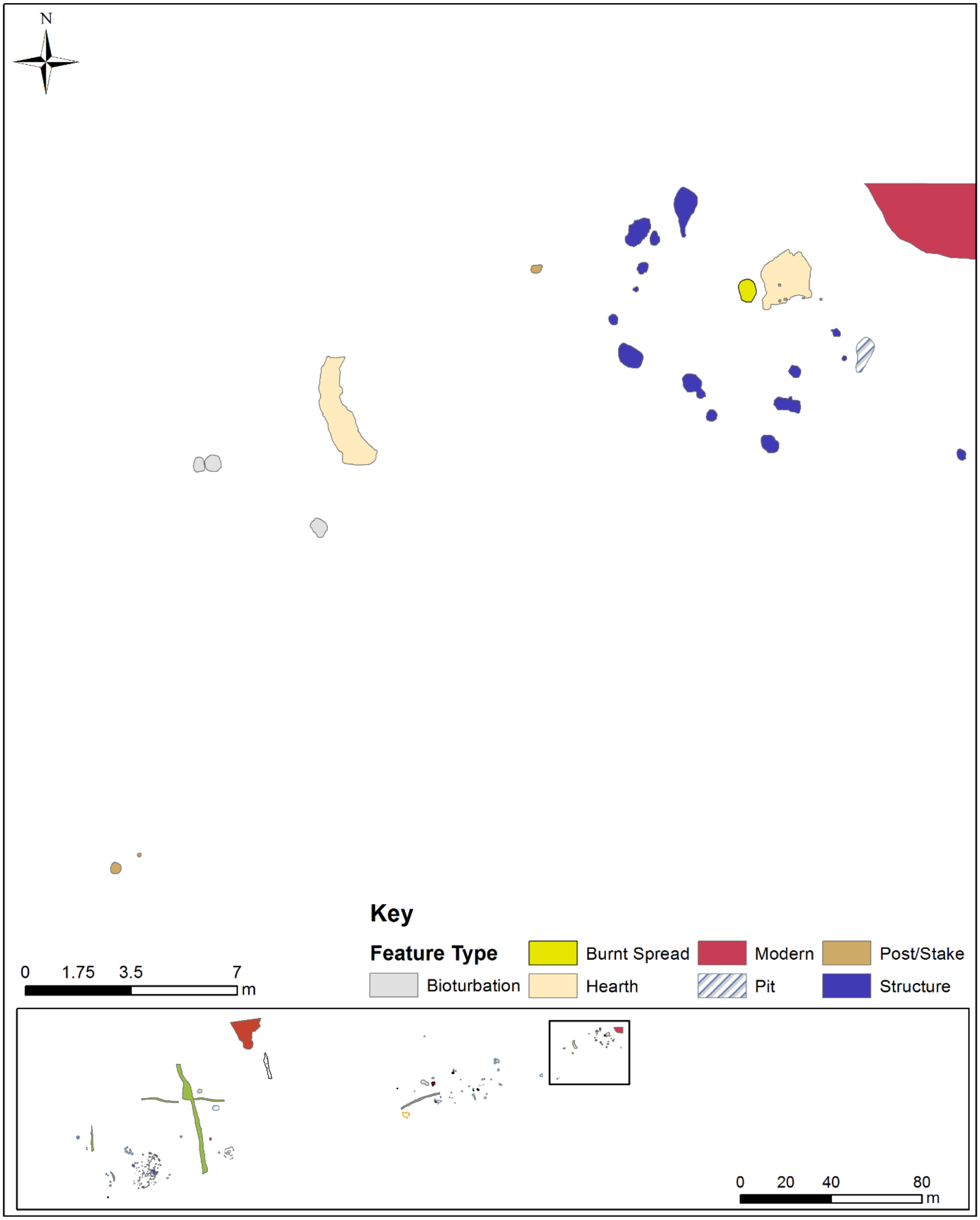
Derryvorrigan 1 (E2193)



Close-up of west side of Derryvorrigan 1 (E2193)



Close-up of Derryvorrigan 1 (E2193) furnaces



Close-up of Derryvorrigan 1 (E2193) Iron Age structure

Site Name: DKIT

County: Louth

Licence Number: 02E0201

Townland: Marshes Upper

ITM East: 705463.626

ITM North: 804815.359

Excavation conducted by Archaeological Consultancy Services Ltd

Smelting: Yes **Number of furnaces:** 1

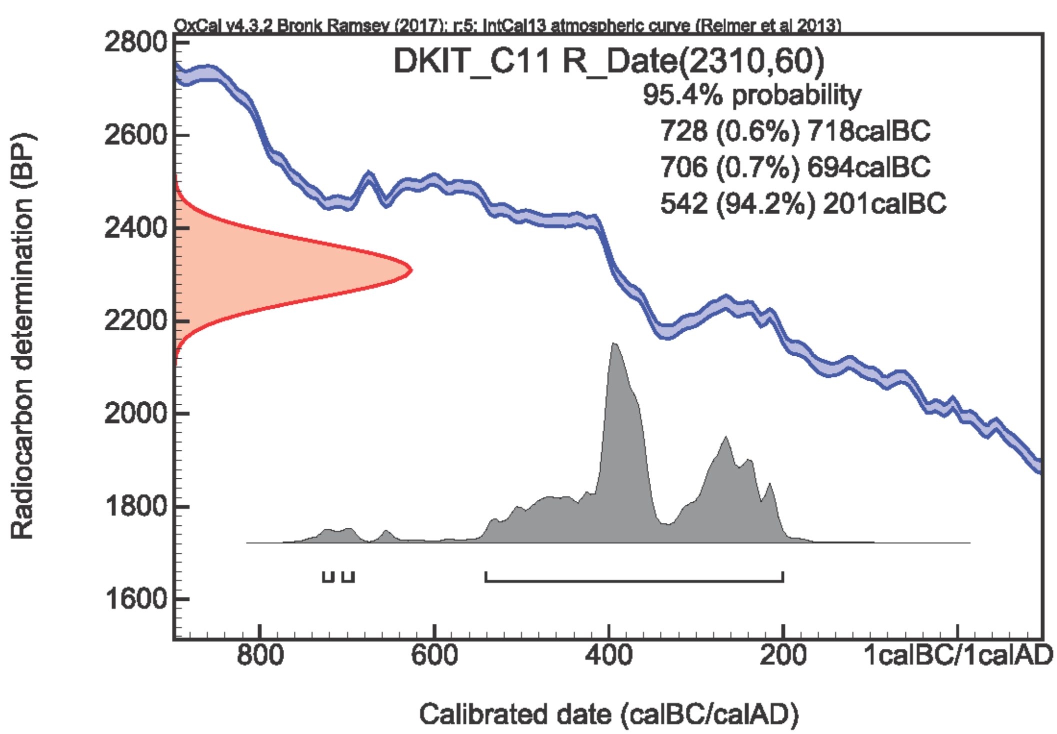
Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: EIA/DIA

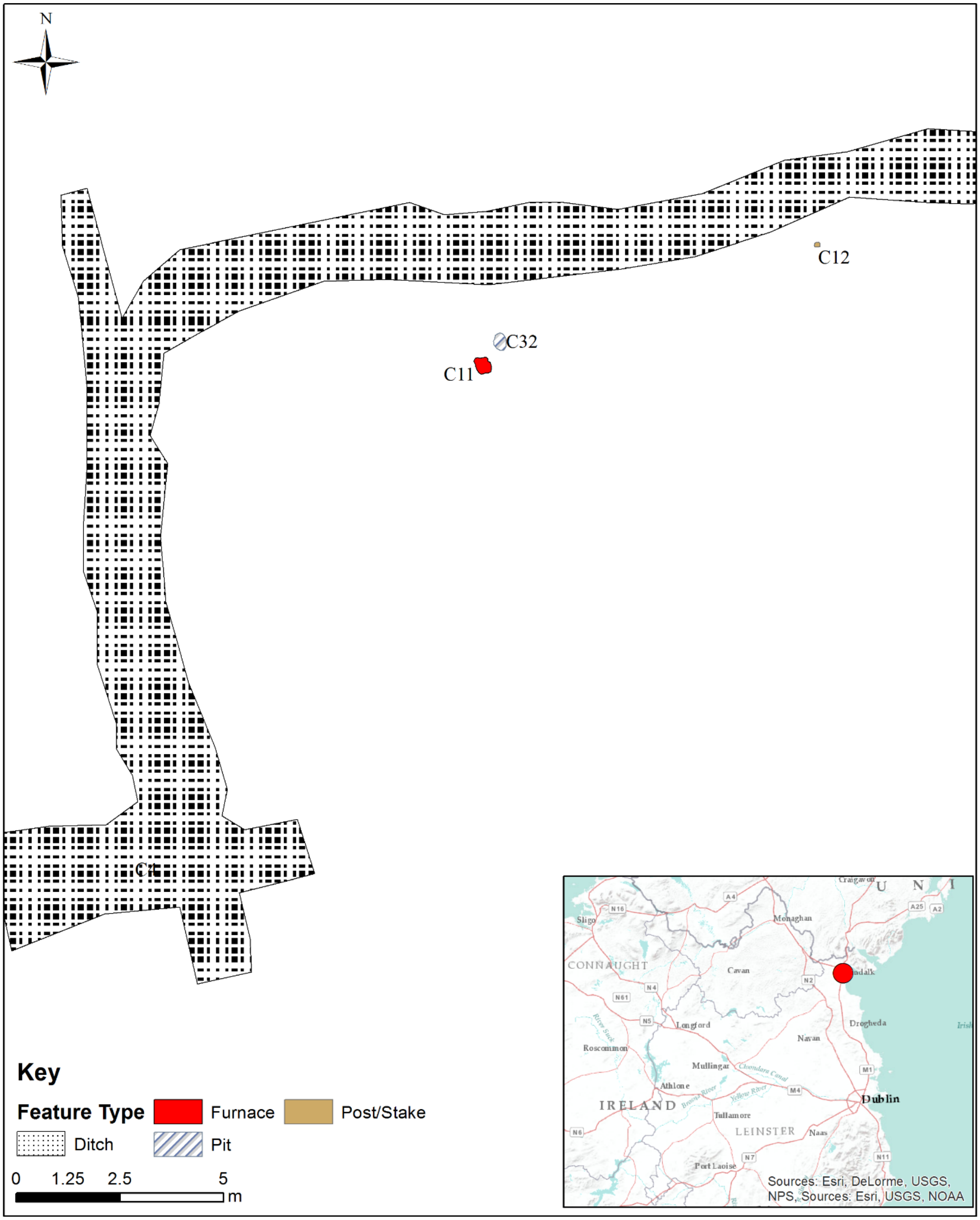
C14 Dates and Context:



Description of Site: This site was uncovered during the archaeological investigation for the construction of a playing-pitch at The Dundalk Institute of Technology. The entire site contained nineteen different areas of excavation that produced evidence of Neolithic and Bronze Age occupation, in addition to Iron Age activity. One furnace produced a 14C date of 420 – 200 cal. BCE. In the near vicinity of the furnace, some LBA and LIA features (trough and corn-drying kiln) were also discovered.

Landscape: "The district of Dundalk and its hinterland encompass two geographical areas. Around the outer limits of the urban district, low drumlins form a crescent whilst from the eastern coastal plain to the 100ft contour, gently undulating farmland rises."

References: Mossop, M. 2002. Archaeological monitoring and investigations for the Dundalk Institute of Technology, Marshes Upper townland, Co. Louth. *Unpublished report for the Dundalk Institute of Technology.* Archaeological Consultancy Services Ltd.



Dundalk Institute of Technology (02E0201)

Site Name: Gormagh 1 **County:** Offaly

Licence Number: 11E87 **Townland:** Gormagh

ITM East: 633177.591 **ITM North:** 728915.611

Excavation conducted by Irish Archaeological Consultancy

Smelting: No **Number of furnaces:** 0

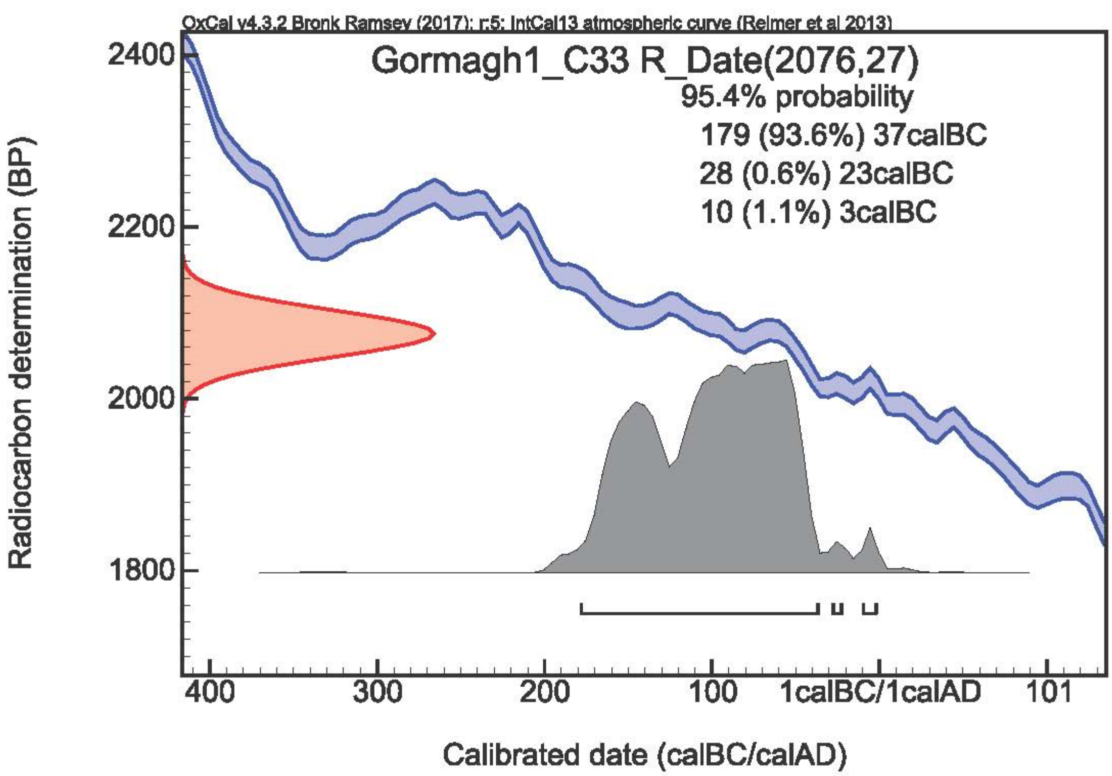
Smithing: Yes **Number of smithing hearths:** 1

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: DIA

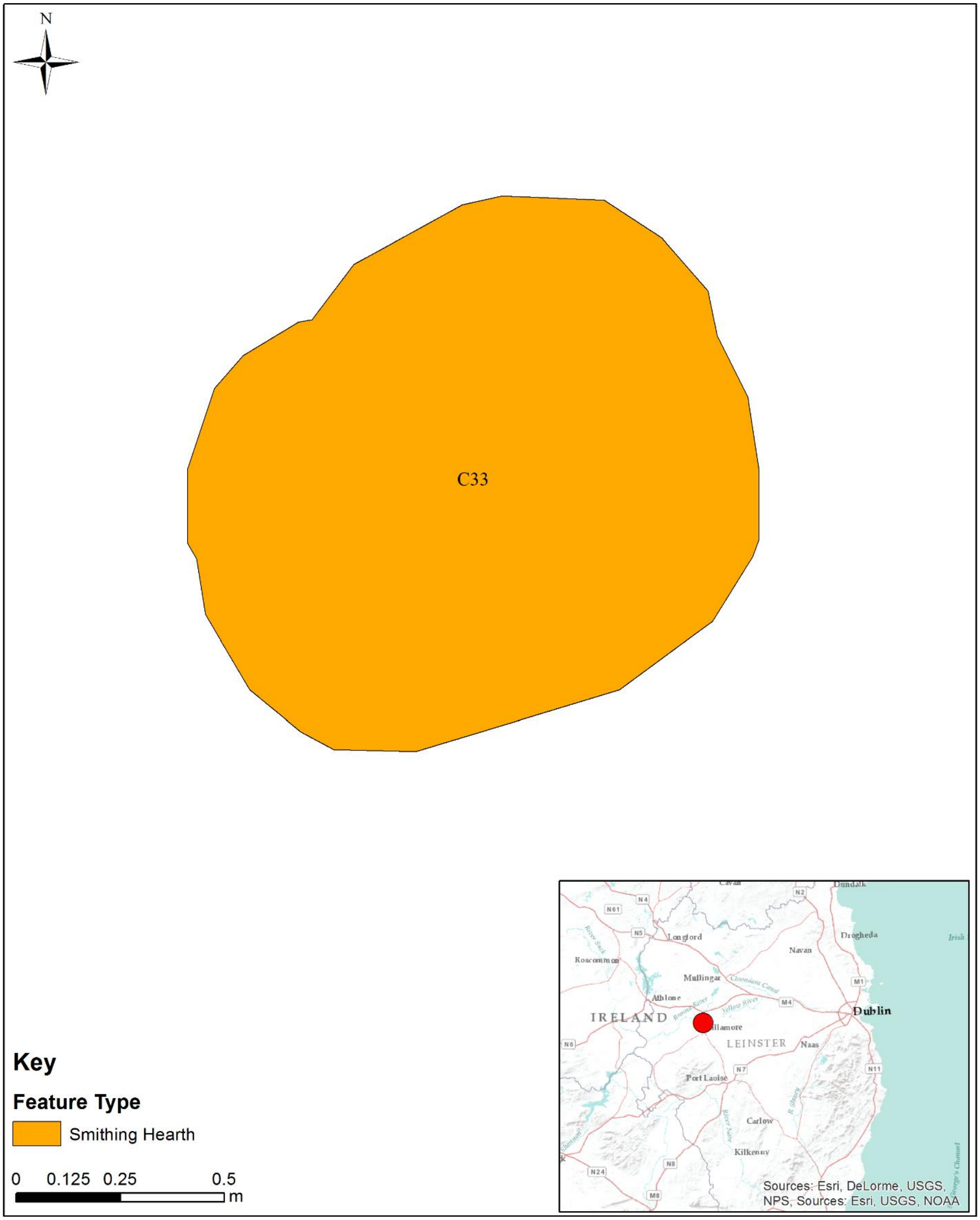
C14 Dates and Context:



Description of Site: This site was found in preparation of the N52 Tullamore to Kilbeggan Link Scheme. This site consisted of a single isolated feature. The shape of the pit, have steep sides and flat base, in additional to the charcoal and slag-rich fill, suggests this feature was used in ironworking. To this point, no analysis on the slag has yet been conducted, or is not yet available. The large size of the feature (1m x 1.2m) makes this feature difficult to interpret. While other features such as this have at times been presented as smithing hearths, the depth (.32m) of the pit makes this less likely. It was initially interpreted as a furnace, despite not having an in situ burning in the excavated section. A 14C sample dated this feature to 177–3 cal. BCE.

Landscape: "The subject lands currently comprise of relatively low flat pasture & arable fields. The physical landscape of the receiving environment consists of an undulating landscape, characterised by a large esker ridge (part of the Esker Riada system), which the proposed route will cross at Balleek Beg and Ballybought. The landscape to the south of the main esker ridge consists of undulating terrain, which for the most part is used for arable production. To the north of the esker the landscape is characterised by large tracts of level, drained bog land."

References: Bayley, D. and F. Walsh. 2011. N52 Tullamore Kilbeggan link scheme. Final report of 11E87, Ballybought, Balleek Beg, Gormagh, Co. Offaly. *Unpublished report for the Offaly County Council and the NRA.* Irish Archaeological Consultancy Ltd.



Gormagh 1 (11E87)

Site Name: Grange

County: Dublin

Licence Number: 13E0435

Townland: Nangor

ITM East: 703601.243

ITM North: 731286.176

Excavation conducted by Courtney Deery Heritage Consultancy

Smelting: Yes **Number of furnaces:** 1

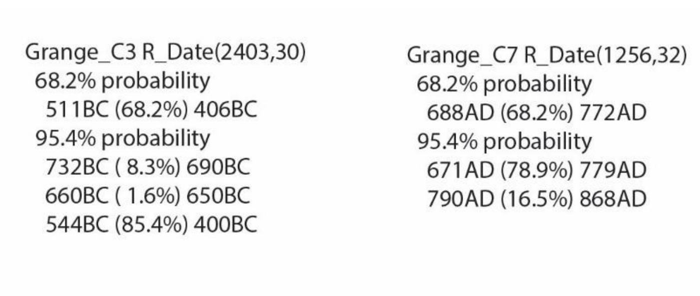
Smithing: No **Number of smithing hearths:** 0

Charcoal Production: Yes

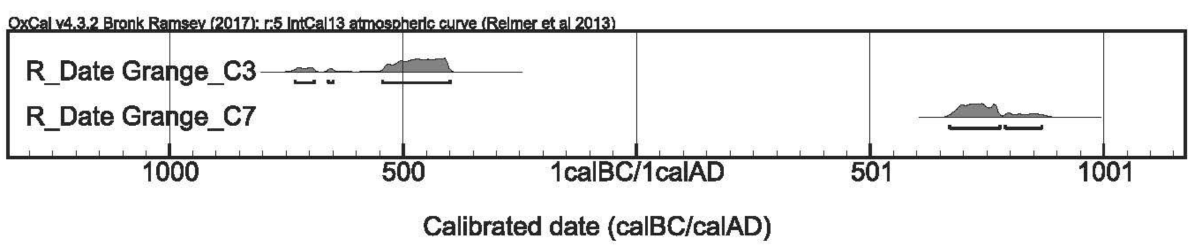
Type of Site: Isolated Metalworking

Chronology: EIA

C14 Dates and Context:


Grange_C3 R_Date(2403,30)
68.2% probability
511BC (68.2%) 406BC
95.4% probability
732BC (8.3%) 690BC
660BC (1.6%) 650BC
544BC (85.4%) 400BC

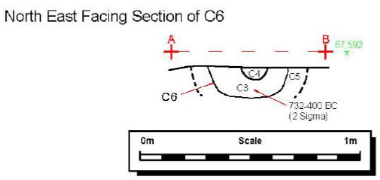
Grange_C7 R_Date(1256,32)
68.2% probability
688AD (68.2%) 772AD
95.4% probability
671AD (78.9%) 779AD
790AD (16.5%) 868AD

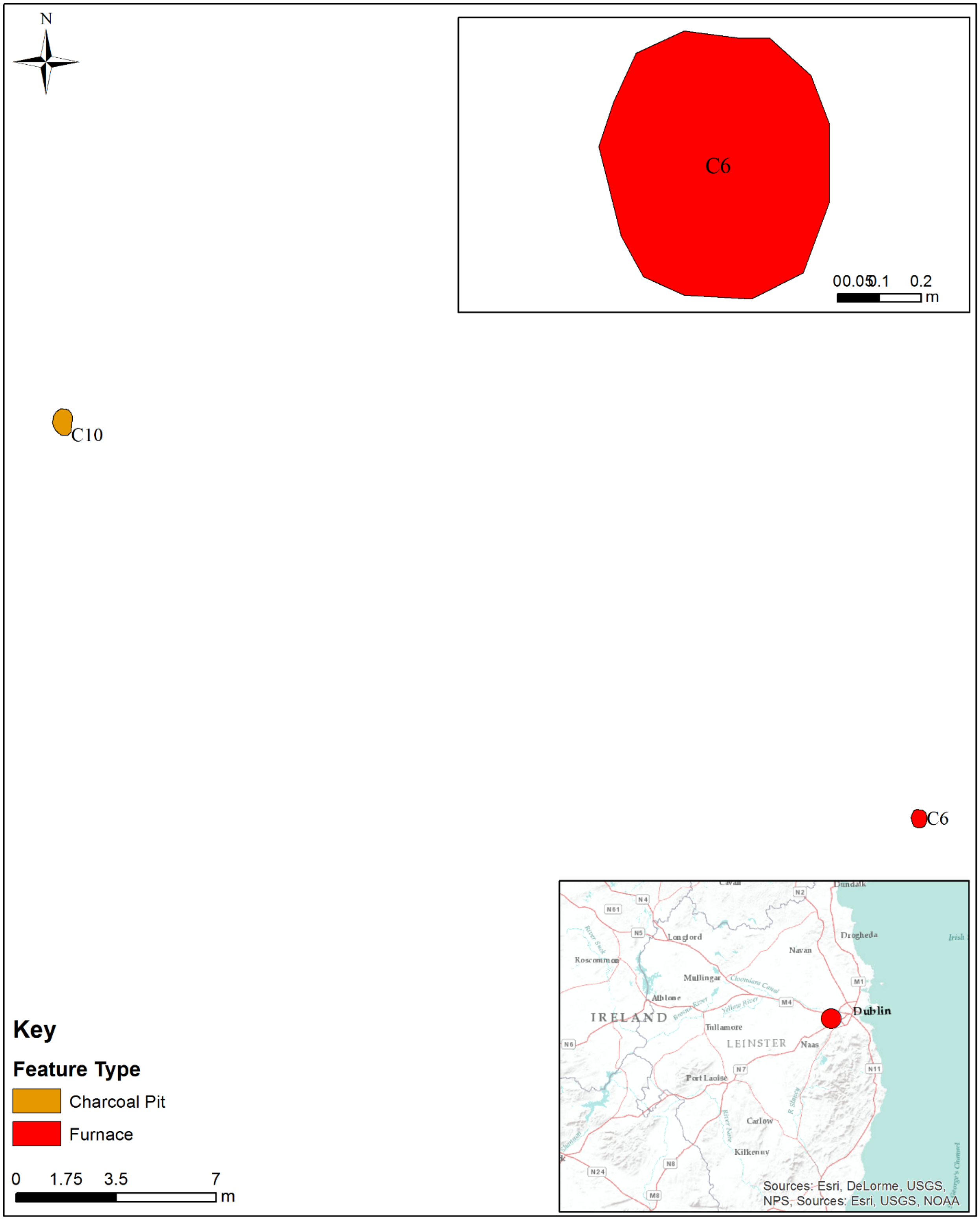


Description of Site: This site was uncovered prior to construction of a proposed carriageway at Grange Castel Business Park. The site consisted of two features, one charcoal production pit or charcoal clamp that dated to the Early Medieval period, and one smelting furnace dating to the EIA (732 – 400 cal. BCE). This furnace was a slag-pit low-shaft furnace, although it is slightly smaller than most other furnaces from this period.

References: McLoughlin, G. 2014. Proposed central carriageway Grange Castle Business Park, Co. Dublin. Final report on archaeological monitoring. *Unpublished report for Clifton Scannell Emerson*. Courtney Deery Heritage Consultancy.

Furnace Section:





Grange (13E0435)

Site Name: Hardwood 3 **County:** Meath

Licence Number: 02E1141 **Townland:** Hardwood

ITM East: 660461.526 **ITM North:** 744340.898

Excavation conducted by Archaeological Consultancy Services Ltd

Smelting: Yes **Number of furnaces:** 4

Smithing: Yes **Number of smithing hearths:** 3

Charcoal Production: No

Type of Site: Isolated Metalworking

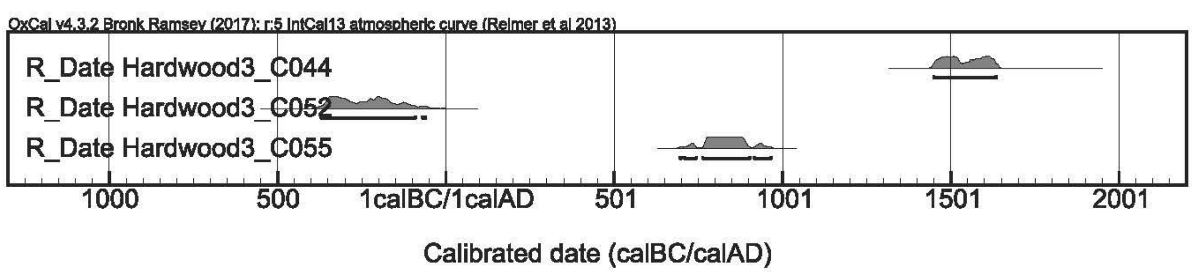
Chronology: EIA/Medieval

C14 Dates and Context:

Hardwood3_C044 R_Date(360,40)
68.2% probability
1464AD (36.1%) 1522AD
1574AD (32.1%) 1628AD
95.4% probability
1450AD (95.4%) 1636AD

Hardwood3_C052 R_Date(2170,50)
68.2% probability
357BC (34.1%) 282BC
257BC (4.1%) 244BC
236BC (30.1%) 166BC
95.4% probability
371BC (94.5%) 91BC
69BC (0.9%) 61BC

Hardwood3_C055 R_Date(1190,40)
68.2% probability
775AD (68.2%) 882AD
95.4% probability
695AD (0.5%) 700AD
710AD (6.8%) 745AD
764AD (79.0%) 904AD
916AD (9.1%) 966AD

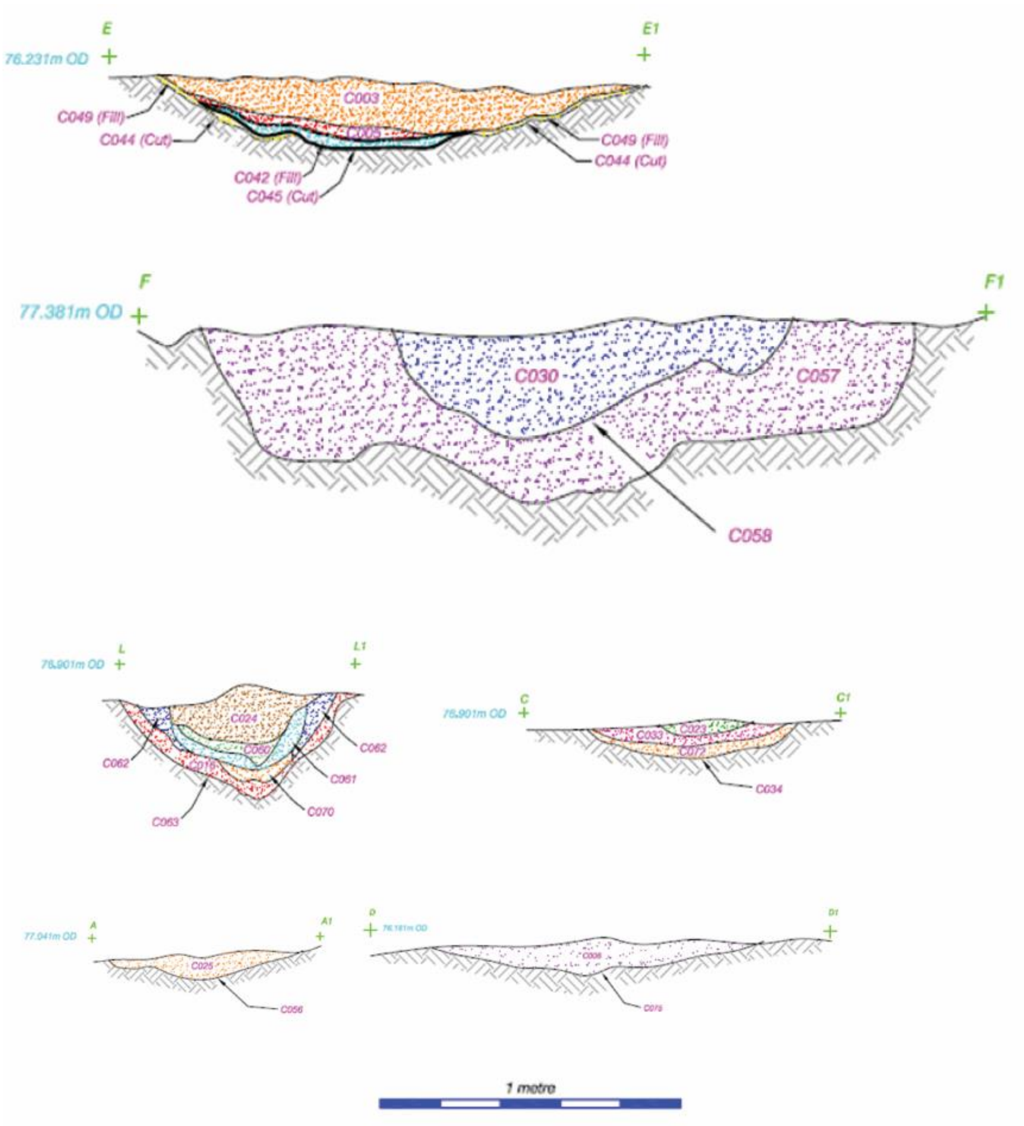


Description of Site: This site was discovered in advance of the construction of the M4 Kinnegad-Enfield-Motorway Scheme. It is represented by seven pits, with various associations with iron production. Four of the features were determined to be furnaces by the excavators. They appear to have different sizes and shapes, and coupled with the dates produced by two of the features, contemporaneous use seems unlikely. One feature produced a date of 380 – 60 cal. BCE, while another produced a date of 1440-1640 cal. CE. Two of the features located at this site were identified as smithing hearths, largely based on their large size (~1.5m diameter), charcoal/slag heavy fill, and in situ burning. In addition to the furnaces and hearths, there was a charcoal kiln dating to 770-970 cal. CE. The varied dates produced by this site makes interpretation difficult, because it is impossible to accurate say which features were utilized during which period, aside from those 14C dated. If the 14C dates are taken as accurate, this site represents an interesting palimpsest of industrial use spanning up to 2000 years. It should be noted that the furnace dated to the DIA does present similar characteristics to others from this period.

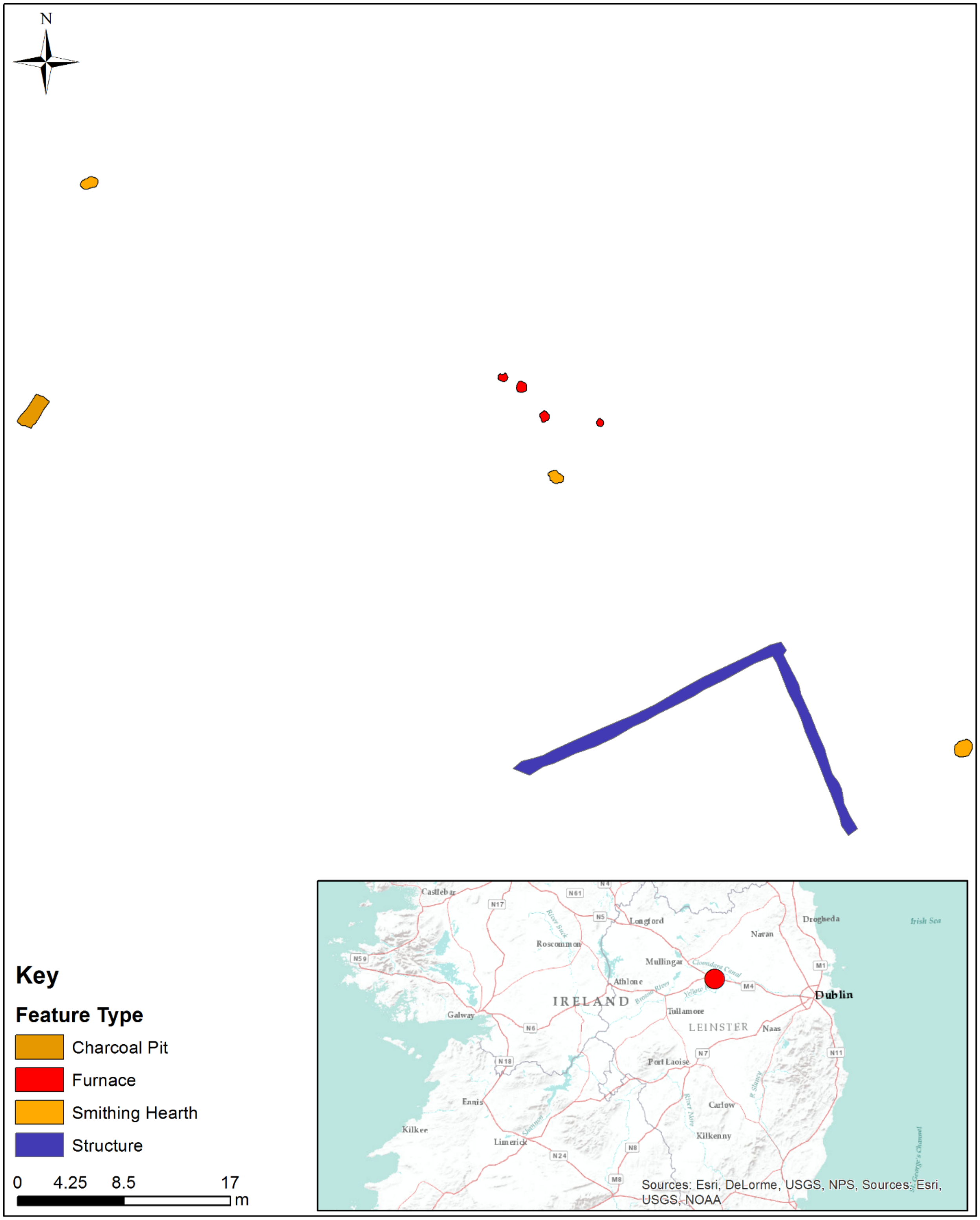
This site also appears to be part of a larger landscape or complex of prehistoric occupation. Within 80m, 250m, and 460m lay the sites of Rossan 1, Rossan 3, and Rossan 6, respectively. Rossan 1 contains a series of pits and charcoal-rich deposits that date to the LBA-IA transition. Rossan 3 contained pits that dated to the medieval period, as well as the Middle – Late Bronze Age. In addition, that site produced three linear features that contained a fair amount of slag. Rossan 6 contained a number of small pits, in addition to a furnace and smithing hearths, which dated to the EIA and DIA. Slightly further afield, 2-3km to the west, lay three other sites with evidence for Iron Age iron production: Kinnegad 2, Griffinstown 3, Monganstown 1. Kinnegad and Monganstown produced radiocarbon dates spanning the EIA into the DIA. No 14C dates were recovered from Griffinstown 3, however the furnace types match those in the surrounding area. It appears that this immediate area was utilized through the Bronze Age into the later Medieval period, and especially during the first part of the Iron Age for iron production.

References: Murphy, D. 2004a. M4 Kinnegad–Enfield–Kilcock Motorway Scheme, Contract 1. Report on Hardwood 3, Co. Meath. *Unpublished report for the Westmeath County Council*. Archaeological Consultancy Services Ltd.

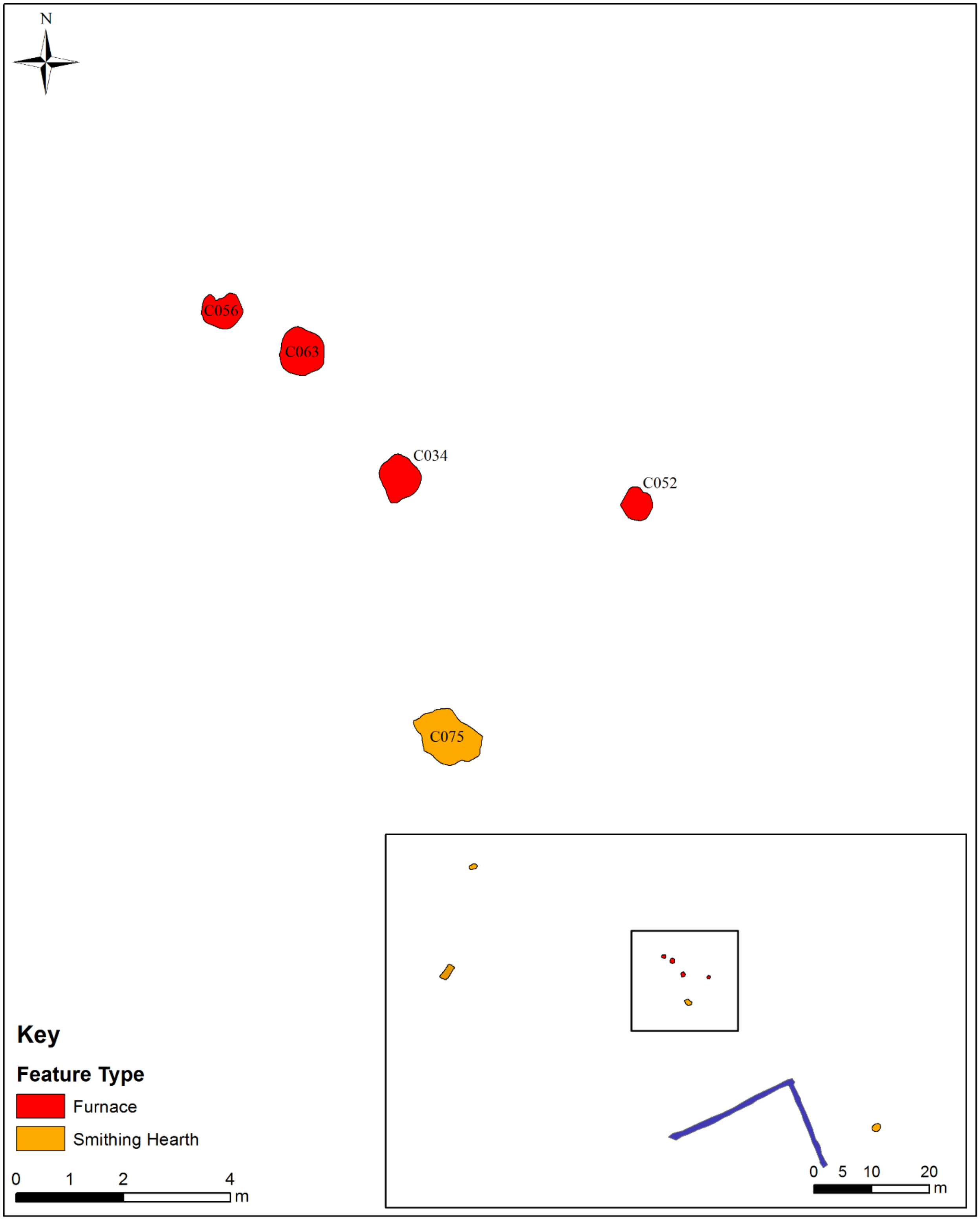
Furnace Sections[1]:



[1] There is a section of C052 but the scale is off on the original drawing, so it is not included here.



Hardwood 3 (02E1141)



Close-up of Hardwood 3 (02E1141)

Site Name: Harlockstown 19

County: Meath

Licence Number: 03E1526

Townland: Harlockstown

ITM East: 704869.9

ITM North: 750175.998

Excavation conducted by Cultural Resource Development Services Ltd.

Smelting: Yes **Number of furnaces:** 1

Smithing: Yes **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Structure/Burial

Chronology: DIA/LIA

^{14}C Dates and Context:

Harlockstown_C355 R_Date(3515,45)
68.2% probability
1896BC (68.2%) 1770BC
95.4% probability
1956BC (93.0%) 1736BC
1716BC (2.4%) 1696BC

Harlockstown_C519 R_Date(3599,36)
68.2% probability
2016BC (14.1%) 1996BC
1980BC (54.1%) 1908BC
95.4% probability
2118BC (2.1%) 2096BC
2040BC (93.0%) 1879BC
1837BC (0.3%) 1832BC

Harlockstown_C231 R_Date(1527,64)
68.2% probability
430AD (30.5%) 493AD
511AD (2.5%) 517AD
528AD (35.2%) 598AD
95.4% probability
408AD (95.4%) 643AD

Harlockstown_C482 R_Date(1273,63)
68.2% probability
662AD (62.4%) 777AD
792AD (2.9%) 802AD
845AD (2.9%) 854AD
95.4% probability
650AD (95.4%) 890AD

Harlockstown_C211 R_Date(1376,31)
68.2% probability
639AD (68.2%) 670AD
95.4% probability
605AD (95.4%) 685AD

Harlockstown_C359 R_Date(3620,41)
68.2% probability
2031BC (68.2%) 1926BC
95.4% probability
2132BC (10.3%) 2084BC
2055BC (85.1%) 1886BC

Harlockstown_C587 R_Date(2057,40)
68.2% probability
158BC (10.6%) 134BC
116BC (48.5%) 36BC
31BC (4.6%) 20BC
11BC (4.5%) 2BC
95.4% probability
180BC (95.4%) 26AD

Harlockstown_C267 R_Date(1408,75)
68.2% probability
560AD (68.2%) 678AD
95.4% probability
430AD (6.0%) 492AD
530AD (89.4%) 770AD

Harlockstown_C322 R_Date(1184,54)
68.2% probability
770AD (63.5%) 896AD
928AD (4.7%) 940AD
95.4% probability
690AD (11.2%) 749AD
761AD (84.2%) 976AD

Harlockstown_C583 R_Date(2000,44)
68.2% probability
45BC (68.2%) 54AD
95.4% probability
157BC (1.9%) 135BC
114BC (93.5%) 85AD

Harlockstown_C147 R_Date(3799,33)
68.2% probability
2288BC (61.8%) 2198BC
2164BC (6.4%) 2152BC
95.4% probability
2397BC (0.8%) 2385BC
2346BC (94.6%) 2136BC

Harlockstown_C278 R_Date(1583,33)
68.2% probability
424AD (9.5%) 437AD
444AD (20.2%) 472AD
486AD (38.5%) 535AD
95.4% probability
403AD (95.4%) 548AD

Harlockstown_C53 R_Date(2315,32)
68.2% probability
405BC (68.2%) 372BC
95.4% probability
429BC (85.7%) 354BC
291BC (9.7%) 231BC

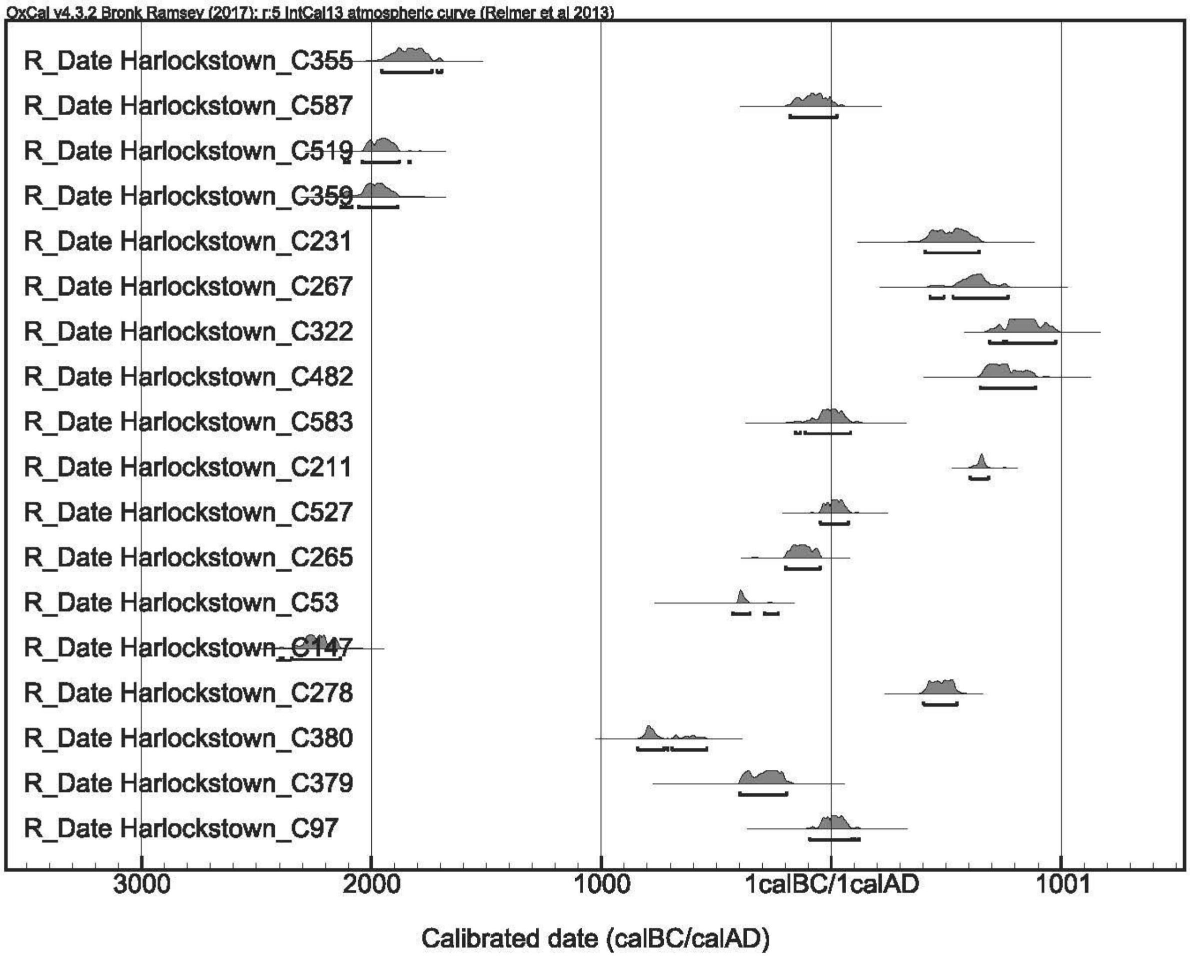
Harlockstown_C380 R_Date(2588,49)
68.2% probability
820BC (56.8%) 752BC
682BC (4.9%) 668BC
612BC (6.5%) 592BC
95.4% probability
842BC (63.2%) 728BC
713BC (0.1%) 710BC
694BC (32.1%) 542BC

Harlockstown_C379 R_Date(2238,50)
68.2% probability
381BC (16.5%) 350BC
304BC (51.7%) 210BC
95.4% probability
398BC (95.4%) 195BC

Harlockstown_C97 R_Date(1987,42)
68.2% probability
38BC (68.2%) 56AD
95.4% probability
93BC (93.1%) 88AD
102AD (2.3%) 122AD

Harlockstown_C265 R_Date(2106,29)
68.2% probability
175BC (63.8%) 91BC
68BC (4.4%) 61BC
95.4% probability
200BC (95.4%) 48BC

Harlockstown_C527 R_Date(1984,31)
68.2% probability
36BC (3.9%) 31BC
20BC (7.5%) 11BC
2BC (56.8%) 55AD
95.4% probability
47BC (95.4%) 76AD

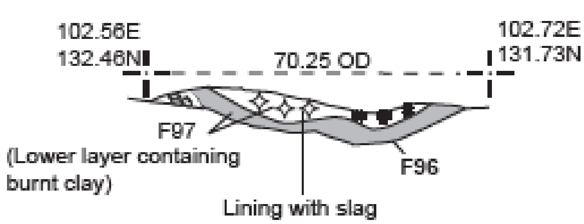


Description of Site: This site was uncovered during the construction of the N2 Finglas to Ashbourne road scheme. It consisted of a large variety of activity phases, from the Late Neolithic to the Early Medieval period. The Neolithic and Early Bronze Age phase consists of some pits containing Beaker pottery (in addition to other material), a cremation pit at the center of a circular enclosure, and two crouched inhumation burials. A large 'D' shaped enclosure, likely representing a farm settlement, was constructed during the Early Medieval period. The main activity occurring at the site during the Iron Age was iron production. There was a smelting furnaces uncovered on the site, which dated to 100 cal. BCE – 130 cal. CE. The shallow curve of the furnace does not conform with the typical slag-pit furnace, so the exact type of furnace remains questionable. Although no smithing hearth was immediately identified, some of the slag present at the site appears to have been produced during the smithing process. There were an additional five pits that were full of slag, but the lack of in situ material suggests they were used as dumps for the metallurgical refuse rather than primary furnaces. Accompanying these features were various pits, hearths, a possible windbreak, a 'keyhole' kiln, a sunken floor feature, possible work-floor surfaces, and a circular ditched structure. Agricultural activity was happening in some form on the site, as pits and kilns contained charred seed remains, specifically barley. The dates for a number of these features place activity possibly back in the EIA (with one 14C date from a posthole), but largely to the DIA and maybe as late as the beginning of the LIA. C. 3.5km north of the Harlockstown lay the site of Rath Site 27, which also contained evidence for a long period of use in prehistory, including iron production.

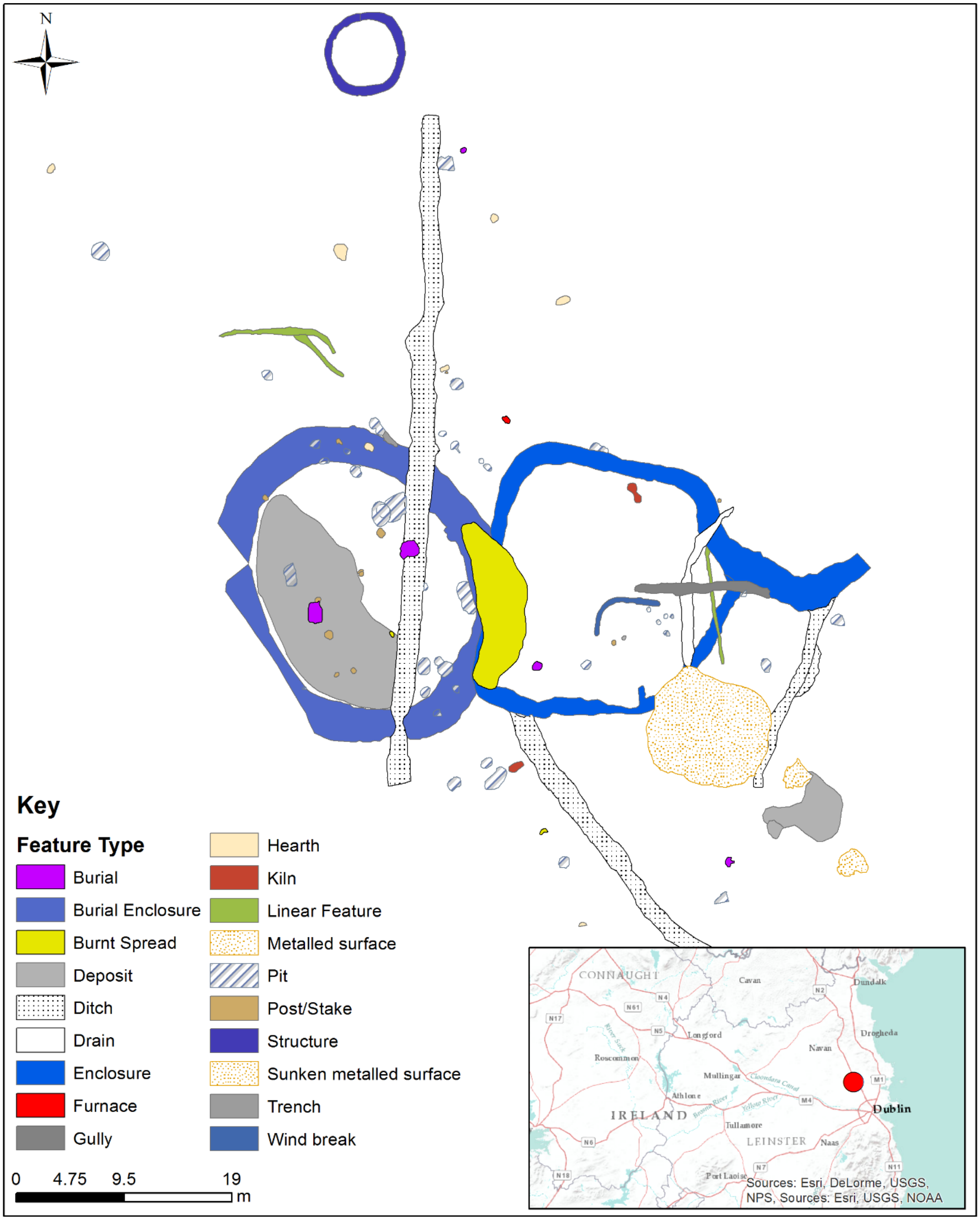
Landscape: "This section of the development was located west of the existing N2 and south of the R125 Ratoath-Swords road, in a field that was in agricultural production prior to the commencement of the project. The field lay on the north-facing slope of a small hill, which is bordered by a tributary of the Broad Meadow river."

References: O'Connor, D. J. 2008. N2 Finglas-Ashbourne road scheme. Report on archaeological excavation of Site 19, Harlockstown, Co. Meath. *Unpublished report for Meath County Council*. Cultural Resource Development Services Ltd.

Furnace Section:



West facing section of pit F96.
Drw 261.



Harlockstown 19 (03E1526)

Site Name: Johnstown 3 **County:** Meath

Licence Number: 02E1094 **Townland:** Johnstown

ITM East: 677456.052 **ITM North:** 739858.853

Excavation conducted by Archaeological Consultancy Services Ltd

Smelting: Yes **Number of furnaces:** 2

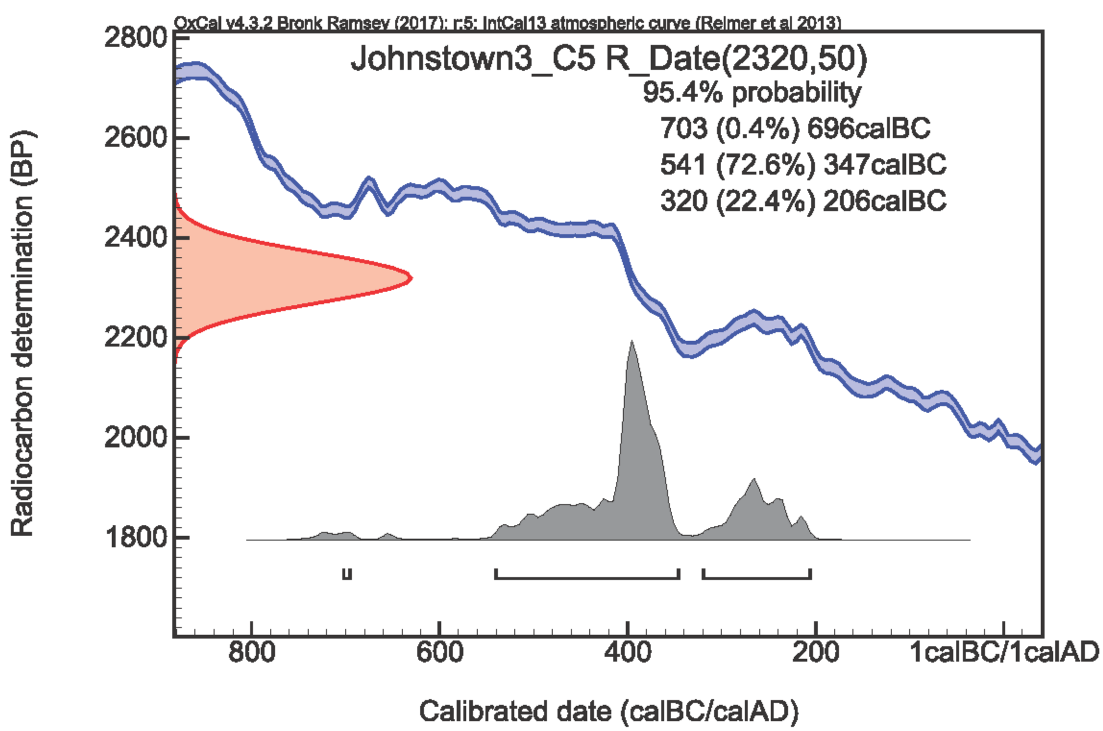
Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: DIA

C14 Dates and Context:

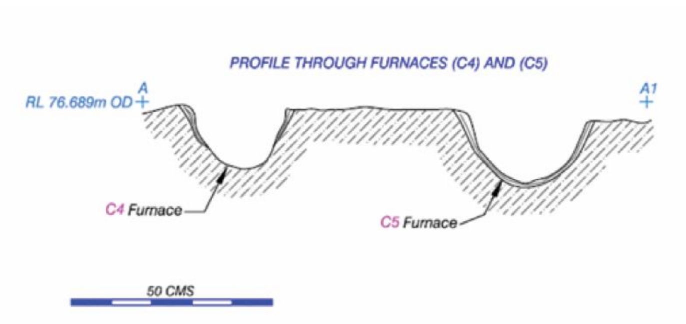


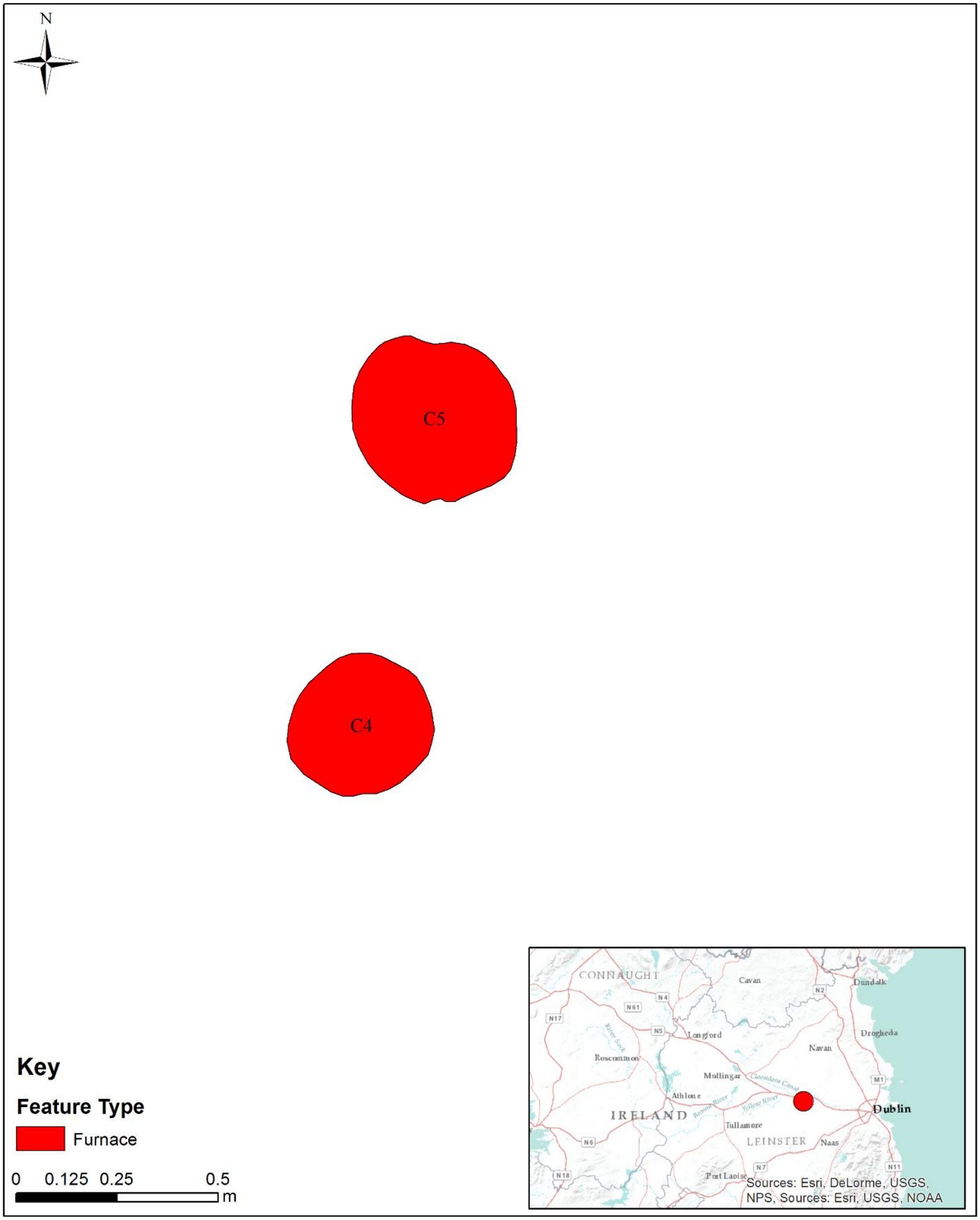
Description of Site: This site was uncovered in advance of the construction of the M4 Kinnegad-Enfield-Kilcock Motorway Scheme. The site consisted of two features, both furnaces that date to 420 – 360 cal. BCE. The shapes of the furnaces were a bit ambiguous, having steep sides but also a rounded base.

Approximately 700m the west was a very large site that consisted of a Medieval burial ground with 398 burials, multiple enclosures, and settlement activity that likely was contemporaneous with the burial ground. There was, however, one DIA date taken from the settlement, suggesting that occupation could have been occurring during that period as well.

References: O'Hara, R. 2003a. Kinnegad–Enfield–Kilcock Bypass Contract 2, report on Johnstown 3, Co. Kildare. *Unpublished report for Westmeath County Council.* Archaeological Consultancy Services Ltd.

Furnace Section:





Johnstown 3 (02E1094)

Site Name: Kilrussane AR 27 **County:** Cork

Licence Number: 01E0701 **Townland:** Kilrussane

ITM East: 574465.07 **ITM North:** 580587.955

Excavation conducted by Sheila Lane & Associates

Smelting: Yes **Number of furnaces:** 4

Smithing: No **Number of smithing hearths:** 0

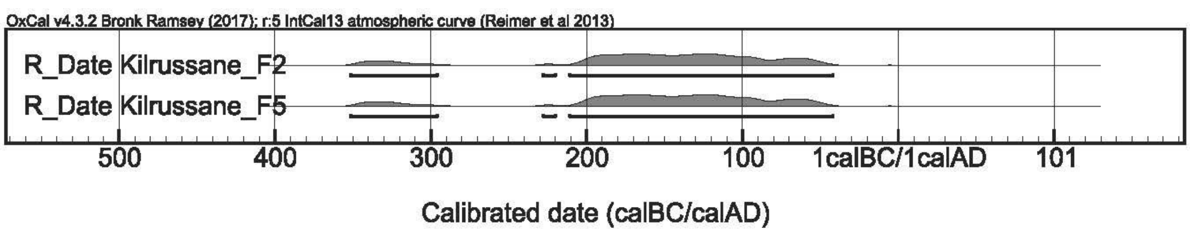
Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: DIA

C14 Dates and Context:

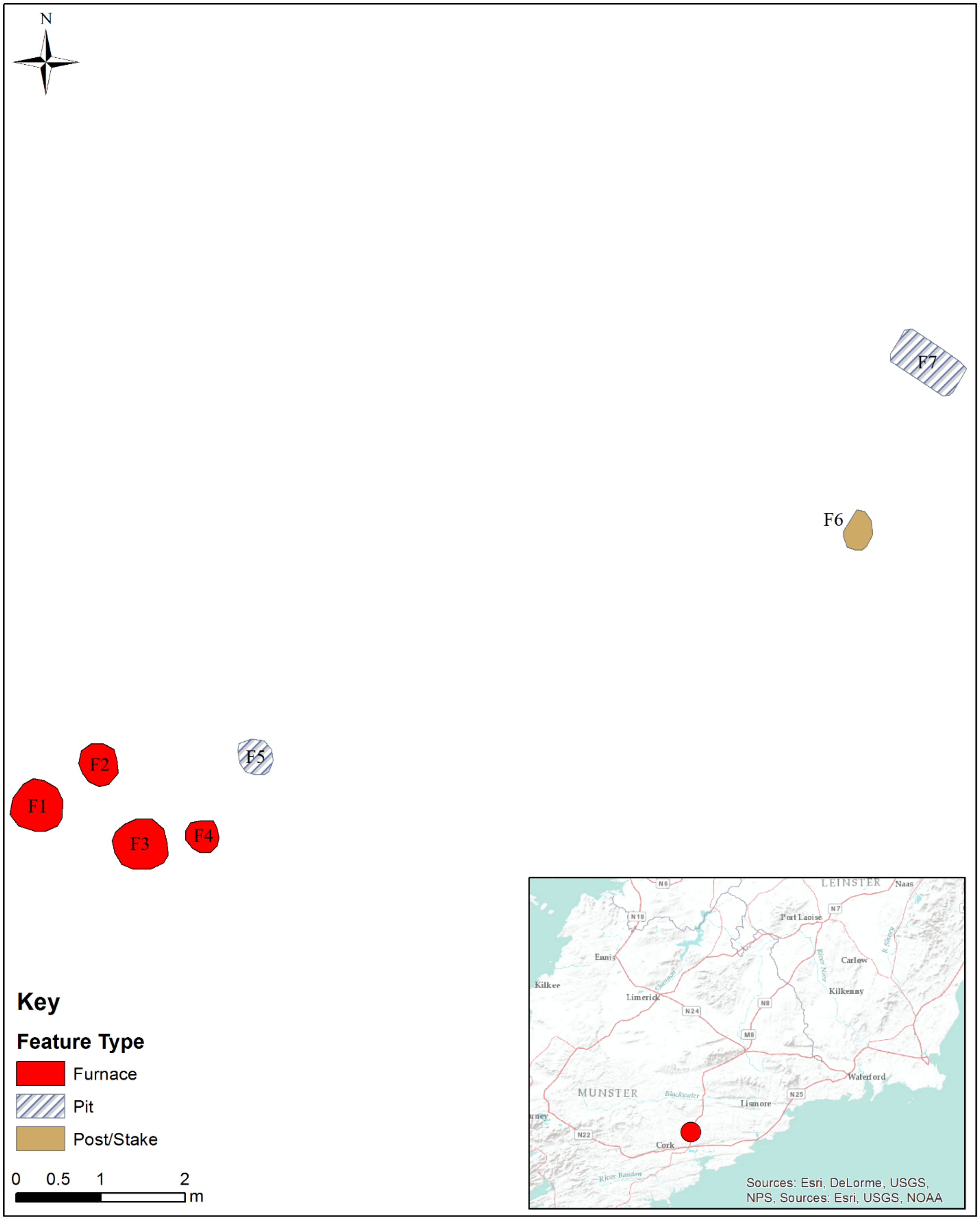
```
Kilrussane_F5 R_Date(2120,40)
  68.2% probability
    200BC (64.9%) 91BC
    68BC ( 3.3%) 61BC
  95.4% probability
    352BC (10.6%) 296BC
    228BC ( 0.8%) 220BC
    212BC (84.1%) 42BC
```



Description of Site: This site was discovered during the N8 Glanmire – Watergrasshill Road Scheme. It consisted of seven small features within an 12m by 7m area. One concentration of four features (F1 – F4) presented similar morphological characteristics and are interpreted as smelting furnaces. An additional feature, F5, is also within this feature concentration but does not present the same clay lining as the other furnaces, and produced very little to no slag. It is therefore suggestion that although it may have been used in conjunction with the furnaces, this feature was not used as a smelting furnace itself (Photos-Jones 2003). Although these smelting furnaces were identified by the excavators as bowl furnaces, the description of the feature cut, having mostly steep sides and a flat base, is actually more indicative of a slag-pit shaft furnace. Two of the features produced radiocarbon dates in the DIA (352 - 42 cal BCE). Approximately 490m to the northeast lay the site of Trantstown (01E0501 AR29), an isolated metalworking site with two furnaces that produced dates parallel with Trantstown. Also, 370m to the southwest of Kilrussane was the site of Ballinvinny North (01E0501 AR 26), which also provided evidence for a furnace with an DIA date. These three sites should probably be considered as a complex of industrial production that extended larger than the site itself.

Landscape: **"**AR 27 was located in a field of tillage prior to the construction of the new road and lay approximately 1km east of the existing N8 Cork - Dublin road. The landscape of the area is dominated by gently sloping hills and the archaeological site was located close to the broad top of such a hill at an elevation of c. 142m OD. The site commands relatively good views over the surrounding landscape, particularly to the north-east and east, though views to the south and west were somewhat limited by slightly higher ground."

References: Sherlock, R. 2005b. Archaeological excavation of a number of Iron Age bowl-shaped smelting furnaces at Kilrussane, Co Cork, site number AR27. *Unpublished report for the Cork County Council and the NRA*. Sheila Lane & Associates



Kilrussane (01E0701)

Site Name: Kinnegad 2 **County:** Westmeath

Licence Number: 02E0926 **Townland:** Kinnegad

ITM East: 658167.276 **ITM North:** 745150.81

Excavation conducted by Archaeological Consultancy Services Ltd

Smelting: Yes **Number of furnaces:** 2

Smithing: Yes **Number of smithing hearths:** 1

Charcoal Production: Yes

Type of Site: Isolated Metalworking

Chronology: EIA

C14 Dates and Context: *Did not have access to uncalibrated dates* F019: 810 - 420 cal BCE; F025: 400 - 340 cal BCE; F025: 320 - 210 cal BCE

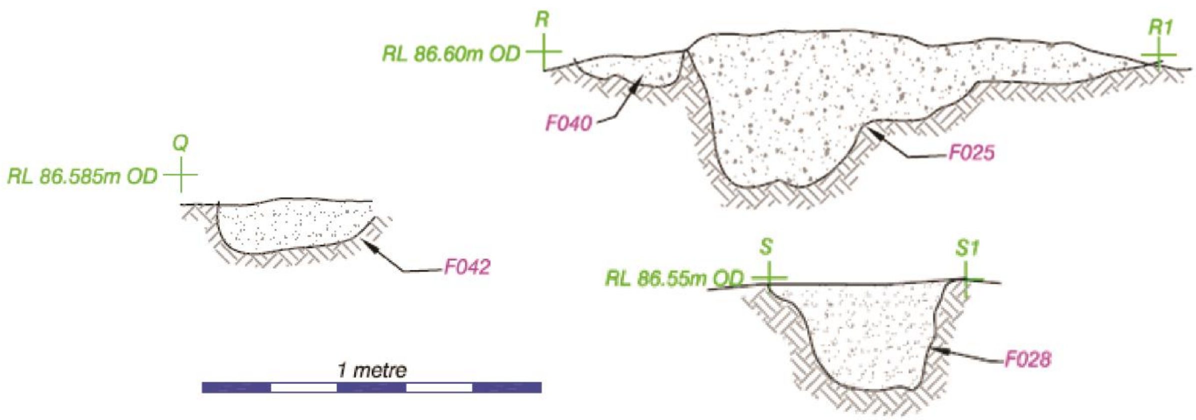
Description of Site: This site was uncovered in advance of the construction of the M4 Kinnegad-Enfield-Kilcock Motorway Scheme. The site consisted of a number of pits and postholes, in addition to two furnaces. A cluster of pits in the southeast of the site provided dates that placed their use in the Early and Late Bronze Age. Separate from these pits, and likely unrelated, were the other features that appear to all date to the DIA. These consisted of at least ten pits associated with the iron production occurring at the site, likely as metallurgical refuse pits. However, the initial use of these pits may have been clay extraction, and were only later filled with refuse. There were two furnaces identified at this site, both identified in the field as bowl furnaces. The pits for these two furnaces seem to actually present characteristics of a slag-pit furnace, with quite vertical sides and a flat bottom. However, one of the furnaces had what was termed as a "bench surface" extending from the main pit. One larger feature is suggested to be a smithing hearth.

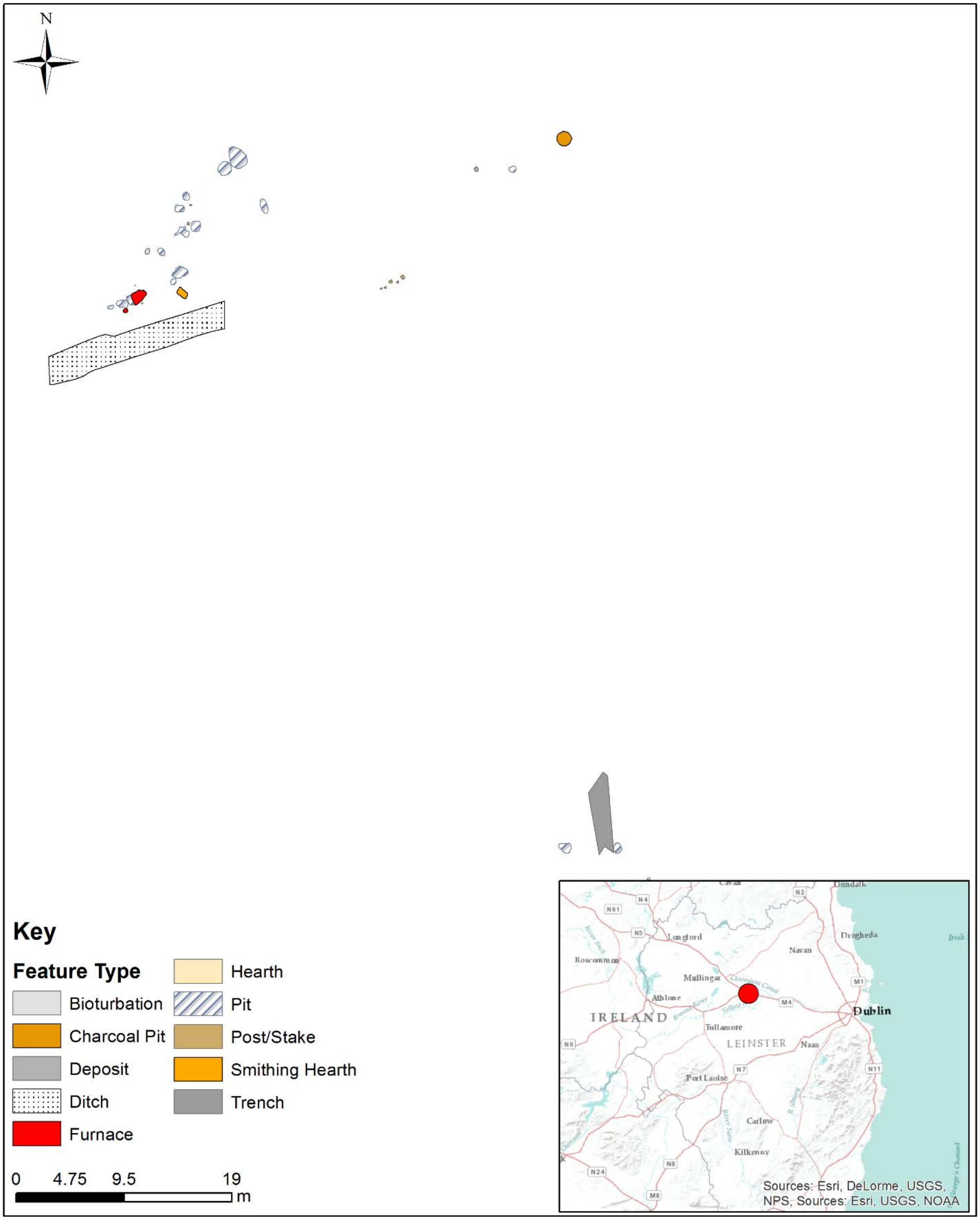
This site appears to be part of a larger landscape or complex of Iron Age activity, specifically related to iron production. 900m to the south was the site of Monganstown 1, which produced evidence for iron production spanning the EIA and DIA. 830m to the northwest, the site of Griffinstown 3 contained furnace types that match those in the surrounding area, although no 14C samples were taken. Additionally, 2 – 2.5km to the southeast lay the sites of Rossan 6 and Hardwood 3, which produced ironworking evidence that spanned the Iron Age and later.

References:

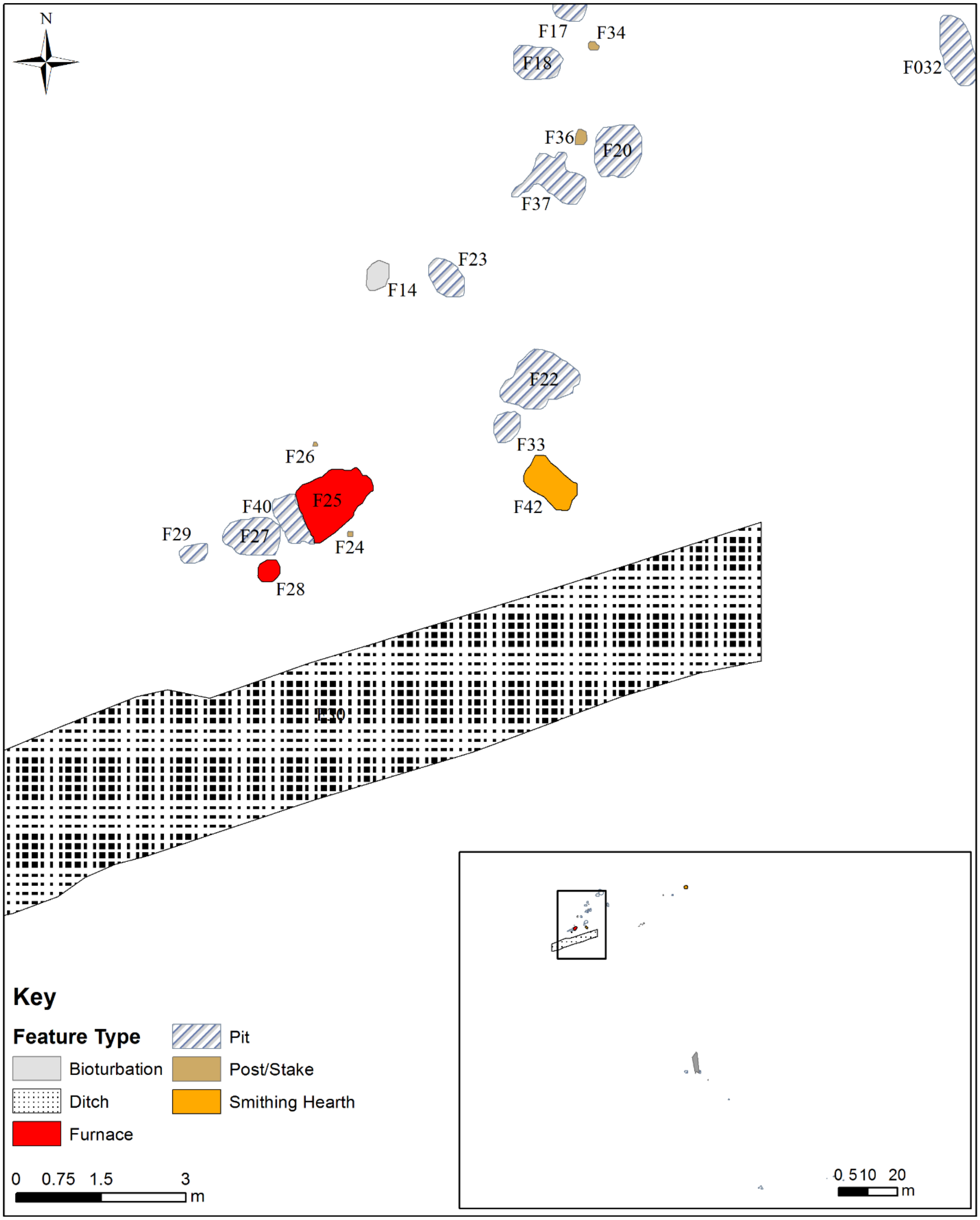
Murphy, D. 2003. K-E-K M4 Motorway, Contract 1, report for Kinnegad 2, Co. Westmeath. Unpublished report. Archaeological Consultancy Services Ltd

Furnace Sections:





Kinnegad 2 (02E0926)



Kinnegad 2 (02E0926)

Site Name: Knockcommane 4700.1b

County: Limerick

Licence Number: E2342

Townland: Knockcommane

ITM East: 587554.763

ITM North: 616079.478

Excavation conducted by Margaret Gowen and Co Ltd.

Smelting: Yes **Number of furnaces:** 1

Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

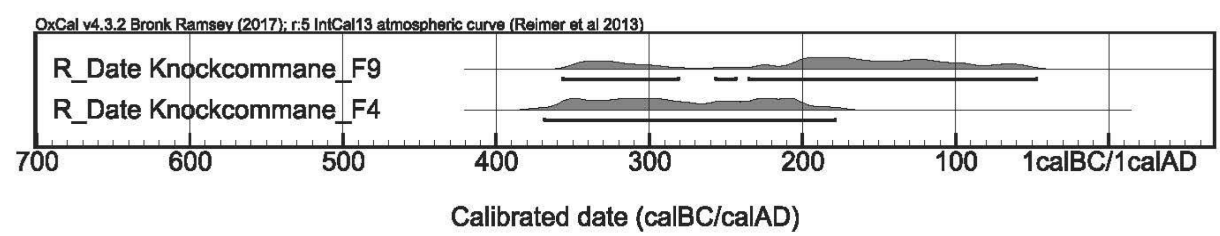
Type of Site: Structure

Chronology: DIA

C14 Dates and Context:

Knockcommane_F9 R_Date(2138,44)
68.2% probability
348BC (12.6%) 318BC
208BC (55.6%) 95BC
95.4% probability
357BC (22.0%) 282BC
257BC (1.4%) 244BC
236BC (72.0%) 48BC

Knockcommane_F4 R_Date(2199,34)
68.2% probability
357BC (43.7%) 283BC
255BC (4.5%) 246BC
236BC (20.0%) 202BC
95.4% probability
369BC (95.4%) 179BC

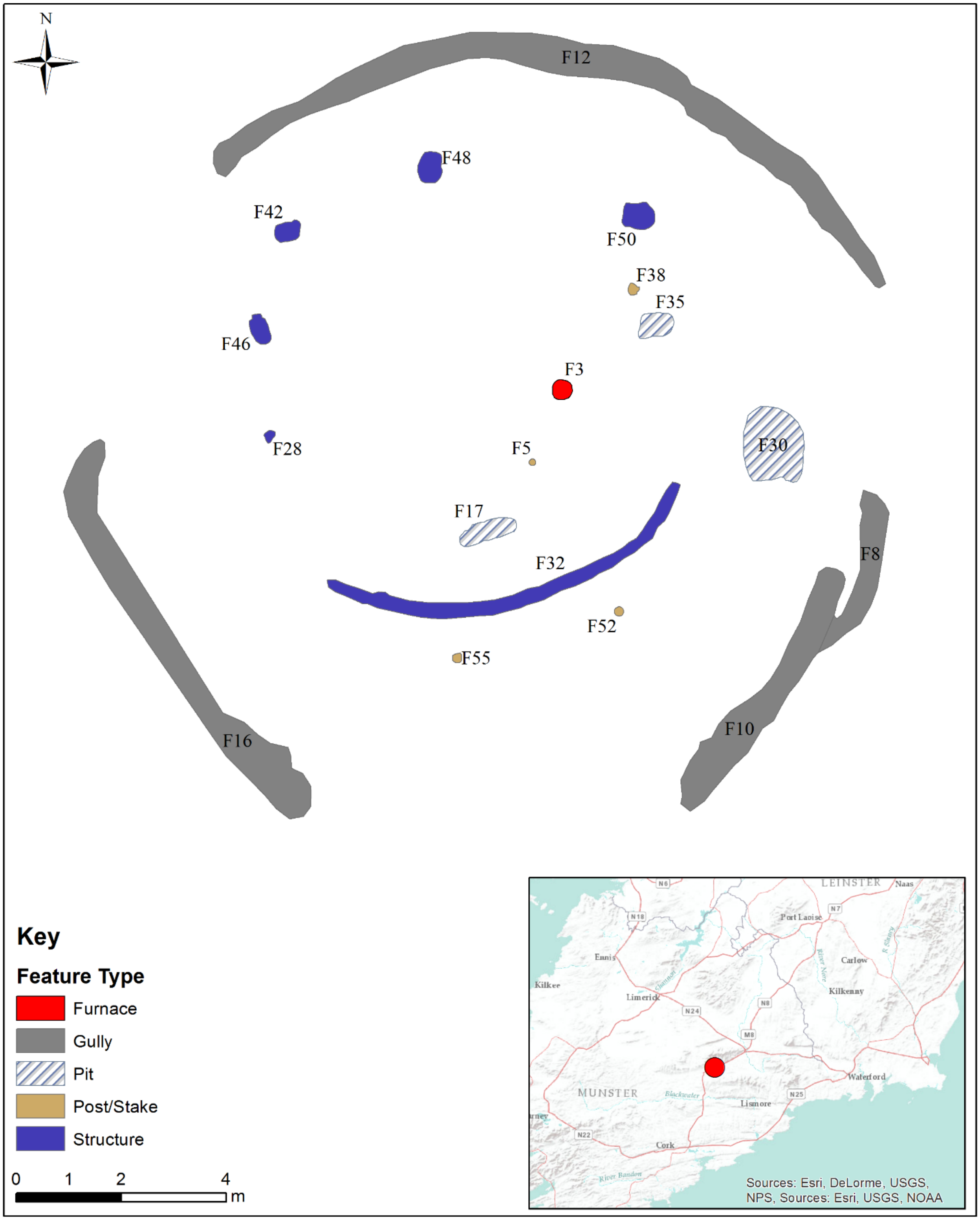


Description of Site: This site was discovered along a section of the N8 Cashel to Mitchelstown Road Scheme. It consisted of an enclosure of about 15m in diameter, in addition to a possible posthole and slot trench structure within the enclosure. One furnace was identified within the center of the enclosure, with a morphology suggesting a slag-pit furnace. The furnace produced a 14C date of 375-182 cal. BCE.

80m to the west of this site was a ring-barrow that also provided an Iron Age date an contained one centrally placed cremation burial.

Landscape: "Site located on the brow of the northwest facing slope. In sight of Galtee Mountains and Kncokmealdown mountains."

References: Molloy, B. 2007. N8 Cashel to Mitchelstown road improvement scheme. Final report Knockcommane, Co. Tipperary. Unpublished report. Margaret Gowen and Co. Ltd



Knockcommane 4700.1b (E2342)

Site Name: Lagavooren 7 **County:** Meath

Licence Number: 00E0914 **Townland:** Lagavooren

ITM East: 707148.65 **ITM North:** 773003.029

Excavation conducted by Irish Archaeological Consultancy

Smelting: Yes **Number of furnaces:** 2

Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: EIA**C14 Dates and Context:**

Lagavooren7_C269 R_Date(3155,30)
68.2% probability
1493BC (10.3%) 1480BC
1455BC (57.9%) 1406BC
95.4% probability
1500BC (90.7%) 1387BC
1338BC (4.7%) 1320BC

Lagavooren7_C140 R_Date(2355,30)
68.2% probability
474BC (14.9%) 444BC
431BC (53.3%) 388BC
95.4% probability
516BC (95.4%) 379BC

Lagavooren7_C345 R_Date(4050,30)
68.2% probability
2620BC (39.8%) 2564BC
2532BC (28.4%) 2495BC
95.4% probability
2835BC (4.5%) 2816BC
2666BC (90.9%) 2476BC

Lagavooren7_C21 R_Date(3215,30)
68.2% probability
1506BC (68.2%) 1446BC
95.4% probability
1600BC (2.4%) 1586BC
1534BC (93.0%) 1420BC

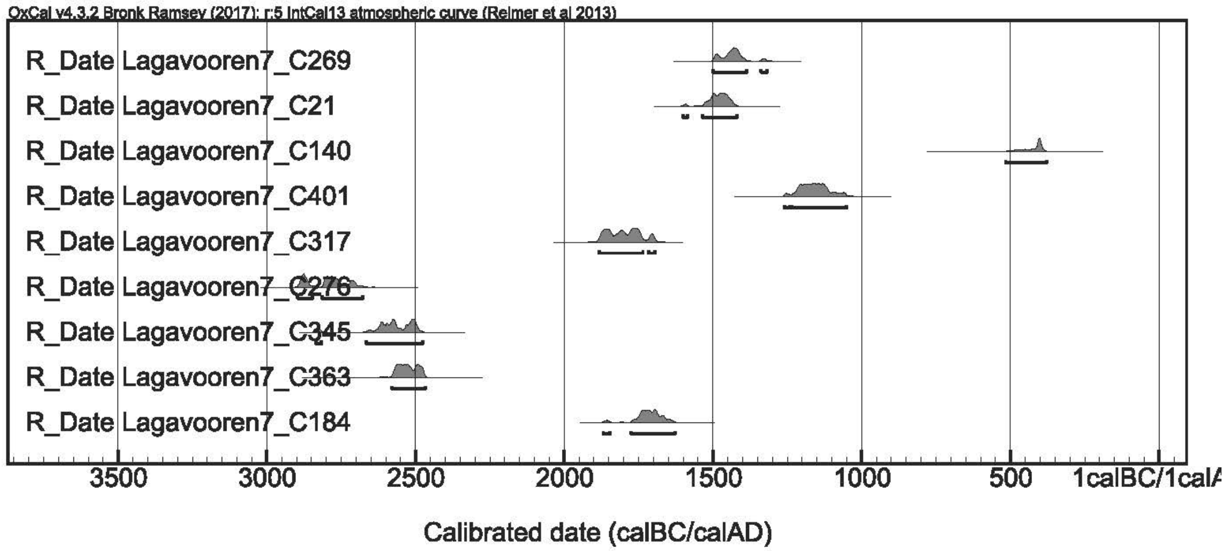
Lagavooren7_C276 R_Date(4205,30)
68.2% probability
2887BC (23.0%) 2864BC
2806BC (41.9%) 2759BC
2716BC (3.4%) 2712BC
95.4% probability
2896BC (29.6%) 2848BC
2814BC (65.8%) 2678BC

Lagavooren7_C401 R_Date(2950,30)
68.2% probability
1214BC (68.2%) 1118BC
95.4% probability
1260BC (3.2%) 1241BC
1236BC (92.2%) 1051BC

Lagavooren7_C317 R_Date(3470,30)
68.2% probability
1876BC (25.1%) 1841BC
1821BC (15.8%) 1796BC
1782BC (27.3%) 1744BC
95.4% probability
1884BC (87.5%) 1736BC
1716BC (7.9%) 1695BC

Lagavooren7_C184 R_Date(3415,30)
68.2% probability
1749BC (62.4%) 1681BC
1675BC (5.8%) 1665BC
95.4% probability
1870BC (4.1%) 1846BC
1775BC (91.3%) 1628BC

Lagavooren7_C363 R_Date(4005,30)
68.2% probability
2568BC (50.5%) 2518BC
2498BC (17.7%) 2480BC
95.4% probability
2580BC (95.4%) 2468BC



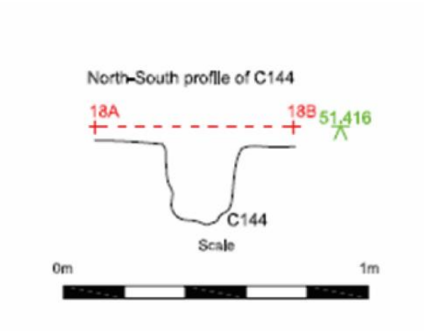
Description of Site: This site was discovered prior to the construction of the M1 Northern Motorway Gormanston – Monasterboice (Drogheda Bypass). The site contains multiple periods of occupation, the first of which was an Early Neolithic cluster of pits, followed by a Late Neolithic timber post circle. There was also a circular slot-trench structure that dated to the Middle Bronze Age (1540 – 1380 cal. BCE). The Iron Age activity on the site consisted of a series of hearths and iron working features. Two features were identified as smelting furnaces, although they were larger than most previously identified furnaces from this period. A 14C date of 520 – 380 cal. BCE was recovered from one of the furnaces. The morphological analysis of the slag recovered from these features suggests they came from a non-tapping slag-pit furnace. Additionally, chemical analysis of some of the slags recovered from these features indicates that the furnaces may have been used for rock ore, rather than bog ore, which seemed to have been the norm during this period.

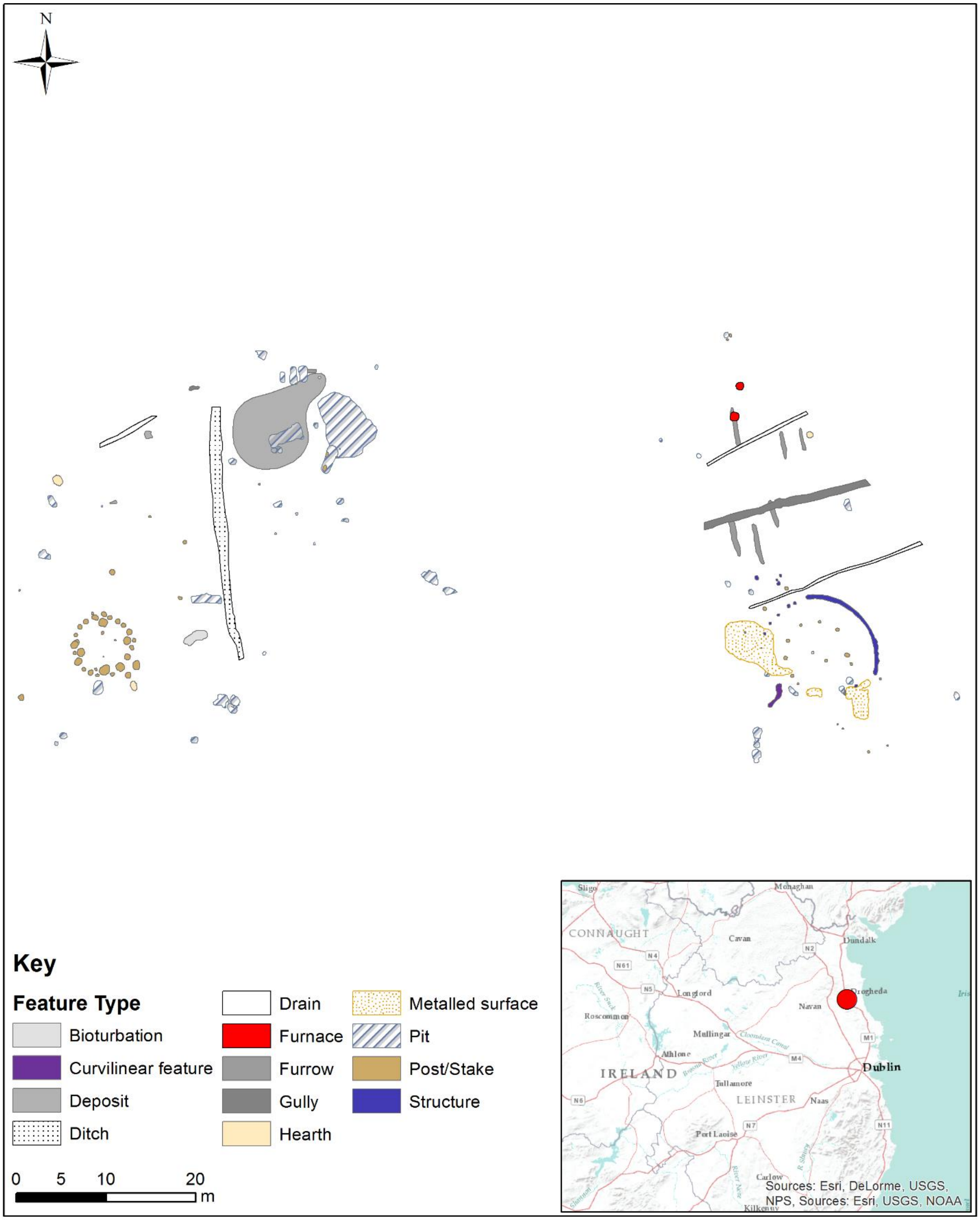
This site is part of a larger landscape of Neolithic and Bronze Age habitation and ceremonial activity, including the LBA ditched enclosure found to the southeast. There is also a larger area of Iron Age activity in the area. Approximately 4km from Lagavooren 7, was the DIA/LIA unenclosed ‘hut’ site of Colp West. While c. 8km south were the site(s) of Claristown 2 and 4, a DIA unenclosed hut and ring-ditch site.

References:

Stafford, E. 2012. M1 Northern motorway Gormanston-Monasterboice. Final report on 00E0914: Lagavooren 7. Unpublished report for Meath County Council. Irish Archaeological Consultancy Ltd

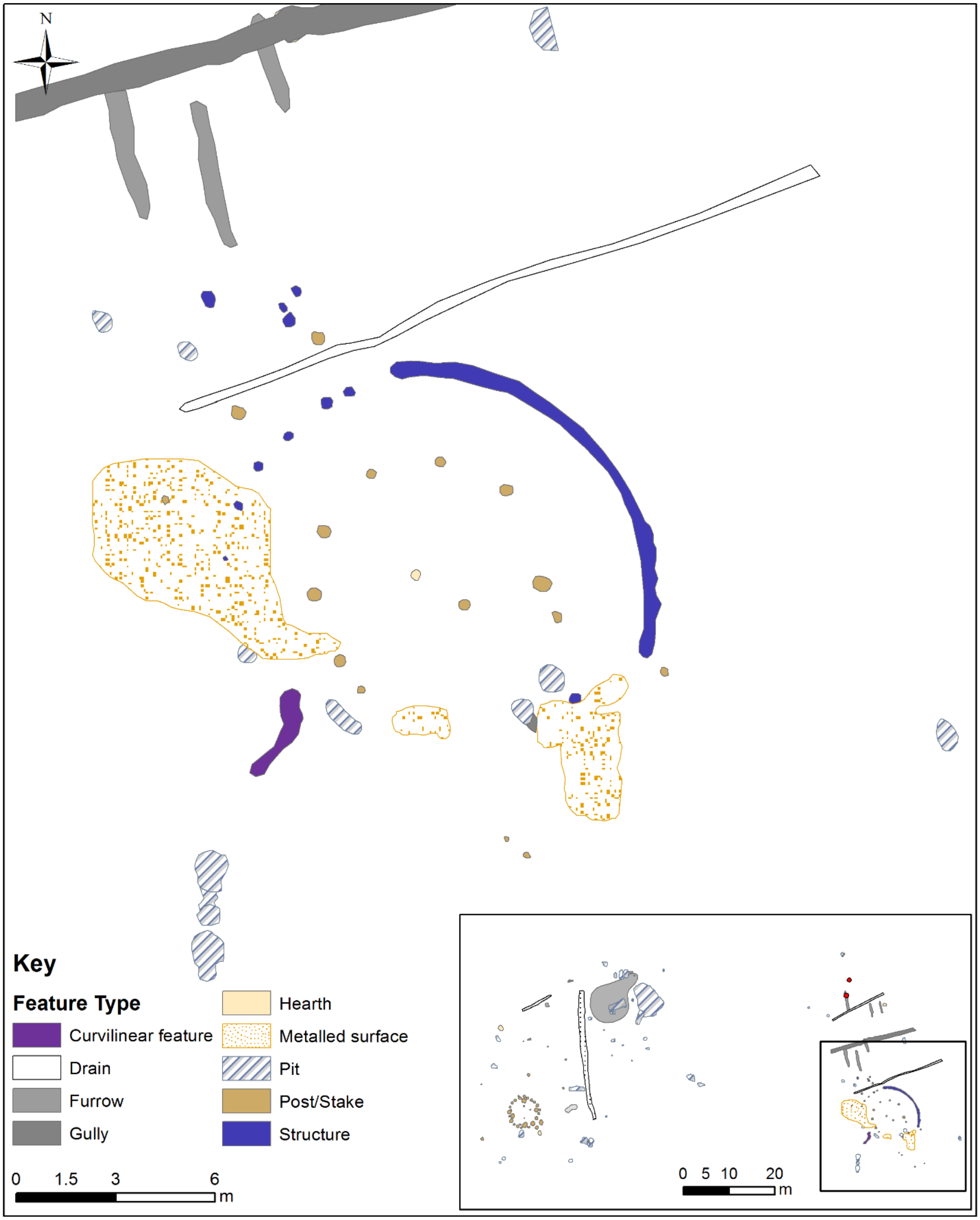
Furnace Section:



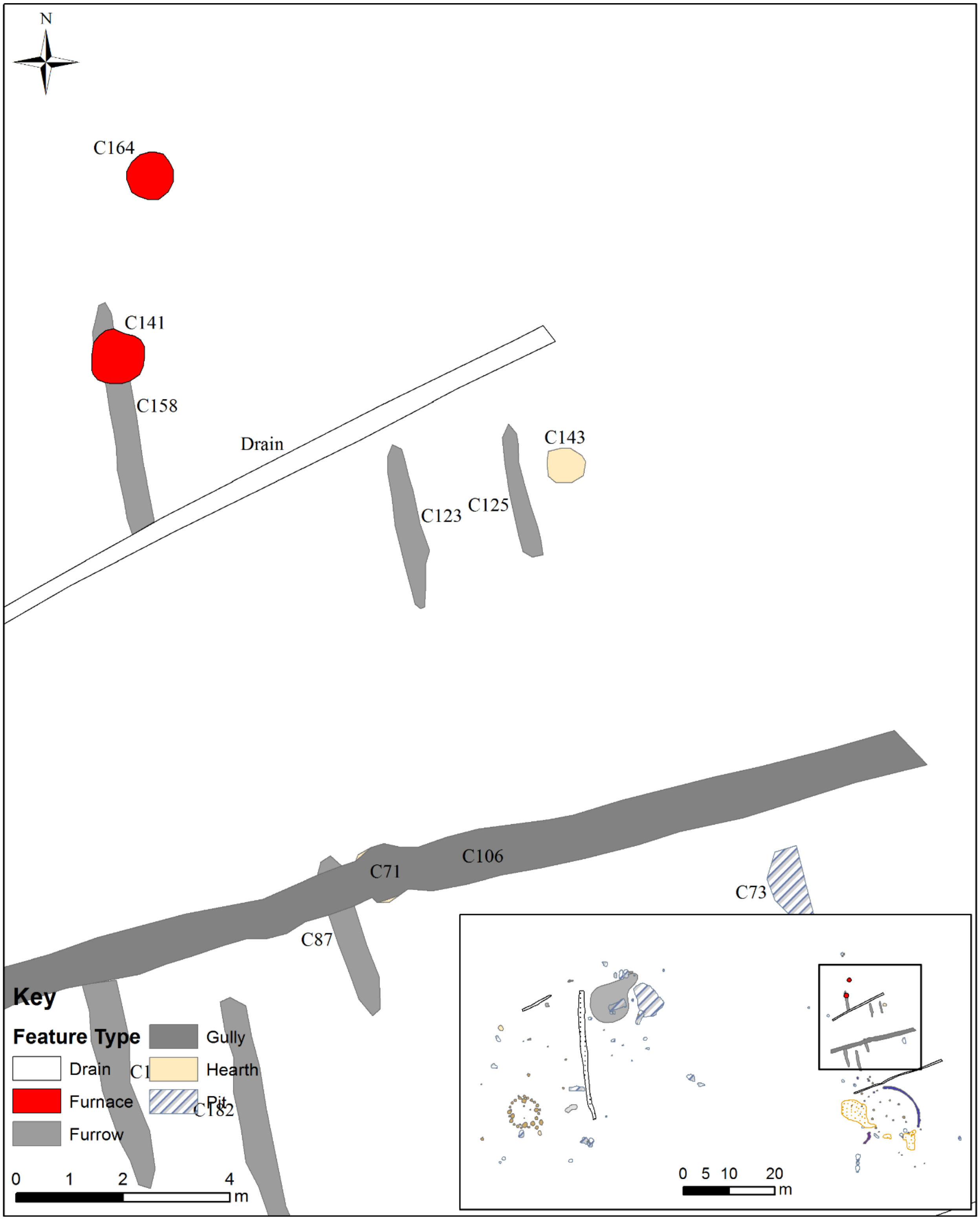


Lagavooren 7 (00E0914)

Close-up of Lagavooren 7 (00E0914)



Close-up of Lagavooren 7 (00E0914)



Close-up of Lagavooren 7 (00E0914)

Site Name: Leap 1 **County:** Laois

Licence Number: E2131 **Townland:** Leap

ITM East: 634050.122 **ITM North:** 682297.814

Excavation conducted by Archaeological Consultancy Services Ltd

Smelting: Yes **Number of furnaces:** 1

Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Isolated Metalworking

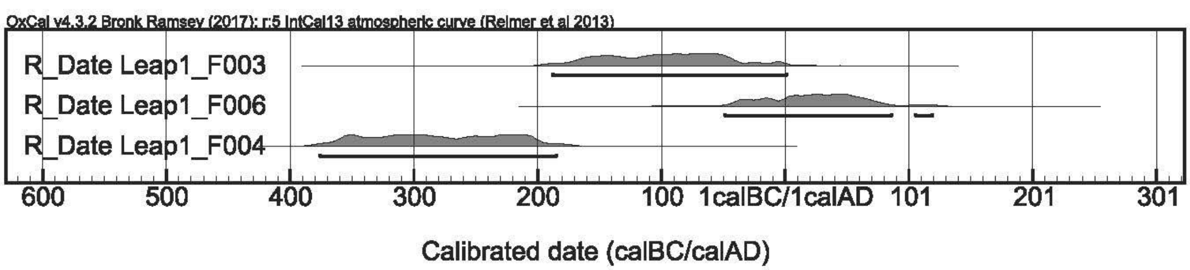
Chronology: DIA

C14 Dates and Context:

Leap1_F003 R_Date(2075,35)
68.2% probability
161BC (18.0%) 131BC
118BC (50.2%) 46BC
95.4% probability
188BC (95.4%) 2AD

Leap1_F006 R_Date(1975,35)
68.2% probability
20BC (6.0%) 11BC
2BC (62.2%) 67AD
95.4% probability
49BC (93.6%) 86AD
106AD (1.8%) 120AD

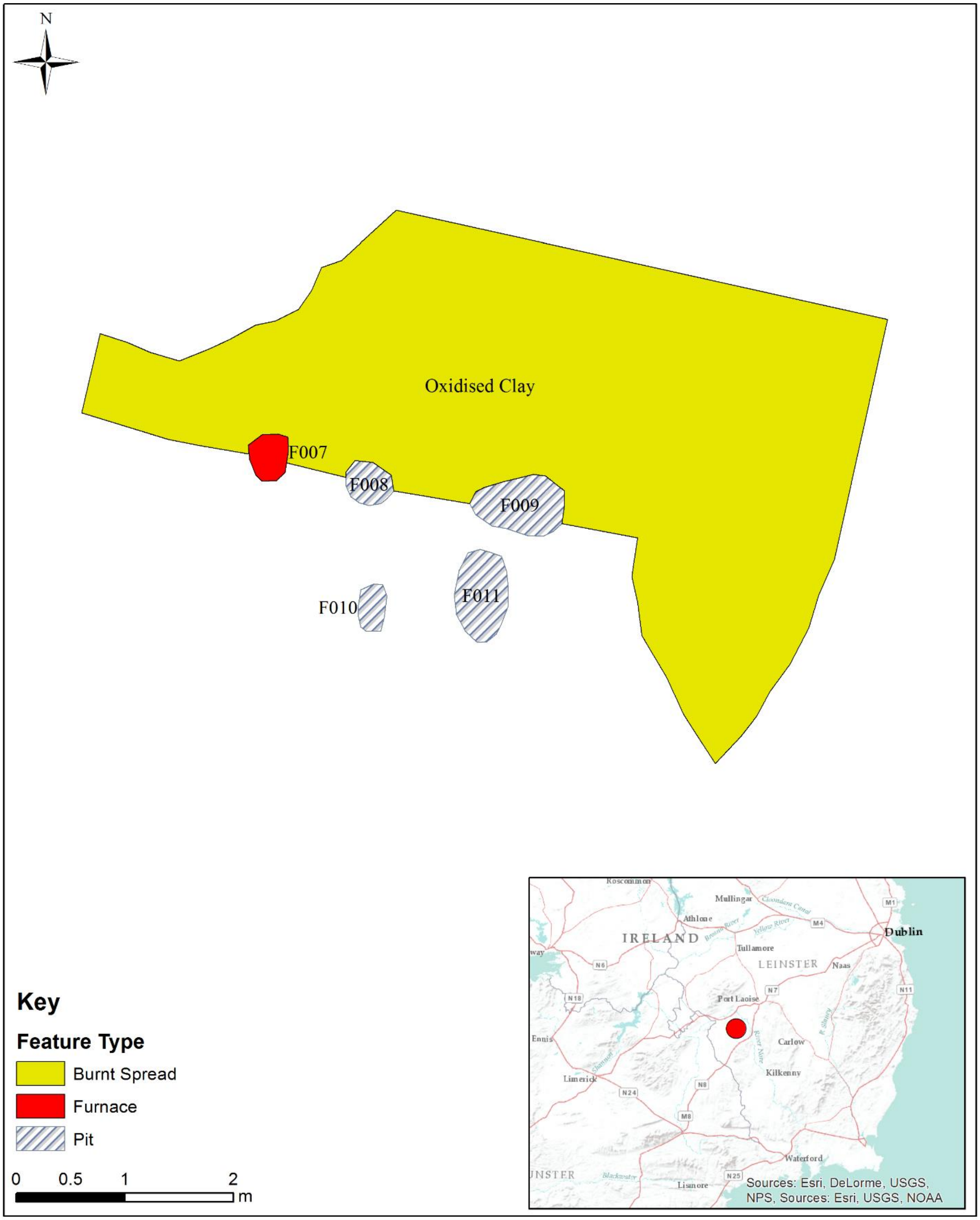
Leap1_F004 R_Date(2205,35)
68.2% probability
358BC (8.7%) 342BC
326BC (28.6%) 277BC
258BC (31.0%) 204BC
95.4% probability
376BC (95.4%) 186BC



Description of Site: This site was discovered prior to the construction of the M7 Portlaoise-Castletown/M8 Portlaoise-Cullahill Motorway Scheme. The site contained an associated five pits, one of which was almost certainly a slag-pit non-tapping furnace. Three additional pits contained slag, and may have been used as metallurgical refuse pits. Three 14C dates recovered from the pits place this site firmly in the DIA. Interestingly, one pit that provided a DIA date also contained several sherds of pottery, which is one of the few instances of pottery found in association with an Iron Age date.

Landscape: "The topography of the Leap and Cuffsborough area is one of undulating countryside, well drained by free flowing streams and streamlets. The current landscape is characterised by rolling tracts of fertile land interspersed with pockets of less fertile and more low-lying, wetter and boggier areas. In prehistoric times, it is likely that this region was much more heavily wooded and probably less well drained than it is today. However, in the greater Leap and Cuffsborough area grey-brown podzolic (medium textured, moderately deep) soils are prevalent (Feehan 1983, 90-3). The grey-brown podzolic soils are among the best soils in Ireland. The soils in this area are medium textured, well-drained, friable podzolics and are especially good for tillage farming, although these soils are also highly suitable for grass production and grazing (Feehan 1983, 92). Consequently it is easy to see why this area became a haven for Bronze Age settlement in the past. It is clear that the domestic settlement in the area occurred in the drier and slightly higher lying areas (such as at Cuffsborough 4) while fulacht fiadh activity occurred right across the wetter and more lower-lying landscape (Cuffsborough 1, 3 and Leap 2) in the vicinity of free flowing streams such as the one at Cuffsborough 3, which flows southwards draining the land of excess water and eventually flowing into the river Erkina."

References:
Kane, E. 2009b. M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill motorway scheme. Report on the archaeological excavation of Leap 1, Co. Laois. Unpublished report for Laois County Council. Archaeological Consultancy Services Ltd


N
Oxidised Clay
F007
F008
F009
F010
F011
Key
Feature Type
Burnt Spread
Furnace
Pit
0 0.5 1 2
m
Roscommon
Mullingar
Athlone
IRELAND
Dublin
Tullamore
LEINSTER
Naas
Port Laoise
Ennis
Carlow
Limerick
Kilkenny
Waterford
Lismore
Sources: Esri, DeLorme, USGS, NPS, Sources: Esri, USGS, NOAA

Leap 1 (E2131)

Site Name: Lisnagar Demesne 1

County: Cork

Licence Number: 03E1510

Townland: Demesne

ITM East: 578993.918

ITM North: 590841.047

Excavation conducted by Archaeological Consultancy Services Ltd

Smelting: Yes **Number of furnaces:** 1

Smithing: Yes **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Isolated Metalworking

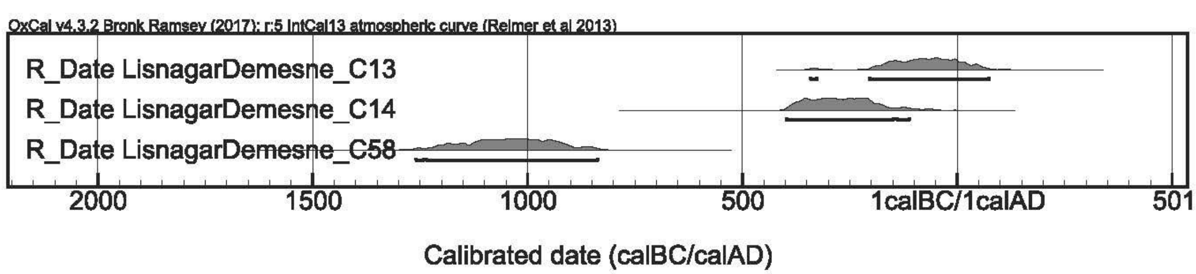
Chronology: DIA/LIA

C14 Dates and Context:

LisnagarDemesne_C13 R_Date(2050,60)
68.2% probability
162BC (12.0%) 130BC
119BC (56.2%) 5AD
95.4% probability
341BC (0.9%) 328BC
204BC (94.5%) 74AD

LisnagarDemesne_C14 R_Date(2210,60)
68.2% probability
361BC (10.5%) 338BC
329BC (57.7%) 204BC
95.4% probability
398BC (92.4%) 149BC
140BC (3.0%) 112BC

LisnagarDemesne_C58 R_Date(2860,80)
68.2% probability
1154BC (1.1%) 1149BC
1128BC (67.1%) 919BC
95.4% probability
1260BC (1.3%) 1242BC
1235BC (94.1%) 837BC



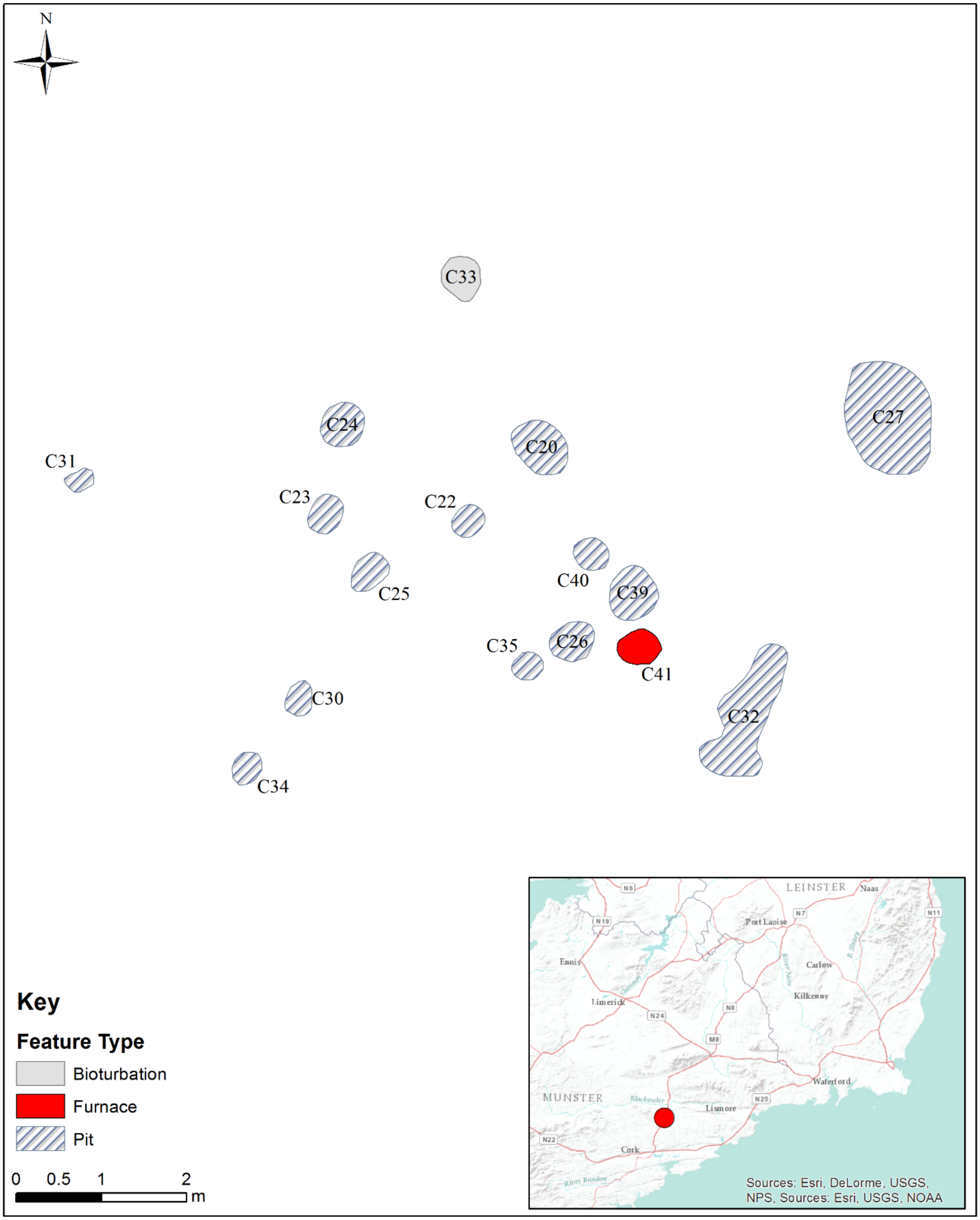
Description of Site: This site was discovered prior to the construction of the proposed N8 Rathcormac Fermoy By-Pass. The site contained multiple areas of activity that spanned the LBA through to the post-medieval period. The farthest south of the site contained a few postholes that were 14C dated to the LBA (1270 – 820 cal. BCE). The north of the site contained a post-medieval limekiln. The center of the site produced an area of Iron Age activity, including pits and a remains of a smelting furnace.

The Iron Age occupation of the site consisted of 13 circular pits, a large oval pit, and a slag-pit low shaft furnace. The function of the majority of the pits remains unclear, although one did produce some slag, indicating it could have been used for metallurgical waste from the furnace. Some of the smaller pits may have actually been used as postholes, but there does not seem to be any noticeable orientation that would suggest this. The furnace morphology suggests a shaft furnace, and the presence of tapped slag means that the furnace was slag-tapping, a type of furnace basically unknown in Ireland during this period. Additionally, a smithing hearth Plano Convex Bottom was recovered from the oval pit, suggesting that smithing was occurring at some place on this site. This pit may have in fact acted as the smithing hearth.

Landscape: "The proposed road scheme with which this report is concerned begins immediately north of the village of Watergrasshill, on the northern flank of the Watergrasshill Anticline and continues northwards to the Fermoy Syncline, ending immediately north of Fermoy town. The northern end of the site at Lisnagar Demesne 1 slopes down to a stream and wooded area."

References:

Murphy, D. 2006. N8 Rathcormac- Fermoy Bypass Scheme. Final report on archaeological excavation of Lisnagar Demesne 1. Unpublished report for Cork County Council and the NRA. Archaeological Consultancy Services Ltd



Lisnagar Demesne 1 (03E1510)

Site Name: Lughil, Site L

County: Kildare

Licence Number: 03E0602

Townland: Lughil

ITM East: 663661.451

ITM North: 707670.783

Excavation conducted by Valerie J. Keeley Ltd.

Smelting: Yes **Number of furnaces:** 5

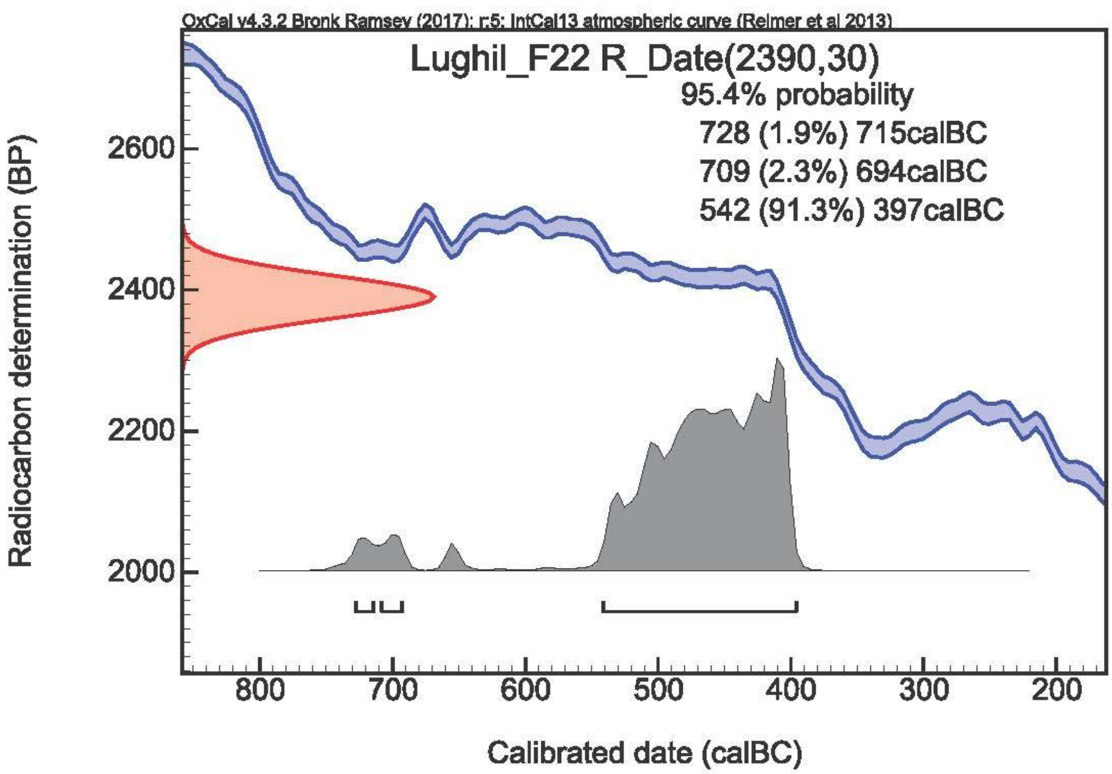
Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: EIA

C14 Dates and Context:

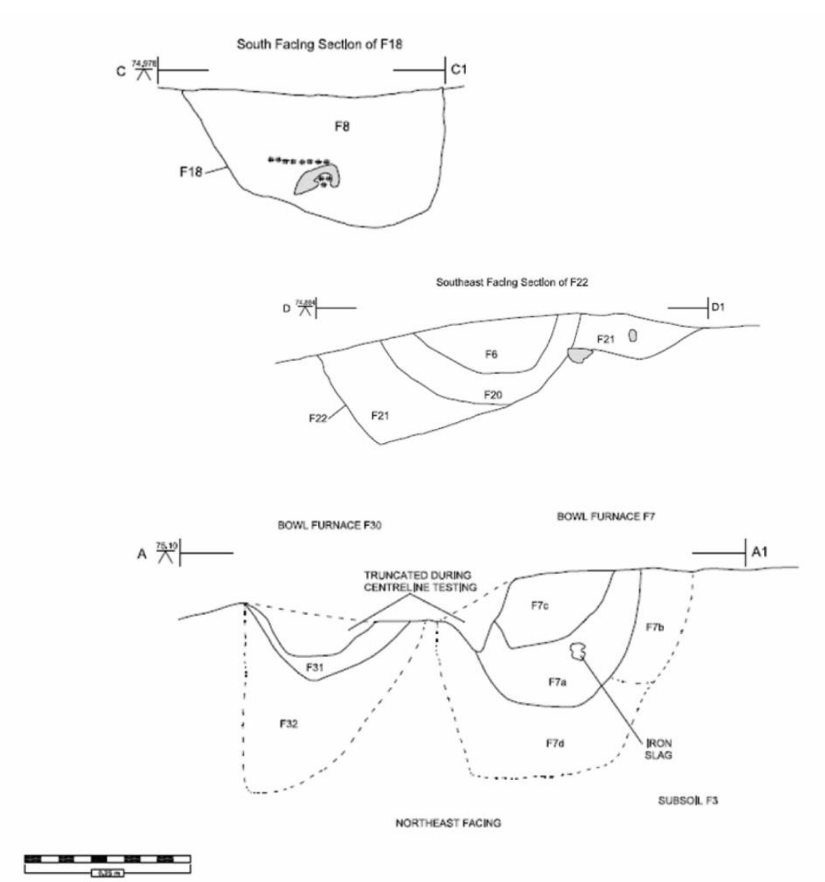


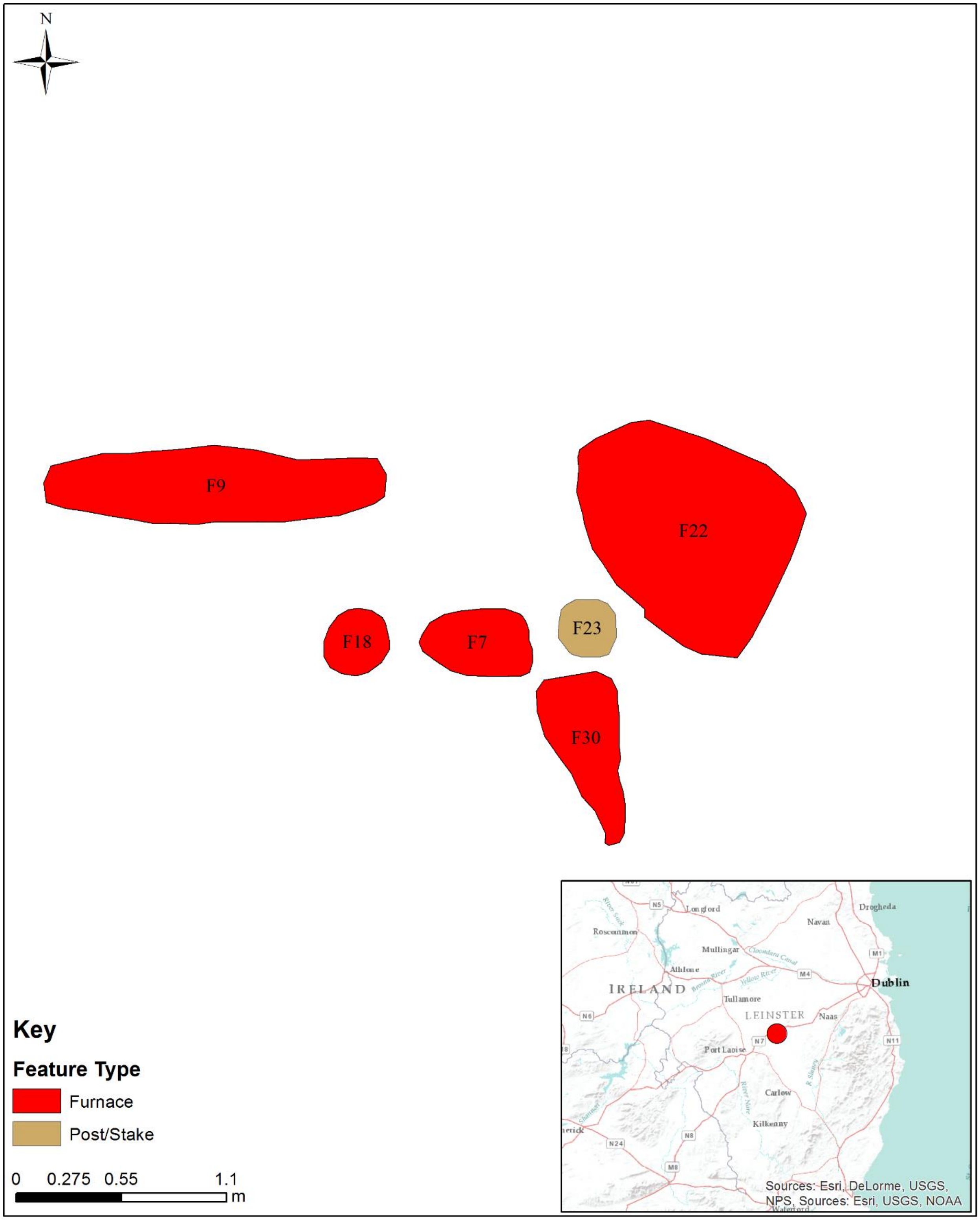
Description of Site: This site was discovered during the construction of the N7 Heath-Mayfield Motorway Scheme. Cutting D from this site produced six different features, most of which were likely associated with iron production. There were potentially five features that were involved in smelting iron. However, the nature of each one is sometimes ambiguous. A few of the furnace shapes parallel that of a slag-pit furnace, while others are less identifiable. It is possible that as few as two of the five features originally identified as furnaces were actually used as such.

References:

Channing, J. 2012. N7 Heath-Mayfield motorway scheme: archaeological resolution. Final report for Site L, Lughil Townland, Co. Kildare. Unpublished report for the Kildare County Council. Valerie J. Keeley Ltd

Furnace Section:





Site L, Lughil (03E0602)

Site Name: Monganstown 1

County: Westmeath

Licence Number: E2771

Townland: Monganstown

ITM East: 657657.711

ITM North: 744386.61

Excavation conducted by Eachtra Archaeological Projects

Smelting: Yes **Number of furnaces:** 6

Smithing: Yes **Number of smithing hearths:**

Charcoal Production: Yes

Type of Site: Isolated Metalworking

Chronology: DIA

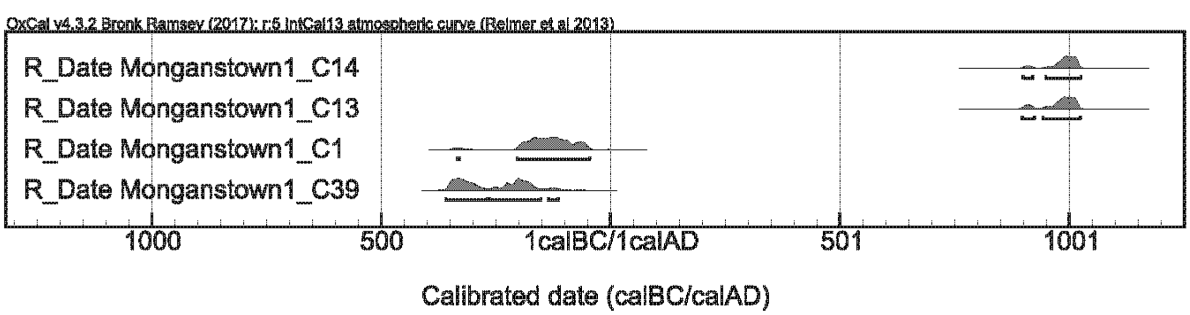
C14 Dates and Context:

Monganstown1_C14 R_Date(1050,29)
68.2% probability
978AD (68.2%) 1020AD
95.4% probability
900AD (8.0%) 922AD
949AD (87.4%) 1026AD

Monganstown1_C13 R_Date(1056,30)
68.2% probability
971AD (68.2%) 1020AD
95.4% probability
898AD (12.2%) 924AD
944AD (83.2%) 1024AD

Monganstown1_C1 R_Date(2110,31)
68.2% probability
182BC (66.0%) 92BC
68BC (2.2%) 64BC
95.4% probability
335BC (0.6%) 330BC
204BC (94.8%) 46BC

Monganstown1_C39 R_Date(2168,31)
68.2% probability
352BC (38.8%) 297BC
228BC (3.6%) 221BC
211BC (25.8%) 174BC
95.4% probability
360BC (46.8%) 270BC
264BC (45.1%) 152BC
136BC (3.5%) 114BC



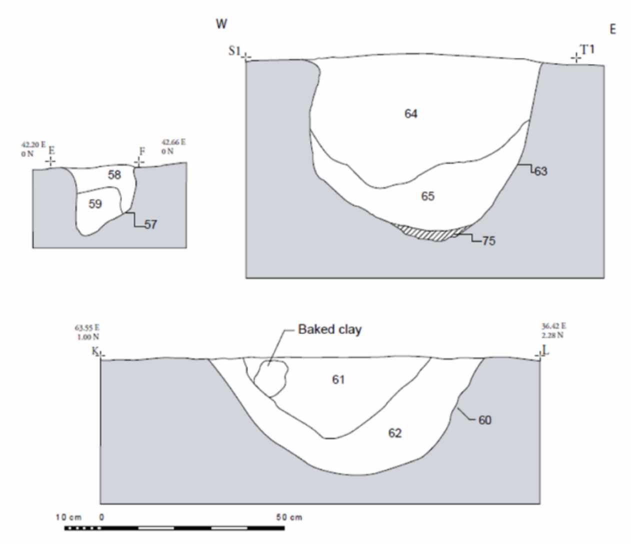
Description of Site: This site was uncovered during the archaeological investigations in advance of the N6 realignment between Kinnegad and Kilbeggan. The site consisted of two charcoal production pits, six furnaces and a number of pits and postholes. The charcoal production pits produced 14C dates of 898 – 920 cal. CE and 897 – 1024 cal. CE. This matches dates for the nearby site of Hardwood 3 (2km to east) which produced a date of 720 – 960 cal. CE. Six features have been interpreted as bloomery furnaces, most with circular or sub-circular shapes. Specifically, these were slag-pit shaft furnaces. One furnace was cut into an earlier furnace, which would have been likely if they were using slag-pits. One furnace provided a 14C date of 361 – 113 cal. BCE, suggesting that the complex of furnaces here were in use during the DIA. Interestingly, there was some tap-slag present in the samples analyzed, which would is not typical of this period. Additionally, metallurgical inspection of the slag recovered from the site suggests that there was some kind of smithing occurring at the site, with the presence of a plano-convex bottom, although no smithing hearth was specifically identified. Six of the pits discovered were likely originally used as clay extraction pits for the clay superstructures of the furnaces, and were later used as deposits for metallurgical refuse. A 14C date from these pits puts them at 338 – 46 cal. BCE, contemporaneous with the furnaces.

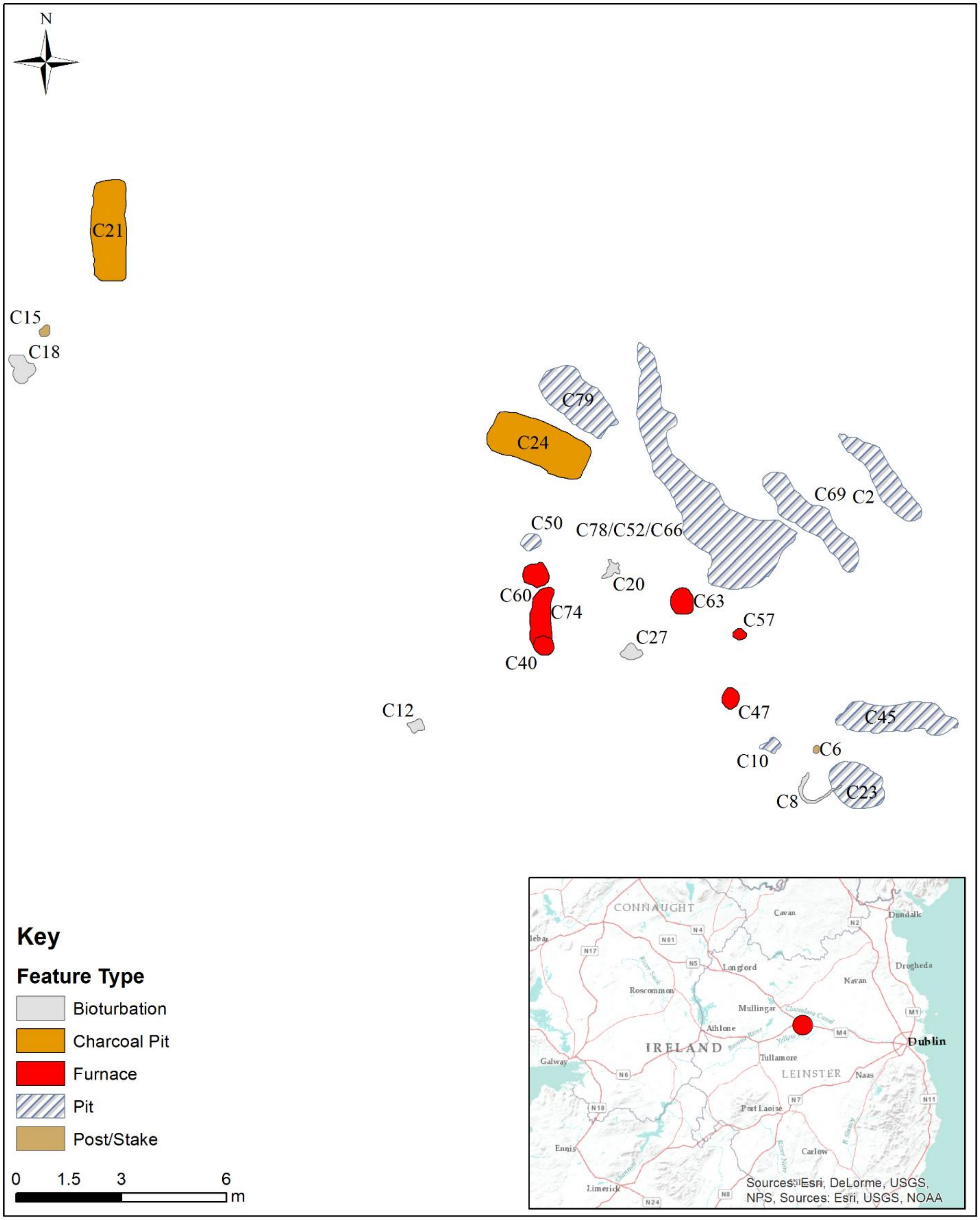
This site appears to be part of a larger landscape or complex of Iron Age activity, specifically related to iron production. 900m to the north was the site of Kinnegad 2, which also produced evidence for iron production in the DIA. 1.3km to the northwest, the site of Griffinstown 3 contained furnace types that match those in the surrounding area, although no 14C samples were taken. Additionally, 2 – 2.5km to the southeast lay the sites of Rossan 6 and Hardwood 3, which produced ironworking evidence that spanned the Iron Age and later.

Landscape: "The landscape followed by the route of the new road from Kinnegad to Athlone is generally lowlying, ranging from the low undulating drift cover east of Athlone to the flat plains of the central boglands and moraine near Kinnegad. Only a 4 km stretch of the corridor east of Tyrellspass rises above 100m in height, most of the land undulating gently along the northern extremities of the Bog of Allen. Outside the area of bogland the landscape is typified by regular enclosed fields, bordered by densely overgrown banks with mature hedgerows of ash, elder and hawthorn. This uniform landscape is broken up by streams, eskers and rivers; the River Brosna and its tributaries drain the western part of the study area, while the land east of Rochfortbridge is drained by the Yellow River and other smaller tributaries of the River Boyne (Casey 2002). The moist climate combined with the low-lying condition of much of the area ensures seasonal flooding, limiting the land-use capability to livestock grazing punctuated by infrequent tillage. In areas of marginal land close to the edges of the raised bogs the pasture is criss-crossed by drainage ditches without the usual accompanying enclosing bank."

References:
Lehane, J. & P. Johnston. 2009. Final archaeological excavation report, Monganstown 1, N6 Kinnegad to Kilbeggan, Co. Westmeath. Metalworking site. Echtra Journal 3

Furnace Section:





Monganstown 1 (E2771)

Site Name: Morett

County: Laois

Licence Number: 03E0461

Townland: Morett

ITM East: 653466.215

ITM North: 703151.954

Excavation conducted by Valerie J. Keeley Ltd

Smelting: Yes **Number of furnaces:** 4

Smithing: No **Number of smithing hearths:** 0

Charcoal Production: Yes

Type of Site: Burial

Chronology: EIA/DIA

C14 Dates and Context:

Morett_C157 R_Date(2480,35)
68.2% probability
757BC (11.0%) 727BC
718BC (4.2%) 705BC
694BC (5.7%) 678BC
672BC (47.2%) 541BC
95.4% probability
775BC (93.0%) 476BC
464BC (0.9%) 454BC
445BC (1.5%) 430BC

Morett_C14 R_Date(2170,35)
68.2% probability
354BC (37.3%) 292BC
231BC (30.9%) 172BC
95.4% probability
361BC (91.0%) 149BC
140BC (4.4%) 112BC

Morett_C295 R_Date(1605,35)
68.2% probability
403AD (23.2%) 434AD
452AD (10.1%) 470AD
487AD (34.9%) 534AD
95.4% probability
387AD (95.4%) 543AD

Morett_C77 R_Date(4105,35)
68.2% probability
2850BC (16.6%) 2813BC
2740BC (3.3%) 2730BC
2693BC (2.2%) 2687BC
2680BC (46.0%) 2580BC
95.4% probability
2866BC (22.7%) 2804BC
2776BC (71.6%) 2571BC
2513BC (1.1%) 2503BC

Morett_C392 R_Date(1580,35)
68.2% probability
426AD (32.1%) 474AD
485AD (36.1%) 536AD
95.4% probability
403AD (95.4%) 554AD

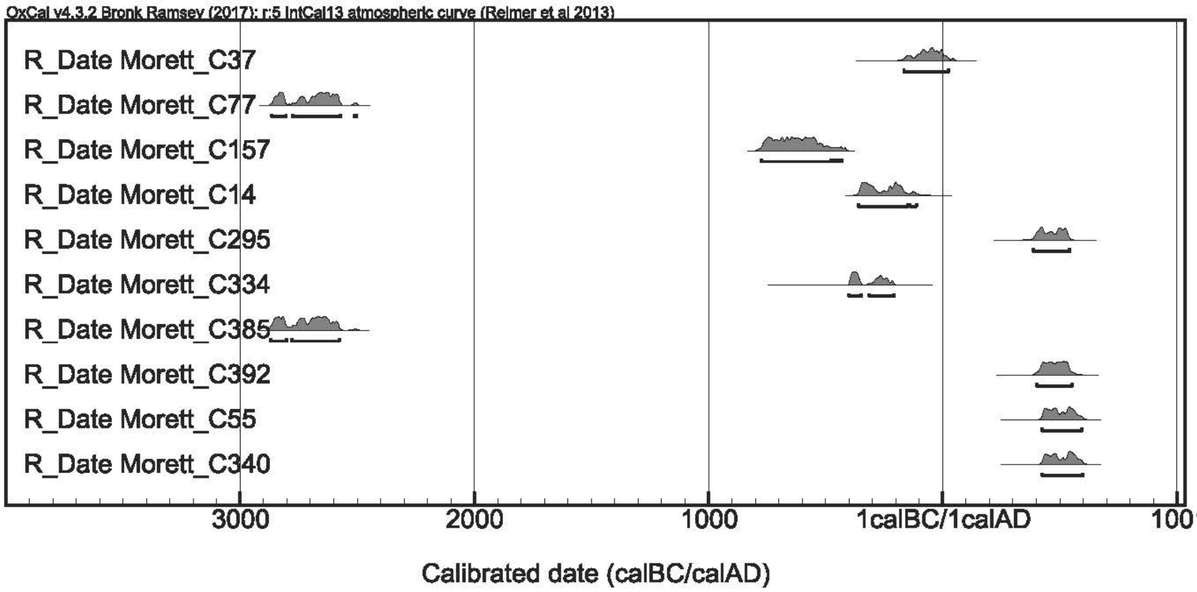
Morett_C334 R_Date(2270,35)
68.2% probability
396BC (38.9%) 356BC
284BC (21.4%) 254BC
248BC (7.9%) 235BC
95.4% probability
400BC (44.6%) 348BC
314BC (50.8%) 208BC

Morett_C385 R_Date(4120,35)
68.2% probability
2858BC (20.9%) 2810BC
2751BC (11.8%) 2722BC
2700BC (35.6%) 2620BC
95.4% probability
2871BC (25.3%) 2801BC
2780BC (70.1%) 2577BC

Morett_C37 R_Date(2045,35)
68.2% probability
104BC (68.2%) 3AD
95.4% probability
166BC (95.4%) 25AD

Morett_C55 R_Date(1540,35)
68.2% probability
430AD (42.1%) 492AD
530AD (26.1%) 566AD
95.4% probability
425AD (95.4%) 594AD

Morett_C340 R_Date(1535,35)
68.2% probability
431AD (38.0%) 491AD
530AD (30.2%) 572AD
95.4% probability
426AD (95.4%) 598AD



Description of Site: This site was discovered prior to the construction of the N7 Heath-Mayfield Motorway Scheme. The occupation at this site was dated back to the Late Neolithic, which included a four-post structure and fence line. The Iron Age activity at the site contained at least three smelting furnaces, two ring-ditches, and two charcoal kilns. Additionally, there is evidence for some Early Medieval occupation in the form of corn-drying kilns and four burials. The cluster of three features that were associated with two possible charcoal kilns that dated to 170 cal. BCE – 30 cal. CE. The furnace features are closely clustered, and suggest use as a slag-pit furnace. Additionally, there are two other features that may have also been used for iron production, one of which being the main furnace while another being a working hollow. The two ring-ditches found in this site produced two Iron Age 14C dates (400 – 200 cal. BCE; 370 – 110 cal. BCE). The larger one was 16m in diameter while the smaller one measured c. 7m in diameter. The Early Medieval Burials are also closely associated with the ring-ditches, suggesting a lasting use of the site for mortuary purposes.

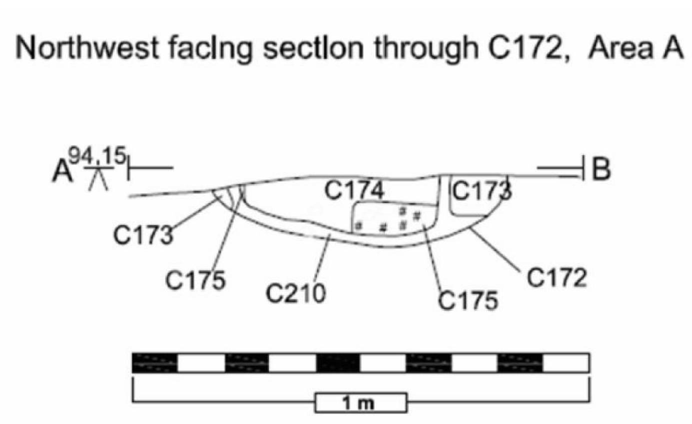
The site of Ballydavis, Site B lay just over 4km to the southwest, indicating a larger Iron Age use and occupation of the region.

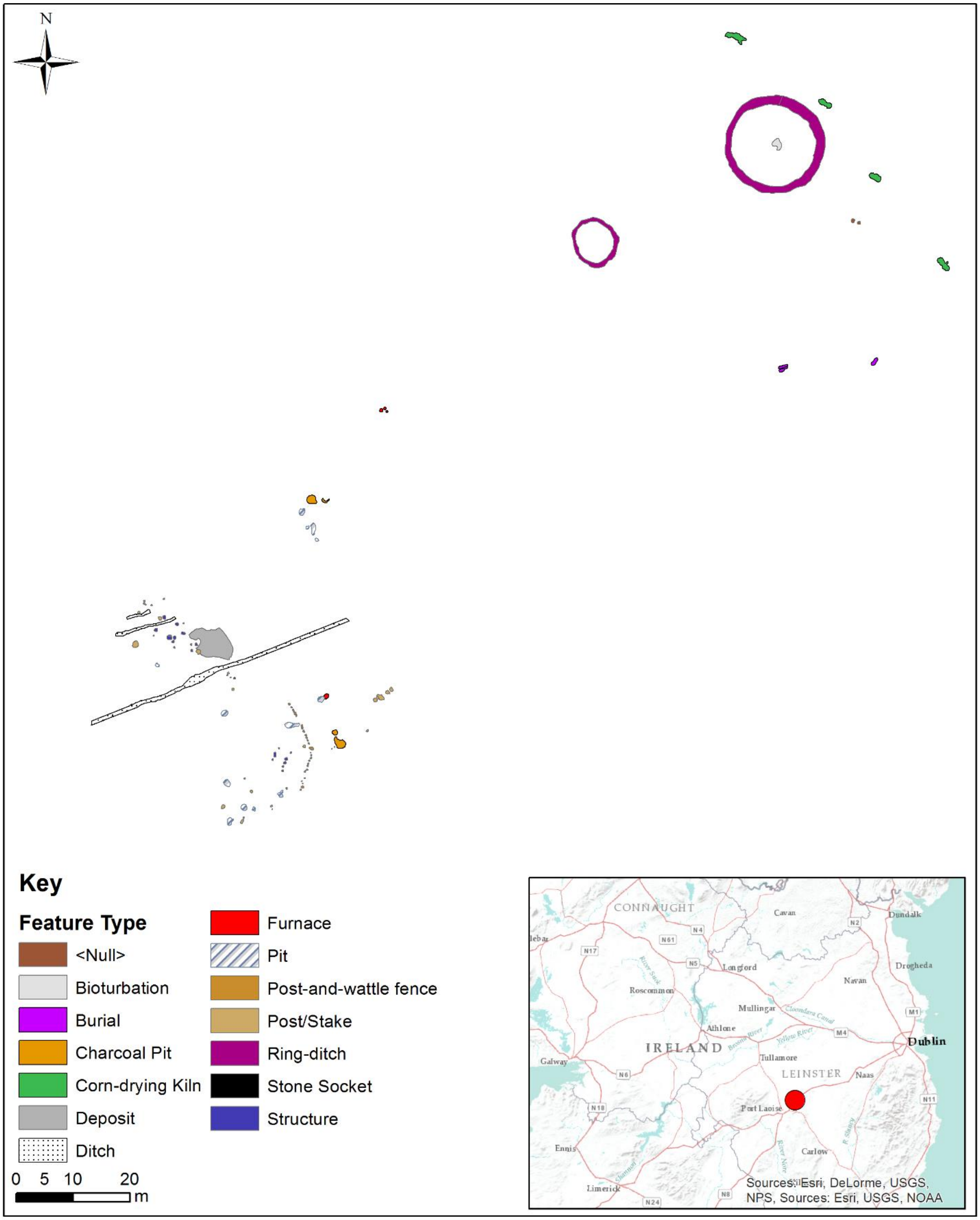
Landscape: "The excavation site was partly located on one of these hills. The ring-ditches and the human burials were located on the hilltop overlooking an extensive area of low-lying wet land to the east and northeast, while the remaining features were located on the plateau which extended to the southwest of the hilltop."

References:

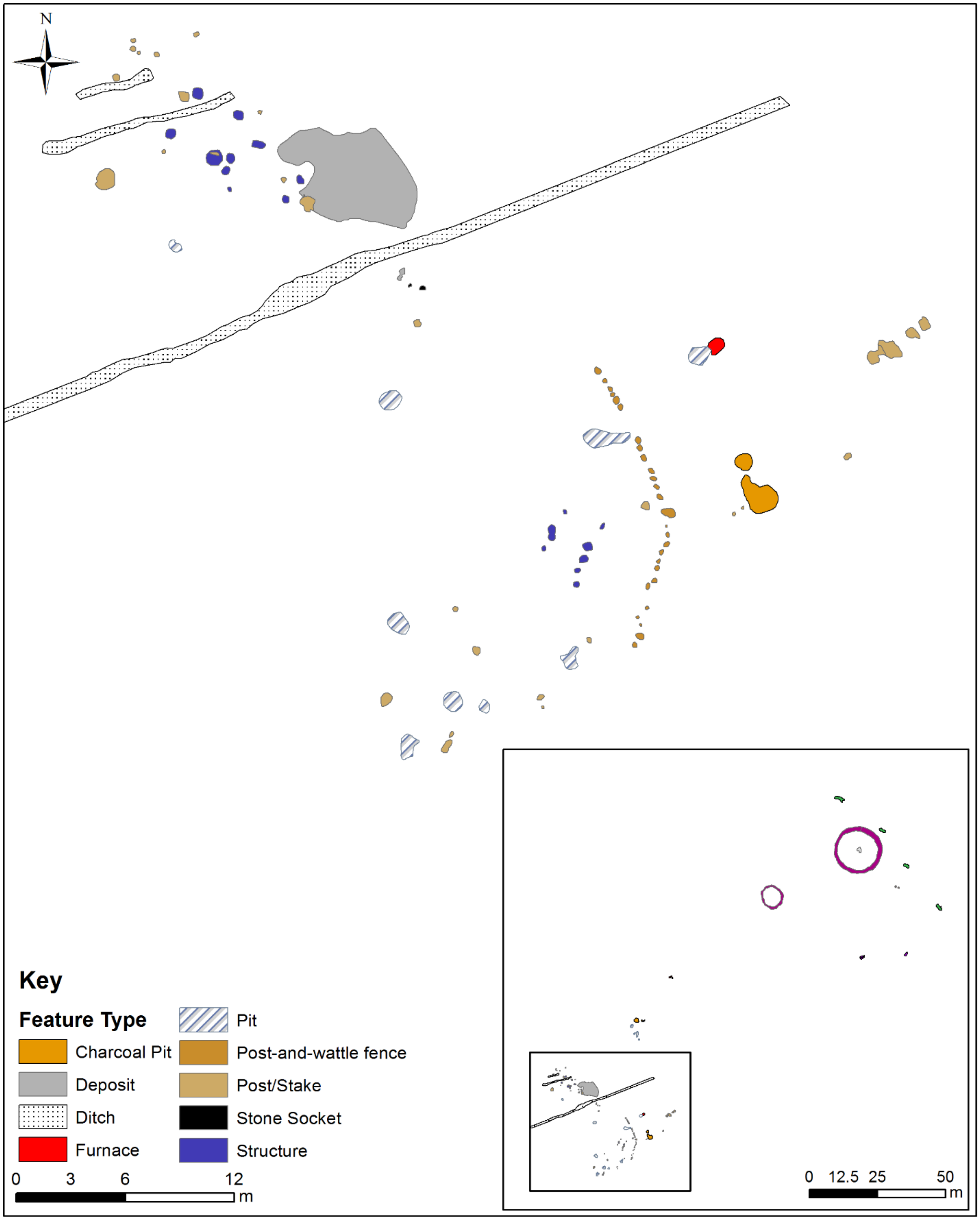
Cotter, E. 2011. N7 Heath-Mayfield motorway scheme: archaeological resolution. Final report for Site D, Morett Townland, Co. Laois. Unpublished report for the Kildare County Council. Valerie J. Keeley Ltd

Furnace Section:

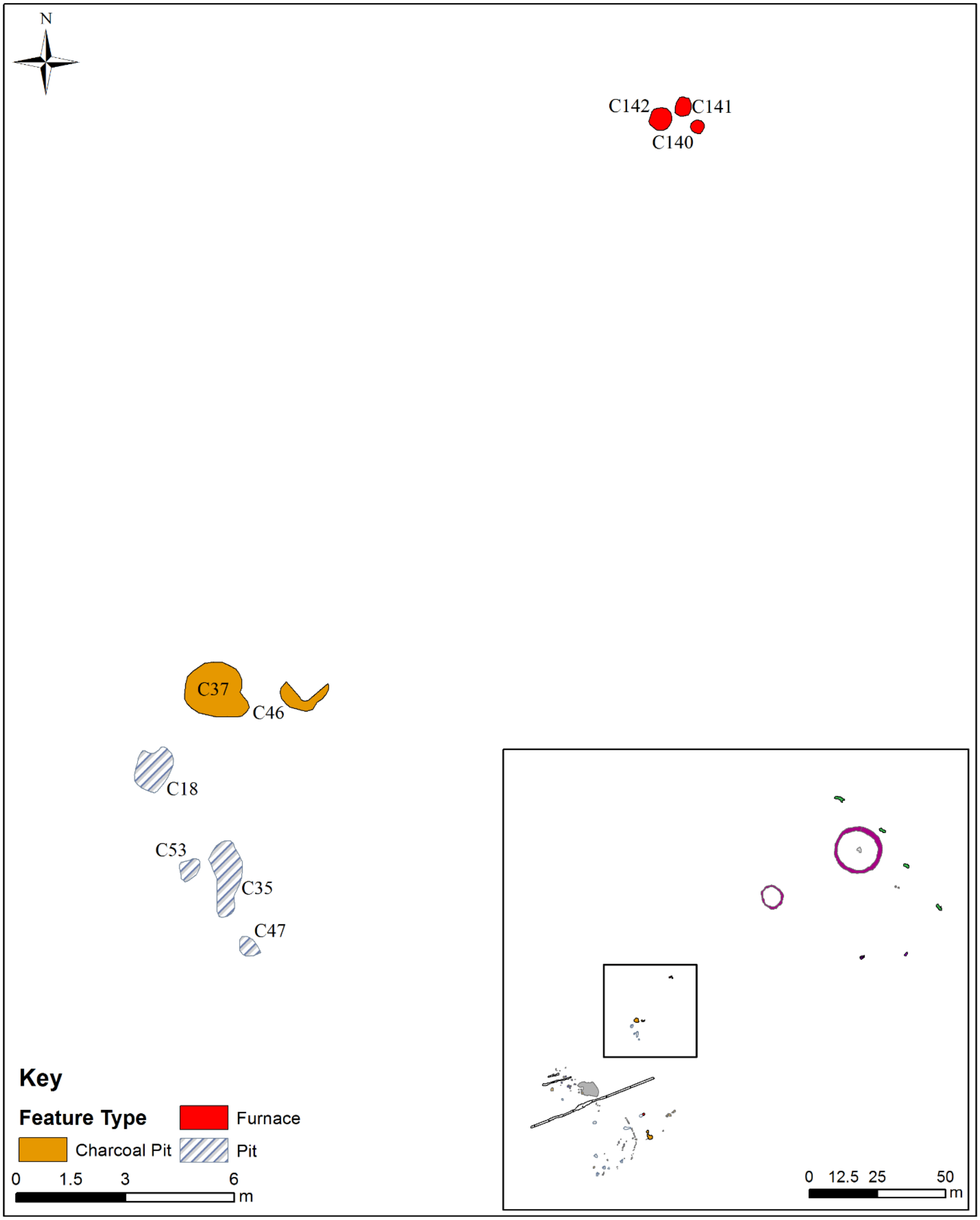




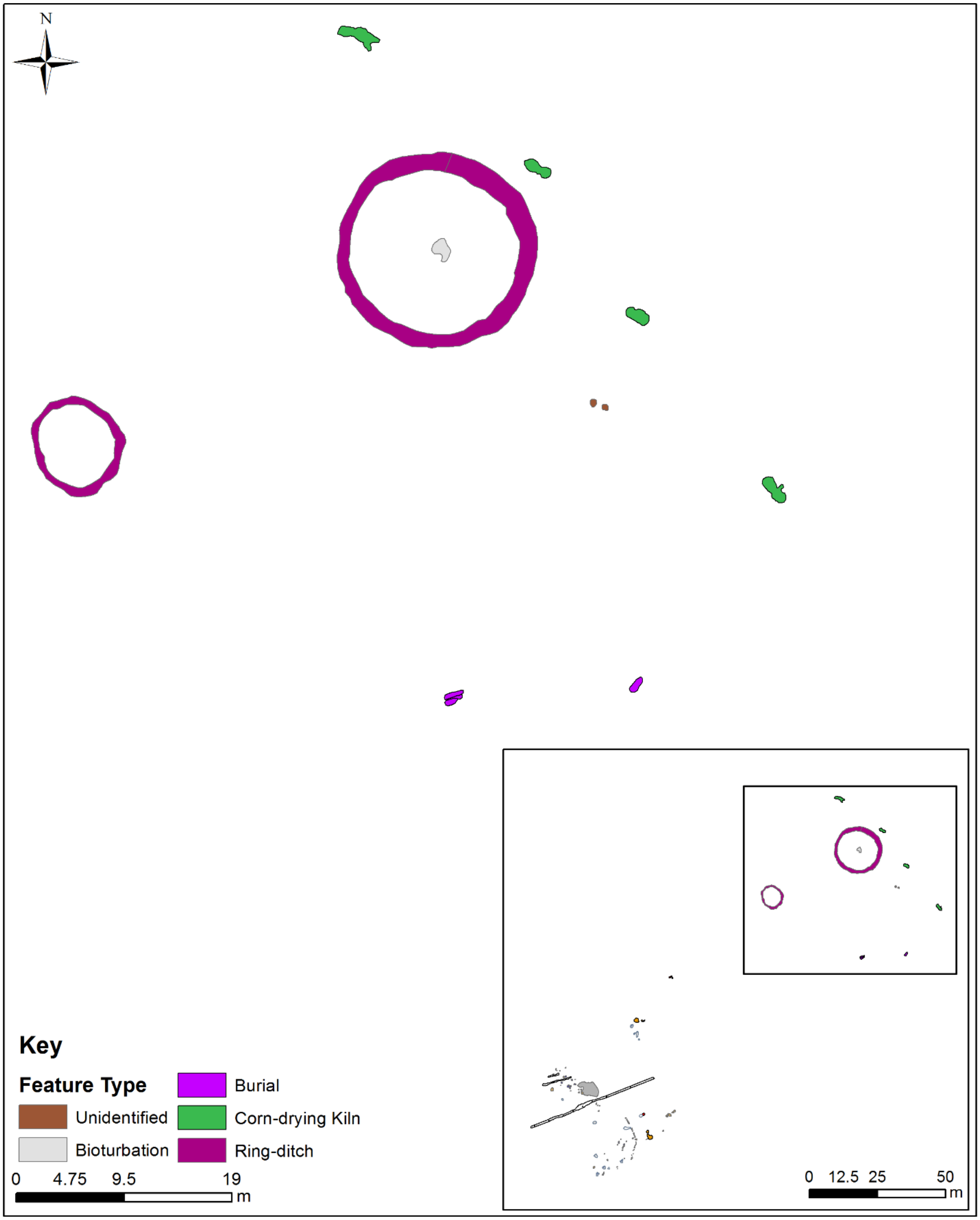
Morett (03E0461)



Close-up of Morett (03E0461)



Close-up of Morett (03E0461)



Close-up of Morett (03E0461)

Site Name: Moyally 2

County: Offaly

Licence Number: E2672

Townland: Moyally

ITM East: 620769.033

ITM North: 737335.289

Excavation conducted by Irish Archaeological Consultancy Ltd

Smelting: Yes **Number of furnaces:** 2

Smithing: Yes **Number of smithing hearths:** 1

Charcoal Production: No

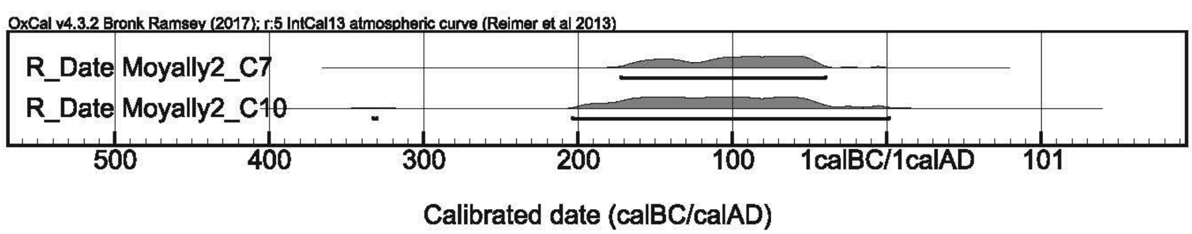
Type of Site: Isolated Metalworking

Chronology: DIA

C14 Dates and Context:

Moyally2_C7 R_Date(2076,24)
68.2% probability
152BC (10.5%) 138BC
113BC (57.7%) 50BC
95.4% probability
172BC (95.4%) 40BC

Moyally2_C10 R_Date(2090,40)
68.2% probability
166BC (68.2%) 54BC
95.4% probability
333BC (0.2%) 330BC
204BC (95.2%) 2AD

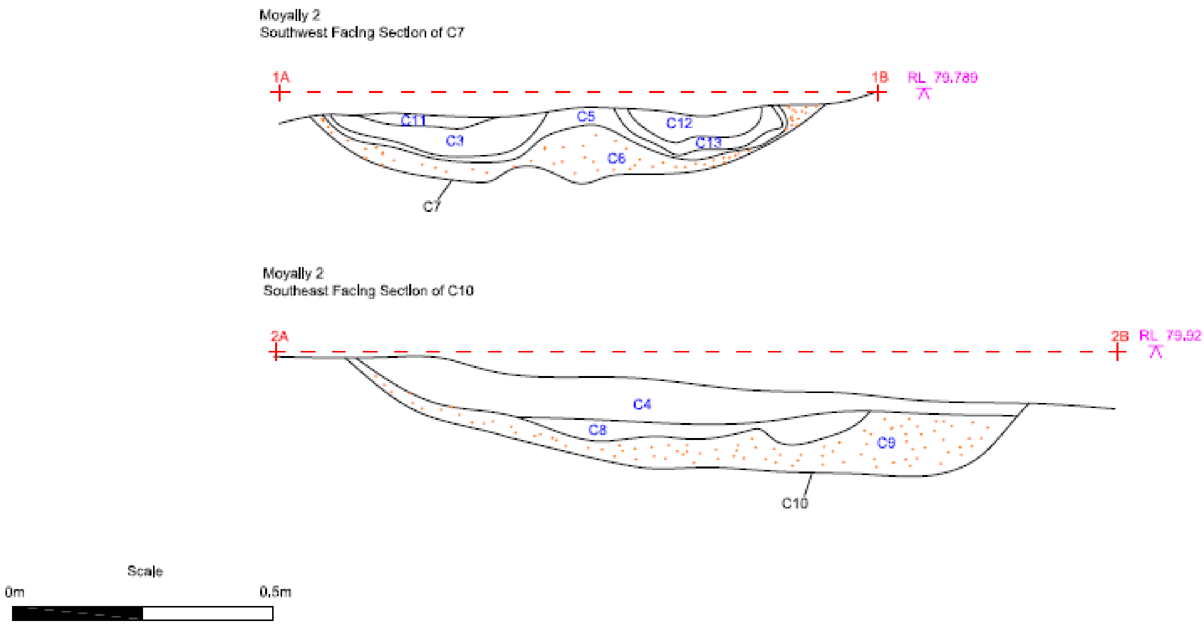


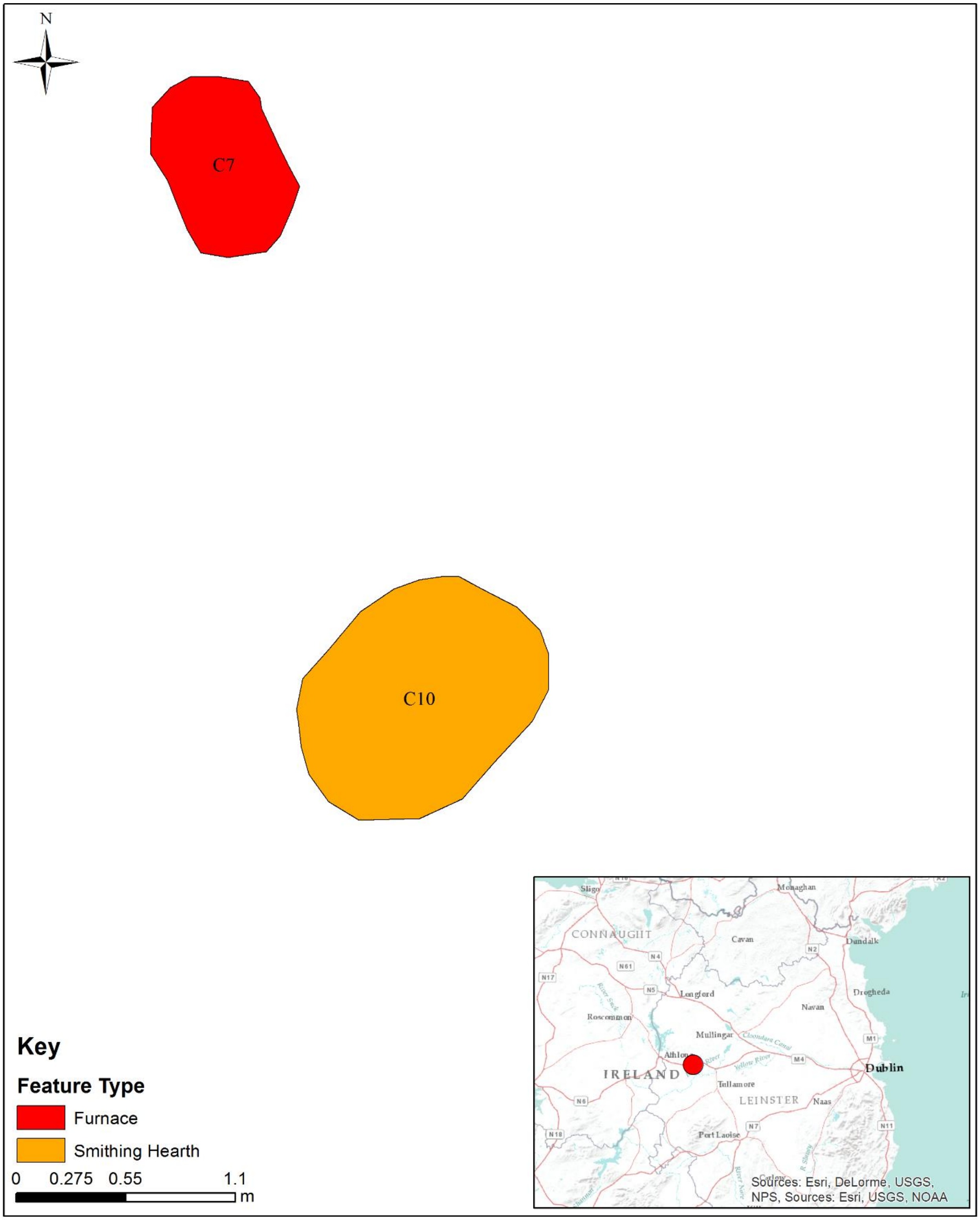
Description of Site: The site consisted of two features, one was likely a smithing hearth, while the other was identified as a ‘figure-of-eight’ smelting furnace. However, this feature was actually likely two separate features, each an individual smelting furnace. These kinds of pair furnaces are not uncommon. Analysis of the metallurgical waste suggests that the ore was of the bog ore variety while fragments of furnace/hearth wall were also identified. The 14C dates recovered from these features (173 - 5 cal. BCE; 200 - 10 cal. BCE) places them squarely into the DIA.

References:

Bayley, D. 2009. N6 Kinnegad - Athlone road scheme. Final report for E2672: Moyally 2. Unpublished report for the Westmeath County Council. Irish Archaeological Consultancy Ltd

Furnace Section:





Moyally 2 (E2672)

Site Name: Moyvalley 1 **County:** Kildare

Licence Number: 02E1088 **Townland:** Moyvalley

ITM East: 671696.029 **ITM North:** 741920.346

Excavation conducted by Archaeological Consultancy Services Ltd

Smelting: No **Number of furnaces:** 0

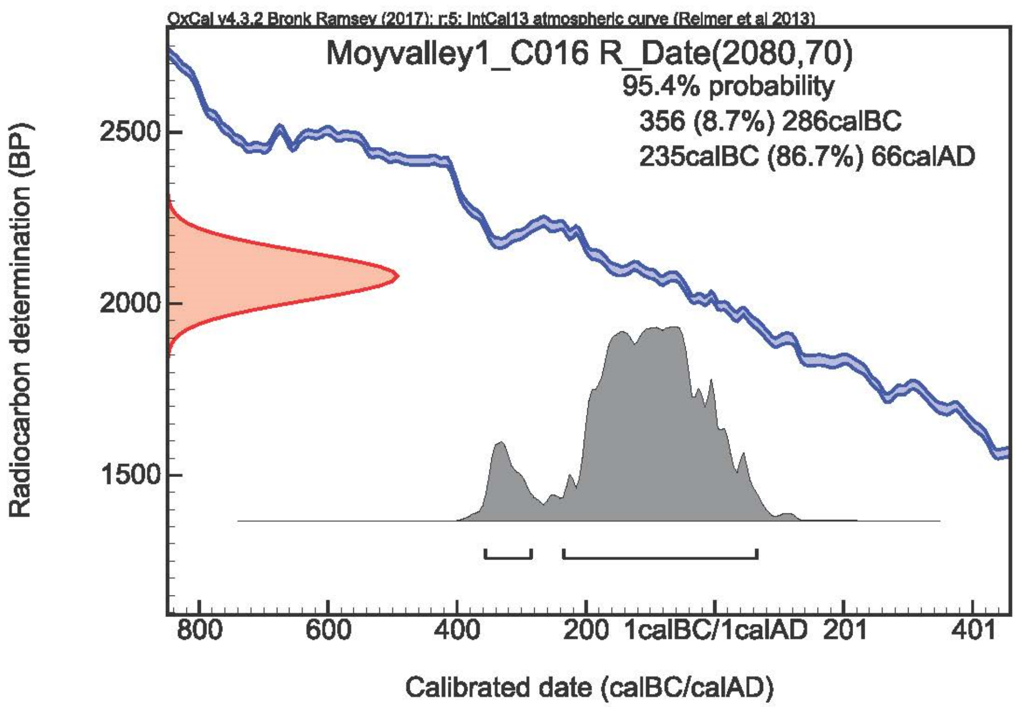
Smithing: Yes **Number of smithing hearths:** 1

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: DIA

C14 Dates and Context:

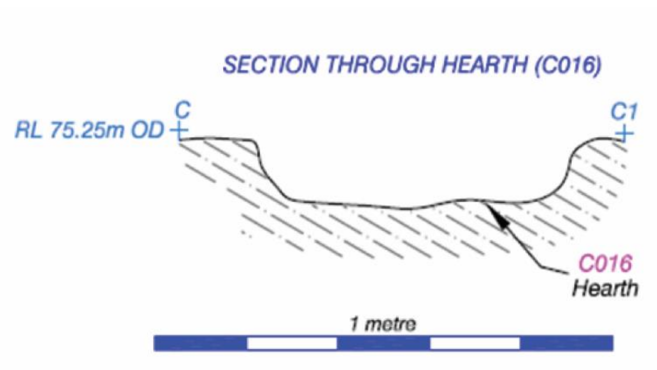


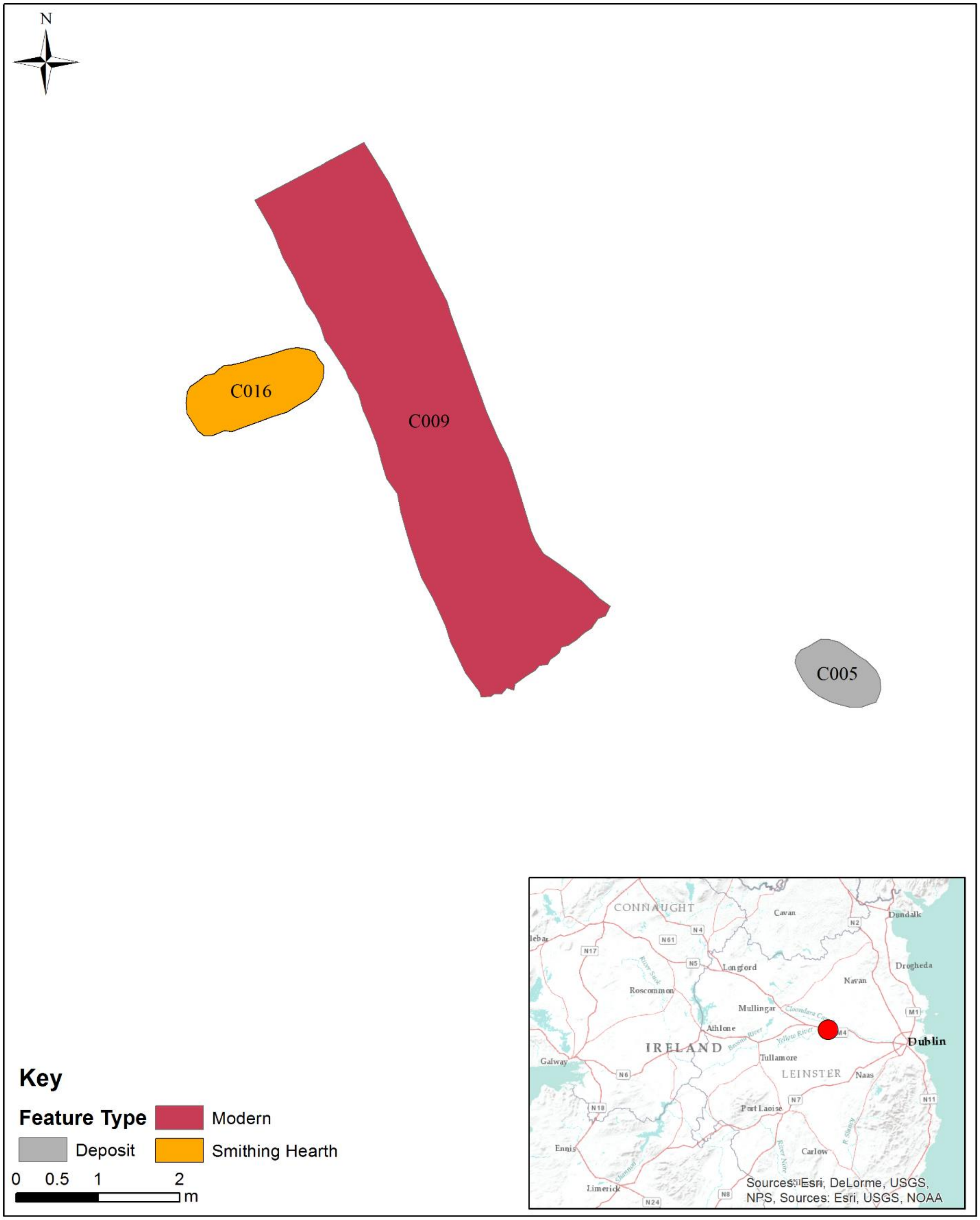
Description of Site: This site was uncovered during preparation for the construction of the M4 Kinnegad-Enfield-Kilcock Motorway Scheme. It consisted of a single smithing hearth, in association with a number of oxidized patches of clay. The 14C date for this hearth places it in the DIA (360 cal. BCE – 70 cal. CE).

References:

O'Hara, R. 2003b. Kinnegad–Enfield–Kilcock Bypass Contract 2, report on Moyvalley 1, Co. Kildare. Unpublished report for Westmeath County Council. Archaeological Consultancy Services Ltd

Furnace Section:





Moyvalley 1 (02E1088)

Site Name: Mullagh **County:** Longford

Licence Number: 09E0311 **Townland:** Mullagh

ITM East: 611412.372 **ITM North:** 775445.191

Excavation conducted by Cultural Resource Development Services Ltd.

Smelting: Yes Number of furnaces: 1

Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: DIA

C14 Dates and Context: : *Did not have access to uncalibrated dates* F6: 409 - 386 cal BCE

Description of Site: This site was discovered during preparation for the construction of a bypass connecting the N4 Dublin-Sligo road and the N5 Dublin-Westport road. The site consisted of only a pit and what was identified by the excavators as a 'bowl furnace.' The furnace had very steep sides and presented a furnace morphology more similar to a slag-pit furnace. Additionally, a small extension from the furnace pit could have acted as a flue.

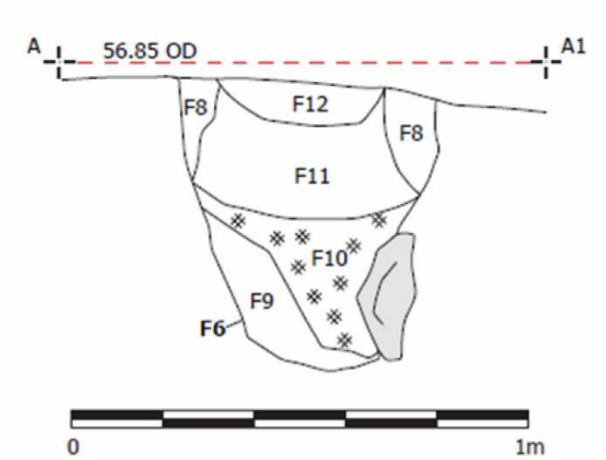
Landscape: Site 1 is located in Mullagh townland 1.95km west of Longford town. The site area measured $68m^2$ and was located north of two further sites (Sites 2 & 3) excavated in the course of this project. The site lies on a low hill, at 54.54m OD, in a landscape of undulating pasture, with areas of marshy ground. There are excellent views of the surrounding landscape and

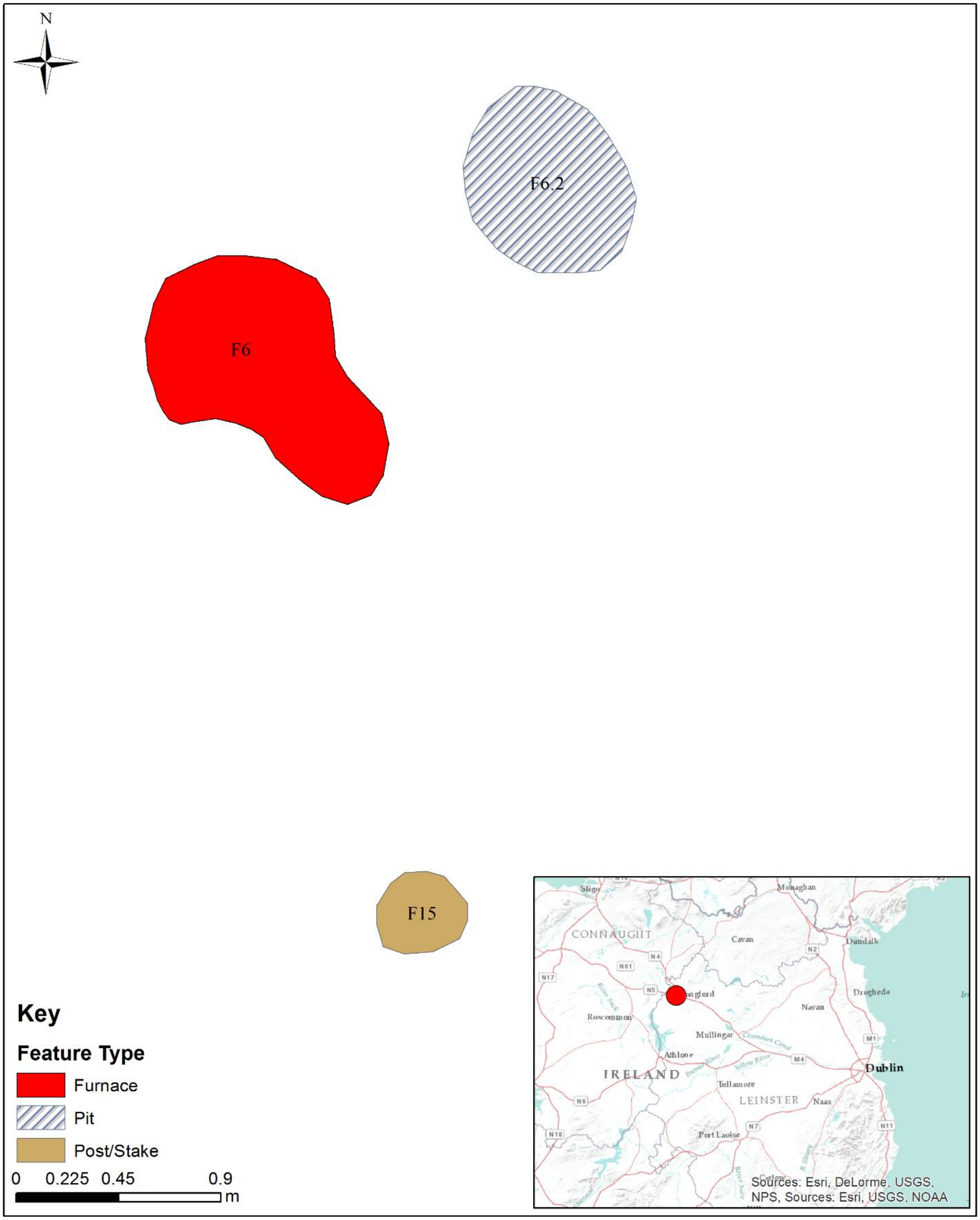
Longford town from the site. The Camlin River, a tributary of the Shannon runs to the north of the hill and forms the townland boundary. Two bogs, Brown Bog and Aghareagh Bog are located west and south west of Mullagh (Figure 3). The site has been characterised as an Iron Age metal working area.

References:

Stephens, M. 2009. N5 Longford Bypass. Final report for Site 1, 09E0311, Mullagh, Co. Longford. Unpublished report. Cultural Resource Development Services Ltd

Furnace Section:





Mullagh (09E0311)

Site Name: Newrath Site 35

County: Kilkenny

Licence Number: 04E0319

Townland: Newrath

ITM East: 658969.873

ITM North: 614288.368

Excavation conducted by Headland Archaeology

Smelting: Yes **Number of furnaces:** 6

Smithing: No **Number of smithing hearths:** 0

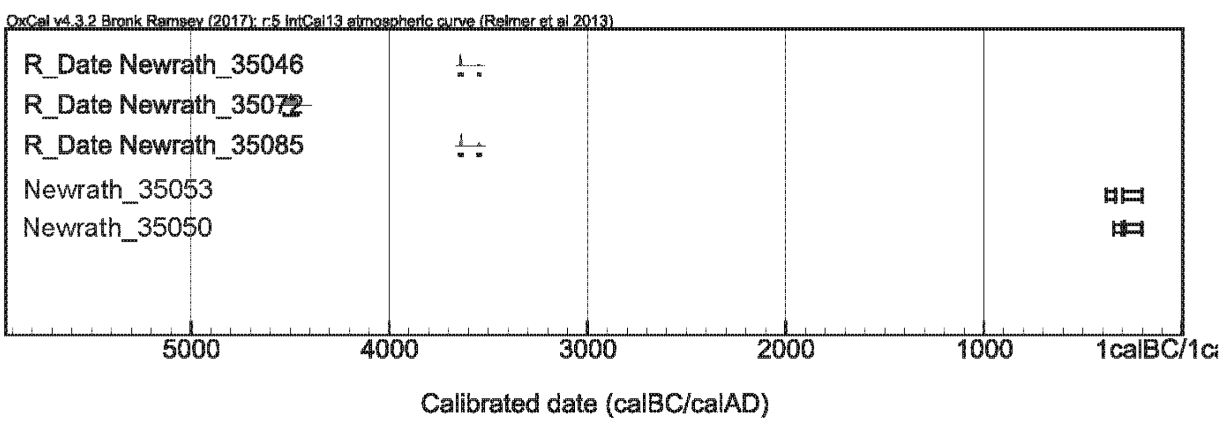
Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: DIA

C14 Dates and Context: *Unknown calibration* 35053(*furnace*): 397 - 207 cal BCE; 35050(*furnace*): 351 - 209 cal BCE.

Newrath_35046 R_Date(4827)	Newrath_35072 R_Date(5669)	Newrath_35085 R_Date(4821)
68.2% probability	68.2% probability	68.2% probability
3644BC (68.2%) 3636BC	4516BC (52.5%) 4486BC	3642BC (68.2%) 3632BC
95.4% probability	4476BC (15.7%) 4466BC	95.4% probability
3646BC (91.4%) 3632BC	95.4% probability	3645BC (73.2%) 3632BC
3550BC (4.0%) 3544BC	4532BC (95.4%) 4462BC	3554BC (22.2%) 3541BC



Description of Site: This site was discovered in advance of the construction of the N25 Waterford Bypass. The site contained numerous periods of occupation, from the Neolithic to the

Iron Age. The Early Neolithic phase of the site was represented by a series of pits containing significant lithic and ceramic material. The Middle Neolithic phase of the site contained a semicircular ring gully, though have actually been a fully circular ring-ditch that had been eroded away. This may have acted as a habitation structure.

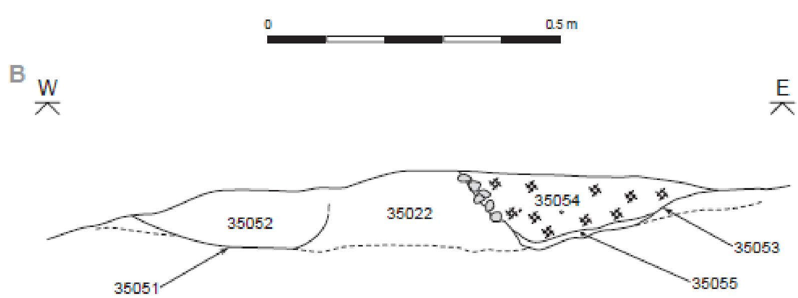
The Iron Age activity at the site consisted of six smelting furnaces, two of which produced DIA 14C dates (351 – 209 cal. BCE; 397-207 cal. BCE). It is however possible that one of the features identified as a smelting furnace was actually a smithing hearth, based on its morphology. Surrounding a few of the possible furnaces were two surfaces identified in the field as "working surfaces." These compact layers appeared to have been trampled with large amounts of slag and burnt clay, presumably from the furnace pits at their centers.

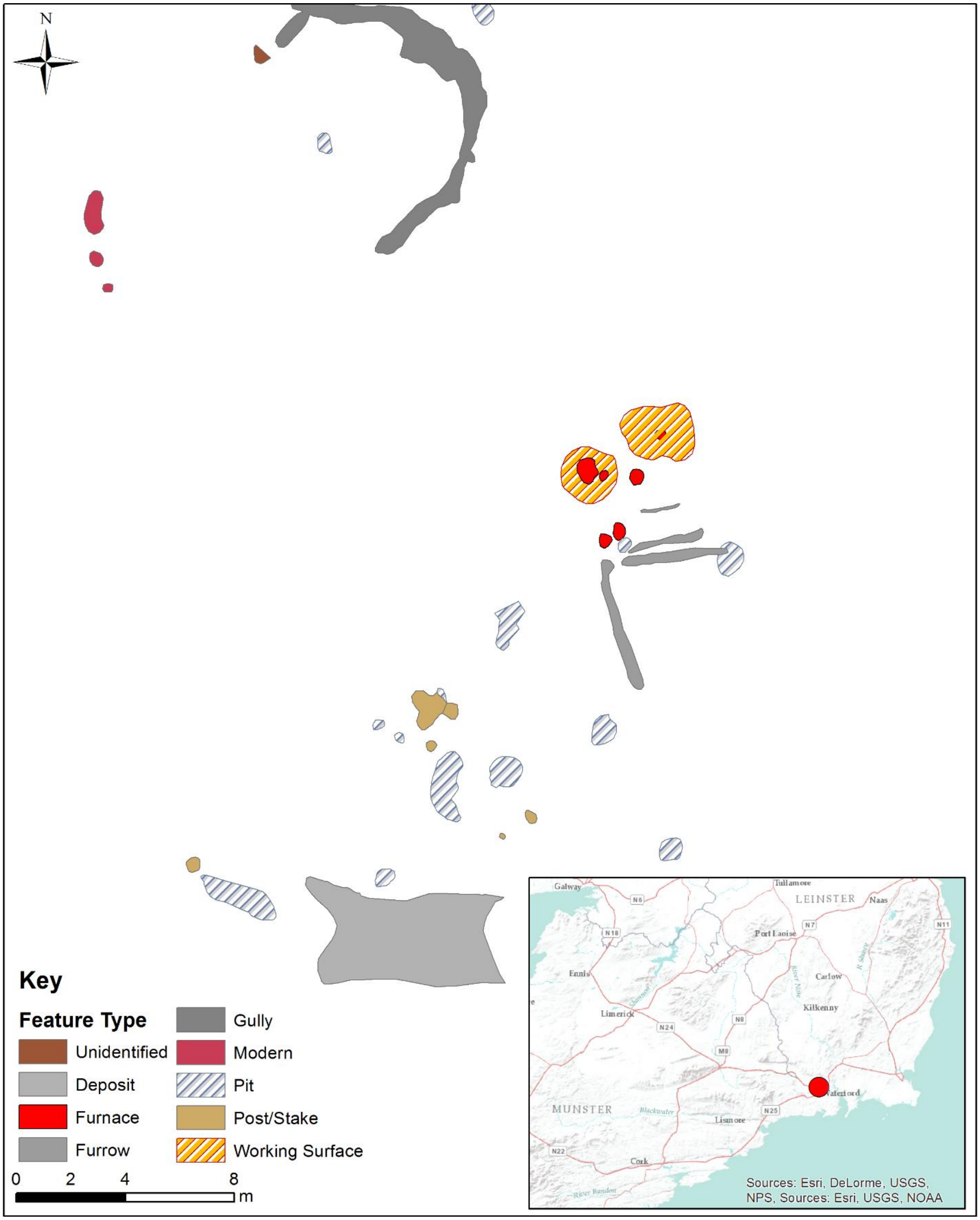
Landscape: "The site was defined on its southern and western boundary by a well-established plantation of mixed deciduous woodland and on its northern and eastern boundary by a field under raspberry cultivation. The site slopped gradually towards the west, with a clear rise towards the eastern boundary. It was reasonably well drained agricultural pasture and the unmodified subsoil comprised glacially derived gravels, sands and clay."

References:

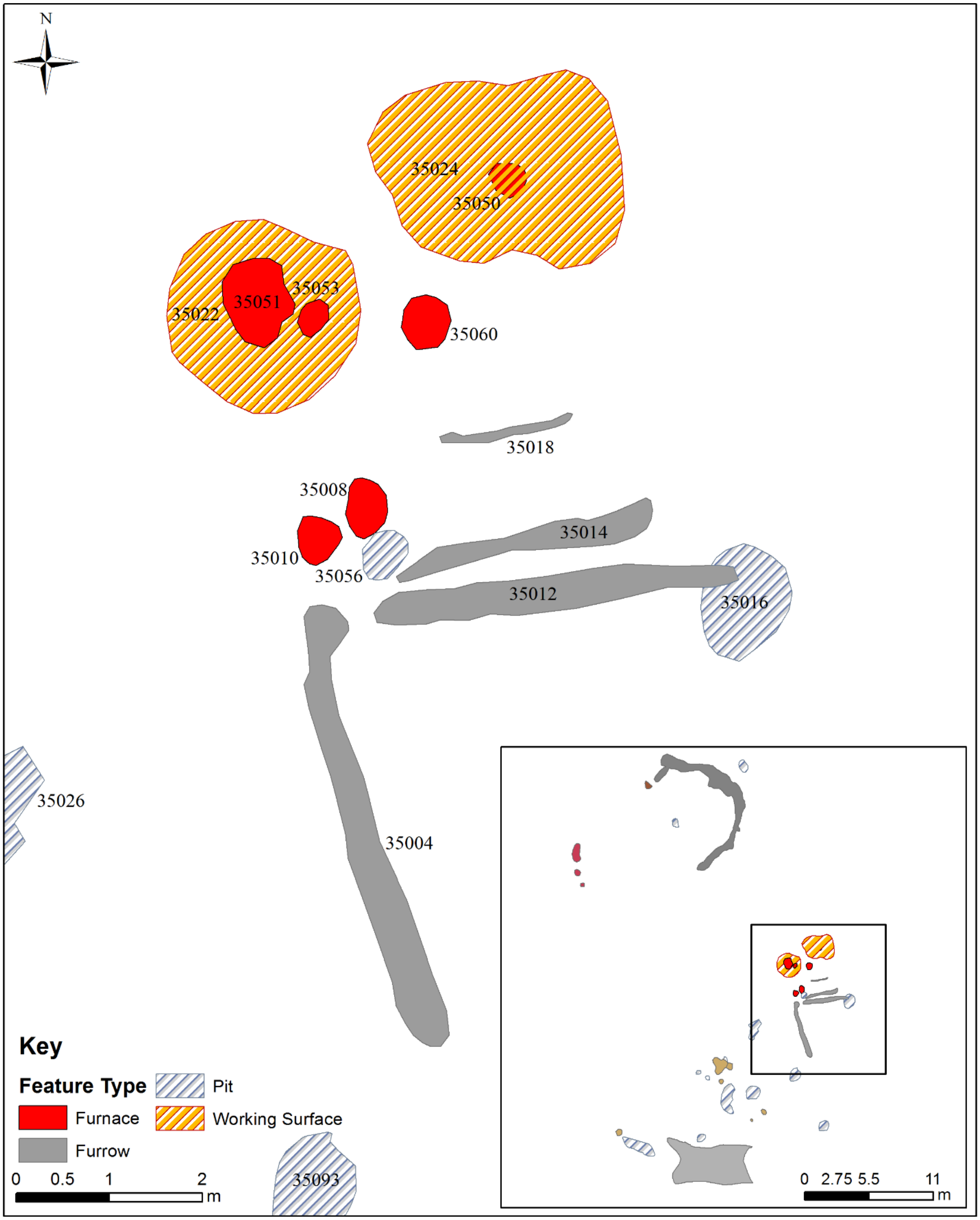
Wilkins, B. 2006. N25 Waterford Bypass, Contract 3. Final report on archaeological investigations at Site 35 in the townland of Newrath, Co Kilkenny. Unpublished report for the Waterford City Council. Headland Archaeology Ltd

Furnace Section:





Newrath Site 35 (04E0319)



Close-up of Newrath Site 35 (04E0319)

Site Name: Parksgrove 1 **County:** Kilkenny

Licence Number: 99E0597 **Townland:** Parksgrove

ITM East: 643285.254 **ITM North:** 670102.272

Excavation conducted by Margaret Gowen & Co. Ltd

Smelting: No **Number of furnaces:** 0

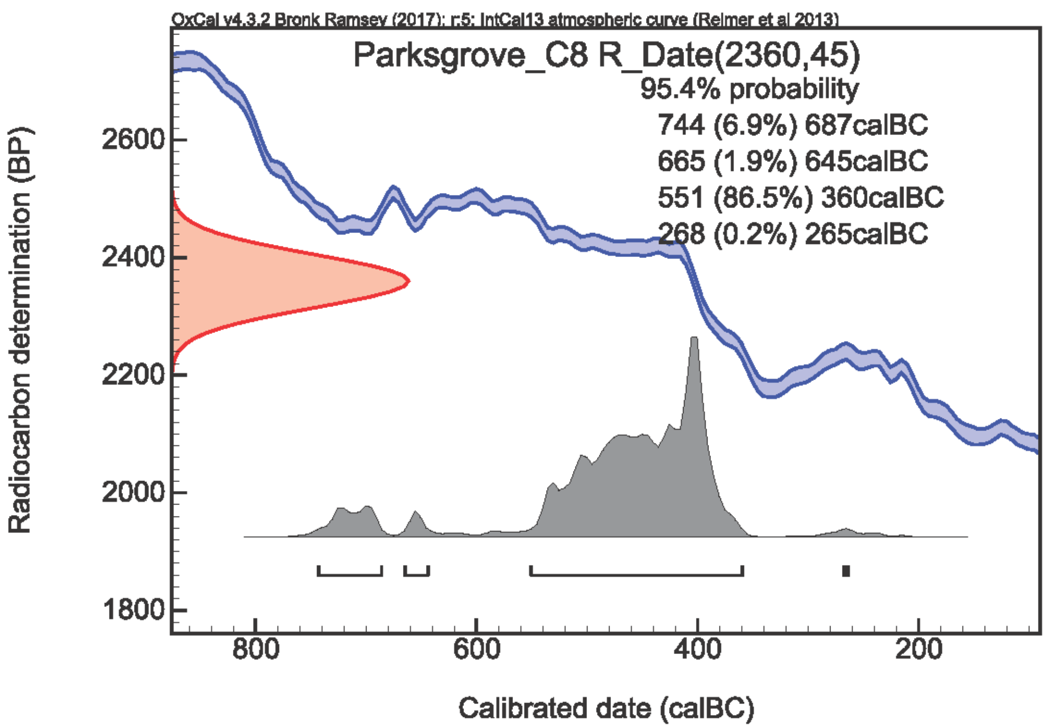
Smithing: Yes **Number of smithing hearths:** 1

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: EIA

C14 Dates and Context:



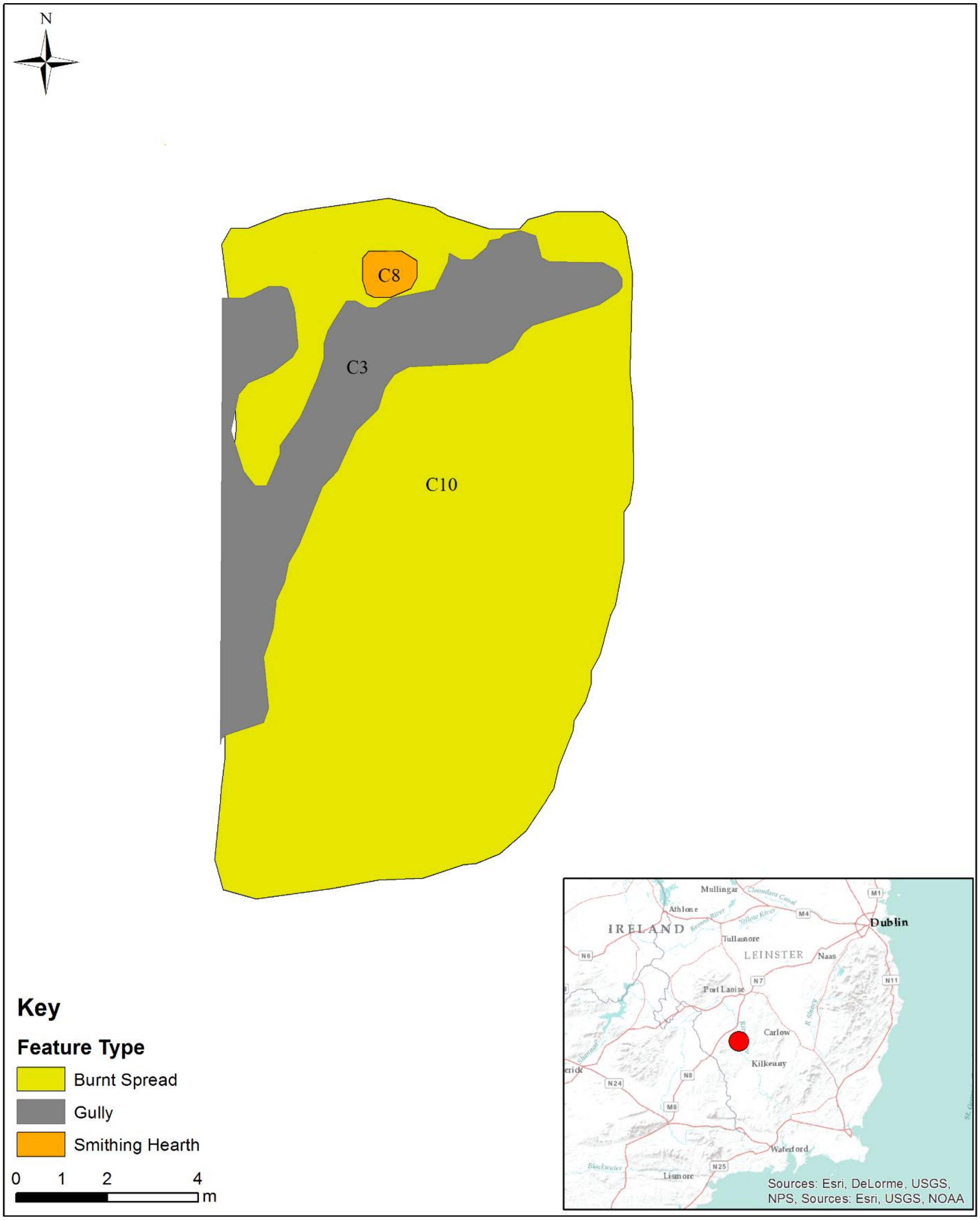
Description of Site: This site was discovered during the construction of a gas pipeline in Kilkenny. The ironworking aspects of this area contained a single iron working feature, surrounded by a spread made of a hard orange, coarse sand and clay. The feature is quite large (1.2m in diameter), which would suggest that it was not a smelting furnace but perhaps a smithing hearth. There was a number of pieces of hammer scale or scrap recovered from the site which would also support a suggestion of smithing. There were also six iron nail fragments recovered, possibly produced on site. 14C dates place the use of this part of the site at 757 – 261 cal. BCE.

The landscape surround this site contained more evidence of prehistoric occupation, including a likely Bronze Age/Iron Age fulacht fiadh sites just c. 8m, 200m, and 400m from the ironworking activity.

Landscape: 1.5km southwest of Ballyragget, within the western flood plain of the River Nore.

References:

Stevens, P. 2005. New evidence for the Bronze and Iron Ages in County Kilkenny: the 1999 gas pipeline excavations. Old Kilkenny Review 57: 7-31



Parksgrove 1 (99E0597)

Site Name: Rath Site 27 **County:** Meath

Licence Number: 03E1214 **Townland:** Rath

ITM East: 705233.05 **ITM North:** 754217.923

Excavation conducted by Cultural Resource Development Services Ltd.

Smelting: Yes **Number of furnaces:** 1

Smithing: Yes **Number of smithing hearths:** 1

Charcoal Production: No

Type of Site: Structure/Burial

Chronology: DIA

C14 Dates and Context:

Rath Site 27_F1105 R_Date(2203,36)
68.2% probability
358BC (10.0%) 340BC
328BC (28.7%) 280BC
257BC (29.5%) 204BC
95.4% probability
376BC (95.4%) 181BC

Rath Site 27_F30 R_Date(2353,41)
68.2% probability
485BC (68.2%) 385BC
95.4% probability
731BC (3.7%) 691BC
660BC (0.7%) 650BC
544BC (91.0%) 361BC

Rath Site 27_F346 R_Date(2170,32)
68.2% probability
352BC (39.7%) 296BC
228BC (4.0%) 220BC
212BC (24.5%) 175BC
95.4% probability
360BC (92.3%) 154BC
136BC (3.1%) 114BC

Rath Site 27_F98 R_Date(1985,28)
68.2% probability
36BC (3.8%) 31BC
20BC (7.5%) 11BC
2BC (56.8%) 54AD
95.4% probability
44BC (95.4%) 70AD

Rath Site 27_F1258 R_Date(2190,35)
68.2% probability
356BC (44.6%) 284BC
253BC (1.8%) 249BC
235BC (21.8%) 198BC
95.4% probability
368BC (95.4%) 169BC

Rath Site 27_F1105 R_Date(2217,36)
68.2% probability
360BC (6.8%) 348BC
316BC (61.4%) 208BC
95.4% probability
382BC (95.4%) 198BC

Rath Site 27_F619 R_Date(2534,31)
68.2% probability
792BC (33.1%) 750BC
684BC (10.1%) 668BC
638BC (25.0%) 590BC
95.4% probability
798BC (38.4%) 732BC
690BC (13.3%) 660BC
650BC (43.7%) 544BC

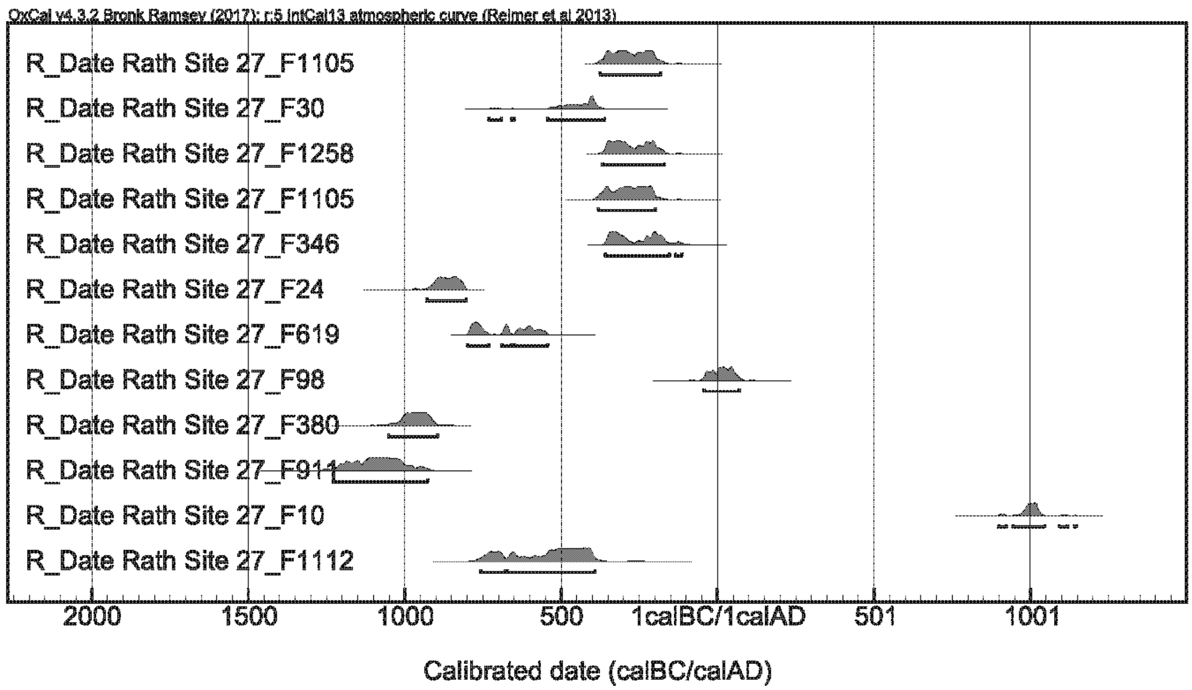
Rath Site 27_F380 R_Date(2812,31)
68.2% probability
1001BC (68.2%) 926BC
95.4% probability
1052BC (95.4%) 894BC

Rath Site 27_F1112 R_Date(2403,61)
68.2% probability
730BC (11.4%) 691BC
660BC (2.5%) 650BC
544BC (54.3%) 400BC
95.4% probability
757BC (18.3%) 678BC
672BC (77.1%) 392BC

Rath Site 27_F10 R_Date(1029,36)
68.2% probability
981AD (68.2%) 1028AD
95.4% probability
898AD (5.3%) 924AD
945AD (85.6%) 1045AD
1094AD (3.8%) 1120AD
1142AD (0.6%) 1146AD

Rath Site 27_F24 R_Date(2716,38)
68.2% probability
898BC (68.2%) 827BC
95.4% probability
930BC (95.4%) 804BC

Rath Site 27_F911 R_Date(2897,53)
68.2% probability
1192BC (5.2%) 1176BC
1162BC (6.5%) 1144BC
1130BC (56.5%) 1006BC
95.4% probability
1229BC (95.4%) 926BC



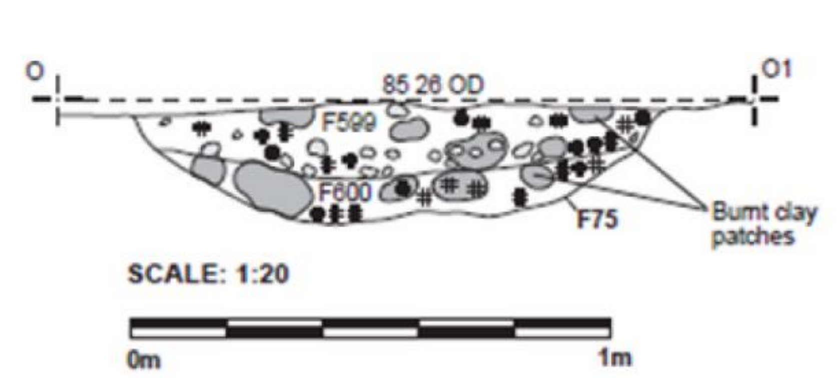
Description of Site: This site was discovered in advance of the N2 Finglas-Ashbourne Road Scheme. It consisted of a large variety of features that spanned the Bronze and Iron Ages. The main aspects of Bronze Age occupation at the site consisted of three ring ditches (at least one of which was reused in the Iron Age), a feature that was designated a waterhole and two structure that were interpreted as a 'steam lodge' and a 'sweat lodge.' Additionally, there were a couple of features associated with agricultural activity (a kiln and a grain store) that also dated to the MBA-LBA. There was a high amount of continuity from the Bronze to the Iron Age. The 'steam lodge' appears to have been reused, in addition to one of the ring ditches and the waterhole. A 'metalworking area' consisted of what may have been a small post structure, in addition to a furnace and possible smithing hearth. The furnace morphology is mostly unknown since it was not sectioned, but was dated to 50 cal. BCE – 80 cal. CE.

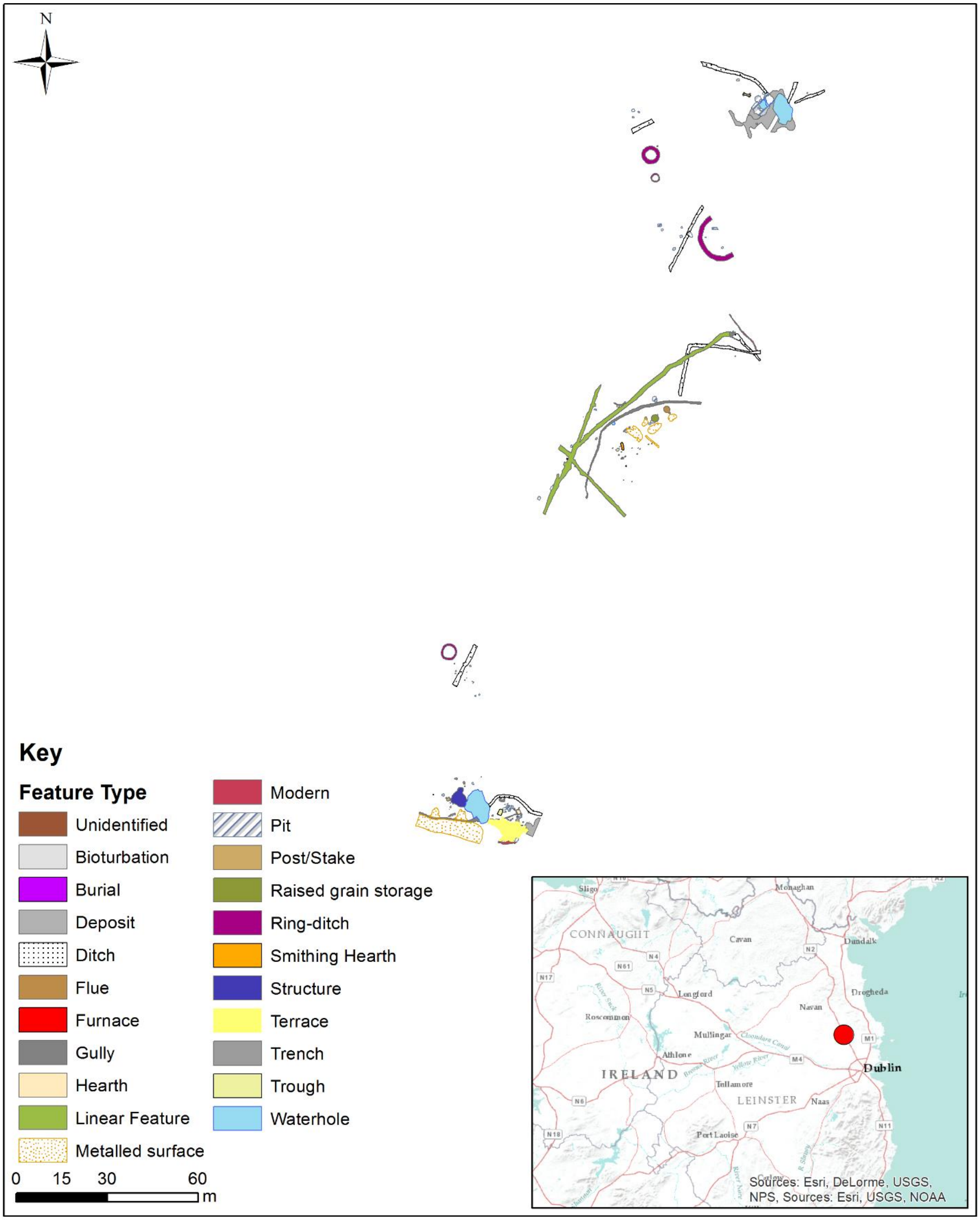
C. 3.5km south of the Rath Site 27 lay the site of Harlockstown, which also contained evidence for a long period of use in prehistory, including iron production.

Landscape: "Site 27 consisted of three separate fields within the townland of Rath. Fields 2 and 3 were located to the south-west of the current N2. Field 3, at the southernmost extent, occupied the base and southern slope of a hill which rises north into Field 2 and levels out, but drops gently toward the west and east.(see Figures 3, 8; Plate 1). Field 1 is a continuation of this level area. Prior to excavation Field 3 was under cultivation with deep plough-ridges covering the field. Field 2 lay between Field 3 to the south-west and the N2 to the north-east. While its southern half was on gently sloping ground towards Field 3, the northern half was on almost level ground at the highest point of the hill. The field was in pasture prior to the archaeological investigation and was used for cattle grazing. The hilltop possesses excellent views to the west, south and east, with the Dublin Mountains visible on most days. The excavation area in Field 1, also situated on the hilltop which slopes gently down to the north, was located to the north-east of the current N2 and was under cultivation prior to the excavation."

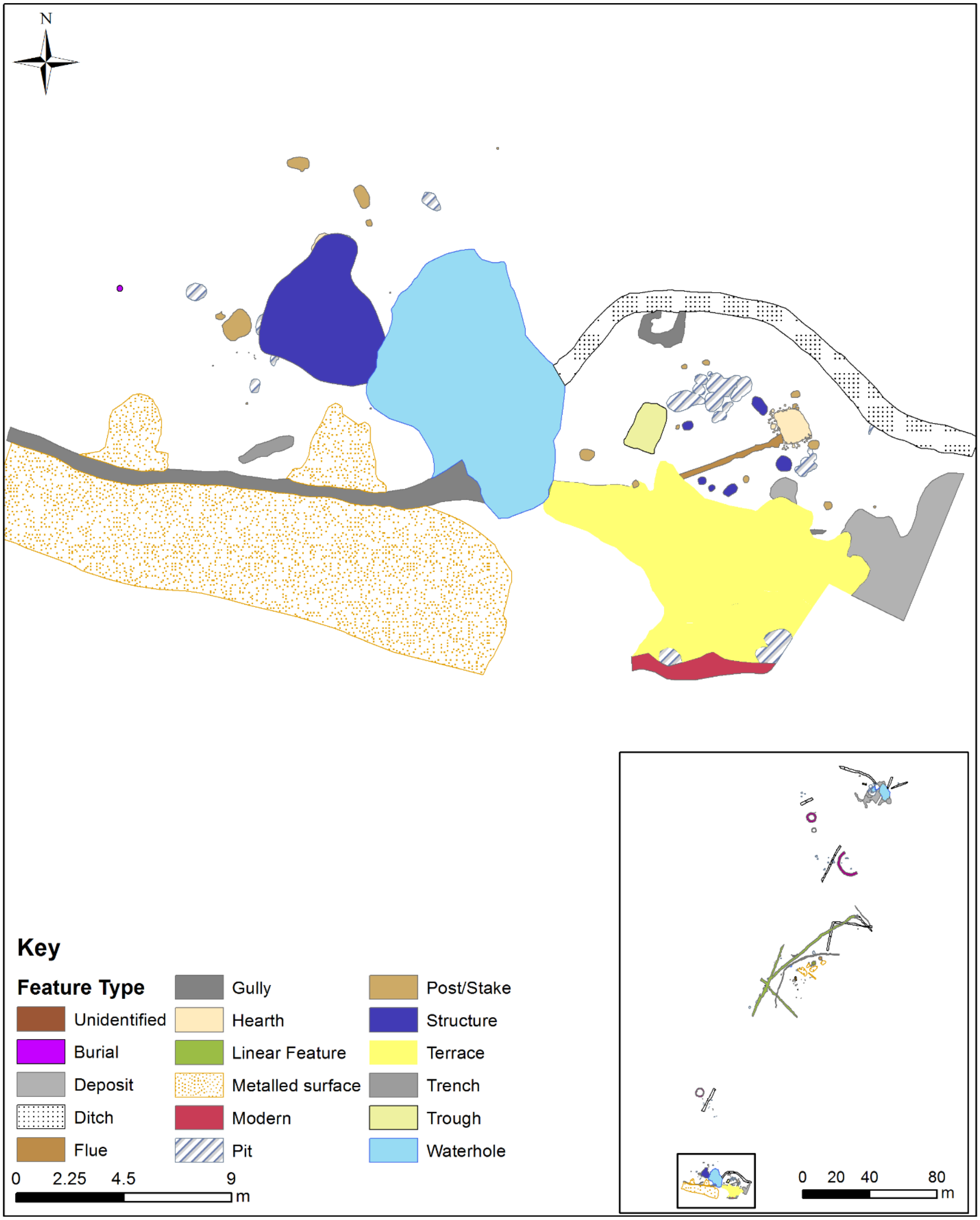
References:
Schweitzer, H. & F. O'Carroll. 2009. N2 Finglas-Ashbourne road scheme. Report on archaeological excavation of Site 27, Rath, Co. Meath. Unpublished report for Meath County Council. Cultural Resource Development Services Ltd

Furnace Section:

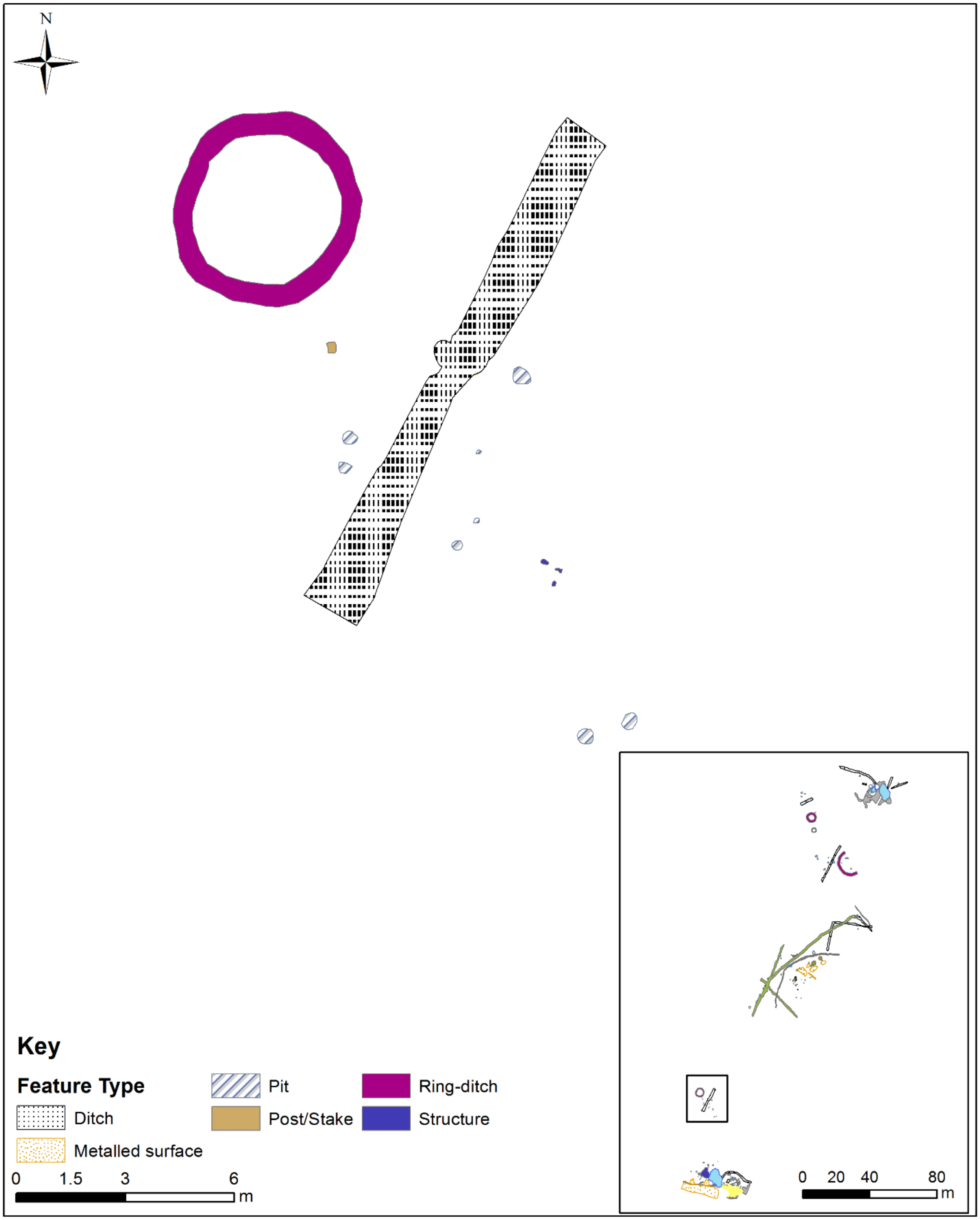




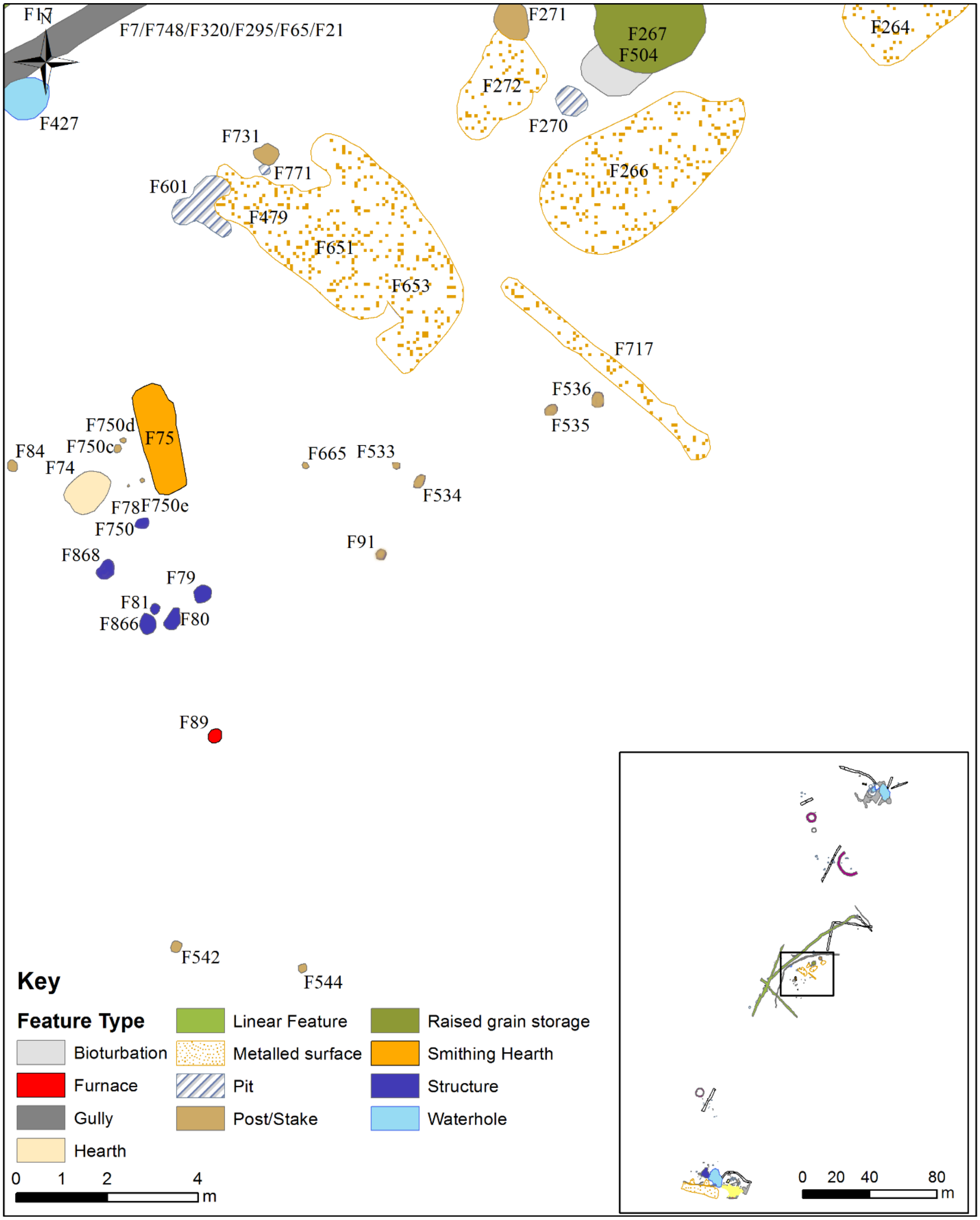
Rath Site 27 (03E1214)



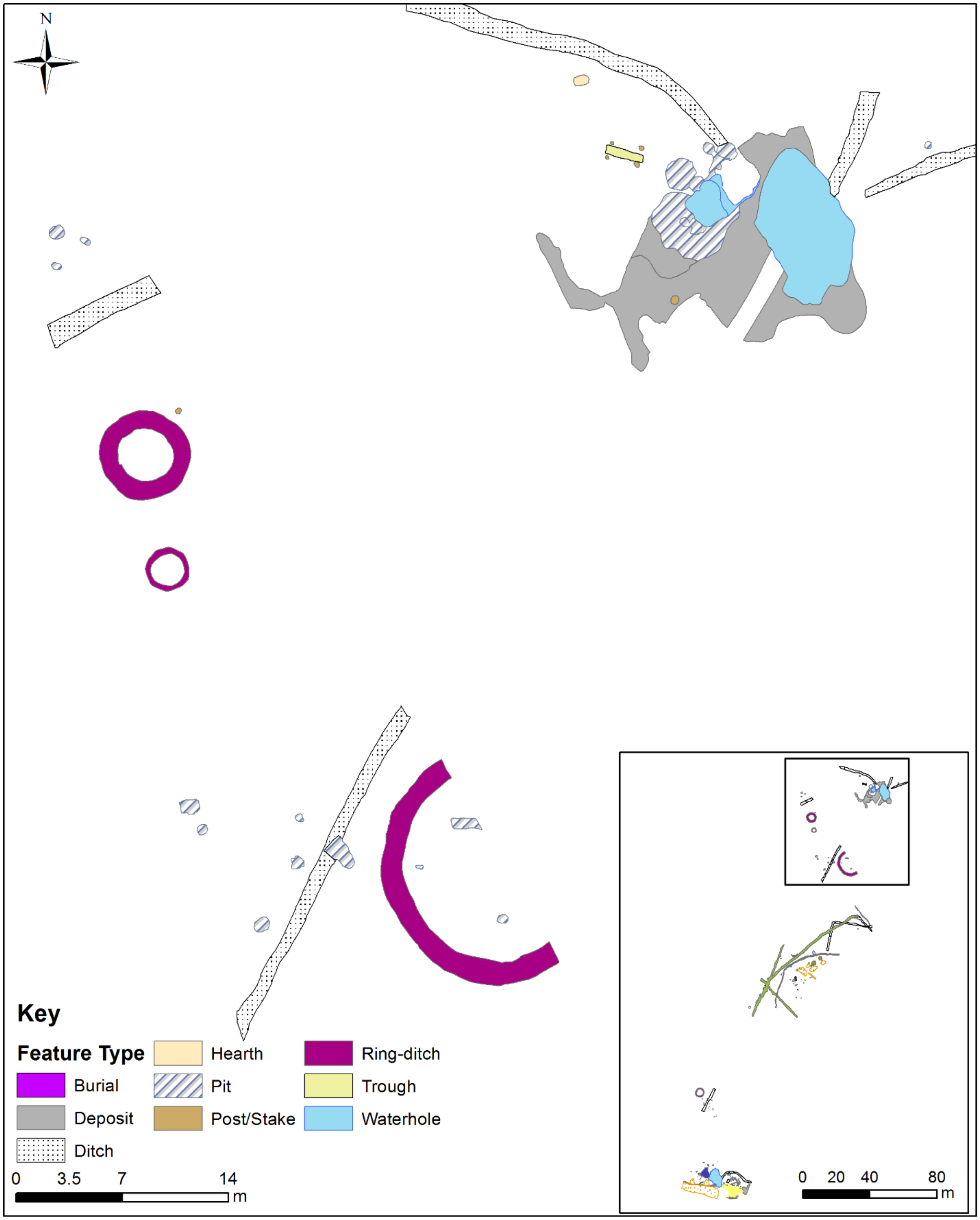
Close-up of Rath Site 27 (03E1214)



Close-up of Rath Site 27 (03E1214)



Close-up of Rath Site 27 (03E1214)



Close-up of Rath Site 27 (03E1214)

Site Name: Rossan 6 **County:** Meath

Licence Number: 02E1068 **Townland:** Rossan

ITM East: 660390.601 **ITM North:** 744809.805

Excavation conducted by Archaeological Consultancy Services Ltd

Smelting: Yes **Number of furnaces:** 1

Smithing: Yes **Number of smithing hearths:** 2

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: EIA

C14 Dates and Context: : *Did not have access to uncalibrated dates* F087: 820-780 cal BCE; 370-50 cal BCE

Description of Site: This site was identified in advance of the construction of the M4 Kinnegad-Enfield-Kilcock Motorway Scheme. It contained 17 pits, three of which were suggested to be directly involved with iron production. Many of the other pits contained some quantity of charcoal within the fill and evidence of in situ burning, leading to the suggestion that these smaller pits were used for the production of charcoal that was used in the ironworking features. The feature that was original identified as a bowl furnace is quite large (~.76m in diameter) for a typical smelting furnace in this period. The sides of the of the feature are steep, often a characteristic of a slag-pit furnace. Two other large features were interpreted as bloom smithing hearths, although the extreme size of one of these features (3.5m in length) suggests that its original use was for charcoal production. The smelting furnace produced a 14C date of 370 – 50 cal. BCE, while the very large pit was dated to 820 – 780 cal. BCE. The unusual morphology of these features suggest either a different methodology involved in the production of iron, or a mistake in assigning function.

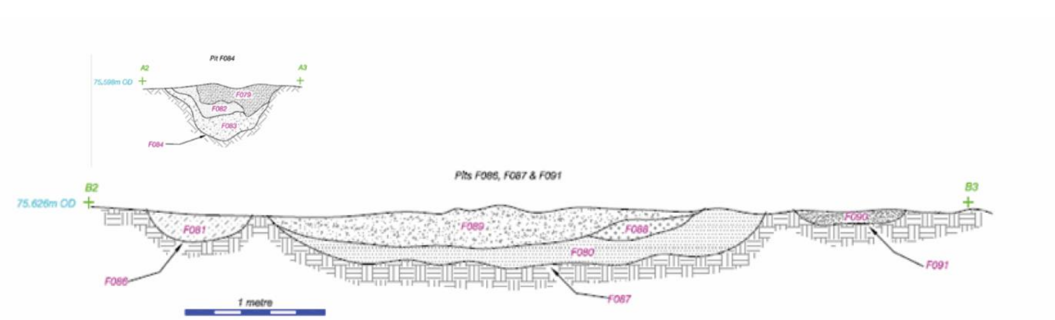
This site also appears to be part of a larger landscape or complex of prehistoric occupation. Within 370 m, 240m, and 460m lay the sites of Rossan 1, Rossan 3, and Hardwood 3, respectively. Rossan 1 contains a series of pits and charcoal-rich deposits that date to the LBA-IA transition. Rossan 3 contained pits that dated to the medieval period, as well as the Middle – Late Bronze Age. In addition, that site produced three linear features that contained a fair amount of slag. Hardwood contained a number furnaces and smithing hearths, which dated from the DIA to the Late Medieval period. Slightly further afield, 2-3km to the west, lay three other sites with evidence for Iron Age iron production: Kinnegad 2, Griffinstown 3, Monganstown 1. Kinnegad and Monganstown produced radiocarbon dates spanning the EIA into the DIA. No 14C dates were recovered from Griffinstown 3, however the furnace types match those in the surrounding area. It appears that this immediate area was utilized through the Bronze Age into the later Medieval period, and especially during the first part of the Iron Age for iron production.

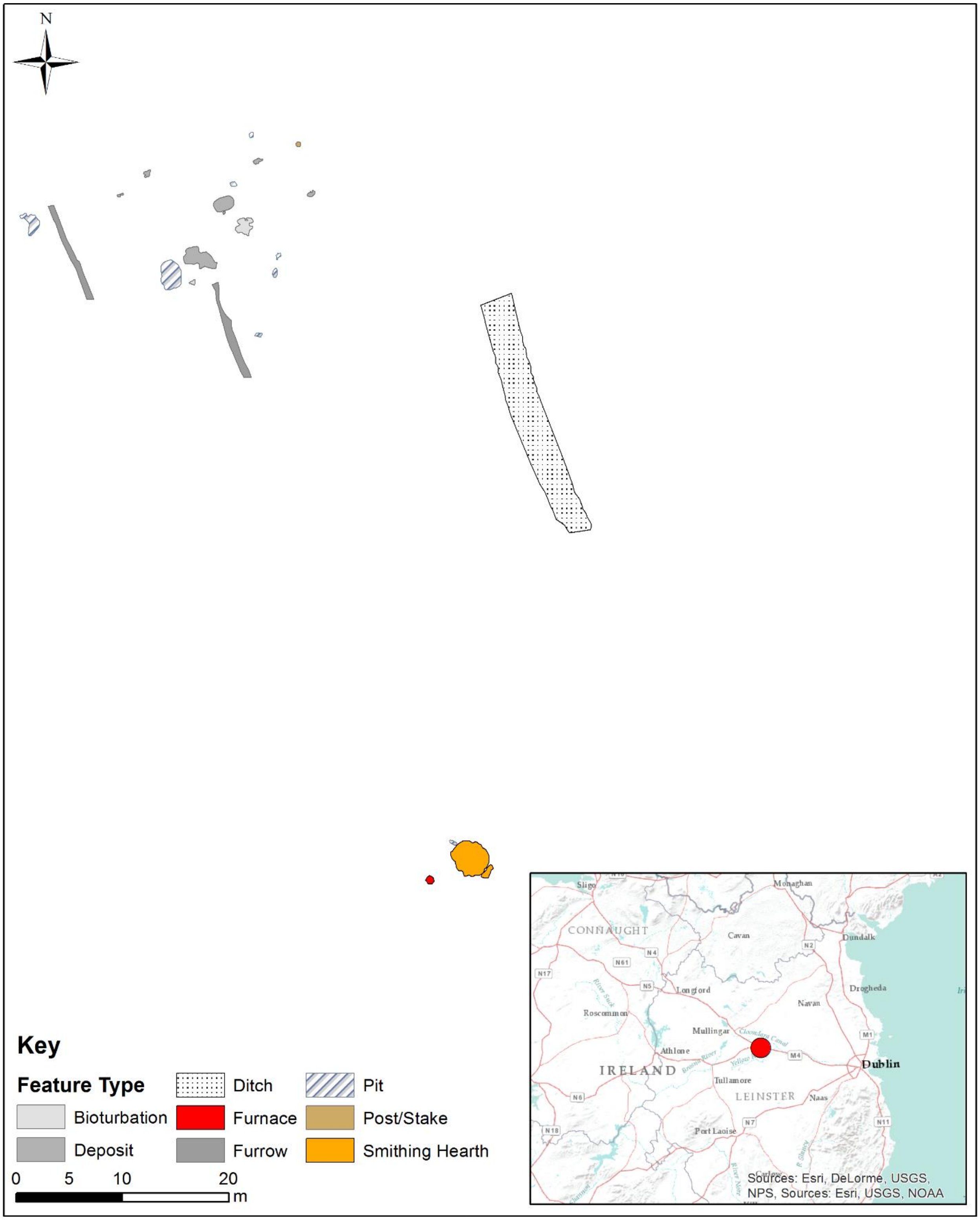
Landscape: Site is located on low ridge in flat average pastureland with bog land to the south.

References:

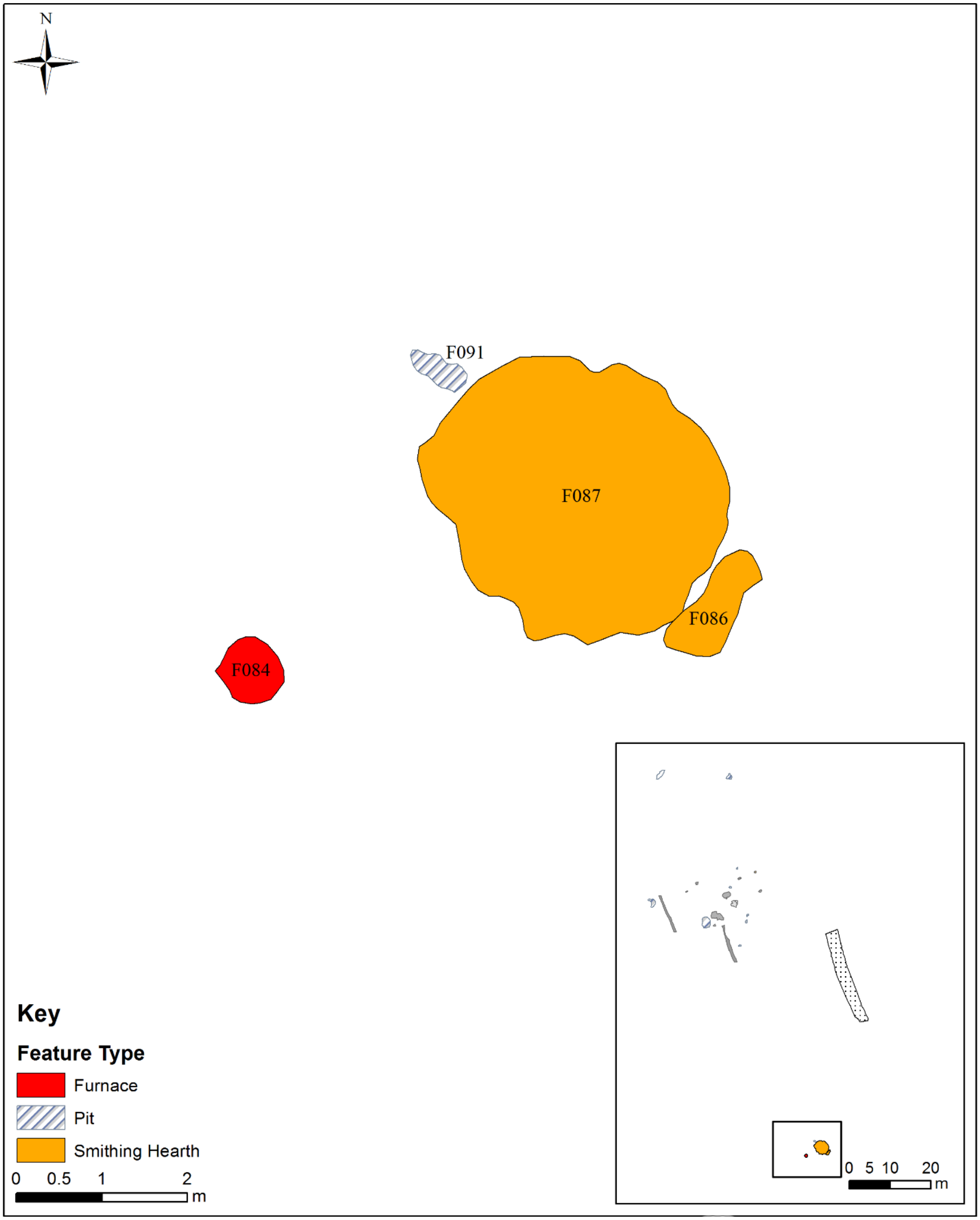
Murphy, D. 2004. M4 Kinnegad–Enfield–Kilcock Motorway Scheme, Contract 1. Report on Rossan 6, Co. Meath. Unpublished report for the Westmeath County Council. Archaeological Consultancy Services Ltd

Furnace Section:





Rossan 6 (02E1068)



Close-up of Rossan 6 (02E1068)

Site Name: Ráith na Ríg, Tara

County: Meath

Licence Number: 97E300

Townland: Castleboy

ITM East: 691893.52

ITM North: 759841.06

Excavation conducted by Discovery Programme

Smelting: No **Number of furnaces:** 0

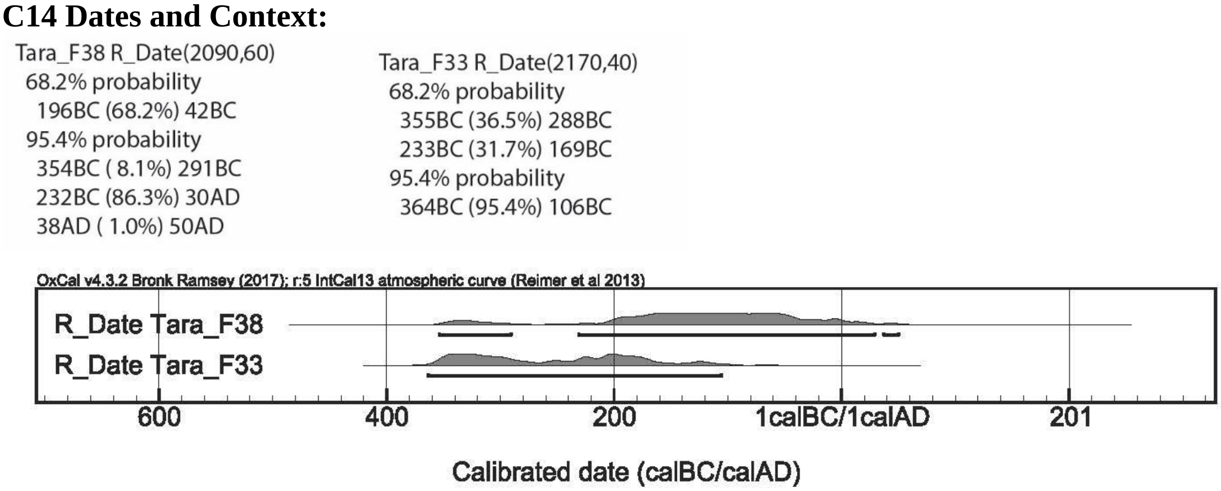
Smithing: Yes **Number of smithing hearths:** 1

Charcoal Production: No

Type of Site: Other

Chronology: DIA

C14 Dates and Context:



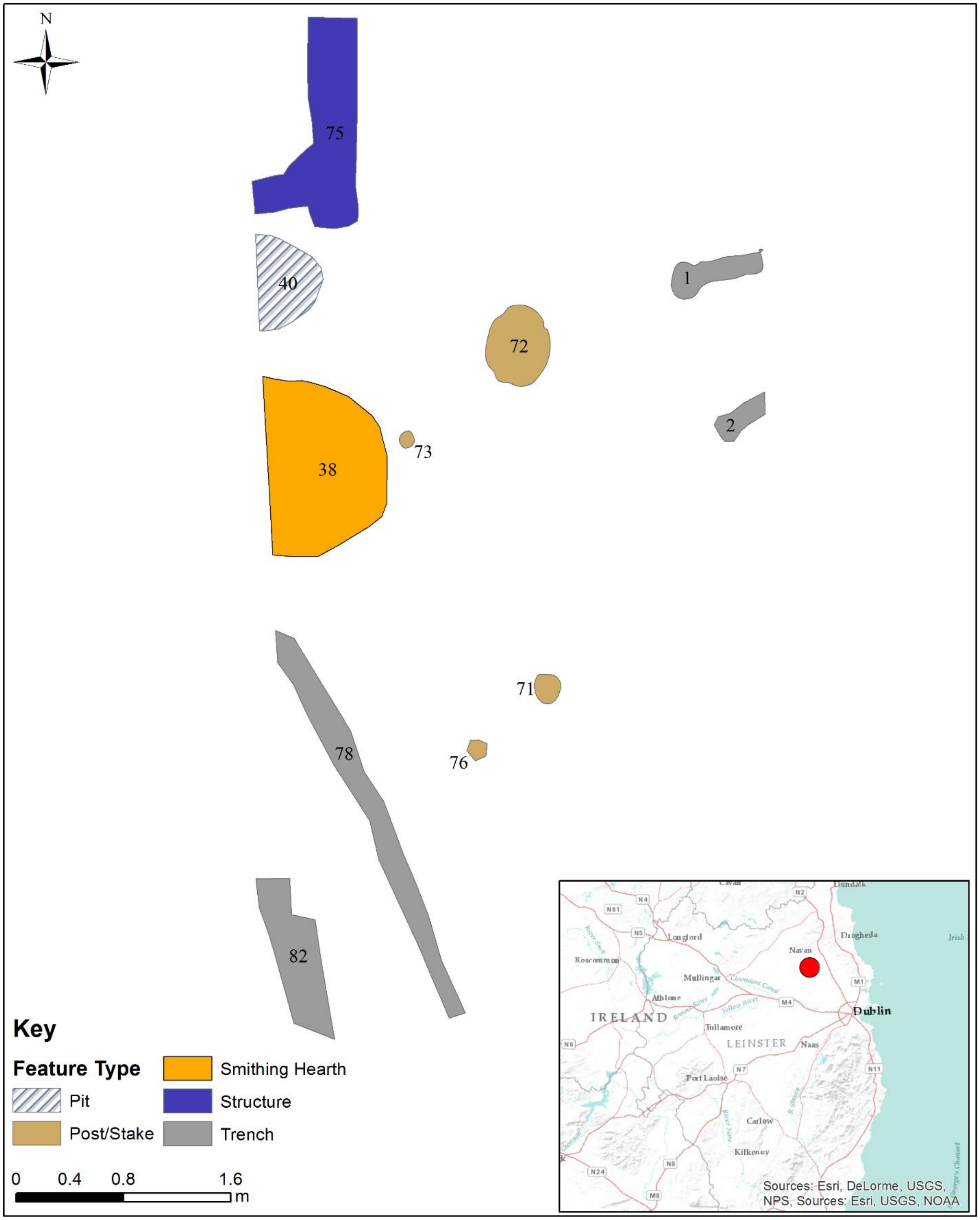
Description of Site: Evidence for iron production at the Hill of Tara was uncovered during 1997 excavations of the Ráith na Ríg by the Discovery Programme. This activity occurred prior to the construction of the bank, with charcoal dating the metalworking area to 200 cal. BCE – 16 cal. CE. One large hearth was identified, surrounded by a number of stake-holes that could have acted as part of a structure. Just north of the hearth was a likely rectangular slot-trench structure. The hearth was utilized for iron smithing, although bronze fragments, crucible fragments, and glass fragments were also found in associated contexts. This suggests that in addition to iron smithing, bronze and glass working may have also been occurring at the site.

The presence of this industrial production at what was otherwise a largely burial and ceremonial complex is interesting. The wider Tara landscape had significant prehistoric and historic occupation, but there does seem to be some additional Iron Age activities. Two likely Early and Developed Iron Age cremation burials were found in the ring-ditch just southeast of where the smithing hearth was located. A child inhumation burial was also found within the Ráith na Ríg, although exact dating is difficult. The iron smithing occurring at this site undoubtedly was part of a larger complex of ritualized behavior and potentially high status occupation.

Landscape: The iron production was located just outside of the Ráith na Ríg to the north, and south of the later constructed Ráith na Senad. It would have been near highest point on the hill.

References:

Roche, Helen. 2002. *Discovery Programme Reports 6 - Tara*. Royal Irish Academy, Dublin.



Ráith na Ríg, Tara (97E300)

Site Name: Trantstown AR 29

County: Cork

Licence Number: 01E0501 AR 29

Townland: Trantstown

ITM East: 575249.277

ITM North: 580951.927

Excavation conducted by Sheila Lane and Associates

Smelting: Yes **Number of furnaces:** 2

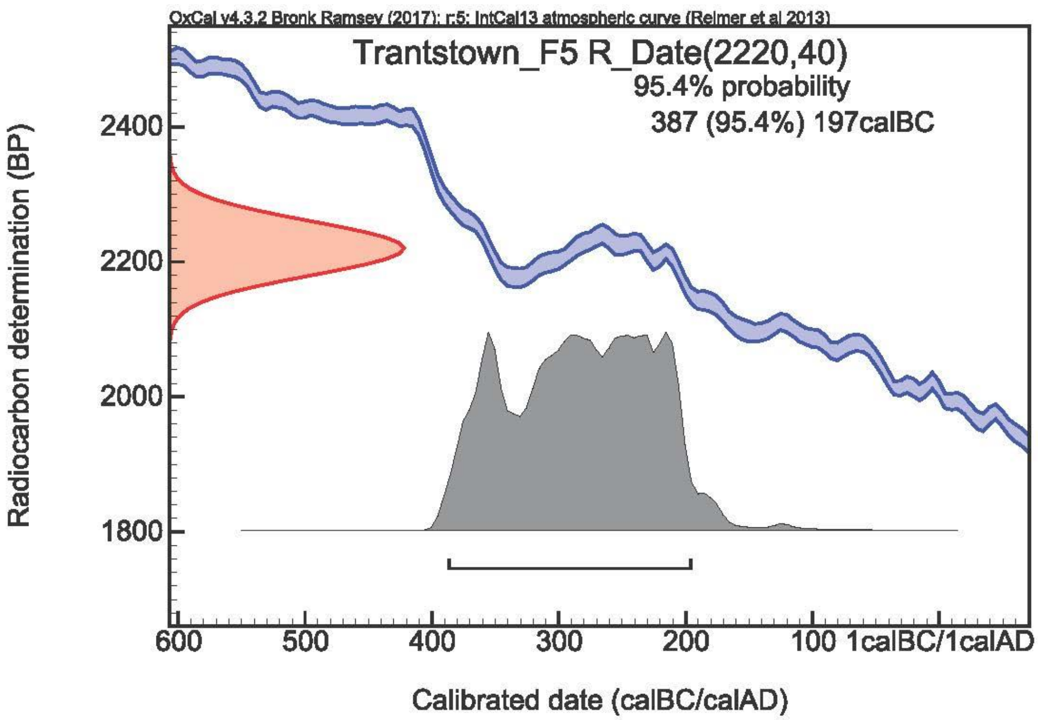
Smithing: No **Number of smithing hearths:** 0

Charcoal Production: No

Type of Site: Isolated Metalworking

Chronology: DIA

C14 Dates and Context:



Description of Site: The site of Trantstown AR29 was discovered during the construction of the N8 Glanmire – Watergrassh Road Scheme. It was given a joint License number with nine other sites: another produced IA smelting activity (AR 26), and one was a LBA cremation (AR 10). This site was made up of four features, at least one of which was an ironworking furnace (F5). Although this was called a bowl furnace, the steep sides and overall size is more representative of a slag-pit furnace. Another feature (F1) produced a lot of smelting slag, though its unusual shape and low magnetic residues leaves the interpretation for its use open. The profile of F1 could present an interesting technological process, if it was indeed a smelting furnace, since it presents a deep cut where slag could collect. A radiocarbon date from the furnace produced a calibrated date of 387 – 197 BCE. The high manganese content in the slag indicates a bog ore source for the iron ore.

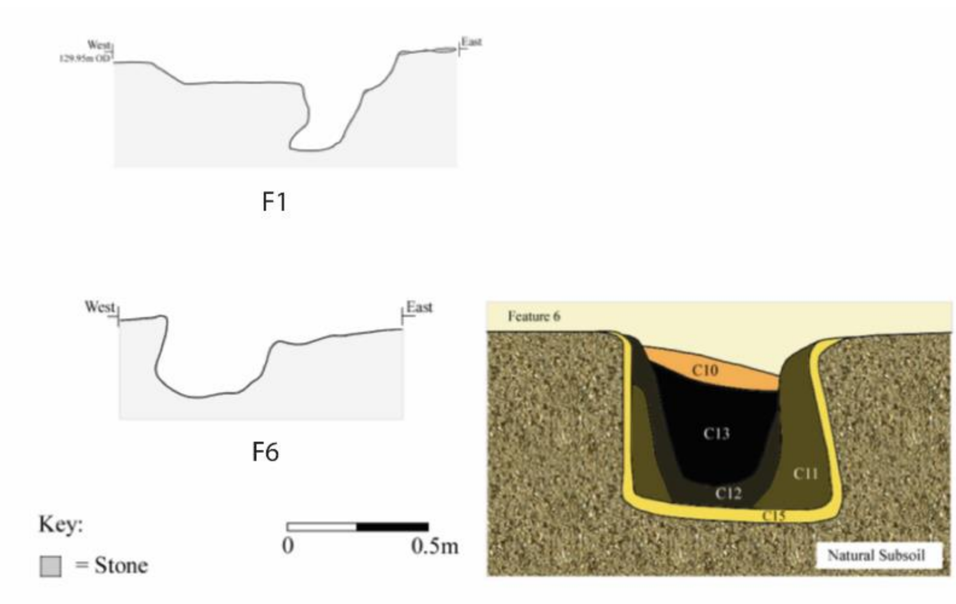
Approximately 460m to the southwest lay the site of Kilrussane AR27 (01E0701), an isolated metalworking site with four furnaces that produced dates parallel with Transtown. Also, 870m to the southwest of Trantstown was the site of Ballinvinny North (01E0501 AR 26), which also provided evidence for a furnace with an DIA date. These three sites should probably be considered as a complex of industrial production that extended larger than the site itself.

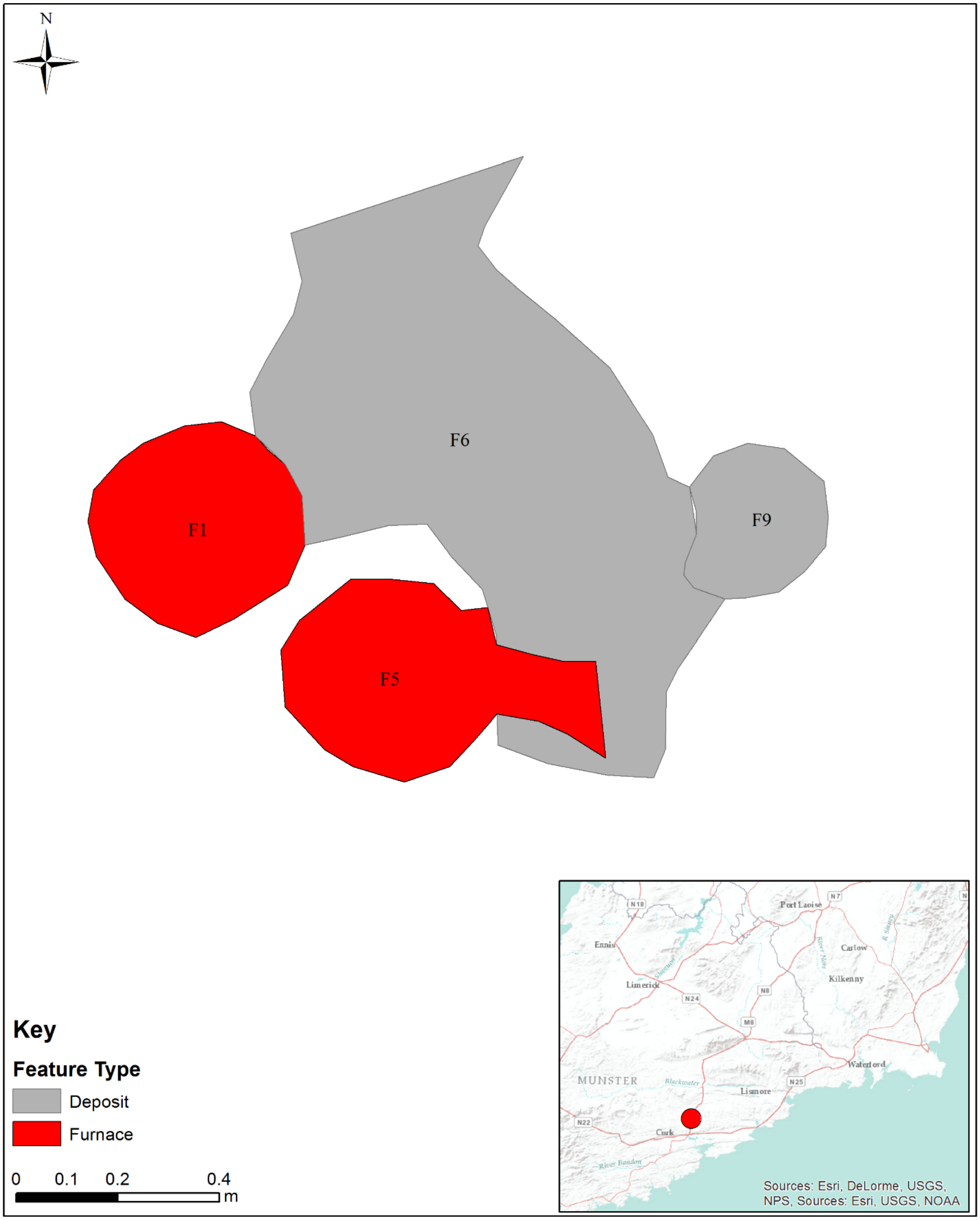
Landscape: "The landscape of the area is dominated by gently sloping hills and these archaeological sites were located on the slopes and broad top of such a hill at elevations of between 83m and 88m OD. AR 26 and AR 29 were located on good quality elevated pasture between two local roads referred to as Ballinvinny Road and Trantstown Road. Both sites were situated on relatively level ground, AR 26 occupying a more exposed position than AR 29, and they were located at elevations of 135m OD and 130m OD respectively.”

References:

Sherlock, R. 2005a. Archaeology excavation of a Bronze Age cremation burial, a number of Iron Age smelting furnaces and other features at Killydonoghoe, Ballinvinny North & Transtown, Co. Cork. Unpublished report Sheila Lane & Associates

Furnace Section:





Trantstown (01E0501 AR29)

Appendix B: Slag Samples

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2850	Cloncollog 2	Offaly	C007	C004	002

Slag Typ: vitrified lining; sinter;

Reference: Young 2008b. Evaluation of archaeometallurgical residues from Cloncollig 2, Co. Offaly NTB06, A033/E2850

Description: vitrified lining, with possible incurve towards blowhole
94 lining with sintery slag attached
245 lining with either foot of wall, with sinter and elephant's foot stalagmitic slag accumulation - or it was a dripping
overhang - former seems more likely
53 3 small pieces vitrified lining
15 2 rough slag blebs

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2850	Cloncollog 2	Offaly	C007	C005	003

Slag Typ: dense slag; sinter

Reference: Young 2008b. Evaluation of archaeometallurgical residues from Cloncollig 2, Co. Offaly NTB06, A033/E2850

Description: 73 4 pieces of dense, mainly horizontal prill, resembles poor wetting of large wood fragments, but no very large
contacts survive
152 slab of sintery material, with poorly formed lobes
63 dust and small fragments
1 or 2 dense blebs, but mainly broken up sinter

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2850	Cloncollog 2	Offaly	C007	C006	004

Slag Typ: bleby slag; prilly slag

Reference: Young 2008b. Evaluation of archaeometallurgical residues from Cloncollig 2, Co. Offaly NTB06, A033/E2850

Description: 42 mainly slag blebs - includes amazing multiple coffee bean - about 16 spheroids in this, plus 1 large prill

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
04E0319	Newrath Site 35	Kilkenny	35050	35049	

Slag Typ: cinders; prilly slag; burnt clay

Reference: Chadburn 2006. N25 North Waterford Bypass. Contract 3. Site 35 Newrath final report. Industrial waste morphological examination report

Description: 307 grams cinders and prills, the associated layer [3502] contained inclusions of burnt red clay
that could relate to a upper furnace structure demolished or removed after the smelting operations

04E0319	Newrath Site 35	Kilkenny	35053	35054	

Slag Typ: prilly slag; vesicular slag

Reference: Chadburn 2006. N25 North Waterford Bypass. Contract 3. Site 35 Newrath final report. Industrial waste morphological examination report

Description: 1075grams of prills, consolidated prills, vesicular slag and charcoal impressions

04E0319	Newrath Site 35	Kilkenny	35008	35009	

Slag Typ: fines; prilly slag

Reference: Chadburn 2006. N25 North Waterford Bypass. Contract 3. Site 35 Newrath final report. Industrial waste morphological examination report

Description: 395grams spherical slag, droplets and prills

04E0319	Newrath Site 35	Kilkenny	35010	35011	

Slag Typ: fired clay; prilly slag

Reference: Chadburn 2006. N25 North Waterford Bypass. Contract 3. Site 35 Newrath final report. Industrial waste morphological examination report

Description: 725 grams of fired clay, slag droplets and prills

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
04E0319	Newrath Site 35	Kilkenny	35060	35061	

Slag Typ	fired clay; prilly slag; slag spheres	Reference	Chadburn 2006. N25 North Waterford Bypass. Contract 3. Site 35 Newrath final report. Industrial waste morphological examination report
Description	309 grams of lightly fired clay droplets prills and slag spheres		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0701	Kilrussane AR 27	Cork	F1	C8	

Slag Typ	slag	Reference	Photos-Jones 2003d. Analysis of metallurgical waste from the N8, Watergrasshill Road Scheme, site No. AR 27.
Description	Most of the fragments of slag recovered from this site are black, dense, drippy and metallic-sounding or clinkery. The large fragments recovered (three in total) were morphologically similar. They resemble blooms but the fact that they have been discarded suggests that they have been assessed and assumed to be low in iron.		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0701	Kilrussane AR 27	Cork	F1	C1	1

Slag Typ	slag	Reference	Photos-Jones 2003d. Analysis of metallurgical waste from the N8, Watergrasshill Road Scheme, site No. AR 27.
Description	Most of the fragments of slag recovered from this site are black, dense, drippy and metallic-sounding or clinkery. The large fragments recovered (three in total) were morphologically similar. They resemble blooms but the fact that they have been discarded suggests that they have been assessed and assumed to be low in iron.		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0701	Kilrussane AR 27	Cork	F2	C2	4

Slag Typ: slag

Reference: Photos-Jones 2003d. Analysis of metallurgical waste from the N8, Watergrasshill Road Scheme, site No. AR 27.

Description: Most of the fragments of slag recovered from this site are black, dense, drippy and metallic-sounding or clinkery. The large fragments recovered (three in total) were morphologically similar. They resemble blooms but the fact that they have been discarded suggests that they have been assessed and assumed to be low in iron.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0701	Kilrussane AR 27	Cork	F2	C2	5

Slag Typ: slag

Reference: Photos-Jones 2003d. Analysis of metallurgical waste from the N8, Watergrasshill Road Scheme, site No. AR 27.

Description: Most of the fragments of slag recovered from this site are black, dense, drippy and metallic-sounding or clinkery. The large fragments recovered (three in total) were morphologically similar. They resemble blooms but the fact that they have been discarded suggests that they have been assessed and assumed to be low in iron.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0701	Kilrussane AR 27	Cork	F3	C7	6

Slag Typ: slag

Reference: Photos-Jones 2003d. Analysis of metallurgical waste from the N8, Watergrasshill Road Scheme, site No. AR 27.

Description: Most of the fragments of slag recovered from this site are black, dense, drippy and metallic-sounding or clinkery. The large fragments recovered (three in total) were morphologically similar. They resemble blooms but the fact that they have been discarded suggests that they have been assessed and assumed to be low in iron.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0701	Kilrussane AR 27	Cork	F4	C16	7

Slag Typ: slag

Reference: Photos-Jones 2003d. Analysis of metallurgical waste from the N8, Watergrasshill Road Scheme, site No. AR 27.

Description: Most of the fragments of slag recovered from this site are black, dense, drippy and metallic-sounding or clinkery. The large fragments recovered (three in total) were morphologically similar. They resemble blooms but the fact that they have been discarded suggests that they have been assessed and assumed to be low in iron.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0701	Kilrussane AR 27	Cork	F5	C19	8

Slag Typ: slag

Reference: Photos-Jones 2003d. Analysis of metallurgical waste from the N8, Watergrasshill Road Scheme, site No. AR 27.

Description: Most of the fragments of slag recovered from this site are black, dense, drippy and metallic-sounding or clinkery. The large fragments recovered (three in total) were morphologically similar. They resemble blooms but the fact that they have been discarded suggests that they have been assessed and assumed to be low in iron.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0701	Kilrussane AR 27	Cork	F7	21	10; 11; 12

Slag Typ: slag

Reference: Photos-Jones 2003d. Analysis of metallurgical waste from the N8, Watergrasshill Road Scheme, site No. AR 27.

Description: Most of the fragments of slag recovered from this site are black, dense, drippy and metallic-sounding or clinkery. The large fragments recovered (three in total) were morphologically similar. They resemble blooms but the fact that they have been discarded suggests that they have been assessed and assumed to be low in iron.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E0926	Kinnegad 2	Westmeath	F22	F22	

Slag Typ: porous slag

Reference: Photos-Jones 2003b. Analysis of metallurgical waste from Kinnegad II.

Description: porous slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E0926	Kinnegad 2	Westmeath	F23	F23	

Slag Typ: drippy slag

Reference: Photos-Jones 2003b. Analysis of metallurgical waste from Kinnegad II.

Description: Pits F23 and F29 (Graph g and Graph b respectively) both produced only a single piece of drippy type slag.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E0926	Kinnegad 2	Westmeath	F24	F24	

Slag Typ: dense slag

Reference: Photos-Jones 2003b. Analysis of metallurgical waste from Kinnegad II.

Description: dense slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E0926	Kinnegad 2	Westmeath	F25	F25	S24

Slag Typ: drippy slag; porous slag

Reference: Photos-Jones 2003b. Analysis of metallurgical waste from Kinnegad II.

Description: Pit F25 also produced a fragment of porous slag in addition to a fragment each of platy cake and drippy slag types

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E0926	Kinnegad 2	Westmeath	F28	F28	

Slag Typ: vitrified clay

Reference: Photos-Jones 2003b. Analysis of metallurgical waste from Kinnegad II.

Description:

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E0926	Kinnegad 2	Westmeath	F25	F35	S32

Slag Typ: porous slag; vitrified lining

Reference: Photos-Jones 2003b. Analysis of metallurgical waste from Kinnegad II.

Description: porous slag; In the charcoal layer F35 (see Graph c) a fragment of furnace wall was found as well as a fragment of partially vitrified clay

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E0926	Kinnegad 2	Westmeath	F42	F42	

Slag Typ	porous slag; dense slag; vitrified clay	Reference	Photos-Jones 2003b. Analysis of metallurgical waste from Kinnegad II.
Description	F42 (see Graph f and Graph d respectively) produced primarily porous slag; Pit F42 produced a fragment of dense crystalline slag; F28, F24 and F42 (see Graph a, Graph h and Graph d) produced one or two fragments of vitrified clay		

E2131	Leap 1	Laois	F007	F002	S1

Slag Typ	flow slag	Reference	Young 2009a. Evaluation of Archaeometallurgical residues from the M7 Portlaoise To Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 1: Leap 1 (E2131).
Description	flow slag in mainly small blebby dense prills, yellow brown colour		

E2131	Leap 1	Laois	F008	F003	S2

Slag Typ	dense slag; sinter	Reference	Young 2009a. Evaluation of Archaeometallurgical residues from the M7 Portlaoise To Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 1: Leap 1 (E2131).
Description	dense prilly anastomosing flows dull sintery slags coffee bean spheroids		

E2131	Leap 1	Laois	F010	F005	S4

Slag Typ	dense flow slag	Reference	Young 2009a. Evaluation of Archaeometallurgical residues from the M7 Portlaoise To Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 1: Leap 1 (E2131).
Description	probably a single fragmented cross floor flow with moulds of large wood pieces; small fragments of dense flow slag		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2131	Leap 1	Laois	F011	F006	S5

Slag Typ: sinter; dense slag

Reference: Young 2009a. Evaluation of Archaeometallurgical residues from the M7 Portlaoise To Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 1: Leap 1 (E2131).

Description: dense blebs and flow lobes
dull, sintery slags
coffee bean spheroids

E2181	Derrinsallagh 5	Laois	C070	C081	9

Slag Typ: smelting slag; sinter

Reference: Young 2008a. Detailed recording of furnace C397, Derrinsallagh 4 (E2180)

Description: mainly coffee bean spheroids, but a few prill fragments, with a couple of possible sinter fragments

E2181	Derrinsallagh 5	Laois	C070	C070	40

Slag Typ: prilly slag; blebby slag

Reference: Young 2008a. Detailed recording of furnace C397, Derrinsallagh 4 (E2180)

Description: mainly fine dense descending prills, with a few more blebby pieces

E2181	Derrinsallagh 5	Laois	C003	C003	37; 38

Slag Typ: undiagnostic slag

Reference: Young 2008a. Detailed recording of furnace C397, Derrinsallagh 4 (E2180)

Description: indeterminate slag fragments, small scrappy slag fragments, mainly rather low density material

E2181	Derrinsallagh 5	Laois	C029	C064	39

Slag Typ: blebby slag

Reference: Young 2008a. Detailed recording of furnace C397, Derrinsallagh 4 (E2180)

Description: rounded, blebby dense slag lumps

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E0461	Morett	Laois	C324	C324	

Slag Typ: smelting slag; lining

Reference: Young 2011b. Evaluation of Archaeometallurgical Residues from the N7 Heath-Mayfield Motorway Scheme (03E0151, 03E0966, 03E0461, 03E0603, 03E0633, 03E0679, 03E0602, 03E0635)

Description: C324 with its fills C323/327 yielded approximately 1kg of a rather derived-looking assemblage of smelting
materials, including various types of slag and lining fragments.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E0461	Morett	Laois	C172	C172	

Slag Typ: burr; pilly slag; lining; dense slag

Reference: Young 2011b. Evaluation of Archaeometallurgical Residues from the N7 Heath-Mayfield Motorway Scheme (03E0151, 03E0966, 03E0461, 03E0603, 03E0633, 03E0679, 03E0602, 03E0635)

Description: C172 with its fills c174/175 contained 1.1kg of a mixed assemblage of larger pieces of slags, including burr
fragments, pieces with a prilly texture, lining fragment and some dense slags bearing moulds of very large charcoal
fragments. As with the fills of c324, this assemblage would be best interpreted as secondary dump of smelting related
materials, rather than an in-situ collection of pieces left in a furnace after smelting.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E0461	Morett	Laois	C140	C140	

Slag Typ: prilly slag; sinter

Reference: Young 2011b. Evaluation of Archaeometallurgical Residues from the N7 Heath-Mayfield Motorway Scheme (03E0151, 03E0966, 03E0461, 03E0603, 03E0633, 03E0679, 03E0602, 03E0635)

Description: C140 was a circular feature 0.37m in diameter and 0.19m deep. The fill of the feature also appears to be assigned
to C140, apart from a basal charcoal-rich layer. The main fill contained 1.5kg of isolated prills and sintery material,
slags consistent with an origin on the base of a basal pit for a smelting furnace.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E0461	Morett	Laois	C141	C141	

Slag Typ	sinter; prilly slag; slag cake; furnace bottom	Reference	Young 2011b. Evaluation of Archaeometallurgical Residues from the N7 Heath-Mayfield Motorway Scheme (03E0151, 03E0966, 03E0461, 03E0603, 03E0633, 03E0679, 03E0602, 03E0635)

Description: Material from C141 and C164 includes a variety of
material types commonly encountered at the base of smelting furnaces, including sintery-appearing slags, prills,
moulds of charcoal fragments and "coffee bean" morphology droplets. The slag from C177 however appears to be
pieces of a single broken prilly slag cake with coarse charcoal moulds, of which further fragments appear in C164,
giving a total weight of this material of approximately 5.6kg. This material closely resembles the textures seen in
the large slag cakes found in the upper part of the basal pits of iron smelting furnaces elsewhere (e.g. Young
2003c, 2003d). Such a slag cake might be termed a "furnace bottom" sensu Crew 1986. However, it seems clear
from the evidence available from the Irish furnaces that the block does not form in the bottom of the furnace, but
slightly higher in the shaft, immediately below the bloom.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E0461	Morett	Laois	C142	C142	

Slag Typ	burr; lining; smelting slag	Reference	Young 2011b. Evaluation of Archaeometallurgical Residues from the N7 Heath-Mayfield Motorway Scheme (03E0151, 03E0966, 03E0461, 03E0603, 03E0633, 03E0679, 03E0602, 03E0635)

Description: It is recorded as having a single fill, c163.
C163 contains 2.2kg of residues comprising large slag pieces, including burr fragments, a piece of slag
accumulation from the foot of the pit wall on the blowing side and a block with very large charcoal moulds, together
with a large proportion of wall and lining debris. This is not likely to be an in-situ assemblage, but comprises the
coarse debris from clearing out a furnace and the demolition or repair of its superstructure.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E0461	Morett	Laois	C395	C397	

Slag Typ: smelting slag; prilly slag; tuyere; vitrified lining; dense slag

Reference: Young 2011b. Evaluation of Archaeometallurgical Residues from the N7 Heath-Mayfield Motorway Scheme (03E0151, 03E0966, 03E0461, 03E0603, 03E0633, 03E0679, 03E0602, 03E0635)

Description: C397, an upper fill of C335, a corn drying kiln, yielded 5.5kg of smelting related debris (dense slags with very large
charcoal moulds, down-wall flows, prills, stalagmitic slag accumulations), but also has a possible large tuyère
fragment, much vitrified lining, and slags with a flow-lobed base overlain by an inclined body of granular slag. This
is not an in-situ deposit. The possibility exists that some of the residues from this context (particularly the dense
slag pieces with smooth, blown tops and the possible tuyère material) might have been produced during ironworking
rather than smelting.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2672	Moyally 2	Offaly	C7	C3	1

Slag Typ: slag

Reference: Photos-Jones 2008 Metallurgical waste excamination & analysis of samples from Moyally 2, Co. Offaly

Description: collection of small fragments of slag ranging in size, dark-brown, porous, ferruginous deriving from bloomery smelting/bloom smithing/smithing

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2672	Moyally 2	Offaly	C7	C5	2

Slag Typ: slag

Reference: Photos-Jones 2008 Metallurgical waste excamination & analysis of samples from Moyally 2, Co. Offaly

Description: two larger fragments with accumulation of many smaller fragments; amorphous, black, highly porous, light, ferruginous material; typical of bloomery smelting but could come from bloom smithing or smelting as well

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2672	Moyally 2	Offaly	C10	C9	11

Slag Typ: lining

Reference: Photos-Jones 2008 Metallurgical waste excamination & analysis of samples from Moyally 2, Co. Offaly

Description: two large plate-like but slightly concave fragments of orange coloured ferruginous mass which appears to consist of part earthy material, part slag; also many smaller fragments of seemingly the same material

E2370	Site AR 26, Ballydavid	Tipperary	C172	C170	70

Slag Typ: clay; smelting slag

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: stone, lots of grains of what appears to be fired clay, 1 angular slag fragment

E2370	Site AR 26, Ballydavid	Tipperary	C172	C170	77

Slag Typ: clay

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: strongly oxidised fired clay - fired to a slightly orangey red

E2370	Site AR 26, Ballydavid	Tipperary	C172	C170	78

Slag Typ: lining;

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: vitrified and/or reduced fired furnace lining, only one fragment shows oxidised firing locally and this is strongly overhanging, suggesting overhanging blowhole area

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C172	C171	72

Slag Typ: smelting slag

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: dense dark flow slag - in much bigger lobes and prills than some of the material from this site

E2370	Site AR 26, Ballydavid	Tipperary	C172	C171	74

Slag Typ: smelting slag

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: blebby flow slag with lots of coffee beans and fine particles of possible sinter/ore

E2370	Site AR 26, Ballydavid	Tipperary	C179	C177	91

Slag Typ: slag

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: mainly stone, but a few pieces of microprilly slag

E2370	Site AR 26, Ballydavid	Tipperary	C179	C177	94

Slag Typ: smelting slag; lining

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: blocks of dense flow slag attached to reduced fired wall, show evidence for very large pit packing; slag/ lining slag on reduced fired wall

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C60	C183	111

Slag Typ: clay

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: variable fired and indurated ceramic, mostly reduced but some oxidised

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C60	C183	112

Slag Typ: clay

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: oxidised fired clay

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C60	C197	132

Slag Typ: smelting slag; lining

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: block of dense slag attached to reduced fired wall

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C60	C197	160

Slag Typ: smelting slag; charcoal

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: large blocks of massive grey, slightly cavernous slag, some charcoal inclusions, slightly prilly base, probably part of the furnace slags but no clear identifying factors

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C60	C221	149

Slag Typ: slag

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: indeterminate amorphous fragment of dense slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C118	C136	45

Slag Typ: lining; smelting slag.

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: vitrified oxidised lining. rather poor flow\slag from furnace floor - crudely lobate but not well developed.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C167	C165	33

Slag Typ: smelting slag

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: small pieces of flow slag, spheroids, possible ore and sinter

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	topsoil	C2	274

Slag Typ: lining

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: small scrap of lining influenced slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C71	C69	81

Slag Typ: smelting slag; ore

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: 52g piece of very dense flow slag, remainder of material is mainly stone, but there are some rounded strongly magnetic pieces that may be ore particles

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C60	C90	75

Slag Typ: hammerscale; charcoal

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: rich assemblage with lots of spheroidal hammerscale,, some flake hammerscale, lots of organic material which appears to be coal reside

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C142	C139	18

Slag Typ: sinter; smelting slag

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: assemblage of fragments of "sinter" with botryoidal overgrowth, a few pieces of flow slags, some coffee bean spheroids, in a background of fired clay and stone

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C142	C140	20

Slag Typ: smelting slag

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: flow slag, but about 250g is more dominated by a very dense sinter. small pieces of flow slag and small sinter fragments probably in roughly equal proportions, much of the slag is in the form of coffee bean spheroids.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C60	C155	26

Slag Typ	smelting slag; sinter; lining	Reference	Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.
Description	dense flow slags. vitrified lining material. dense slags with trend to include sintered ore? fines mainly sinter, but some slag and piece of corroded iron, together with a significant amount of fired clay and vitrified lining.		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C157	C156	27

Slag Typ	sinter; smelting slag; lining	Reference	Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.
Description	fines mainly sinter and\ stone, but some flow slag blebs. flow slag, in rather stouter flows than some other contexts. dense lag from against wall, 1 piece is a burr fragment. vitrified wall. iron?		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C161	C158	29

Slag Typ	smelting slag; lining	Reference	Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.
Description	pieces of flow slag, mainly in very fine prills - some large blocks the small prills appear to curve around large fuel moulds. large pieces of vitrified lining - in very strange rounded lumps, suggesting failure. corroded iron. small pieces of flow slag. small pieces of vitrified lining. fine material with some flow slag fragments, but this is ostly fired clay bedris - including a number of pieces with a bright blue glaze.		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C161	C159	30

Slag Typ: sinter; smelting slag

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: rich assemblage, flow slag debris, fine sinter fragments lots of coffee beans and small spheroids. flow slag pieces, in v delicate descending prills, these pick out the ghosted shapes of large wood fragments.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C161	C160	31

Slag Typ: smelting slag; lining; sinter

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: pieces of flow slag, mainly delicate prills, but down to spheroids. vitrified wall and stones. spiky slag and/or sinter

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C167	C165	33

Slag Typ: smelting slag; sinter; ore

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: flow slag in small pieces, coffee beans, ore debris and sinter

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C167	C165	36

Slag Typ: smelting slag; sinter

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: flow slag in fairly thin prills and lobes (thinner than 171) not as thin as some others. "sinter"

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C169	C168	66

Slag Typ: clay

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: oxidised fired clay

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C169	C168	67

Slag Typ: smelting slag; lining

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: dense slag attached to wall, clearly some interaction so near burr, one piece has some pendent prills. lobate flow slags. massive iron slags related to the wall slags above. slagged oxidised fired lining

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C169	C168	115

Slag Typ: lining; smelting slag

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: chip of vitrified oxidised lining. 2 pieces of dense slightly lobate slag attached to grey wall - gravel from wall appears to be incorporated into slag - so probably close to the burr. 2 pieces of dense flow slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2370	Site AR 26, Ballydavid	Tipperary	C169	C168	116

Slag Typ: smelting slag

Reference: Young 2009c. Final Report E2370 Site AR 26, Ballydavid, Tipperary. Archaeometallurgical report.

Description: stone with a few pieces of slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
13E0435	Grange	Dublin	C6	C3	

Slag Typ: flow slag

Reference: Rondelez 2014b. Report on the metalworking remains at Nangor (Grange Castle Business Park), Co. Dublin

Description: Numerous pieces of relatively dense drippy slag showing flow-structure. Maximum length 6cm. Outer surface predominatly dull, but occasionally shiny. Many small pieces are droplets

13E0435	Grange	Dublin	C6	C3	

Slag Typ: droplets;

Reference: Rondelez 2014b. Report on the metalworking remains at Nangor (Grange Castle Business Park), Co. Dublin

Description: Multiple fragments of yellowish orange iron oxide concretions. Many have charcoal and slag droplet components.

13E0435	Grange	Dublin	C6	C4	

Slag Typ: vitrified lining

Reference: Rondelez 2014b. Report on the metalworking remains at Nangor (Grange Castle Business Park), Co. Dublin

Description: Many rounded pieces of heat-affected clay, several of which have a concave vitrified surface. Furnace wall fragments.

00E0914	Lagavooren 7	Meath	C141	C140	391

Slag Typ: flow slag; sinter; vitrified lining

Reference: Young 2011a. Archaeometallurgical residues: Lagavooren 7 (00E0914), Co. Meath

Description: Dense flow slag, ranging from large stalactitic blocks down to small individual prills. Good moulds of large
wood/charcoal pieces seen. Some piece grade into more sintery material with possible ore debris. Some fragments
show mixing with highly vitrified quartz-rich sediment/lining similar to that seen in sample 163 below.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
00E0914	Lagavooren 7	Meath	C164	C163	390

Slag Typ: sinter; dense slag

Reference: Young 2011a. Archaeometallurgical residues: Lagavooren 7 (00E0914), Co. Meath

Description: ragments of slag, some with rather sintery appearance, rusty in areas - the largest piece is very dense with
embedded pebbles and slightly maroon tinged pendent lobes, this may be a burr. Other pieces are rich in
moderately large charcoal inclusions and two show interaction with a coarse sandy lining slag..

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
00E0914	Lagavooren 7	Meath	C198	C199	99

Slag Typ: Stone

Reference: Young 2011a. Archaeometallurgical residues: Lagavooren 7 (00E0914), Co. Meath

Description: fragments of chert and quartz-replaced fossils (Syringopora; Carboniferous coral) - natural

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
00E0914	Lagavooren 7	Meath	C410	C409	395

Slag Typ: fired clay

Reference: Young 2011a. Archaeometallurgical residues: Lagavooren 7 (00E0914), Co. Meath

Description: tiny fragments of fired clay; fragments of fired clay, gravelly and rich in charcoal; lightly oxidised fired clay; irregularly shaped fragment of lightly fired clay, slightly oxidised, contains small stone

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E0602	Site L, Lughil	Kildare	F7	F7	13

Slag Typ: pilly slag

Reference: Young 2012b. 2012b Evaluation of Archaeometallurgical Residues from the N7 Heath-Mayfield Motorway Scheme: Site L (03E0602), Lughil, Co. Kildare

Description: 3 pieces of prill, one broken in 3, 1 piece shows flowage past a large charcoal piece.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E0602	Site L, Lughil	Kildare	F7	F7b	11

Slag Typ: prilly slag; lobate slag

Reference: Young 2012b. 2012b Evaluation of Archaeometallurgical Residues from the N7 Heath-Mayfield Motorway Scheme: Site L (03E0602), Lughil, Co. Kildare

Description: Single complex obliquely descending prill, lobate, penetrating between large pieces of charcoal,
110x40x40mm overall.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2342	Knockcommane 4700.1b	Limerick	F10	F11	3

Slag Typ: metallurgical ceramic

Reference: Photos-Jones 2007a. Analysis of metallurgical waste from Knockcommane

Description: A collection of fragments of metallurgical ceramic. One large fragment of furnace wall which has been exposed to the hot zone of the furnace (Figures 2d and e) i.e. near the tuyere and has vitrified, to a varying degree, from the surface to the interior. Figure 2e shows that there is a gradient in colour (see shades of grey reflecting the oxidation state of iron in the ceramic fabric, in Figure 2e), as well as degree of vitrification, from one end of
the fragment to the other; the part exposed to the hot and reducing environment of the interior of the furnace being porous, vitrified and grey; the part further away from it, being cool, red/orange heated and partially cintered. The fabric of the matrix contains large quartz inclusions, an essential addition to render the metallurgical ceramic more refractory. There may have been some partial reaction of the furnace wall with the furnace contents to produce either metallic inclusions (see discussion below and Figure 4a) or a thin layer of slag.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2342	Knockcommane 4700.1b	Limerick	F12	F13	4

Slag Typ: drippy slag

Reference: Photos-Jones 2007a. Analysis of metallurgical waste from Knockcommane

Description: A single small fragment of drippy slag, essentially one of a collection of fragments recovered from within the furnace

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2342	Knockcommane 4700.1b	Limerick	F3	F4	1

Slag Typ: drippy slag

Reference: Photos-Jones 2007a. Analysis of metallurgical waste from Knockcommane

Description: A considerable quantity of small fragments of drippy slag weighing 1568 grams after sieving of the associated soils and recovered from the interior of the furnace at the end of
the last smelt. The drop-like physiognomy of these slags reflect their low viscosity –they
are iron and manganese rich; the quantities of slag generated (c. 2kgs) and by extension
the amount of ore charged was not large.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2342	Knockcommane 4700.1b	Limerick	F3	F4	1a

Slag Typ: sinter

Reference: Photos-Jones 2007a. Analysis of metallurgical waste from Knockcommane

Description: A quantity of heat-affected earthy (natural) material, and not slag, partly ferrougenous, but not exceeding c. 6% in iron, mixed with charcoal, small quartz pebbles and ash, all in
a low-fired, partially sintered state.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2342	Knockcommane 4700.1b	Limerick	F8	F9	2

Slag Typ: bloom

Reference: Photos-Jones 2007a. Analysis of metallurgical waste from Knockcommane

Description: Small fragment of a bloom enveloped within iron oxide and slag. This bloom forms part
of a small collection of ferrougenous materials of unspecified iron content. Further investigation is carried out on the bloom.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1214	Site 27, Rath	Meath	F89	F98	1005

Slag Typ: dense slag; clinkery slag

Reference: Photos-Jones 2009 2009 N2 Finglas-Ashbourne road scheme. Report on archaeological excavation of Site 27, Rath, Co. Meath Industrial waste examination & analysis.

Description: drippy/clinkery slag (Large fragments: dark grey, dense. Small fragments: porous)

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1214	Site 27, Rath	Meath	F557	F558	1001

Slag Typ: ore

Reference: Photos-Jones 2009 2009 N2 Finglas-Ashbourne road scheme. Report on archaeological excavation of Site 27, Rath, Co. Meath Industrial waste examination & analysis.

Description: ore

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1214	Site 27, Rath	Meath	F75	F599	1004

Slag Typ: dense slag; clinkery slag

Reference: Photos-Jones 2009 2009 N2 Finglas-Ashbourne road scheme. Report on archaeological excavation of Site 27, Rath, Co. Meath Industrial waste examination & analysis.

Description: drippy/clinkery slag (Large fragments: dark grey, dense. Small fragments: porous) &VFA

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1214	Site 27, Rath	Meath	F557	F681	1003

Slag Typ: ore

Reference: Photos-Jones 2009 2009 N2 Finglas-Ashbourne road scheme. Report on archaeological excavation of Site 27, Rath, Co. Meath Industrial waste examination & analysis.

Description: light, rusty-coloured, fragment of an ore.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1214	Site 27, Rath	Meath	F557	F681	1000

Slag Typ: slag

Reference: Photos-Jones 2009 2009 N2 Finglas-Ashbourne road scheme. Report on archaeological excavation of Site 27, Rath, Co. Meath Industrial waste examination & analysis.

Description: siliceous, light, frothy slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1214	Site 27, Rath	Meath	F557	F684	

Slag Typ: slag

Reference: Photos-Jones 2009 2009 N2 Finglas-Ashbourne road scheme. Report on archaeological excavation of Site 27, Rath, Co. Meath Industrial waste examination & analysis.

Description: light, frothy, rusty-coloured slag. Free Fe rather than as iron silicate

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2167	Clonrud 4	Laois	F003	F010	4; 15

Slag Typ: flow slag; sinter; ore; fired clay

Reference: Young 2008c. Evaluation of Archaeometallurgical residues from Clonrud 4

Description: Flow slag (90); fines (34); indeterminate slag (27); sinter (28); ore (1); fired clay (60)

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2167	Clonrud 4	Laois	F003	F009	8

Slag Typ	Collapsed superstructure	Reference	Young 2008c. Evaluation of Archaeometallurgical residues from Clonrud 4
Description	Collapsed superstructure (5040)		

E2167	Clonrud 4	Laois	F005	F011	1

Slag Typ	fired clay	Reference	Young 2008c. Evaluation of Archaeometallurgical residues from Clonrud 4
Description	fired clay (1450)		

E2167	Clonrud 4	Laois	F005	F007	3; 16

Slag Typ	flow slag	Reference	Young 2008c. Evaluation of Archaeometallurgical residues from Clonrud 4
Description	flow slag (1825); fines (798)		

E2167	Clonrud 4	Laois	F005	F006	7

Slag Typ	Collapsed superstructure	Reference	Young 2008c. Evaluation of Archaeometallurgical residues from Clonrud 4
Description	Collapsed superstructure (4100)		

E2167	Clonrud 4	Laois	F004	C013	5; 6; 7; 8; 9; 10; 11; 12; 13

Slag Typ	flow slag; dense slag; fired clay	Reference	Young 2008c. Evaluation of Archaeometallurgical residues from Clonrud 4
Description	flow slag (21894); fines (692); large dense slag (3340); fired clay (1463)		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0501 AR26	Ballinvinny North AR26	Cork	C3	C3	AR26.1; 3

Slag Typ	smelting slag	Reference	Photos-Jones 2003. Analysis of Metallurgical Waste from N8 Glanmire, Watergrasshill Road Scheme, Site Nos. AR 26 & AR 29.
Description	The bags contained fragments of slag mixed with an organic-rich clay soil. The slag was of the black dense heavy and metallic sounding (clinkery) variety.		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F2	C45	215

Slag Typ	charcoal; smelting slag; tap-slag	Reference	Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12
Description	18g 1 piece slag rich in fine charcoal; 92g piece with flow lobed base, top missing, inside has free large olivine crystals; 240g 37 pieces of tap-slag like floor flows, very brittle, very shiny; 2g 2 crumbs of charcoal-rich slag		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F2	C8	122

Slag Typ	prilly slag; smelting slag; sinter; clay lining	Reference	Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12
Description	38g 9 pieces of very sandy lining and lining slag, has some organic temper; 506g 50 pieces of dense prilly slag, mainly descending, shiny dense, dark, one piece is very thin flow between floor and flat wood piece; 90g 24 pieces of duller and/or less dense blebby slag; 156g basal sintery material - this is fine like that from Celbridge, a few bits of included flow blebs.		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F3	C72	383

Slag Typ	smelting slag	Reference	Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12
Description	small corrosion ball, 3 small dimpled slag pieces, 1 exploding accreted slag fragment		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F3	C9-C36	309

Slag Typ	vitrified lining; stone; prilly slag; smelting slag	Reference	Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12
Description	326g 11 pieces of vitrified lining; 20g 2 pieces of stone; 80g 2 pieces of corrosion/concretion; 8g 2 tiny blebby slag pieces; 30g shiny complex descending prill; 662g 5 pieces of burr or shc material, massive, dense, has some attached sediment; 374g 3 pieces charcoal rich massive slag; 64g 2 pieces of lobate slab with granules (ore?) on lower surface.		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F3	53	53

Slag Typ	vitrified lining; dense slag block	Reference	Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12
Description	178g 5 pieces of vitrified lining/lining slag (all reduced-fired), 220g large block of dense slag with very large charcoal moulds; 60g very dense slightly granular slag nub; 52g dense slag with moderately large charcoal moulds and sediment contact; 72g 3 pieces of amorphous dense slag.		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F3	C81	238

Slag Typ	vitrified lining; prilly slag; furnace bottom	Reference	Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12
Description	34g vitrified lining piece; 238g irregularly prilly/microprilly/blebby slag coalesced around poor medium charcoal mouldspossibly from Tullyallen-style furnace bottom		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F3	C75	381

Slag Typ	dense slag	Reference	Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12
Description	1 piece of dense slag with the moulds of large charcoal pieces		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F3	C68	240

Slag Typ	iron corrosion	Reference	Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12
Description	76g several pieces of stone; 76g 2 lumps of Fe-corrosion/concretion		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F4	C24	382

Slag Typ	vitrified lining; amorphous slag	Reference	Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12
Description	28g vitrified lining; 36g partially flow-lobed material; 2g fine debris		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F4	C6	47

Slag Typ: plano-convex hearth bottom; vitirfied lining; smithing hearth cake

Reference: Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12

Description: 2 pieces of granular hearth bottom: one very hard, dense and plano-convex, suggests dish-shaped base with side
springing up at 50-60 degrees, the other irregular and not certainly from furnace base. Big piece has lots of small slag
fragments apparently welded to top of true basal flow - itself mixed into the underlying clay and possibly ash. 46 pieces of vitrified lining and lining slag, 2 pieces in particular are extremely dense and massive thick blocks. Part of moderately small, dense smithing hearth cake. Top concave. Suggestive of original cake of 130mm diameter -
making this piece about 1/3. Crust 20-30mm thick. Upper and lower faces both fairly smooth. 3 small pieces of very dense burr material. 16 indeterminate pieces of dense slag. 20 pieces of dense slag with descending prills and sheets and/or enclosing very large charcoal fragments. Largest piece
is 652g and has slightly radiating prills. 66g 13 pieces of lining + associated lining slag; 92g 12 pieces of dense prilly material; rest small pieces of dull, indeterminate or coarsely crystalline iron slags

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F5	C5	37

Slag Typ: lining; dense slag

Reference: Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12

Description: large material, 816g 13 pieces of lining and lining slag; 518g 3 pieces of flowed and charcoal-rich material attached to
wall; 740g 7 pieces of probable descending smelting slag in prills and large charcoal moulds; 204g piece of large burr;
896g 10 pieces of amorphous dense slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F5	C27	49

Slag Typ: dense slag; lining

Reference: Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12

Description: 94g possibly worn but ash-covered slag lump with charcoal inclusions and moulds in dense massive piece; 158g very
dense piece of burr-type development, but dense slag appears to be a sheet attached to the lining, rather than being of a
characteristic burr shape

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F6	C4	27

Slag Typ: lining; prilly slag

Reference: Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12

Description: 176g 16 pieces of lining/lining slag - note that only two tiny pieces are oxidised fired; 82g small dense prilly slag pieces;
258g duller slag pieces - still mainly fairly dense. approximately 110 small indeterminate slag pieces

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F7	17	34

Slag Typ: prilly slag; blebs

Reference: Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12

Description: 260g 10 pieces of descending prills and blebs, brittle, shiny; 178g granular/sintered furnace floor material with at least 2
fused-in low density blebs, in many pieces down to dust size

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0955	Cherryville Site 12	Kildare	F7	C3	380

Slag Typ	dense prilly slag; blebs; lining; sinter	Reference	Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12
Description	10g 5 pieces of dense prilly slag; 2g 3 coffee-bean slag drops; 28g 14 pieces of dull blebby slags; 2g 4 pieces of lining debris; rest is sintery basal material		

01E0955	Cherryville Site 12	Kildare	F9	C7	155

Slag Typ	vitrifing lining; small lobes	Reference	Young 2005. Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12
Description	72g large block of vitrified lining material; 52g fairly small lobes around charcoal moulds; 12g single flow lobe; 10g charcoal-rich tiny piece		

E2180	Derrinsallagh 4	Laois	C001	F1	547

Slag Typ	dense slag	Reference	Young 2008d. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derrinsallagh 4
Description	single piece of dense, probably flow-, slag, broken in 2		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2180	Derrinsallagh 4	Laois	C656	F659	525

Slag Typ: flow slag; lining; sinter; clay; prilly slag

Reference: Young 2008d. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derrinsallagh 4

Description: flow slag, mainly in small blebby prills with small charcoal moulds; lining slags, gravelly
; rusty sinter; dull blebs associated with sinter; fragments of clay and stones, many glazed and/or vesicular; slag formed of small prills with small charcoal moulds; bits and dust

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2180	Derrinsallagh 4	Laois	C656	F660	535

Slag Typ: flow slag; prilly slag; lining; slag cake;

Reference: Young 2008d. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derrinsallagh 4

Description: flow slag, blebby, small charcoal moulds; fragments of massive to prilly slag blocks - some with faces suggesting they originated adjacent to the wall; Block of lining 170 wide, 100 wide incurved densely vitrified pad, attached to small prilly slag cake extending 60 into hearth,
curve suggests that the blowhole area was overhanging and curved – possible to interpret this as the base of a dome.; fired wall; dust and small bits

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2180	Derrinsallagh 4	Laois	C667	F676	528

Slag Typ: sinter; flow slag

Reference: Young 2008d. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derrinsallagh 4

Description: sintery material; well developed flow slag prills; dull flows on sintery material

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C92	C187	50

Slag Typ: furnace bottom flow slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: block of indurated "furnace base" with down-wall slag flows and horizontally-layered charcoal-rich pit infill; charcoal-rich slag with a large mould, includes 120g bits; block of slag and wall with scooped margin suggesting this is blowhole side; large block of "furnace bottom" with only a small wall attachment

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C92	C181	41

Slag Typ: flow slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: flow slag penetrating pit wall

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C92	C179	42

Slag Typ: burr; dense slag; ceramic

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: burr with well marked rim of grey wall against fine charcoal rich slag; possibly also a burr- rather messy piece involving dense slag and wall, with a ceramic/slag breccia - could equally well be wall foot?

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C92	C180	43

Slag Typ: ceramic;

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: oxidised fired clay, not vitrified

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C92	C155	40; 46

Slag Typ: furnace bottom; flow slag; fines

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: large collection of basal slag fines - coffee bean spheroids, prills, slag fragments, sinter; flow slags amalgamated into "furnace bottom"?; good free flow slags

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C92	C200	52

Slag Typ: furnace bottom; ceramic

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: 4 blocks with a basal crust with tubular vesicles, all possibly fragments from medium sized SHCs; reduced fired furnace lining; wall contact of charcoal-rich slag with a large wood mould; slightly lobate-structured charcoal-rich blocks

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C157	197	53

Slag Typ: flow slag; fines

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: flow slags; assemblage of slag fines, coffee bean spheroids, sinter and small prills

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C157	C198	54

Slag Typ: furnace bottom; flow slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: flow slag; (now broken but probably 1 originally) wall foot? Accumulation of flow slags with large wood moulds (photo); broken up "furnace bottom" and other flow slags

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C56	C201	63

Slag Typ: flow slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: small assemblage of flow slag fragments plus small amount of possible sinter

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C56	C185	61

Slag Typ: flow slag; fines

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: 3 fragments of prill/bleb, 3 possible sinter fragments

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C57	C212	73

Slag Typ: flow slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: flow slag in rather stout prills mainly

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C58	C183	69

Slag Typ: flow slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: rather scrappy assemblage of blebs and flow slags

E2193	Derryvorrigan 1	Laois	C59	C190	48

Slag Typ: flow slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: prilly and blebby slags concreted in ash

E2193	Derryvorrigan 1	Laois	C15	C132	29

Slag Typ: flow slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: 5 flow slag scraps

E2193	Derryvorrigan 1	Laois	C76	C123	

Slag Typ: fines; ceramic

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: 10 fragments of possibly sintery thin sheet, 1 small prill

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C91	C203	58; 59

Slag Typ: slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: scrappy assemblage of small slag blebs, fragments and films; scrappy slag pieces, many lining-related, many in rather flat pieces; rounded concretionary lumps - not clear if slag or iron is inside

E2193	Derryvorrigan 1	Laois	C94	C153	23

Slag Typ: slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: scrappy fragments of vesicular slag

E2193	Derryvorrigan 1	Laois	C16	C121	10

Slag Typ: furnace bottom

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: massive block of flow slag with large wood moulds

E2193	Derryvorrigan 1	Laois	C70	C131	7

Slag Typ: slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: rusty iron slag fragments

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C61	C141	30

Slag Typ: flow slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: flow slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C9	C150	20

Slag Typ: fines

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: spheroids and prill fragments in gravelly residue (wt slag only)

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C84	C211	65; 66

Slag Typ: slag; ore

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: small scraps of mainly grey vesicular slag, not diagnostic; sintery or charcoal rich slags; bog ore particles - very important for any future analysis

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C85	C143	13

Slag Typ: flow slag;

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: flow slag, grading into massive, slightly granular-appearing slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C64	C154	24; 26; 28

Slag Typ: furnace bottom; fines; ceramic

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: vitrified oxidised fired furnace wall; assemblage with coffee bean spheroids and sinter but dominated by small resinous multiple contorted prills; flow slags, but 75% of this material is "furnace bottom"-related

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C169	C169	36

Slag Typ: furnace bottom; flow slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: good flow slag; amalgamated prills and more massive material - presumably from "furnace bottom"

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C169	C170	37

Slag Typ: prills; sinter; fines

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: slag fines including coffee bean spheroids, prills, films and a little sinter

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C65	C218	75; 77

Slag Typ: flow slag; fines

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: mainly sinter fragments, some prill material and one charcoal-rich slag fragment; flow slag; dull slags grading into sinter

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C216	C236	81

Slag Typ: ceramic

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: vitrified lining, largest piece shows change of direction, possibly top of scoop above b/h - but other geometries are possible oxidised ceramic - lots as ground powder

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C216	C237	82

Slag Typ: fines; flow slag

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: flow slag, mainly in rather thick stubby flows, grading into sintery/blebby floor material

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2193	Derryvorrigan 1	Laois	C92	C156	25; 45

Slag Typ: flow slag; fines; sinter; prills

Reference: Young 2008e. Evaluation of Archaeometallurgical residues from the M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2: Derryvorrigan 1

Description: flow slags, with associated lining fragments; slag fines including coffee bean spheroids, prills, films and a little sinter

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E1141	Hardwood 3	Meath	C063	C024	22

Slag Typ: dense slag; porous slag; vitrified lining

Reference: Photos-Jones 2003a. Analysis of metallurgical waste from Hardwood III

Description: 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 3259gm.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E1141	Hardwood 3	Meath	C056	C025	20

Slag Typ: porous slag; drippy slag; vitrified lining

Reference: Photos-Jones 2003a. Analysis of metallurgical waste from Hardwood III

Description: 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

02E1141	Hardwood 3	Meath	C055	C029	16

Slag Typ: fines

Reference: Photos-Jones 2003a. Analysis of metallurgical waste from Hardwood III

Description: Context F029 produced only fines weighing 29gm.

02E1141	Hardwood 3	Meath	C058	C030	17

Slag Typ: dense slag; porous slag; vitrified lining

Reference: Photos-Jones 2003a. Analysis of metallurgical waste from Hardwood III

Description: 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.

02E1141	Hardwood 3	Meath	C063	C060	5

Slag Typ: drippy slag; porous slag; vitrified lining

Reference: Photos-Jones 2003a. Analysis of metallurgical waste from Hardwood III

Description: 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.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1526	Harlockstown 19	Meath	F227	F227	562

Slag Typ: furnace lining

Reference: Photos-Jones 2007b. Site 19: Harlockstown, Co. Meath (03E1526): industrial waste assessment and SEM-EDAX analysis of select samples.

Description: part of furnace/hearth wall. Gradient in colour from orange-yellow to black-orange.

03E1526	Harlockstown 19	Meath	F227	F227	500

Slag Typ: furnace lining

Reference: Photos-Jones 2007b. Site 19: Harlockstown, Co. Meath (03E1526): industrial waste assessment and SEM-EDAX analysis of select samples.

Description: part of furnace/hearth wall. Gradient in colour from orange-yellow to black-orange

03E1526	Harlockstown 19	Meath	F341	F341	567

Slag Typ: furnace lining

Reference: Photos-Jones 2007b. Site 19: Harlockstown, Co. Meath (03E1526): industrial waste assessment and SEM-EDAX analysis of select samples.

Description: part of furnace/hearth wall. Gradient in colour from orange-yellow to black-orange

03E1526	Harlockstown 19	Meath	F036	F036	573

Slag Typ: furnace lining

Reference: Photos-Jones 2007b. Site 19: Harlockstown, Co. Meath (03E1526): industrial waste assessment and SEM-EDAX analysis of select samples.

Description: part of furnace/hearth wall. Gradient in colour from orange-yellow to black-orange.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1526	Harlockstown 19	Meath	F86	F086	528

Slag Typ	dense slag	Reference	Photos-Jones 2007b. Site 19: Harlockstown, Co. Meath (03E1526): industrial waste assessment and SEM-EDAX analysis of select samples.
Description	drippy/clinkery slag - large fragments: dark grey, dense. Small fragments: porous.		

03E1526	Harlockstown 19	Meath	F96	F096	575

Slag Typ	furnace lining	Reference	Photos-Jones 2007b. Site 19: Harlockstown, Co. Meath (03E1526): industrial waste assessment and SEM-EDAX analysis of select samples.
Description	part of furnace/hearth wall. Gradient in colour from orange-yellow to black-orange		

03E1526	Harlockstown 19	Meath	F84	F084	535

Slag Typ	dense slag	Reference	Photos-Jones 2007b. Site 19: Harlockstown, Co. Meath (03E1526): industrial waste assessment and SEM-EDAX analysis of select samples.
Description	dense black slag with fine-medium porosity		

03E1526	Harlockstown 19	Meath	F202	F202	589

Slag Typ	furnace lining	Reference	Photos-Jones 2007b. Site 19: Harlockstown, Co. Meath (03E1526): industrial waste assessment and SEM-EDAX analysis of select samples.
Description	part of furnace/hearth wall. Gradient in colour from orange-yellow to black-orange		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1526	Harlockstown 19	Meath	F216	F216	596

Slag Typ: furnace lining

Reference: Photos-Jones 2007b. Site 19: Harlockstown, Co. Meath (03E1526): industrial waste assessment and SEM-EDAX analysis of select samples.

Description: part of furnace/hearth wall. Gradient in colour from orange-yellow to black-orange

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1526	Harlockstown 19	Meath	F036	F036	583

Slag Typ: furnace lining

Reference: Photos-Jones 2007b. Site 19: Harlockstown, Co. Meath (03E1526): industrial waste assessment and SEM-EDAX analysis of select samples.

Description: part of furnace/hearth wall. Gradient in colour from orange-yellow to black-orange

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1526	Harlockstown 19	Meath	F036	F036	508

Slag Typ: dense slag; furnace lining

Reference: Photos-Jones 2007b. Site 19: Harlockstown, Co. Meath (03E1526): industrial waste assessment and SEM-EDAX analysis of select samples.

Description: 2 x dense slag, 1 x part of furnace/hearth wall. Gradient in colour from orange-yellow to blackorange.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1526	Harlockstown 19	Meath	F82	F082	560

Slag Typ: dense slag; ceramic

Reference: Photos-Jones 2007b. Site 19: Harlockstown, Co. Meath (03E1526): industrial waste assessment and SEM-EDAX analysis of select samples.

Description: dense black slag with fine-medium porosity and evidence of ceramic fabric

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1526	Harlockstown 19	Meath	F220		572

Slag Typ: bloom

Reference: Photos-Jones 2007

Description: Metal, small fragment of a bloom: This is a fragment of a small bloom; the metallic component consists of iron (presumably ferritic or low carbon iron) with traces of phosphorus; analysis of a single slag inclusion within the metal suggests that the ore used was probably bog iron ore. Phosphorus partitions between both the metal and the slag but manganese is to be found primarily within the slag.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E1094	Johnstown 3	Meath	C4	C002	S1

Slag Typ: dense slag; drippy slag

Reference: Photos-Jones 2003f. Kinnegad–Enfield–Kilcock Bypass Contract 2, report on Johnstown 3, Co. Kildare. Slag analysis.

Description: Context C002 (see Figure 1) fill of possible bowl furnace C004 produced three different types
of slag, predominately the drippy type with nine pieces being collected; also fragments of
each of dense crystalline and platy cake types. The total amount of MW from this context is
1602gr.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E1094	Johnstown 3	Meath	C5	C003	S2

Slag Typ: slag

Reference: Photos-Jones 2003f. Kinnegad–Enfield–Kilcock Bypass Contract 2, report on Johnstown 3, Co. Kildare. Slag analysis.

Description:

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E1510	Lisnagar Demesne 1	Cork	C41	C014	

Slag Typ: tap slag; amorphous slag; tuyere; vitrified lining

Reference: Fairburn 2005. Assessment of Industrial Residues from Excavations at Lisnagar Demesne 1, Co. Cork.

Description: tap slag (3000g); amorphous slag (340g); tuyere (40g); vitrified lining (80g)

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num	Slag Typ	Reference	Description
03E1510	Lisnagar Demesne 1	Cork	C27	C029		smithing plano-convex bottom	Fairburn 2005. Assessment of Industrial Residues from Excavations at Lisnagar Demesne 1, Co. Cork.	smithing plano-convex bottom - The Lisnagar Demesne 1 PCB, is a small thin plate of slag and represents material that has accumulated in a very very short time period within the smithing hearth.
03E1510	Lisnagar Demesne 1	Cork	C27	C016		vitrified lining	Fairburn 2005. Assessment of Industrial Residues from Excavations at Lisnagar Demesne 1, Co. Cork.	vitrified clay lining
E2771	Monganstown 1	Westmeath	C47	F47	21	furance slag	Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.	
E2771	Monganstown 1	Westmeath	C40	F39	21	furnace lining	Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.	

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C40	F39	11

Slag Typ: tap slag; slag unreduced; amorphous slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: tap slag; slag unreduced; amorphous slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C40	F39	4

Slag Typ: furance slag; amorphous slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: furance slag; amorphous slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C50	F51	1

Slag Typ: furnace lining; tap slag; amorphous slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: furnace lining; tap slag; amorphous slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C24	F13	17

Slag Typ: furnace slag; amorphous slag; tap slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: furnace slag; amorphous slag; tap slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C40	F39	19

Slag Typ: furnace slag; amorphous slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: furnace slag; amorphous slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C69	C71	23

Slag Typ	amorphous slag	Reference	Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.
Description	amorphous slag		

E2771	Monganstown 1	Westmeath	C66	F68	10

Slag Typ	furnace slag; amorphous slag; tap slag	Reference	Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.
Description	furnace slag; amorphous slag; tap slag		

E2771	Monganstown 1	Westmeath	C45	C56	12

Slag Typ	amorphous slag	Reference	Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.
Description	amorphous slag		

E2771	Monganstown 1	Westmeath	C40	F38	18

Slag Typ	tap slag	Reference	Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.
Description	tap slag		

E2771	Monganstown 1	Westmeath	C45	C55	10

Slag Typ	tap slag; amorphous slag	Reference	Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.
Description	tap slag; amorphous slag		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num	Slag Typ	Reference	Description
E2771	Monganstown 1	Westmeath	C57	F58	24	amorphous slag	Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.	amorphous slag
E2771	Monganstown 1	Westmeath		F42	7	tap slag; amorphous slag	Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.	tap slag; amorphous slag
E2771	Monganstown 1	Westmeath	C2	F1	1	fluid slag; amorphous slag	Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.	fluid slag; amorphous slag
E2771	Monganstown 1	Westmeath	C47	F46	8	furnace slag; amorphous slag; fluid slag	Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.	furnace slag; amorphous slag; fluid slag
E2771	Monganstown 1	Westmeath	C57	F59	25	amorphous slag; tap slag	Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.	amorphous slag; tap slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C52	C53	

Slag Typ: furnace slag; amorphous slag; tap slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: furnace slag; amorphous slag; tap slag

E2771	Monganstown 1	Westmeath	C40	F38	3

Slag Typ: furnace lining; tap slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: furnace lining; tap slag

E2771	Monganstown 1	Westmeath	C60	F61	12

Slag Typ: amorphous slag; tap slag; furnace lining

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: amorphous slag; tap slag; furnace lining

E2771	Monganstown 1	Westmeath	C40	F38	31

Slag Typ: furnace lining

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: furnace lining

E2771	Monganstown 1	Westmeath	C45	C44	11

Slag Typ: furnace lining; furnace slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: furnace lining; furnace slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C2	C4	5

Slag Typ: amorphous slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: amorphous slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C60	F62	9

Slag Typ: tap slag; plano-convex bottom slag cake

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: tap slag; plano-convex bottom slag cake

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C63	F65	15

Slag Typ: tap slag; furnace lining

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: tap slag; furnace lining

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C2	F4	

Slag Typ: furnace lining; amorphous slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: furnace lining; amorphous slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath		A002	17

Slag Typ: furnace lining

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: furnace lining

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C63	F75	14

Slag Typ: tap slag; furnace lining; amorphous

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: tap slag; furnace lining; amorphous

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C23	F22	1

Slag Typ: tap slag; furnace lining; amorphous slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: tap slag; furnace lining; amorphous slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath	C2	F1	2

Slag Typ: fluid slag; furnace lining; amorphous slag; furnace slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: fluid slag; furnace lining; amorphous slag; furnace slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
E2771	Monganstown 1	Westmeath		F41	6

Slag Typ: furnace lining; tap slag

Reference: Fairburn 2006. Assessment of industrial residues from excavations at Monganstown 1.

Description: furnace lining; tap slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E1068	Rossan 6	Meath	F084	F79	6

Slag Typ: furnace wall; porous slag

Reference: Photos-Jones 2003c. Analysis of metallurgical waste from Rossan VI

Description: 6 furnace wall fragments; 1 porous slag;

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E1068	Rossan 6	Meath	F087	F80	10

Slag Typ: vitrified clay; porous slag

Reference: Photos-Jones 2003c. Analysis of metallurgical waste from Rossan VI

Description: 6 partially vitrified clay pieces; porous slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E1068	Rossan 6	Meath	F086	F81	11

Slag Typ: vitrified clay; porous slag

Reference: Photos-Jones 2003c. Analysis of metallurgical waste from Rossan VI

Description: 3 pieces vitrified clay fragments; porous slag

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E1068	Rossan 6	Meath	F084	F82	7

Slag Typ: partially vitrified clay; porous slag

Reference: Photos-Jones 2003c. Analysis of metallurgical waste from Rossan VI

Description: 1 piece partially vitrified clay; 3 pieces porous slag ; 1 pieces

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
02E1068	Rossan 6	Meath	F084	F83	9

Slag Typ: slag

Reference: Photos-Jones 2003c. Analysis of metallurgical waste from Rossan VI

Description: Fragment of manganiferous slag consisting of very fine dendrites of wustite in a predominantly fayalitic-iron silicate- matrix. The interstitial glass is minimal

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0501 AR29	Trantstown AR 29	Cork	F1	C1	

Slag Typ: smelting slag

Reference: Photos-Jones 2003e. Analysis of Metallurgical Waste from N8 Glanmire, Watergrasshill Road Scheme, Site Nos. AR 26 and 29.

Description: The slag is of the black, dense drippy type which gives a clinkery metallic sound when tapped.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0501 AR29	Trantstown AR 29	Cork	F5	C13	

Slag Typ: smelting slag

Reference: Photos-Jones 2003e. Analysis of Metallurgical Waste from N8 Glanmire, Watergrasshill Road Scheme, Site Nos. AR 26 and 29.

Description: The slag
is of the black, dense drippy type which gives a clinkery metallic sound when tapped.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0501 AR29	Trantstown AR 29	Cork	F5	C12	

Slag Typ: smelting slag

Reference: Photos-Jones 2003e. Analysis of Metallurgical Waste from N8 Glanmire, Watergrasshill Road Scheme, Site Nos. AR 26 and 29.

Description: The slag
is of the black, dense drippy type which gives a clinkery metallic sound when tapped.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0501 AR29	Trantstown AR 29	Cork	F5	C13	AR29.1; 9

Slag Typ: smelting slag

Reference: Photos-Jones 2003. Analysis of Metallurgical Waste from N8 Glanmire, Watergrasshill Road Scheme, Site Nos. AR 26 & AR 29.

Description: SEM-BS images at low
(Figure 4c) and high magnification (Figure 4d) show nicely formed long needles of fayalite with angular grains of hercynite and interstitial glass. Dendrites of iron oxide are relatively absent. The composition of fayalite and glass denotes manganese-rich slag which must have derived from a bog iron source. Manganese occurs in the form of manganese oxide nodules associated with iron oxy-hydroxide which are of noncrystalline
form of iron oxide.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0501 AR29	Trantstown AR 29	Cork	F5	C12	AR29.2; 8

Slag Typ: smelting slag

Reference: Photos-Jones 2003. Analysis of Metallurgical Waste from N8 Glanmire, Watergrasshill Road Scheme, Site Nos. AR 26 & AR 29.

Description: The sample is characterised by the presence of long needles of fayalite with limited presence of dendrites of wustite, remnants of metallic iron and very small prills thereof. Extensive evidence for weathering at places is seen in the glassy phase, the fayalite and the iron oxide.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0501 AR29	Trantstown AR 29	Cork	F5	C12	AR29.3; 8

Slag Typ: smelting slag

Reference: Photos-Jones 2003. Analysis of Metallurgical Waste from N8 Glanmire, Watergrasshill Road Scheme, Site Nos. AR 26 & AR 29.

Description: This is primarily a fayalitic slag with fully grown needles of the said mineral. There is little wustite and interstitial glass. It is extensively weathered at the edges and also at the centre. Grain growth suggests slow cooling rates.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
01E0501 AR29	Trantstown AR 29	Cork	F1	C1	AR29.4; 7

Slag Typ: smelting slag

Reference: Photos-Jones 2003. Analysis of Metallurgical Waste from N8 Glanmire, Watergrasshill Road Scheme, Site Nos. AR 26 & AR 29.

Description: The sample has elongated grains of fayalite in the absence of metallic prills and with relatively little amounts of interstitial glass. The sample has also extensive evidence for hercynite.

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E0966	Site B, Ballydavis	Laois	C015	C016	2

Slag Typ	Dense prills; smelting slag; tap-slag	Reference	Young 2012a. Evaluation of archaeometallurgical residues from the M7 Heath-Mayfield Motorway Scheme: Site B (03E0966), Ballydavis, Co. Laois
Description	820g dense prills 127 pieces, 700g 12 pieces of floor flow-lobed material, looks like tap slag, but generally rather dull, at least one piece shows flow around moderately coarse charcoal. 34g dull irregular nub of dark slag with charcoal inclusions. All slags dense and dark. Some of the basal flows show sourcing in a central drip with radiating outward flows in one case at least, and of stacked lobes on basal obstacle in another.		

Site Licence Nu	Site Name	County	Feature	Context Num	Sample Num
03E0966	Site B, Ballydavis	Laois	C017	C018	1

Slag Typ	smelting slag	Reference	Young 2012a. Evaluation of archaeometallurgical residues from the M7 Heath-Mayfield Motorway Scheme: Site B (03E0966), Ballydavis, Co. Laois
Description	152g downwall flow with lobed wrinkly base, 66g flow lobe from furnace floor		

Appendix C: Radiocarbon Dates

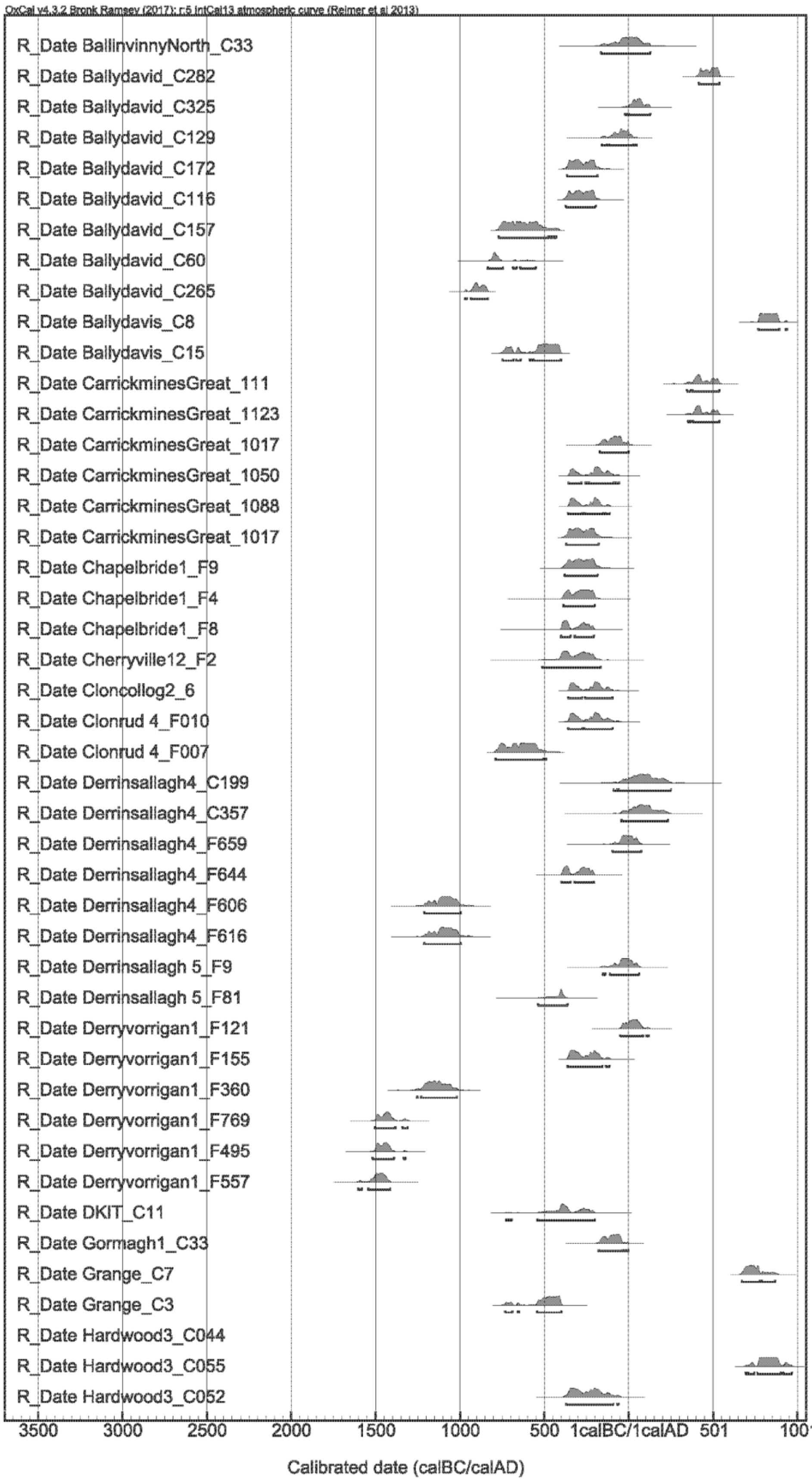
Table Appendix C.1 All radiocarbon dates recovered from the 35 sites used in this dissertation.

Context/Name	BP	±	Feature Type	Sample Material	Company
BallinvinnyNorth_C33	1990	60	Furnace(unknown)	Charcoal	University of Groningen
Ballydavid_C116	2209	31		Charcoal, prunus	14CHRONO Centre
Ballydavid_C129	2038	30		Charcoal, hazel	14CHRONO Centre
Ballydavid_C157	2474	30	Furnace(slagpit)	Charcoal, promoideae	14CHRONO Centre
Ballydavid_C172	2199	30	Furnace(unknown)	Charcoal, oak brushwood	14CHRONO Centre
Ballydavid_C265	2755	20		Charcoal, hazel	14CHRONO Centre
Ballydavid_C282	1587	22		Barly grain	14CHRONO Centre
Ballydavid_C325	1946	30		Charcoal, hazel	14CHRONO Centre
Ballydavid_C60	2596	42		Animal bone	14CHRONO Centre
Ballydavis_C15	2424	31	Furnace(slagpit)	Charcoal, oak	14CHRONO Centre
Ballydavis_C8	1188	24		Charcoal, hazel	14CHRONO Centre
CarrickminesGreat_1017	2200	35		Charred sloe twig	N/A
CarrickminesGreat_1017	2065	30		Single charred wheat grain	N/A
CarrickminesGreat_1050	2150	35		Charred sloe twig	N/A
CarrickminesGreat_1088	2165	30	Furnace(slagpit)	Charcoal, oak	N/A
CarrickminesGreat_111	1625	35		Human femur	N/A
CarrickminesGreat_1123	1625	30		Charred bark	N/A
Chapelbride1_F4	2230	40		Charcoal, oak	Beta Analytic
Chapelbride1_F8	2270	40	Hearth	Charcoal, oak	Beta Analytic
Chapelbride1_F9	2210	40		Charcoal, oak	Beta Analytic
Cherryville12_F2	2271	67	Furnace(slagpit)	Charcoal, alder	The University of Waikato
Cloncollog2_6	2158	34	Furnace(slagpit)	Charcoal, oak	14CHRONO Centre
Clonrud 4_F007	2495	35	Furnace(slagpit)	Oak	SUERC
Clonrud 4_F010	2160	35	Furnace(slagpit)	Willow	SUERC
Derrinsallagh 5_F81	2345	35	Furnace(slagpit)	Oak	SUERC
Derrinsallagh 5_F9	2020	35		Ash and hazel	SUERC
Derrinsallagh4_C199	1920	70	Furnace(unknown)	Charred material	SUERC
Derrinsallagh4_C357	1920	60	Furnace(unknown)	Charred material	SUERC
Derrinsallagh4_F606	2900	35		Pomoideae/hazel/ash/alder	SUERC
Derrinsallagh4_F616	2900	35		Elm	SUERC
Derrinsallagh4_F644	2255	35		Ash	SUERC
Derrinsallagh4_F659	2005	35	Furnace(slagpit)	Ash	SUERC
Derryvorrigan1_F121	1975	35		Charcoal, alder and hazel	SUERC
Derryvorrigan1_F155	2175	35		Charcoal, oak	SUERC
Derryvorrigan1_F360	2935	35		Charcoal, ash	SUERC
Derryvorrigan1_F495	3175	35		Charcoal, alder	SUERC
Derryvorrigan1_F557	3210	35		Charcoal, alder	SUERC

Derryvorrigan1_F769	3160	35		Charcoal, ash and hazel	SUERC
DKIT_C11	2310	60	Furnace(unknown)	Charred material	Beta Analytic
Gormagh1_C33	2076	27		Hazelnut shell	14CHRONO Centre
Grange_C3	2403	30	Furnace(slagpit)	Charcoal	14CHRONO Centre
Grange_C7	1256	32		Charcoal	14CHRONO Centre
Hardwood3_C044	360	40		N/A	Beta Analytic
Hardwood3_C052	2170	50		N/A	Beta Analytic
Hardwood3_C055	1190	40		N/A	Beta Analytic
Harlockstown_C147	3799	33		Ash, pom. + alder	The University of Waikato
Harlockstown_C211	1376	31		Pig metacarpal	The University of Waikato
Harlockstown_C231	1527	64		Cattle metacarpal	The University of Waikato
Harlockstown_C265	2106	29		Pomoidea	The University of Waikato
Harlockstown_C267	1408	75		Left distal cattle humerus	The University of Waikato
Harlockstown_C278	1583	33		Blackthorn	The University of Waikato
Harlockstown_C322	1184	54		Cattle metacarpal - fused (right)	The University of Waikato
Harlockstown_C355	3515	45		Charcoal	The University of Waikato
Harlockstown_C359	3620	41		Cattle scapula	The University of Waikato
Harlockstown_C379	2238	50		Alder + bark	The University of Waikato
Harlockstown_C380	2588	49		Blackthorn	The University of Waikato
Harlockstown_C482	1273	63		Cattle scapula	The University of Waikato
Harlockstown_C519	3599	36		Human bone	The University of Waikato
Harlockstown_C527	1984	31		Cattle pre molar	The University of Waikato
Harlockstown_C53	2315	32		Hazel, blackthorn twigs	The University of Waikato
Harlockstown_C583	2000	44		Cattle scapula	The University of Waikato
Harlockstown_C587	2057	40		Charcoal	The University of Waikato
Harlockstown_C97	1987	42	Furnace(unknown)	N/A	The University of Waikato
Johnstown3_C5	2320	50	Furnace(unknown)	N/A	Beta Analytic
Kilrussane_F2	2120	40	Furnace(slagpit)	Charcoal, oak	University of Groningen
Kilrussane_F5	2120	40		Charcoal, oak	University of Groningen
Kinnegad2_F012	Calibrated date: 820 - 410 cal BCE. Could not get radiocarbon report				
Kinnegad2_F025	Calibrated date: 400-340 BCE. Furnace(slagpit) Could not get radiocarbon report				
Kinnegad2_F025	Calibrated date: 320-210 BCE Furnace(slagpit) Could not get radiocarbon report				
Knockcommane_F4	2199	34	Furnace(slagpit)	Charcoal hazel	14CHRONO Centre
Knockcommane_F9	2138	44		Charcoal hazel	14CHRONO Centre
Lagavooren7_C140	2355	30	Furnace(slagpit)	Charcoal, hazel	SUERC

Lagavooren7_C184	3415	30		Burnt bone	SUERC
Lagavooren7_C21	3215	30		Charcoal, promoideae	SUERC
Lagavooren7_C269	3155	30		Charcoal, ash	SUERC
Lagavooren7_C276	4205	30		Burnt bone	SUERC
Lagavooren7_C317	3470	30		Animal bone, Cow molar	SUERC
Lagavooren7_C345	4050	30		Burnt bone	SUERC
Lagavooren7_C363	4005	30		Burnt bone	SUERC
Lagavooren7_C401	2950	30		Wood, hazel -ten years old	SUERC
Leap1_F003	2075	35		Alder	SUERC
Leap1_F004	2205	35		Oak	SUERC
Leap1_F006	1975	35		Alder	SUERC
LisnagarDemesne_C13	2050	60		Charred material	Beta Analytic
LisnagarDemesne_C14	2210	60		Charred material	Beta Analytic
LisnagarDemesne_C58	2860	80		Charred material	Beta Analytic
Lughil_F22	2390	30	Furnace(unknown)	Oak	Poznań
Monganstown1_C1	2110	31		Charcoal, oak	14CHRONO Centre
Monganstown1_C13	1056	30		Charcoal, oak	14CHRONO Centre
Monganstown1_C14	1050	29		Charcoal, oak	14CHRONO Centre
Monganstown1_C39	2168	31	Furnace(arched slagpit)	Charcoal, diffuse-porous	14CHRONO Centre
Morett_C14	2170	35		Charcoal, oak	SUERC
Morett_C157	2480	35		Charcoal, oak	SUERC
Morett_C295	1605	35		Charcoal, hazel	SUERC
Morett_C334	2270	35		Charcoal, oak	SUERC
Morett_C340	1535	35		Human bone, femur, rib	SUERC
Morett_C37	2045	35		Charcoal, hazel and oak	SUERC
Morett_C385	4120	35		Charcoal, oak	SUERC
Morett_C392	1580	35		Charcoal, hazel	SUERC
Morett_C55	1540	35		Human bone, rib, femur	SUERC
Morett_C77	4105	35		Charcoal, oak	SUERC
Moyally2_C10	2090	40		Oak	Beta Analytic
Moyally2_C7	2076	24	Furnace(arched slagpit)	Oak brushwood	Beta Analytic
Moyvalley1_C016	2080	70	Hearth	N/A	Beta Analytic
Mullagh_F6	Calibrated date: 409-386 BCE. Furnace(slagpit). Could not get radiocarbon report				
Newrath_35046	4827	39		N/A	14CHRONO Centre
Newrath_35050	Calibrated date: 351-312; 294-209 BCE Furnace(slagpit)				
Newrath_35053	Calibrated date: 397-348; 316-207 BCE. Furnace(unknown)				
Newrath_35072	5669	40		N/A	14CHRONO Centre
Newrath_35085	4821	38		N/A	14CHRONO Centre
Parksgrove_C8	2360	45	Hearth	N/A	N/A
Rath Site 27_F10	1029	36		Hazel, blackthorn and ash	The University of Waikato
Rath Site 27_F1105	2203	36		Wood	The University of Waikato

Rath Site 27_F1105	2217	36		Wood	The University of Waikato
Rath Site 27_F1112	2403	61		Blackthorn	The University of Waikato
Rath Site 27_F1258	2190	35		Wood	The University of Waikato
Rath Site 27_F24	2716	38		Oak	The University of Waikato
Rath Site 27_F30	2353	41		Charcoal	The University of Waikato
Rath Site 27_F346	2170	32		Charcoal	The University of Waikato
Rath Site 27_F380	2812	31		Blackthorn	The University of Waikato
Rath Site 27_F619	2534	31		Prunus (cherry/plum type)	The University of Waikato
Rath Site 27_F911	2897	53		Alder	The University of Waikato
Rath Site 27_F98	1985	28	Furnace(unknown)	Alder	The University of Waikato
Rossan6_F087	Calibrated date: 820-780 BCE. Hearth. Could not get radiocarbon report				
Tara_F33	2170	40		Bone	N/A
Tara_F38	2090	60	Hearth	Charcoal, oak	N/A
Trantstown_F5	2220	40	Furnace(slagpit)	Charcoal, oak	University of Groningen


OxCal v4.3.2 Bronk Ramsey (2017); r:5 IntCal13 atmospheric curve (Reimer et al 2013)
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R_Date Ballydavid_C129
R_Date Ballydavid_C172
R_Date Ballydavid_C116
R_Date Ballydavid_C157
R_Date Ballydavid_C60
R_Date Ballydavid_C265
R_Date Ballydavis_C8
R_Date Ballydavis_C15
R_Date CarrickminesGreat_111
R_Date CarrickminesGreat_1123
R_Date CarrickminesGreat_1017
R_Date CarrickminesGreat_1050
R_Date CarrickminesGreat_1088
R_Date CarrickminesGreat_1017
R_Date Chapelbride1_F9
R_Date Chapelbride1_F4
R_Date Chapelbride1_F8
R_Date Cherryville12_F2
R_Date Cloncollog2_6
R_Date Clonrud 4_F010
R_Date Clonrud 4_F007
R_Date Derrinsallagh4_C199
R_Date Derrinsallagh4_C357
R_Date Derrinsallagh4_F659
R_Date Derrinsallagh4_F644
R_Date Derrinsallagh4_F606
R_Date Derrinsallagh4_F616
R_Date Derrinsallagh 5_F9
R_Date Derrinsallagh 5_F81
R_Date Derryvorrigan1_F121
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R_Date Derryvorrigan1_F360
R_Date Derryvorrigan1_F769
R_Date Derryvorrigan1_F495
R_Date Derryvorrigan1_F557
R_Date DKIT_C11
R_Date Gormagh1_C33
R_Date Grange_C7
R_Date Grange_C3
R_Date Hardwood3_C044
R_Date Hardwood3_C055
R_Date Hardwood3_C052
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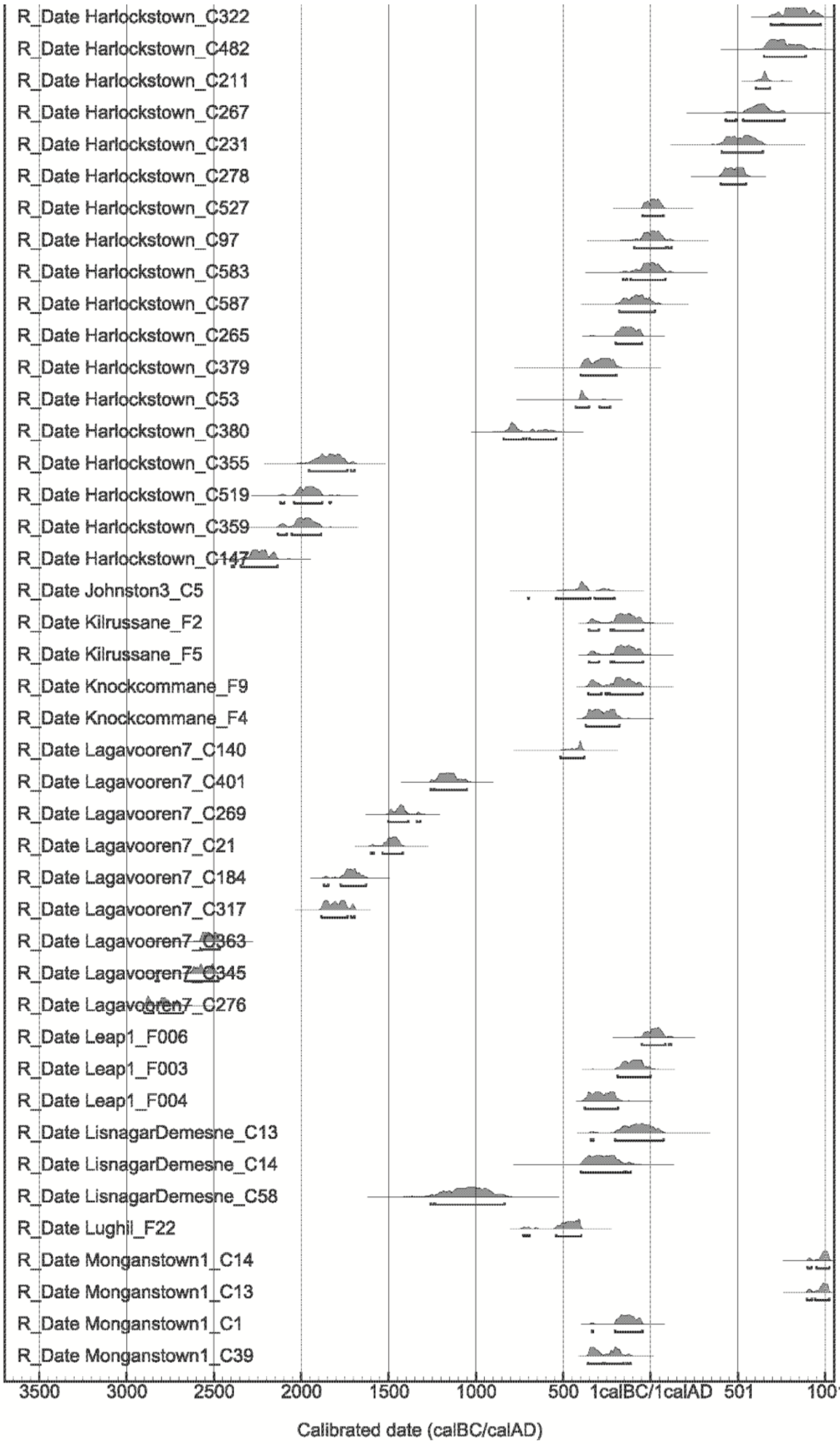
2500
2000
1500
1000
500
1calBC/1calAD
501
1001
Calibrated date (calBC/calAD)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R_Date Harlockstown_C267
R_Date Harlockstown_C231
R_Date Harlockstown_C278
R_Date Harlockstown_C527
R_Date Harlockstown_C97
R_Date Harlockstown_C583
R_Date Harlockstown_C587
R_Date Harlockstown_C265
R_Date Harlockstown_C379
R_Date Harlockstown_C53
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R_Date Johnston3_C5
R_Date Kilrussane_F2
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R_Date Knockcommane_F9
R_Date Knockcommane_F4
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R_Date Lagavooren7_C345
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R_Date Leap1_F003
R_Date Leap1_F004
R_Date LisnagarDemesne_C13
R_Date LisnagarDemesne_C14
R_Date LisnagarDemesne_C58
R_Date Lughil_F22
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Calibrated date (calBC/calAD)

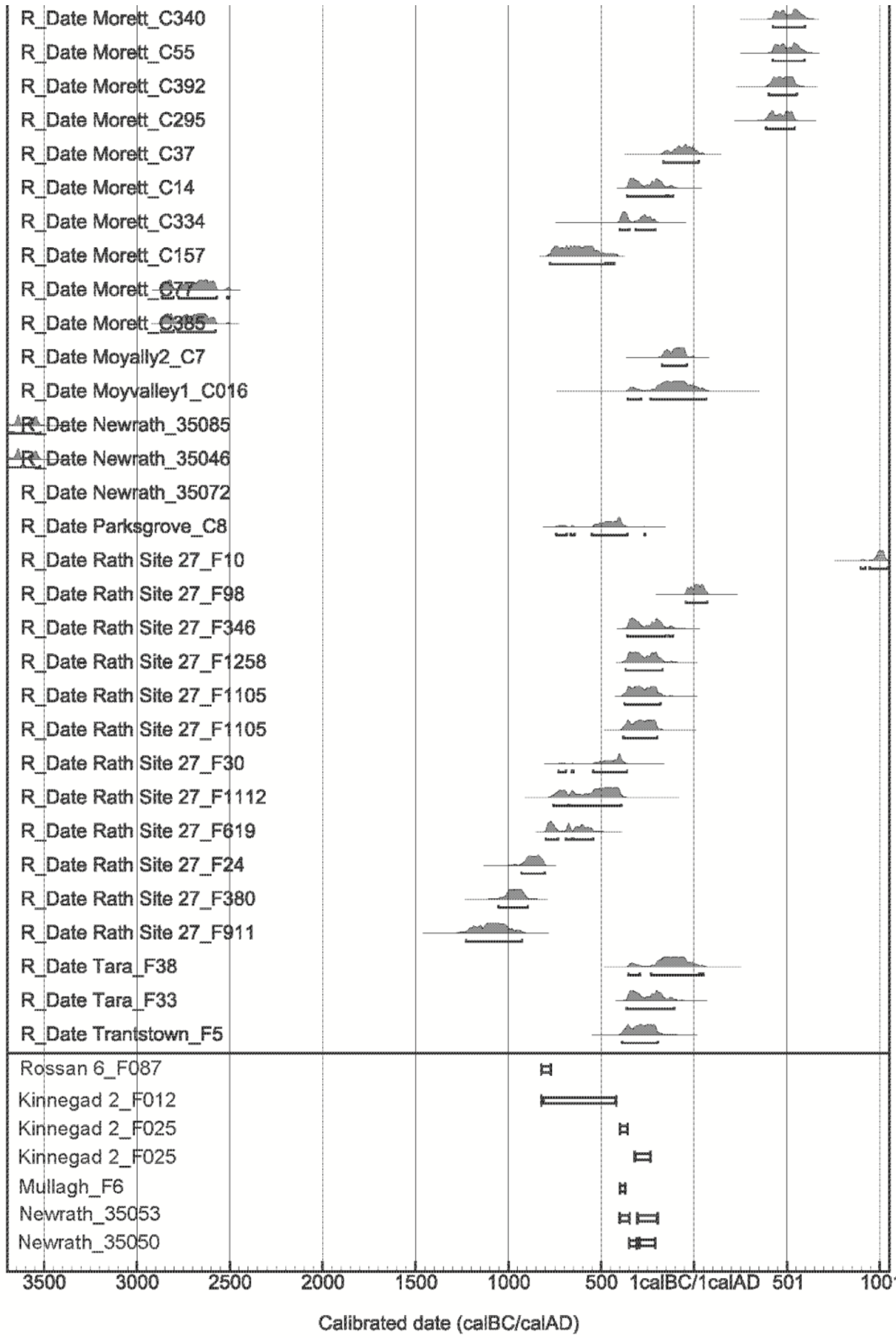
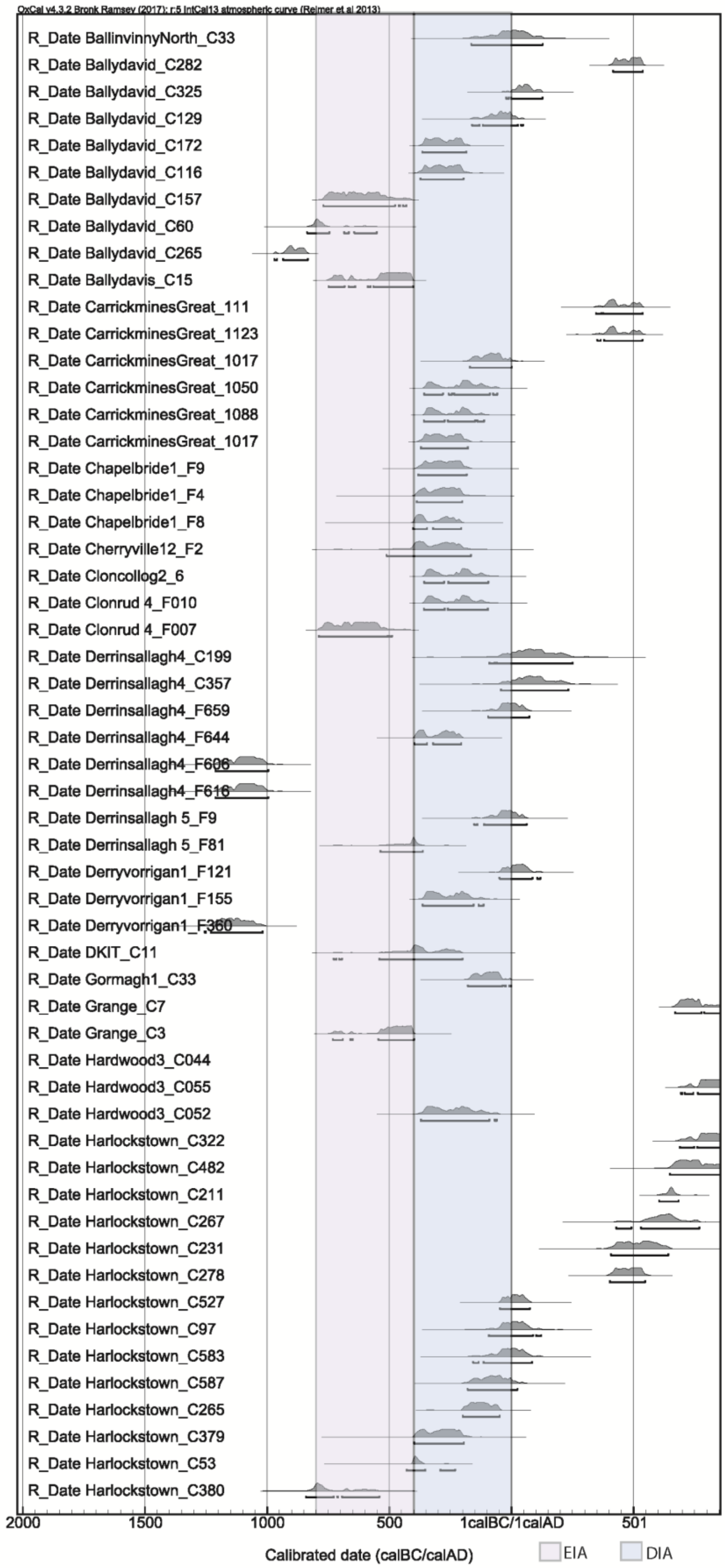


Figure Appendix C.1 All radiocarbon dates recovered from the dissertation ironworking sites, all calibrated using OxCal v4.3.2 IntCal13. Bottom section includes calibrated dates not processed by the author.


OxCal v4.3.2 Bronk Ramsey (2017); r:5 IntCal13 atmospheric curve (Reimer et al 2013)
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R_Date Ballydavid_C325
R_Date Ballydavid_C129
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R_Date Ballydavid_C157
R_Date Ballydavid_C60
R_Date Ballydavid_C265
R_Date Ballydavis_C15
R_Date CarrickminesGreat_111
R_Date CarrickminesGreat_1123
R_Date CarrickminesGreat_1017
R_Date CarrickminesGreat_1050
R_Date CarrickminesGreat_1088
R_Date CarrickminesGreat_1017
R_Date Chapelbride1_F9
R_Date Chapelbride1_F4
R_Date Chapelbride1_F8
R_Date Cherryville12_F2
R_Date Cloncollog2_6
R_Date Clonrud 4_F010
R_Date Clonrud 4_F007
R_Date Derrinsallagh4_C199
R_Date Derrinsallagh4_C357
R_Date Derrinsallagh4_F659
R_Date Derrinsallagh4_F644
R_Date Derrinsallagh4_F606
R_Date Derrinsallagh4_F616
R_Date Derrinsallagh 5_F9
R_Date Derrinsallagh 5_F81
R_Date Derryvorrigan1_F121
R_Date Derryvorrigan1_F155
R_Date Derryvorrigan1_F360
R_Date DKIT_C11
R_Date Gormagh1_C33
R_Date Grange_C7
R_Date Grange_C3
R_Date Hardwood3_C044
R_Date Hardwood3_C055
R_Date Hardwood3_C052
R_Date Harlockstown_C322
R_Date Harlockstown_C482
R_Date Harlockstown_C211
R_Date Harlockstown_C267
R_Date Harlockstown_C231
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R_Date Harlockstown_C527
R_Date Harlockstown_C97
R_Date Harlockstown_C583
R_Date Harlockstown_C587
R_Date Harlockstown_C265
R_Date Harlockstown_C379
R_Date Harlockstown_C53
R_Date Harlockstown_C380
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1500
1000
500
1calBC/1calAD
501
Calibrated date (calBC/calAD)
EIA
DIA

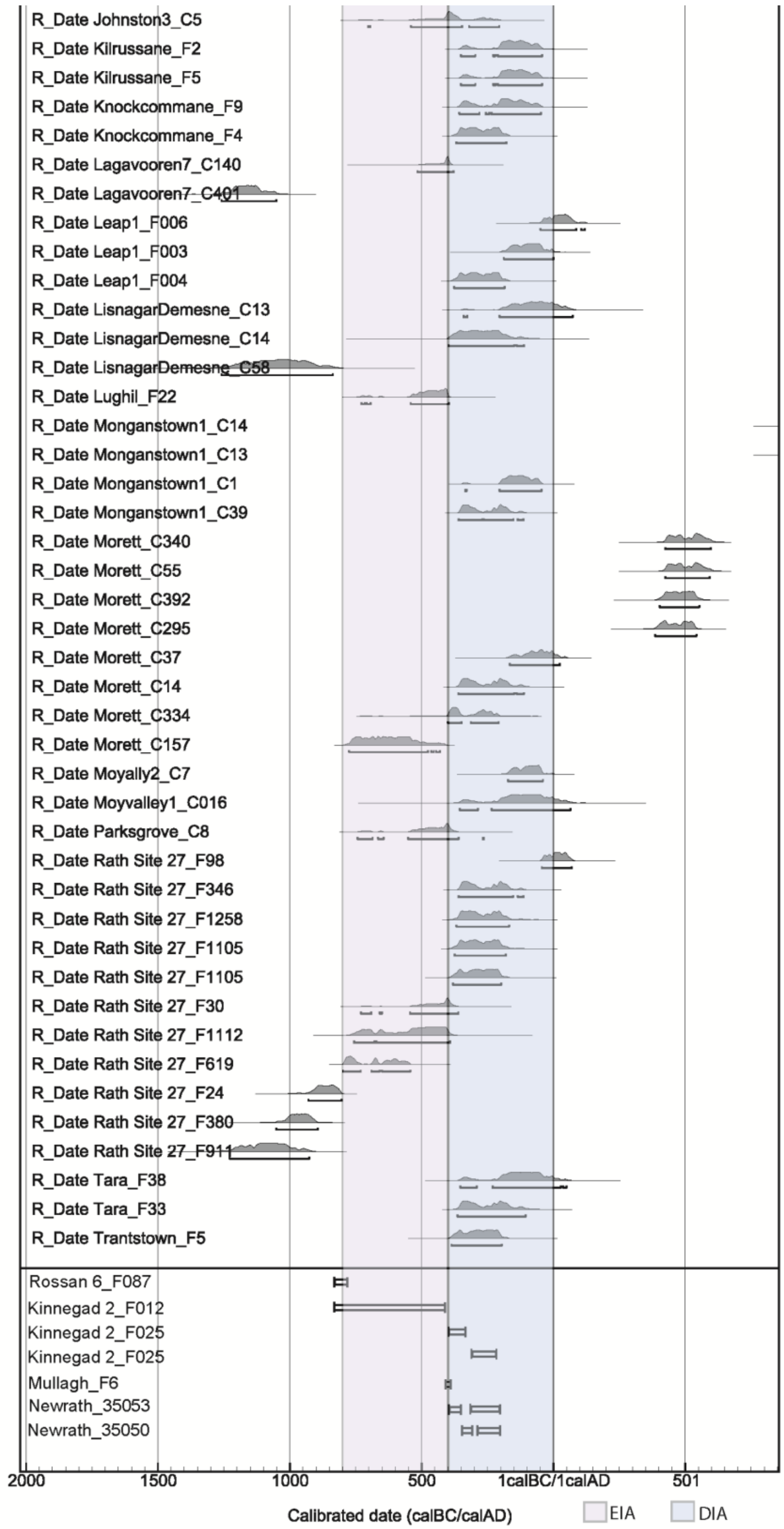

Figure Appendix C.2 Iron Age dates from dissertation ironworking sites, all calibrated using OxCal v4.3.2 IntCal13. Bottom section includes calibrated dates not processed by the author.

Kevin J. Garstki

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Curriculum Vita

Education

University of Wisconsin, Milwaukee May 2017

Ph.D. Archaeology/Anthropology

Dissertation: *Production and Technological Change: Ironworking in Prehistoric Ireland*

University of Chicago June 2009

Master of the Arts in the Program of Social Science

Thesis*: Society and the Sword: Analysis of Bronze and Iron Sword Production as a part of the Social Organization in Ireland*

University of Illinois at Urbana-Champaign May 2008

Bachelor of Arts, College of Liberal Arts and Science

Major in Anthropology, Focus in Archaeology

Major in Religious Studies, Focus in Religion and Culture

Publications

Single Authored:

Garstki, Kevin
Forthcoming. Virtual Authority and the Expanding Role of 3D Digital Artefacts. In *Authenticity and Cultural Heritage in the Age of 3D Digital Reproductions*, P. Di Giuseppantonio Di Franco, F. Galeazzi, and V. Vassallo, eds. Cambridge University Press.

Garstki, Kevin
2016. Virtual Representation: The Production of 3D Digital Artifacts. *Journal of Archaeological Method and Theory*. DOI 10.1007/s10816-016-9285-z

Garstki, Kevin
2016. Assembling the Ironsmith. In *Incomplete Archaeologies: Assembling Knowledge in the Past and Present*, E. M. Bonney, K. J. Franklin, and J. A. Johnson, eds. Oxbow Books. Pp. 98-114

Co-Authored:

Counts, Derek B., Averett, Erin W., and Kevin Garstki.
2016. 3D Artifact Modeling and Customized Structured Light Scanning at Athienou-*Malloura*, Cyprus. *Antiquity*. 90(349): 206-218.

Garstki, Kevin, Bettina Arnold, and Matthew Murray
2015. Reconstituting Community: 3D Visualization and Early Iron Age Social Organization on the Heuneburg Mortuary Landscape. *Journal of Archaeological Science*.54: 23-30.

Commentaries:
Garstki, Kevin
Forthcoming. Representation vs. Reproduction, Recording vs. Interpretation, Comment on "3D Virtual Replicas and Simulations of the Past: 'Real' or 'Fake' Representations?" by Fabrizio Galeazzi. *Current Anthropology*.

Book Reviews:
2012 *e-Keltoi: Journal of Interdisciplinary Celtic Studies Book Reviews* 43-47.
Celtic from the West: Alternative perspectives from archaeology, genetics, language and Literature. Edited by Barry Cunliffe and John T. Koch. Oxbow Books 2010.
http://www4.uwm.edu/celtic/ekeltoi/bookreviews/vol01/pdf/garstki09.pdf

Submitted:
(with Marcus Schulenburg) The Practical Application of Photogrammetry for Field Documentation in an American Midwestern Context. *Advances in Archaeological Practice.*

Conference Presentations

Invited Sessions:
Kevin Garstki. *Producing Knowledge Through the Production of 3D Digital Artifacts.* In Archaeological Epistemology in the Digital Age. Society of American Archaeology Annual Meeting. March 2017. Vancouver, Canada.

Kevin Garstki. *Assembling the Ironsmith in Irish Prehistory* European Association of Archaeologists Annual Meeting. September 2013. Pilsen, Czech Republic.

Single Authored:
Virtual Authenticity: The Materiality of 3D Digital Artifacts. European Association of Archaeologists Annual Meeting. September 2015. Glasgow, U.K.

From the Physical to the Social: Iron as a technological enabler. European Association of Archaeologists Annual Meeting. September 2014. Istanbul, Turkey.

Technologies of Change: Iron and Transitioning Societies in Ireland European Association of Archaeologists Annual Meeting. September 2013. Pilsen, Czech Republic.

On the Boundaries of Society: The Ironsmith in Ireland Second City Anthropology Conference. March 2013. Chicago, Illinois.

The practice of power: reassessing the Irish Late Bronze and Iron Ages Theoretical Archaeological Group. May 2012. Buffalo, New York.

Sacred capital in Ireland: construction and maintenance of power in the face of changing metal technologies. UWM Anthropology Student Union Colloquium. May 2011. Milwaukee, Wisconsin.

Co-Authored:
Kevin J. Garstki, Derek B. Counts, Erin W. Averett, and Michael K. Toumazou. *From Scanner to Scholar: Updates on the Athienou Archaeological Project's Adventures in 3D Scanning.* 35th Annual CAARI Archaeological Workshop. July 2016. Nicosia, Cyprus.

Erin Walcek Averett, Derek Counts, and Kevin Garstki. *(Re)Constructing Antiquity: 3D Modeling and Cypriot Votive Sculpture from Athienou-Malloura, Cyprus*. AAR/SBL/ASOR Rocky Mountain-Great Plains Regional Meeting. March 2015. Omaha, Nebraska.

Bettina Arnold, Kevin Garstki, and Matthew Murray *Reconstituting Community: ArcGIS and Early Iron Age Social Organization in the Heuneburg Mortuary Landscape* European Association of Archaeologists Annual Meeting. September 2013. Pilsen, Czech Republic.

Matthew Terry and Kevin Garstki. *New insights into East St. Louis storage structures*. Midwest Archaeological Conference. October 2010. Bloomington, Indiana.

Posters:
Erin W. Averett, Derek B. Counts, Kevin Garstki, Adam Whidden, Qing Zhang, Bo Fu, Brent Seales, Ruigang Yang, Caitlyn Ewers, and Michael K. Toumazou. (*Re)Constructing Antiquity: 3D Modeling and Cypriot Votive Sculpture from Athienou-Malloura, Cyprus*. American Institute of Archaeology Annual Meeting. January 2015. New Orleans, Louisiana.

Teaching Experience

University of Wisconsin-Milwaukee
Biological Sciences 202: Anatomy and Physiology 1
Teaching Assistant (2 Sections per semester) Fall 2013-Fall 2014; Fall 2015- Spring 2016

Anthropology 568: Introduction to Anthropological Statistics
Teaching Assistant Spring 2013

Anthropology 568: Introduction to Anthropological Statistics
Primary Instructor Fall 2012

Anthropology 101: Human Origins
Teaching Assistant (3 Sections per semester) Fall 2010 - Spring 2012 (4 semesters)

Archaeological Experience

Athienou Archaeological Program June 2012 - Present
Davidson College (Athienou, Cyprus)
Senior Staff

Historic Resource Management Services August 2011-2015
University of Wisconsin-Milwaukee
Field Technician

Czech Republic Institute of Archaeology Mušov Excavation June 2011-July 2011
Field Technician

Illinois State Archaeological Survey January 2010-August 2010
Crew Chief

Illinois State Archaeological Survey August 2009-January 2010
Field and Lab Technician

National University of Ireland at Galway June 2007-July 2007
Achill Archaeological Field School, County Mayo, Ireland
Student

Related Work and Research

UWM RGI-Funded Project: From Scanner to Scholar: The Publication of 3D Models in the Digital Age July 2016-June 2017
Research Assistant

American Journal of Archaeology, Book Reviews September 2015-October 2016
Editorial Assistant

(Re)Constructing Antiquity: 3D Modeling the Terracotta Figurines from Athienou-*Malloura*, Cyprus 2014, 2015
Research Assistant

A Landscape of Ancestors: The Heuneburg Archaeological Project Fall 2012-Present
Digital and Imaging Coordinator

e-Keltoi: Journal of Interdisciplinary Celtic Studies Fall 2012-Present
Book Reviews Editor

University of Chicago February 2009-May 2009
St. Antoine's Garden Assemblage Lab Analysis
Lab Technician

University of Illinois at Urbana-Champaign August 2007-May 2008
Spurlock Museum Seal Project: An Inscriptifact Project
Research Assistant

Invited Talks/Lectures

"An Age of 'Digital Surrogacy'?: Archaeology and 3D Visualization"
Guest Lecture for UWM ARTHIST 710 March 2017

UWM Graduate Student Anthropology Workshop
An Introduction to 3D Modeling and Scanning in Archaeology:
Uses in the Field and Lab, and Concerns for the Future. March 2016

Athienou Archaeological Project Field School Lecture
Statistics in Archaeology; 3D Visualization in Archaeology Summer 2013;2015

UWM Celtic Studies 133: Celtic Crossings
Guest Lecture September 2011

Service

UWM Anthropology Student Union Fall 2012-Fall 2013
President

UWM Anthropology Student Union Fall 2011-Spring 2012
Newsletter Editor

UWM Anthropology Department Fall 2011-Spring 2012
Monthly Colloquium Organizer

Scholastic Honors, Grants, and Awards

Alternate – Fulbright US Student Program (Ireland)
Shamrock Club of Wisconsin Scholarship 2012
UWM Anthropology Chancellor's Graduate Student Awards 2010-2012

Professional Associations

Archaeological Institute of America
European Association of Archaeologists
Prehistoric Society
Society of American Archaeology