KEVIN GARSTKI

THE SOCIAL PRODUCTION OF IRON IN FIRST MILLENNIUM BC IRELAND

Summary. *Archaeological data available for reconstructing the Irish Iron Age have expanded rapidly due to the large number of excavations conducted in recent decades as part of large infrastructure projects. This article interprets iron-production sites dating to the first millennium BC, many of which were discovered as part of those projects, as representing discrete but overlapping communities of ironworking practice. Through a synthesis of recent excavation data, I outline the evidence for different modes of iron production that range from very small scale to ironworking specialists attached to high-status persons. Developing a socially-driven reconstruction of this technology provides insight into various aspects of Iron Age society as embedded in local, regional, and pan-regional communities.*

INTRODUCTION

The Iron Age in Ireland has historically been a period of uncertainty. The paucity of well-dated sites, the apparent absence of pottery, and the minimal burial evidence presented archaeologists with a larger question than the evidence could answer: where were the people in the Iron Age? While a significant corpus of indigenously produced Iron Age material has been known for some time (Raftery 1983; 1984), the absence of secure provenience for most of the objects meant their use in reconstructing the larger temporal or spatial landscape of the Irish Iron Age was limited. What has changed is a major influx of archaeological data from infrastructure projects of the late 1990s and mid-2000s, bolstered by an ambitious program of radiocarbon dating, which has shed light on Iron Age peoples in Ireland. The large number of ^{14}C dates generated during this period drastically changed the way that the prehistoric record could be interpreted (Becker *et al*. 2011; Armit *et al*. 2013; 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. Several works in the past decade have used these new data to address various aspects of early iron production in Ireland (Carlin 2008; Wallace and Anguilano 2010; Photos-Jones and Hall 2011; Dolan 2012; 2014; 2016; Garstki 2017). Additionally, several sites excavated through National Roads Authority projects (now the Transport Infrastructure Ireland) have been preliminarily analysed by consulting companies such as GeoArch and Scottish Analytical Service for Art and Archaeology, among others (e.g. Fairburn 2005; 2006; Cosham 2009; Keys 2010; Rondelez

OXFORD JOURNAL OF ARCHAEOLOGY 38(4) 443–463 2019

2014). The data now available for iron smelting, and to a lesser extent smithing, are allowing us to construct plausible scenarios for the role of iron production in broader Iron Age society.

This article proposes one way to view iron production during the Early Iron Age (EIA) and Developed Iron Age (DIA) in Ireland(Table 1), as a part of numerous overlapping yet distinct communities of practice, with different knowledge bases and traditions. As the settlement and production data now stand, it appears there were at least three iron-producing communities: from very small-scale household level production, to full-time smiths working to service the iron needs of a regional community, to attached specialists who may have also engaged in other pyrotechnic work like bronze and glass production. The recent excavation data for iron production sites are situated in contexts involving other aspects of Iron Age life. The production of iron objects did not occur in isolation, but was rather embedded within a network of social production that included archaeologically less visible activities such as ore acquisition and charcoal production. By identifying the different contexts in which iron ore was smelted and later turned into finished iron objects, it is possible to gain insight into the ways people were sharing technical knowledge, which also provides a glimpse into the broader organization of Iron Age society.

EARLY AND DEVELOPED IRON AGE IN IRELAND

The transition from the Late Bronze Age (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 archaeological evidence, typified by the absence of ceramics (Raftery 1994; 1995). This phenomenon may actually be due to a lack of distinguishable wares that has resulted in mis-dating particular deposits – in other words, Iron Age peoples may have 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 small sherds were found in 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). While this is indeed a small sample to suggest more widespread ceramic usage at this time, it does demonstrate that as more sites are dated through absolute methods, long-held beliefs about the Iron Age may be challenged.

The paucity of EIA sites in Ireland had previously led to a suggestion that there was a drastic depopulating of Ireland after the LBA, and only with the appearance of La Tène material in the third century BC did Irish society return to practices that made it archaeological visible. Peatland and pollen records indicate a climate shift in the eighth century BC; however, Armit *et*

TABLE 1
Late Bronze and Iron Age Periods in Ireland

Irish Chronology	
Late Bronze Age	1200 – 800 BC
Early Iron Age	800 – 400 BC
Developed Iron Age	400 – 1 BC
Late Iron Age	1 BC – AD 300

al. (2014, 17046) conclude that 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. The prevailing thought amongst archaeologists is that there was relative population continuity between the LBA and the EIA, but also a gradual change in behaviours. 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 (as of 2004), compared to 65 LBA sites (Becker *et al*. 2008; Becker 2013).

During the EIA, there are no settlements larger than what have been termed homesteads or farmsteads. A variety of settlement site types are known from the broader Iron Age, including unenclosed settlements (post-built, circular or sub-circular in plan), enclosed settlements, hilltop enclosures, and lake settlements (Becker *et al*. 2008). One possible unenclosed structure whose dates span the EIA–DIA was identified at Ballinaspig More, Co. Cork (Danaher 2012), while another unenclosed settlement with two structures was found at Coolbeg, Co. Wicklow that also spans the EIA–DIA (Frazer 2012). Irish hillforts pose another interesting dilemma when reconstructing Iron Age settlements. They do not correspond to the eponymous phenomenon on the Continent or to the larger hillforts in Britain. Instead, Irish hillforts were more analogous to small British hillforts that likely supported individual farmsteads (if they were domestic at all). They were long considered solely an Iron Age phenomenon (Raftery 1976), though radiocarbon dates show a more complicated history. They begin to appear on the landscape in the Late Bronze Age, with a longer occupation that in some cases extends into the early medieval period. Dún Aonghusa, Co. Galway, Rathgall, Co. Wicklow, Donegore, Co. Antrim, Raffin Fort, Co. Meath, and Clogher, Co. Tyrone all have dates that indicate some occupation during the EIA, although they were occupied in other periods of prehistory as well (Becker *et al*. 2008).

The second complicating factor when discussing EIA settlements is the ephemeral nature of many of the identified sites. Sites radiocarbon dated to the EIA are frequently not what one would traditionally call settlements, instead producing evidence of simple hearths, pits, cereal-drying kilns, or burnt mounds: these demonstrate human activity but are insufficient to allow the reconstruction of settlement pattern. Sites such as Claristown 4, Co. Meath (Russell 2003a), Kilsharvan 5, Co. Meath (Russell 2003b), or Cloongownagh, Co. Roscommon (Henry 2000) are examples of isolated pits with no other associated features, but whose ^{14}C dates provided evidence for EIA activity. The term 'isolated' may in fact be misleading. While many of the recently identified sites discovered during major infrastructure programs were given separate site designations and license numbers, per standard practice, they were likely part of a landscape of Iron Age occupation. Take for example the aforementioned Claristown 4, Co. Meath; found very close by was a site with two pits and two hearths dating to the DIA (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). In some instances, there are landscapes of ironworking sites that should probably be considered parts of complexes of sites rather than individual occupations (Garstki 2017, 151). For example, surrounding the modern town of Kinnegad, Co. Westmeath seven sites[1] have been identified within 3 km of each other that span the EIA and DIA and contained features associated with iron production. While it is outside of the scope of this article to investigate all of the larger Iron Age landscapes of occupation, it is worth considering in future reconstructions of Irish prehistory.

Even with this more recent evidence, the EIA appears to have been characterized by a dispersed population without any significant agglomeration. One suggestion concerning the low numbers of settlements (as compared to the LBA or even the DIA) is that the EIA saw a more

nomadic lifestyle (Raftery 1994; Armit 2007; Becker 2009; Dolan 2014). Raftery noted that if tents became the dominant form of housing, they would leave little or no archaeological evidence (1994, 113). However, he also presents the caveat that there is no old Irish word for 'tent' (Raftery 1994, 113). A nomadic way of life could be considered as a possible 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 is a possibility, and some have noted a shift towards pastoralism at the end of the LBA (Plunkett 2009).

However, more recent secondary evidence of agricultural activity 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 some new examples of Iron Age cereal-drying kilns, such as the DIA site of Cookstown, Co. Meath (Clutterbuck 2012), which were used to process grains for a variety of purposes. The increase in archaeobotanical data from more recently excavated sites is now beginning to demonstrate patterns of land use and the types of crops 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). In addition, broader temporal studies from the Neolithic to the Iron Age at Kerloge, Co. Wexford, suggest 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).[2]

The settlement evidence does expand in the DIA, as compared to the EIA. Ó Drisceoil and Devine (2012) have identified eight settlements with house structures that have produced ^{14}C dates spanning the DIA, to which can be added Coolbeg, Co. Wicklow (Frazer 2012). The lack of a single settlement type continues during this period, with occupation continuing at some enclosed sites like Haughey's Fort, Co. Armagh, or Johnstown 1, Co. Meath (Becker *et al.* 2008). Additionally, as in the EIA, there are a number of more ephemeral activity sites that only include pits, hearths, or remains of industrial activities. Currently, 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 came together for larger building projects. Iron Age trackways demonstrate the ability of large groups of people to gather and construct a means of transport across otherwise unpassable terrain. The Corlea trackway in Co. Longford, the most famous of these examples (Raftery 1994; 1996), dates to 148 BC. It consisted of large timber beams laid sequentially for upwards of 2 km – a minimum of 200 and 300 large oak trees were required for the construction of this trackway (Raftery 1994, 99). 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). Perhaps the most well-investigated communal gathering places are the so-called 'royal sites': Tara, Co. Meath, Navan, Co. Armagh, Knockaulin, Co. Kildare, and Rathcroghan, Co. Roscommon. Although most of these sites stand as prime examples of archaeological palimpsests, they document large-scale ceremonial activity during the DIA (Newman 1997; Mallory and Lynn 2002; Johnston and Wailes 2007; Grogan 2008; Waddell *et al.* 2009; Waddell 2010). These sites, as well as the recently discovered Lismullin, Co. Meath (O'Connell 2012; 2013; Prendergast 2012), contain large timber structures that point to locations on the landscape that served as foci of congregation. The evidence for iron production during this period should be considered as a part of the social fission-fusion that appeared to be occurring.

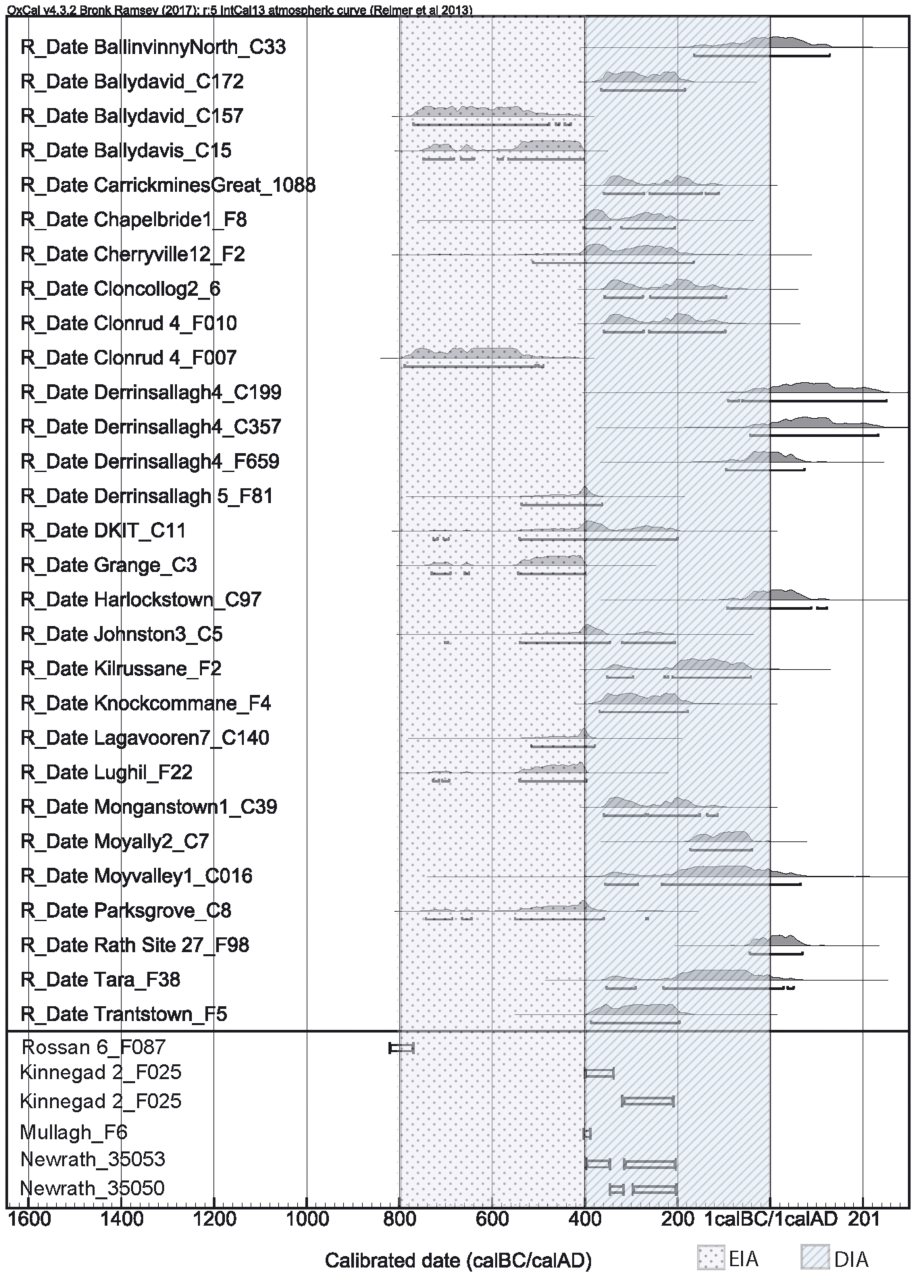

Figure 1
Sites that provided Iron Age ^{14}C (2 σ) dates from a smelting furnace or smithing-hearth context. Context number of feature listed after the site name. The separated contexts on the bottom of the figure were not calibrated by the author and the calibration curve is unknown. [Colour figure can be viewed at wileyonlinelibrary.com] [Colour figure can be viewed at wileyonlinelibrary.com]

IRON TECHNOLOGY

During the eighth or seventh centuries BC, 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 elsewhere, or from individuals travelling outside of Ireland learning the skills of iron smelting and returning home to share that knowledge. Despite also being a metallurgical technology, ironworking differed from the bronze-working technology in a number of ways that required knowledge to be shared from the outside rather than develop *in situ*. For example, the production of iron requires a higher temperature than earlier copper smelting, facilitated in part by a specialized furnace. Additionally, the shaping of an iron bloom after smelting requires a completely different knowledge base than does bronze casting.

Figure 1 shows the directly dated ironworking features in Ireland, with some dates that span the eighth century. Dating the initial adoption of these technologies is difficult; the 2 sigma ^{14}C dates provide a wide range, meaning that any of the EIA furnaces and hearths may have been used either at the beginning or end of the period. Yet despite these limitations, I would argue against the assertion that the EIA in Ireland was a period of 'iron use' as opposed to 'iron production' (Becker 2012, 9). Sites with direct ^{14}C dates taken from furnaces and smithing hearths demonstrate that the knowledge required for iron production existed in Ireland during the EIA at least at a small scale. Production continued to increase over time, from the EIA through to the LIA, to judge from the increased number of sites and the higher number of furnaces at those sites. Thirty-seven sites dating to these periods have been identified that contain evidence of smithing or smelting, representing a total of 123 smelting furnaces and 13 smithing hearths (Table 2 Garstki 2017).[3] The strong concentration of these sites in the eastern half of the Republic (Fig. 2) closely follows development-led investigations from road projects extending out from Dublin.

Smelting

In his seminal work on Irish ironworking, Scott (1990) suggests that the bowl furnace was likely used during the Iron Age. Recently, there has been a significant critique of the 'bowl furnace' categorization of these features (Crew and Rehren 2002; Young 2003; Chadburn 2006; Fairburn 2006; Rondelez 2018). Building on this foundation, it is possible to now paint a more complete picture of iron production technology. Throughout the EIA and DIA, the current archaeological evidence suggests that the main type of furnace used was the non-slag tapping slag-pit and low shaft furnace.[4] Slag assemblages from these furnaces, as well as the shape of the basal pits, mirror contemporaneous examples from Britain that have been studied in detail and experimentally reconstructed (Crew 1991; Young 2003). During this period, an altered form of this furnace came into use. The site of Derrinsallagh 4 in Co. Laois was excavated in 2005/2006 in preparation for the M8 Portlaoise to Castletown Motorway Scheme (Lennon and Kane 2009a). This site is the largest known prehistoric iron production site in Ireland, with upwards of 44 smelting furnaces. One of these furnaces, C397, was lifted en bloc in order to excavate the feature off site. The excavation and analysis was carried out by Dr. Tim Young of GeoArch (2008). Based on his analysis, we now know of a variant of the common furnace in which a furnace arch, mostly or completely below the original surface, connected the furnace pit to a separate working hollow (Fig. 3). In plan view this furnace would have had a 'figure-of-eight' shape; the bloom could be removed from the furnace through the arch and initially

TABLE 2
Ironworking sites that date to the Early or Developed Iron Age

Site Name	Type of Site	Date	Smelting (No. of furnaces)	Smithing (No. of hearths)
Clonrud 4, Co. Laois (E2167)	Isolated Metalworking	LBA/EIA	X (2)	
Grange, Co. Dublin (13E0435)	Isolated Metalworking	EIA	X (1)	
Kinnegad 2, Co. Westmeath (02E0926)	Isolated Metalworking	EIA	X (2)	X (1)
Lagavooren 7, Co. Meath (00E0914)	Structure	EIA	X (2)	
Parksgrove 1, Co. Kilkenny (99E0597)	Isolated Metalworking	EIA		X (1)
Rossan 6, Co. Meath (02E1068)	Isolated Metalworking	EIA	X (1)	X (2)
Site 27, Rath, Co. Meath (03E1214)	Structure/Burial	EIA	X (1)	X (1)
Site B, Ballydavis, Co. Laois (03E0966)	Isolated Metalworking	EIA	X (2)	
Site L, Lughil, Co. Kildare (03E0602)	Isolated Metalworking	EIA	X (5)	
Cherryville Site 12, Co. Kildare (01E0955)	Isolated Metalworking	EIA/DIA	X (4)	X (slag)
DKIT, Co. Louth (02E0201)	Isolated Metalworking	EIA/DIA	X (1)	
Morett, Co. Laois (03E0461)	Burial	EIA/DIA	X (4)	
Site AR 26, Ballydavid, Co. Tipperary (E2370)	Enclosure	EIA/DIA	X (6)	
Derrinsallagh 5, Co. Laois (E2181)	Isolated Metalworking	EIA/DIA/LIA	X (1)	
Hardwood 3, Co. Meath (02E1141)	Isolated Metalworking	EIA/Medieval	X (4)	X (3)
Carrickmines Great, Co. Dublin (02E0272)	Structure	DIA	X (1)	
Chapelbride 1, Co. Meath (E3172)	Isolated Metalworking	DIA		X (1)
Cloncollog 2, Co. Offaly (E2850)	Isolated Metalworking	DIA	X (1)	
Gormagh 1, Co. Offaly (11E87)	Isolated Metalworking	DIA		X (1)
Johnstown 3, Co. Meath (02E1094)	Isolated Metalworking	DIA	X (2)	
Kilrussane AR 27, Co. Cork (01E0701)	Isolated Metalworking	DIA	X (4)	
Knockcommane 4700.1b, Co. Cork (E2342)	Structure	DIA	X (1)	
Leap 1, Co. Laois (E2131)	Isolated Metalworking	DIA	X (1)	
Monganstown 1, Co. Westmeath (E2771)	Isolated Metalworking	DIA	X (6)	X (slag)
Moyally 2, Co. Offaly (E2672)	Isolated Metalworking	DIA	X (2)	X (1)
Moyvalley 1, Co. Kildare (02E1088)	Isolated Metalworking	DIA		X (1)
Mullagh, Co. Longford (09E0311)	Isolated Metalworking	DIA	X (1)	
Newrath Site 35, Co. Kilkenny (04E0319)	Isolated Metalworking	DIA	X (6)	
Ráith na Ríg, Tara, Co. Meath (97E300)	Other	DIA		X (1)
Trantstown AR 29, Co. Cork (01E0501 AR29)	Isolated Metalworking	DIA	X (2)	
Ballinvinny North AR26, Co. Cork (01E0501 AR26)	Isolated Metalworking	DIA/LIA	X (1)	
Derrinsallagh 4, Co. Laois (E2180)	Structure	DIA/LIA	X (44)	
Derryvorrigan 1, Co. Laois (E2193)	Structure	DIA/LIA	X (8)	
Harlockstown 19, Co. Meath (03E1526)	Structure/Burial	DIA/LIA	X (1)	X (slag)
Lisnagar Demesne 1, Co. Cork (03E1510)	Isolated Metalworking	DIA/LIA	X (1)	X (slag)

(Continues)

TABLE 2
(Continued)

Site Name	Type of Site	Date	Smelting (No. of furnaces)	Smithing (No. of hearths)
Ballydavis, Co. Laois (95E111)	Burial	IA	X (8)	
Knockaulin	Ritual	IA		X (slag)

worked in the adjacent hollow, or the hollow could have been used for depositing 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 2008, 210). The arch was about 16 cm 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 in its liquid state and at that point settles in the base of the furnace. Peter Crew has noted this type of furnace technology during excavations at Bryn y Castell and Crawcwellt in Wales (1991; 1998). A very complete slag-pit shaft furnace was also recovered at Grange 2, Co. Meath, including a basal arch, dating to the Early Medieval period (Kelly 2011). Additional examples of this furnace type have been tentatively identified at other sites dating to the EIA/DIA (Garstki 2017, 98). Its appearance indicates both a level of experimentation by iron producers and variability in practices during this period, as well as potential participation in knowledge held by communities outside Ireland.

Smithing

The identification of a primary or secondary smithing hearth[5] is quite difficult when based solely on the 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 to make the bloom 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 needed to maintain a high heat. Currently, 10 sites indicate some level of iron smithing based on the remains of a hearth. Other sites exhibit evidence of smithing slag without the presence of any identifiable smithing features: Cherryville Site 12, Knockaulin, Lisnagar Demesne I, Monganstown, and Harlockstown 19 (Fairburn 2005; 2006; Young 2008; Johnston and Wailes 2007; Photos-Jones 2007). There is an unfortunate dearth of remains dating to this period to provide an insight into the final production stages of ironworking. The few smithing tools identified by Scott date to a later period or have no secure date (1990, 23), and finished objects are very rarely found in securely datable contexts. As noted above, many iron objects have been known to date to the Iron Age since the early in the last century (Raftery 1983; 1984). However, as Raftery specifically states, using art styles to date unprovenanced material is extremely unreliable (1983, 4–5). Of course, the possible archaeological knowledge that can be derived from these materials, and other iron objects found more recently, through techniques such as metallography is still significant. The focus of this paper, however, is a contextual view of iron-production sites on the landscape.

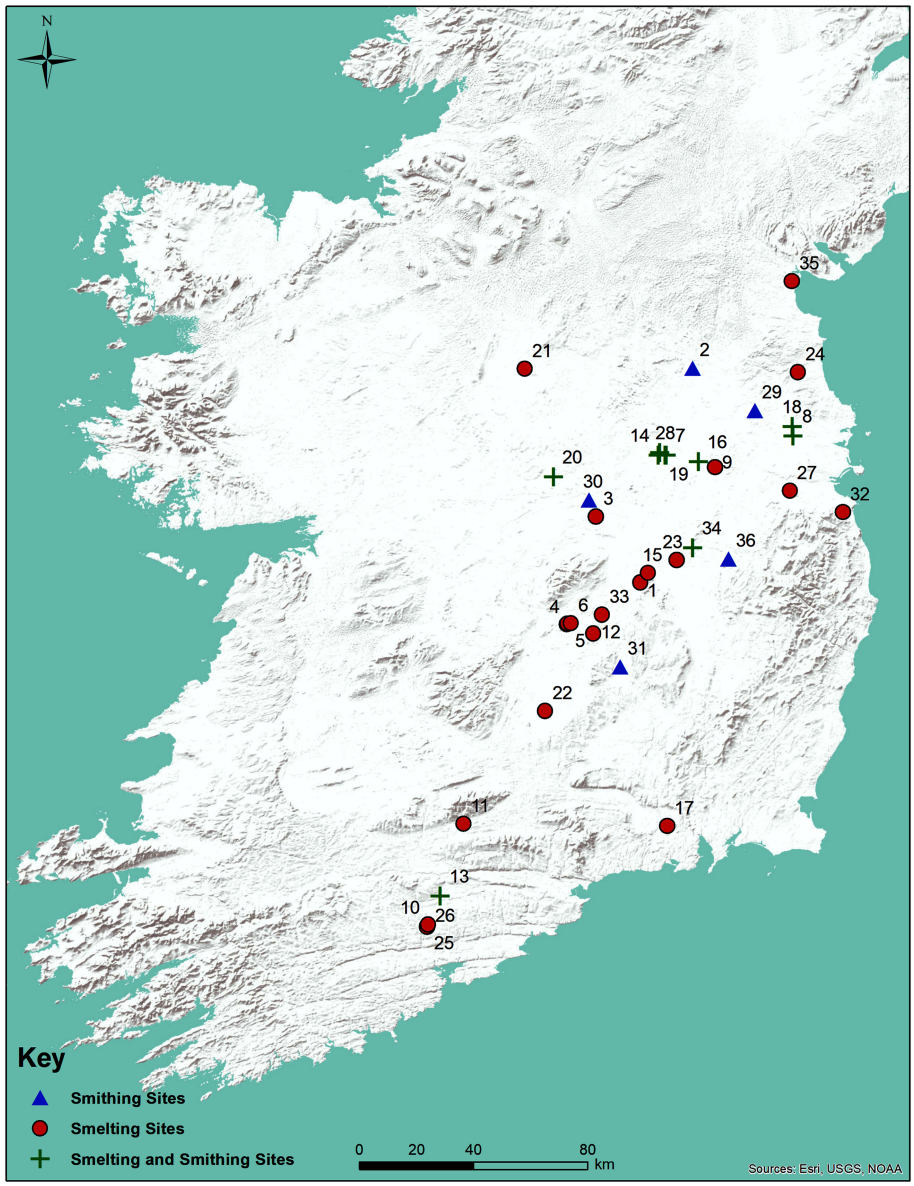

Figure 2
Sites with evidence for smithing and/or smelting. 1: Ballydavis; 2: Chapelbride 1; 3: Cloncollog 2; 4: Derrinsallagh 4; 5: Derrinsallagh 5; 6: Derryvorrigan 1; 7: Hardwood 3; 8: Harlockstown 19; 9: Johnstown 3; 10: Kilrussane; 11: Knockcommane; 12: Leap 1; 13: Lisnagar Demesne 1; 14: Monganstown 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. [Colour figure can be viewed at wileyonlinelibrary.com] [Colour figure can be viewed at wileyonlinelibrary.com]

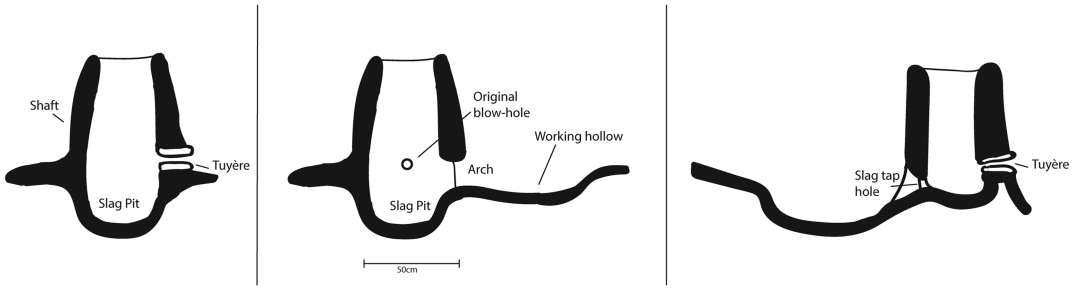

Figure 3
Schematic of smelting-furnace types. *Left*: slag-pit furnace; *middle*: arched slag-pit furnace; *right*: slag-tapping furnace (not used in Iron Age Ireland).

Iron Working Sites

The features associated with iron-working residues also provide important insights into production in this period. By far the most common site type is termed Isolated Metalworking. These sites consist solely of features used for some level of ironworking, along with some associated pits or undiagnostic features, but lack clear structures; twenty-six sites (70% of the total) have been given this designation (Table 2). Although these sites are grouped together for sake of classification, they should be analysed individually in their own landscapes due to the above mentioned issue with 'isolated' sites. As I will discuss below, these sites suggest a few different modes of iron production, either household level smelting or periodic smelting events conducted by full-time smiths.

Although most smithing sites are categorized as isolated metalworking sites, others, including Ráith na Ríg, Tara, Harlockstown 19, Rath Site 27, and Knockaulin, demonstrate the varied contexts in which iron production was occurring. 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 complex. The presence of post and stake-holes surrounding the smithing hearth suggests that there may have been some small structure surrounding the production area (Roche 2002, 73). Possibly the most important aspect of the ironworking activity at this site is that it was not the only industrial process. The hearth used for iron smithing may have also been used for bronze smithing and glass working, based on the residues from both activities, as well as moulds for bronze casting (Crew and Rehren 2002; Schot 2018). These associations point to yet another kind of iron production, where a craftsperson is responsible for high-level pyrotechnic activities, tied to a person of high status (or kingship, as argued by Schot [2018]).Three sites in this sample produced evidence for mortuary contexts in association with ironworking activities: Morett, Rath Site 27, and Harlockstown 19. Morett contained a cluster of smelting furnaces. Roughly 45 m north-east of the site were two Iron Age ring-ditches dated to 400–200 cal. BC and 370–110 cal. BC (Cotter 2011). 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. Rath Site 27 consisted of a large number of features that demonstrated continuity 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). In addition, a unique feature dating to this period was termed a 'sweat lodge', associated with two waterholes with wooden superstructures. The bloomery furnace and smithing hearth were in the centre of the site, between the ring-ditches and other features. The final site associated with mortuary activities is Harlockstown 19, which was established on top of an Early Bronze Age ditched enclosure containing cremations and inhumations. The Iron Age occupation included a single bloomery furnace in the centre of the site (F96), as well as large burnt spreads, possible work floors, and a sunken-floor feature. F3, a circular ditched feature (likely a ring-ditch) almost 8 m in diameter at the north end of the site, is contemporaneous with the ironworking (O'Connor 2008). Melanie Giles (2007, 405) and Roseanne Schot (2018) have highlighted the shared liminality of burial and metalworking, as both often inhabit a peripheral place in society, socially and at times spatially. This shared liminality is also embedded in the performance of each activity. 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.

Four sites in this sample produced clearer evidence for some type of structure associated directly with the iron production features. 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 12 m north-west of two structures. One structure is a *c*.5 x 2 m post-structure, while the other is a smaller 2 x 2 m post-and-trench-structure (Fig. 4). 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 precedes most of the ironworking activity but could have remained in use during the industrial activity at the site (Lennon and Kane 2009a). Pits associated with the feature suggest that it may have been used for domestic purposes, and the botanicals recovered also suggest domestic cultivation (see Ó Drisceoil 2007 for discussion). The smelting and smithing features are dotted throughout the site, with none closer than 10 m to the structure. 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 5 m, and was found at the north-east part of the site, roughly 40 m from the ironworking activity. 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 (8.5 m in diameter) made up of a slot trench and a series of posts, surrounded by a circle of gullies (Molloy 2007) (Fig. 5). Within the structure was a single slag-pit furnace.

The remaining category of site type involves the ironworking features associated with the enclosure at Ballydavid. A large, 125 m diameter enclosure was uncovered at the top of a hill, with occupation from the Middle and Late Bronze Age, possibly extending into the Iron Age (Hardy *et al.* 2010). Surprisingly, there is no evidence for any structures within the enclosure. Only a series of pits and fill in the enclosure ditch indicate occupation through these periods. Bloomery furnaces were found outside the enclosure, sometimes immediately outside it, while others were over 50 m to the north-east. 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 settlement in this period.

These sites suggest a varied tradition of iron production in the Early and Developed Iron Age, with different scales of production occurring in different contexts on the landscape. Very small sites consisting of only iron-smelting furnaces are the dominant form of production, and they could represent a household level of production as well as local smiths conducting biannual smelts or

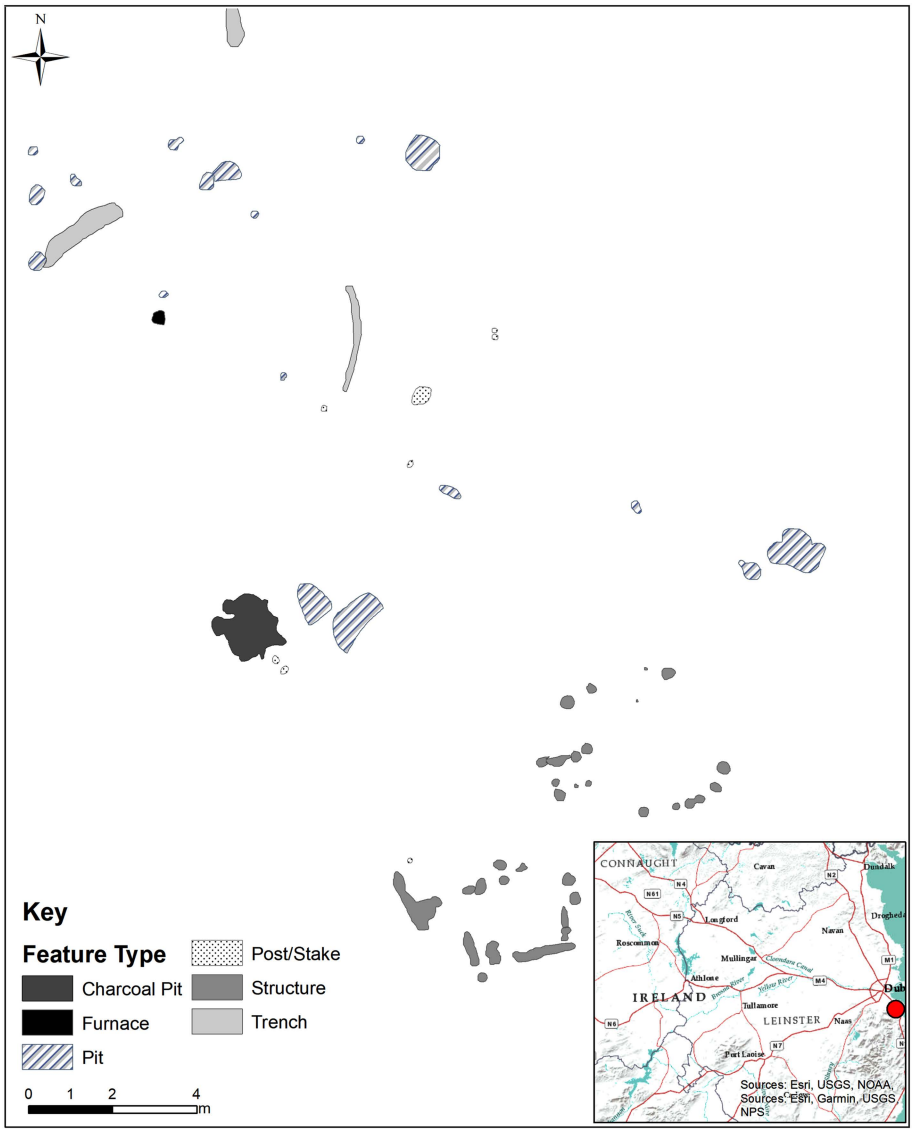

Figure 4
Excavation plan map of Carrickmines Great (after Ó Drisceoil 2007).

itinerant metalworkers. Sites that indicate high-level smithing, especially associated with other pyrotechnic production, point to yet another community involved in iron production. The diversity of sites with evidence of iron production suggests that a standardized mode of production did not exist in this period of Irish prehistory, but that, as will be discussed below, iron production was undertaken by numerous communities.

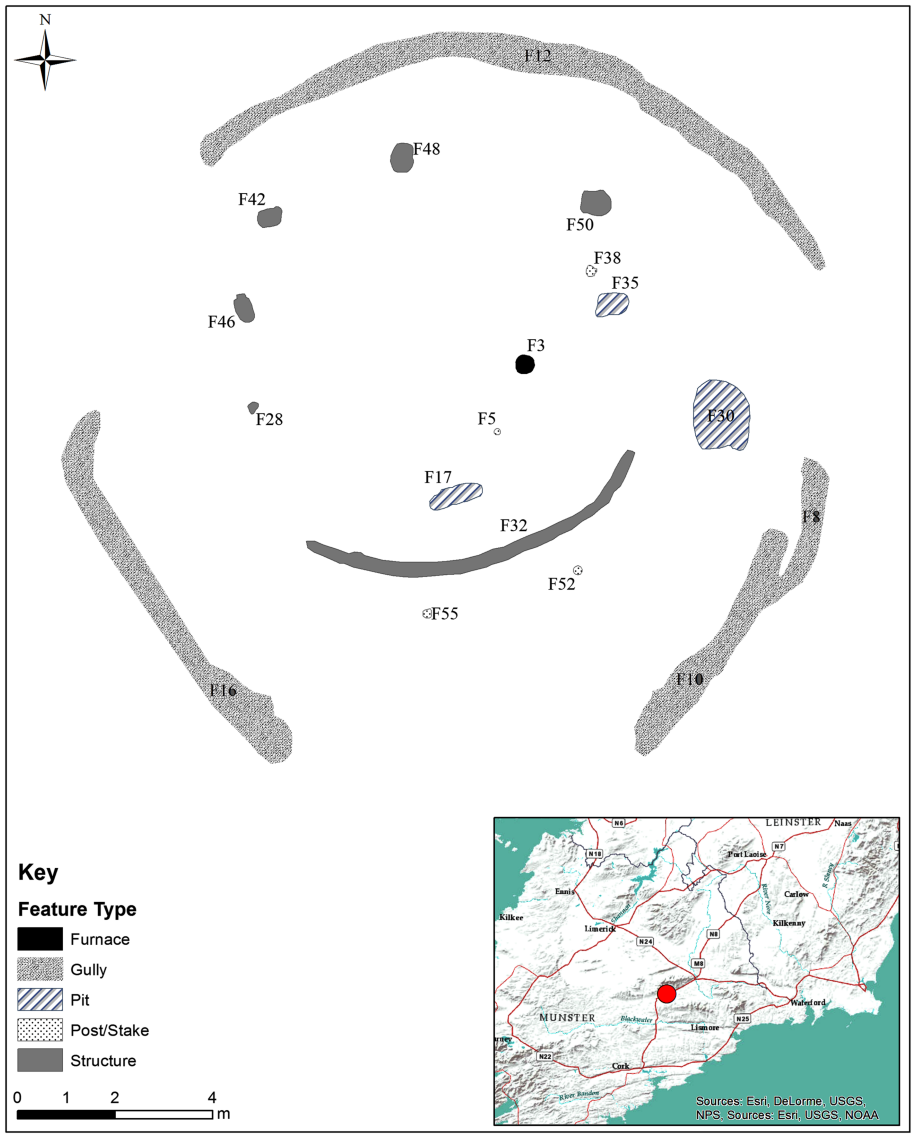

Figure 5
Excavation plan map of Knockcommane (after Molloy 2007). [Colour figure can be viewed at wileyonlinelibrary.com

DISCUSSION

The knowledge required to produce iron could not have been simply 'picked up' or developed through a series of trial and error experiments. At some point this knowledge had to be transferred to Ireland, possibly from Wales based on similarities of furnace technology (as discussed in Garstki 2017, 186). One possible explanation for this transfer is the permanent settlement of

people from abroad with knowledge of iron production. This idea was prominent during the early 20th century, tying iron production to the 'coming of the Celts.' Although there is no archaeological evidence of any such large-scale population movement and replacement, we cannot discount the small-scale movement of people across the Irish Sea, especially if the arguments for the strong connections with the Atlantic Zone throughout prehistory are correct (cf. Waddell 1991; Henderson 2007; Cunliffe and Koch 2010). Recent work has identified frequent small-scale movement occurring throughout the European Iron Age (Scheeres *et al*. 2013; 2014; Knipper *et al*. 2014), and strontium and oxygen isotope analysis of LIA Irish burials confirm that people were in fact moving into Ireland in this period (Cahill Wilson 2014; Cahill Wilson and Standish 2016). 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.[6] At this point, the data do not indicate precisely how the technological knowledge of iron production made its way to Ireland, but once there it then had to be transferred, maintained, altered, and utilized by different communities and generations.

Those involved in iron production at all levels participated in multiple, overlapping communities of practice. Etienne Wenger (1998) expanded upon 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 behaviour, and how the enactment of that knowledge (re)constructs 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 knowledge transfer the development of competence and grasp of concepts is a major focus, but in archaeology the *practice* of the communities of practice is what is manifested in the evidence. As Dobres (2000, 128–9) 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.'

The archaeological evidence of Early and Developed Iron Age communities 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 was transferred between individuals.

The production of charcoal as an activity supporting iron technology 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 the project on which this article is based suggest that there were various sized and shaped pits used in the production of charcoal during the early part of the Iron Age in Ireland, while some charcoal also appears to have been produced using charcoal piles (Garstki 2017, 160–8). Since charcoal was not solely used for iron production, the existence of different communities of practice for this activity should not be surprising. Charcoal production 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 iron smelting, it is logical that the patterns of furnace types and charcoal pits are not shared between the two.

The separation of the other communities of practice involved in iron technologies is more difficult. The question of whether those acquiring the ore were also involved in smelting remains open. The exploitation of bog ore[7] or bedded ores would have only required knowledge of where

to find it and how to identify it. The knowledge of a place could have been passed down through generations as individuals visited set locations in order to find iron ore. This knowledge is enacted simply enough, by travelling to the procurement site and recovering the ore.

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. One may even argue that this community extended across the Irish Sea, with those who also shared this furnace style in Wales. The tradition consisted of digging a circular pit in the ground of roughly 35–60 cm in diameter. The sides of the pit were largely vertical and the bottom was mostly flat. Clay was then used to build a shaft up from the pit. This structure was then filled with wood 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. However, the variability within these practices, as evidenced by the different sizes and shapes of pits, and different associated contexts (settlement, mortuary, etc.), suggests that the tradition was far from rigid and there were different communities of practice responsible for the smelting and smithing of iron.

It is perhaps naïve to assume that a single mode of production could account for all of the activities that constituted early iron technology in Ireland, which have been found spread throughout many parts of the country (Fig. 2). 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, there is 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 the domestic site of Carrickmines Great, some of the production occurring in connection with ritualized activities such as at Morett, or the small-scale production sites without evidence of primary smithing on site, such as at Lughil or Newrath. This type of ad-hoc smithing supports Carlin's (2008) suggestion of the farmer-smith as responsible for much of the iron production in medieval Ireland. Another possibility is that the inhabitants of these households practiced only smelting, and that the unconsolidated bloom was taken to an expert smith to produce the final iron product. In this case, individuals who had knowledge of how to create a bloom may not necessarily have shaped that bloom into a sword or agricultural tool. A much later reference to the significance of unprocessed blooms appears 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 may be represented by small isolated smithing sites, and/or at the larger smelting sites which could have supported an unattached, more specialized smith. This type of organization could have revolved around itinerant smiths (Garstki 2016), 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 concentration of production evidenced in contemporary Britain (Cleere 1984; Paynter 2006; 2007) or in Ireland during the Early Medieval period[8] (Clarke 2004; Wallace and Anguilano 2010; O'Sullivan *et al.* 2014). However, the Derrinsallagh complex (which can be argued to include Derrinsallagh 4 and 5, Derryvorrigan 1, and Barnasallagh 1) or even the Kinnegad complex discussed above could be centres of production. If the archaeological remains at these sites were the product of itinerant workers, the sites would have been revisited to produce the large numbers of furnaces evidenced at the Derrinsallgh complex. They may also represent locations of stable, sedentary smiths. These concentrations of ironworking activity speak of a more intensive scale of production than previously identified. We can look to the well-preserved furnace, C397, from Derrinsallagh 4 for archaeological evidence of the skill and knowledge maintained by these

smelters. 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 (Young 2008). Using their knowledge of smelting technology, the smelters were able to diagnose the problem and move the blow-hole to a different part of the furnace.

A further subset of iron production taking place during the EIA and DIA involved an association with high-status or ceremonial sites. The smithing activity at Tara seems to have been connected not only to the ceremonial and elite aspects of the site (Schot 2018), but was likely conducted by smiths who were also engaged in bronze-working and potentially glass-working. These activities taken together are highly suggestive of the presence of pyrotechnic specialists, or someone who utilized their control over fire to produce a variety of materials. Although we may consider these pyrotechnic activities as discrete skillsets, it is possible that elite practitioners of metalwork and glasswork were one and the same. This association may also be indicated at Ballydavis Site 1 and at Knockaulin where we see associations between elite activities or other metalwork. These smiths could have been tied more directly to a high-status individual or community who had the resources to provide not only the material used in these technologies, but to support the craftsperson as well, as an attached specialist.

In this multi-scaled organization of production, many people in Iron Age Irish society would have been involved in the production of iron to some extent. 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, similar to the production of ceramics in many other prehistoric contexts. The next scale of organization involved larger smelting centres like the Derrinsallagh complex or isolated smithing sites, likely manned by the community smith or an itinerant worker. The last scale of production occurred at hilltop or ceremonial sites conducted 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 or pyrotechnic production.

Once the knowledge of iron production existed within a community of practice and could be performed and replicated, there were many avenues for 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 choices necessary to create 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 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. 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 governed by the social conventions and ritualized practices of Irish society at the time.

CONCLUSION

This 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 broadly. There seem to be multiple levels of production in this period: from

the household level, through full-time smiths responsible for servicing local or regional communities, to the specialized smiths who were likely tied to elite persons and also involved in other pyrotechnic activities. These modes of production required different, but nonetheless intersecting, knowledge and would have relied on varying social relations for their maintenance. This concept of multiple communities of practice could be applied to other areas of Iron Age life to identify patterns of learning and behaviour, as well as the social integration of various scales of communities through technological exchange and interaction. A multi-scaled and intersecting mode of iron production also provides insight into how otherwise dispersed family groups in small farmsteads were integrated into larger communities and regional identities; Iron Age people were not solely existing in spheres of interaction with their immediate kin but as illustrated in this example of ironworking, they were involved in many communities of practice that were created and maintained through activities of production.

Acknowledgements

The data for this article was collected as part of a PhD dissertation project at the University of Wisconsin-Milwaukee, USA. I would like to thank Bettina Arnold, Derek Counts, John Richards, Pat Richards, and Thomas Malaby for their guidance during the design of the project and collection of data. Special thanks are due to Adrienne Frie for her comments and direction on this paper, and to Michael Stanley of the Transportation Infrastructure Ireland for accommodating numerous requests for excavation reports.

() Department of Anthropology
University of Wisconsin-Milwaukee
413 N. Downer Ave. Sabin Hall 390
Milwaukee, WI, 53211
USA
E-mail: kevin.garstki@gmail.com

doi: 10.1111/ojoa.12179

ENDNOTES

1. Rossan 1, Rossan 3, Rossan 6, Hardwood 3, Kinnegad 2, Griffinstown 3, Monganstown 1.
2. The rise in barley and oats in the LBA and Iron Age, and the decline of wheat, may be due to the deteriorating weather ca. 800 BC, as barley can thrive in colder and wetter conditions than wheat (Monk *et al*. 1998).
3. This is not necessarily an exhaustive list, since other excavations have uncovered evidence of ironworking in the form of only metallurgical residues. This list contains only sites with direct evidence, in the form of identified pyrotechnic structures like furnaces or hearths, for iron production. Access to information on these sites can be found at http://webgis.uwm.edu/kgarstki/
4. Rondelez (2018) has recently challenged the use of >'low-shaft' since the original height of the furnace shaft is not known, and suggests the use of the phrase 'slag-pit (shaft) furnace.'
5. Primary smithing refers to the initial forming of the iron bloom and continued refinement of the iron. Secondary smithing works the iron refined in the earlier stage into a finished product.
6. A reliance on long-distance exchange relationships that were cultivated by specific powerful members of society likely included the exchange of elite markers such as feasting equipment, v-notched shields, and weapons (Waddell 2010).
7. 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 2014, 91).
8. Johnstown 1, Co. Meath produced ~2,000 kg of slag and Lowpark, Co. Mayo produced ~1,365 kg of slag.

REFERENCES

ARMIT, I. 2007: Social landscapes and identities in the Irish Iron Age. In HASELGROVE, C. and MOORE, T. (eds.), *The Later Iron Age in Britain and Beyond* (Oxford), 130–9.

ARMIT, I., SWINDLES, G.T. and BECKER, K. 2013: From dates to demography in later prehistoric Ireland? Experimental approaches to the meta-analysis of large 14C data-sets.*Journal of Archaeological Science* 40, 433–8.

ARMIT, I., SWINDLES, G.T., BECKER, K., PLUNKETT, G. and BLAAUW, M. 2014: Rapid climate change did not cause population collapse at the end of the European Bronze Age. *Proceedings of the National Academy of Sciences of the United States of America* 111(48), 17045–9.

BECKER, K. 2009: 'But I still haven't found what I'm looking for'. New agendas in Irish Iron Age research. In KARL, R. and LESKOVAR, J. (eds.), *Interpretierte Eisenzeiten: Fallstudien, Methoden, Theorie* (Linz), 163–76.

BECKER, K. 2012: Redefining the Irish Iron Age. In CORLETT, C. and POTTERTON, M. (eds.), *Life and Death in Iron Age Ireland in the Light of Recent Archaeological Excavations* (Dublin), 1–14.

BECKER, K. 2013: Transforming identities – new approaches to Bronze Age deposition in Ireland.*Proceedings of the Prehistoric Society* 79, 1–39.

BECKER, K., ARMIT, I., EOGAN, J. and SWINDLES, G.T. 2011: Later prehistoric radiocarbon dates from Ireland: an audit.*The Journal of Irish Archaeology* 20, 19–25.

BECKER, K., O'NEILL, J. and O'FLYNN, L. 2008: *Iron Age Ireland: Finding an Invisible People*. Vol. 16365 (Ireland).

BRONK RAMSEY, C. 2017: Methods for summarizing radiocarbon datasets.*Radiocarbon* 59(2), 1809–33.

CAHILL WILSON, J. 2014: *Romans and Roman material in Ireland: a wider social perspective. In Late Iron Age and 'Roman' Ireland* (Dublin, Discovery Programme Reports 8), 11–58.

CAHILL WILSON, J. and STANDISH, C.D. 2016: Mobility and migration in late Iron Age and early Medieval Ireland. *Journal of Archaeological Science: Reports* 6, 230–41.

CARLIN, N. 2008: Ironworking and Production. In CARLIN, N., CLARKE, L. and WALSH, F. (eds.), *The Archaeology of Life and Death in the Boyne Floodplain: the Linear Landscape of the M4, Kinnegad-Enfield-Kilcock Motorway* (Dublin), 87–112.

CHADBURN, R. 2006: N25 North Waterford Bypass. Contract 3. Site 35 Newrath final report. Industrial Waste Morphological Examination Report (Unpublished Report).

CLARKE, L. 2004: Report on the Archaeological Resolution of a Multi-period Burial, Settlement and Industrial Site at Johnstown 1, Enfield, County Meath (Unpublished Report for the Westmeath County Council. Archaeological Consultancy Services Ltd).

CLEERE, H. 1984: Ironmaking in the economy of the ancient world: the potential of archaeometallurgy. In SCOTT, B.G. and CLEERE, H. (eds.), *The Crafts of the Blacksmith* (Belfast), 1–6.

CLUTTERBUCK, R. 2012: Iron Age ritual and settlement at Cookstown, Co. Meath. In CORLETT, C. and POTTERTON, M. (eds.), *Life and Death in Iron Age Ireland in the Light of Recent Archaeological Excavations* (Dublin), 35–52.

CORLETT, C. and POTTERTON, M. (eds.) 2013: *Life and Death in Iron Age Ireland in the Light of Recent Archaeological Excavations* (Dublin).

COSHAM, B. 2009: Assessment of Metallurgical Remains from Moyle Big E2598 Based on Visual Examination. (Unpublished Final Excavation Report, Headland Archaeology Ltd).

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).

CREW, P. 1991: The experimental production of a prehistoric bar iron.*Historical Metallurgy* 25, 21–36.

CREW, P. 1998: Excavations at Crawcwellt West, Merioneth, 1990–1998: a later prehistoric upland iron-working settlement.*Archaeology in Wales* 38, 22–35.

CREW, P. and REHREN, T. 2002: High-temperature workshop residues from Tara: iron, bronze and glass. In DISCOVERY, P, (ed.), *Discovery Programme Reports 6* (Dublin), 83-103.

CUNLIFFE, B. and KOCH, J.T. (eds.) 2010: *Celtic from the West: Alternative Perspectives from Archaeology, Genetics, Language and Literature* (Oxford).

DANAHER, E. 2012: A possible Iron Age homestead at Ballinaspig More, Co. Cork. In CORLETT, C. and POTTERTON, M. (eds.), *Life and Death in Iron Age Ireland in the Light of Recent Archaeological Excavations* (Dublin), 79–92.

DOBRES, M.-A. 2000: *Technology and Social Agency: Outlining a Practice Framework for Archaeology* (Oxford).

DOLAN, B. 2012: The Social and Technological Context of Iron Production in Iron Age and Early Medieval Ireland c. 600 BC–AD 900 (Unpublished Doctoral Dissertation, University College Dublin).

DOLAN, B. 2014: Beyond elites: reassessing Irish Iron Age society.*Oxford Journal of Archaeology* 33(4), 361–77.

DOLAN, B. 2016: Making iron in the Irish midlands: the social and symbolic role of Iron Age ironworkers.*The Journal of Irish Archaeology* XXV, 31–48.

FAIRBURN, N. 2005: Assessment of Industrial Residues from Excavations at Lisnagar Demesne 1, Co. Cork. (Unpublished Report for ACS Ltd).

FAIRBURN, N 2006: Assessment of industrial residues from excavations at Monganstown 1. (Unpublished Report).

FRAZER, W.O. 2012: Mud hut redux: roundhouse vernacular at Coolbeg, Co. Wicklow, and Iron Age social organization. In CORLETT, C. and POTTERTON, M. (eds.), *Life and Death in Iron Age Ireland in the Light of Recent Archaeological Excavations* (Dublin), 121–40.

GARSTKI, K. 2016: Assembling the ironsmith. In BONNEY, E.M., FRANKLIN, K.J. and JOHNSON, J.A. (eds.), *Incomplete Archaeologies: Assembling Knowledge in the Past and Present* (Oxford), 98–114.

GARSTKI, K. 2017: Production and Technological Change: Ironworking in Prehistoric Ireland. (Unpublished Doctoral Dissertation, University of Wisconsin-Milwaukee).

GILES, M. 2007: Making metal and forging relations: ironworking in the British Iron Age.*Oxford Journal of Archaeology* 26(4), 395–413.

GROGAN, E. 2008: *Rath of the Synods Tara, Co. Meath, excavations by Seán P. Ó Ríordáin* (Dublin).

HARDY, C., GREEN, B. and STEVENS, P. 2010: M8/N8 Cullahill to Cashel Road Improvement Scheme: Archaeological Resolution. Final Report for Site AR 26, Ballydavid Townland, Co. Tipperary. (Unpublished Report for the Kilkenny County Council, Valerie J. Keeley Ltd).

HENDERSON, J. 2007: *The Atlantic Iron Age: Settlement and Identity in the First Millennium BC* (London).

HENRY, M. 2000: Cloongownagh. In BENNETT, I. (ed.), *Excavations 1999: Summary Accounts of Archaeological Excavations in Ireland No. 765* (Bray).

JOHNSTON, S.A. and WAILES, B. 2007: *Dún Ailinne: Excavations at an Irish Royal Site, 1968–1975* (Philadelphia).

KELLER, C.M. and KELLER, J.D. 1996: *Cognition and Tool Use: The Blacksmith at Work* (Cambridge).

KELLY, A. 2011: E3124: Grange 2 Final Report. (Unpublished Report, Irish Archaeological Consultancy Ltd).

KEYS, L. 2010: Iron Slag Report. Final Report on the Excavation of a Burnt Mound in the Townland of Taduff East, Co. Roscommon. E3272 Taduff East 2. (Unpublished Final Excavation Report, Valerie J. Keeley Ltd).

KNIPPER, C., MEYER, C., JACOBI, F., ROTH, C., FECHER, M., STEPHAN, E., SCHATZ, K., HANSEN, L., POLUSCHNEY, A., HÖPPNER, B., MAUS, M., PARE, C. and ALT, K.W. 2014: Social differentiation and land use at an Early Iron Age 'princely seat': bioarchaeological investigations at the Glauberg (Germany).*Journal of Archaeological Science* 41, 818–35.

LARSSON, E. 2012: An early Iron Age farmstead at Ballycullen, CO. Dublin. In CORLETT, C. and POTTERTON, M. (eds.), *Life and Death in Iron Age Ireland in the Light of Recent Archaeological Excavations* (Dublin), 141–57.

LENNON, A.M. and KANE, E. 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).

LENNON, A.M. and KANE, E. 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).

MALLORY, J.P. and LYNN, C.J. 2002: Recent excavations and speculations on the Navan complex. *Antiquity* 76, 532–41.

MCDERMOTT, C., MOORE, C., MURRAY, C., PLUNKETT, G. and STANLEY, M. 2009: A colossus of roads: the Iron Age archaeology of Ireland's peatlands. In COONEY, G., BECKER, K., COLES, J., RYAN, M. and SIEVERS, S. (eds.), *Relics of Old Decency: Archaeological Studies in Later Prehistory* (Bray), 49–66.

MCLAUGHLIN, T.R., WHITEHOUSE, N.J., SCHULTING, R.J., MCCLATCHIE, M., BARRATT, P. and BOGAARD, A. 2016: The changing face of Neolithic and Bronze Age Ireland: a big data approach to the settlement and burial records.*Journal of World Prehistory* 29, 117–53.

MCLOUGHLIN, C. 2012: Excavation of an Iron Age ring-ditch and associated features at Kerloge, Co. Wexford. In CORLETT, C. and POTTERTON, M. (eds.), *Life and Death in Iron Age Ireland in the Light of Recent Archaeological Excavations* (Dublin), 161–74.

MOLLOY, B. 2007: N8 Cashel to Mitchelstown Road Improvement Scheme. Final Report Knockcommane, Co. Tipperary. (Unpublished Report, Margaret Gowen and Co. Ltd).

MONK, M.A., TIERNEY, J. and HANNON, M. 1998: Archaeobotanical studies and early Medieval Munster. In MONK, M. A. and SHEEHAN, J. (eds.), *Early Medieval Munster: Archaeology, History and Society* (Cork), 65–75.

NEWMAN, C. 1997: *Tara: An Archaeological Survey* (Dublin).

O'CONNELL, A. 2012: Stars in their eyes: the ceremonial complex at Lismullin, Co. Meath. In CORLETT, C. and POTTERTON, M. (eds.), *Life and Death in Iron Age Ireland in the Light of Recent Archaeological Excavations* (Dublin), 233–44.

O'CONNELL, A. 2013: *Harvesting the Stars: A Pagan Temple at Lismullin, Co. Meath* (Dublin).

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).

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 DEVINE, E. 2012: Invisible people or invisible archaeology? Carrickmines Great, Co. Dublin, and the problem of Irish Iron Age settlement. In CORLETT, C. and POTTERTON, M. (eds.), *Life and Death in Iron Age Ireland in the Light of Recent Archaeological Excavations* (Dublin), 249–66.

O'SULLIVAN, A., MCCORMICK, F., KERR, T.R. and HARNEY, L. 2014: *Early Medieval Ireland, AD 400–1100: Evidence from Archaeological Excavations* (Dublin).

PAYNTER, S. 2006: Regional variations in bloomery smelting slag of the Iron Age and Romano-British periods. *Archaeometry* 48(2), 271–92.

PAYNTER, S. 2007: Innovations in bloomery smelting in Iron Age and Romano-British England. In LA NIECE, S., HOOK, D. and CRADDOCK, P. (eds.), *Metals and Mines: Studies in Archaeometallurgy* (London), 201–10.

PHOTOS-JONES, E. 2007: Site 19: Harlockstown, Co. Meath (03E1526): Industrial Waste Assessment and SEM-EDAX Analysis of Select Samples. (Unpublished Report).

PHOTOS-JONES, E. and HALL, A.J. 2011: 'Harvesting' the ore: the use of iron seepages in the early bloomery furnace in Ireland. In TURBANTI-MEMMI, L. (ed.), *Proceedings of the 37th International Symposium on Archaeometry* (Berlin), 629–35.

PLUNKETT, G. 2009: Land-use patterns and cultural change in the Middle to Late Bronze Age in Ireland; inferences from pollen records.*Vegetation History and Archaeobotany* 18, 273–95.

PRENDERGAST, F. 2012: The Lismullin enclosure: design beyond the obvious in the Iron Age. In KELLY, B., ROYCROFT, N. and STANLEY, M. (eds.), *Encounters Between Peoples* (Dublin), 15–30.

RAFTERY, B. 1976: Rathgall and Irish hillfort problems. In HARDING, D.W. (ed.), *Hillforts: Later Prehistoric Earthworks in Britain and Ireland* (London), 339–57.

RAFTERY, B. 1983: *A Catalogue of Irish Iron Age Antiquities*. Veröffentlichung des Vorgeschichtelichen Seminars Marburg, Sonderband 1 (Marburg).

RAFTERY, B. 1984: *La Tène in Ireland: Problems of Origin and Chronology*. Veröffentlichung des Vorgeschichtelichen Seminars Marburg, Sonderband 2 (Marburg).

RAFTERY, B. 1994: *Pagan Celtic Ireland: The Enigma of the Irish Iron Age* (London).

RAFTERY, B. 1995: The conundrum of Irish Iron Age pottery. In RAFTERY, B., MEGAW, V. and RIGBY, V. (eds.), *Sites and Sights of the Iron Age: Essays of Fieldwork and Museum Research, Presented to Ian Mathieson Stead* (Oxford), 149–56.

RAFTERY, B. 1996: *Trackway Excavations in the Mountdillon Bogs, Co. Longford, 1985–1991* (Dublin, Archaeological Wetland Unit Transactions 3).

REIMER, P.J., BARD, E., BAYLISS, A., BECK, J.W., BLACKWELL, P.G., BRONK RAMSEY, C., GROOTES, P.M., GUILDERSON, T.P., HAFLIDASON, H., HAJDAS, I., HATTŽ, C., HEATON, T.J., HOFFMANN, D.J., HOGG, A.G., HUGHEN, K.A., KAISER, K.F., KROMER, B., MANNING, NIU, M., REIMER, R.W., RICHARDS, D.A., SCOTT, E.M., SOUTHON, J.R., STAFF, R.A., TURNEY, C.S.M. and VAN DER PLICHT, J. 2013: IntCal13 and Marine13 radiocarbon age calibration curves 0-50,000 Years cal BP.*Radiocarbon*, 55(4), 1869–87.

ROCHE, H. 2002: *Discovery Programme Reports 6 - Tara* (Dublin).

RONDELEZ, P. 2014: Report on the Metalworking Remains at Nangor (Grange Castle Business Park), Co. Dublin (13E0435) (Unpublished Report).

RONDELEZ, P. 2018: The Irish bowl furnace: origin, history and demise.*The Journal of Irish Archaeology* XXVI, 101–16.

RUSSELL, I.R. 2003a: Claristown 4, Claristown. In BENNETT, I. (ed.), *Excavations 2001: Summary Accounts of Archaeological Excavations in Ireland No 949* (Bray).

RUSSELL, I.R. 2003b: Kilsharvan 5, Kilsharvan. In BENNETT, I. (ed.), *Excavations 2001: Summary Accounts of Archaeological Excavations in Ireland No. 990* (Bray).

RUSSELL, I.R. 2012: The excavation of an Iron Age site at Claristown, Co. Meath. In CORLETT, C. and POTTERTON, M. (eds.), *Life and Death in Iron Age Ireland in the Light of Recent Archaeological Excavations* (Dublin), 267–72.

SCHEERES, M., KNIPPER, C., HAUSCHILD, M., SCHÖNFELDER, M., SIEBEL, W., VITALI, D., PARE, C. and ALT, K.W. 2013: Evidence for 'Celtic migrations'? Strontium isotope analysis at the early La Tène (LT B) cemeteries of Nebringen (Germany) and Monte Bibele (Italy).*Journal of Archaeological Science* 40, 3614–25.

SCHEERES, M., KNIPPER, C., HAUSCHILD, M., SCHÖNFELDER, M., SIEBEL, W., VITALI, D., PARE, C. and ALT, K.W. 2014: 'Celtic migrations': Fact or fiction? Strontium and oxygen isotope analysis of the Czech cemeteries of Radovesice and Kutná Hora in Bohemia.*American Journal of Physical Anthropology* 155, 496–512.

SCHOT, R. 2018: Forging life amid the dead: crafting and kingship at Iron Age Tara. In *A Research Miscellany (*Dublin*,* Discovery Programme Reports 9), 107–28.

SCHWEITZER, H. and O'CARROLL, F. 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).

SCOTT, B.G. 1990: *Early Irish Ironworking* (Ulster).

TAYLOR, K. 2012: An Iron Age timber causeway in Annaholty Bog, Co. Tipperary. In CORLETT, C. and POTTERTON, M. (eds.), *Life and Death in Iron Age Ireland in the Light of Recent Archaeological Excavations* (Dublin), 291–302.

WALLACE, A. and ANGUILANO, L. 2010: Iron-smelting and smithing: new evidence emerging on Irish road schemes. In STANLEY, M., DANAHER, E. and EOGAN, J. (eds.), *Creative Minds: Production, Manufacturing and Invention in Ancient Ireland* (Dublin, National Roads Authority Monograph Series No. 7), 69–84.

WADDELL, J. 1991: The Irish sea in prehistory.*The Journal of Irish Archaeology* 6, 29–40.

WADDELL, J. 2010: *The Prehistoric Archaeology of Ireland* (revised edition) (Dublin).

WADDELL, J., FENWICK, J. and BARTON, K. 2009: *Rathcroghan: Archaeological and Geophysical Survey in a Ritual Landscape* (Bray).

WENGER, E. 1998: *Communities of Practice: Learning, Meaning, and Identity* (Cambridge).

YOUNG, T. 2003: Is the Irish Iron-smelting Bowl Furnace a Myth? A Discussion of New Evidence for Irish Bloomer Iron Making (Unpublished GeoArch Report 2003/09).

YOUNG, T. 2005: Evaluation of archaeometallurgical residues from the Kildare Town Bypass, Co. Kildare; Loughlion Site 8 and Cherryville Site 12 (01E0846 and 01E0955) (Unpublished GeoArch Report 2005/16).

YOUNG, T. 2008: Detailed Recording of Furnace C397, Derrinsallagh 4 (E2180), M7 Portlaoise to Castletown/M8 Portlaoise to Cullahill Motorway Scheme Contract 2, Co. Laois (Unpublished GeoArch Report 2008/34).

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Data S1. Supporting Information