Ironworking in late medieval Ireland, *c*. AD. 1200 to 1600

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Volume I: Text

By

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I hereby declare that this thesis is my own work and has not been submitted for another degree, either at University College Cork or elsewhere,

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Abstract

The landscape of late medieval Ireland, like most places in Europe, was characterized by intensified agricultural exploitation, the growth and founding of towns and cities and the construction of large stone edifices, such as castles and monasteries. None of these could have taken place without iron. Axes were needed for clearing woodland, ploughs for turning the soil, saws for wooden buildings and hammers and chisels for the stone ones, all of which could not realistically have been made from any other material. The many battles, waged with ever increasingly sophisticated weaponry, needed a steady supply of iron and steel. During the same period, the European iron industry itself underwent its most fundamental transformation since its inception; at the beginning of the period it was almost exclusively based on small furnaces producing solid blooms and by the turn of the seventeenth century it was largely based on liquid-iron production in blast-furnaces the size of a house.

One of the great advantages of studying the archaeology of ironworking is that its main residue, slag, is often produced in copious amounts both during smelting and smithing, is virtually indestructible and has very little secondary use. This means that most sites where ironworking was carried out are readily recognizable as such by the occurrence of this slag. Moreover, visual examination can distinguish between various types of slag, which are often characteristic for the activity from which they derive. The ubiquity of ironworking in the period under study further means that we have large amounts of residues available for study, allowing us to distinguish patterns both inside assemblages and between sites. Disadvantages of the nature of the remains related to ironworking include the poor preservation of the installations used, especially the furnaces, which were often built out of clay and located above ground. Added to this are the many parameters contributing to the formation of the above-mentioned slag, making its composition difficult to connect to a certain technology or activity.

Ironworking technology in late medieval Ireland has thus far not been studied in detail. Much of the archaeological literature on the subject is still tainted by the erroneous attribution of the main type of slag, bun-shaped cakes, to smelting activities. The large-scale infrastructure works of the first decade of the twenty-first century have led to an exponential increase in the amount of sites available for study. At the same time, much of the material related to metalworking recovered during these boom-years

was subjected to specialist analysis. This has led to a near-complete overhaul of our knowledge of early ironworking in Ireland. Although many of these new insights are quickly seeping into the general literature, no concise overviews on the current understanding of the early Irish ironworking technology have been published to date.

The above then presented a unique opportunity to apply these new insights to the extensive body of archaeological data we now possess. The resulting archaeological information was supplemented with, and compared to, that contained in the historical sources relating to Ireland for the same period. This added insights into aspects of the industry often difficult to grasp solely through the archaeological sources, such as the people involved and the trade in iron. Additionally, overviews on several other topics, such as a new distribution map of Irish iron ores and a first analysis of the information on iron smelting and smithing in late medieval western Europe, were compiled to allow this new knowledge on late medieval Irish ironworking to be put into a wider context.

Contrary to current views, it appears that it is not smelting technology which differentiates Irish ironworking from the rest of Europe in the late medieval period, but its smithing technology and organisation. The Irish iron-smelting furnaces are generally of the slag-tapping variety, like their other European counterparts. Smithing, on the other hand, is carried out at ground-level until at least the sixteenth century in Ireland, whereas waist-level hearths become the norm further afield from the fourteenth century onwards. Ceramic tuyeres continue to be used as bellows protectors, whereas these are unknown elsewhere on the continent. Moreover, the lack of market centres at different times in late medieval Ireland, led to the appearance of isolated rural forges, a type of site unencountered in other European countries during that period. When these market centres are present, they appear to be the settings where bloom smithing is carried out.

In summary, the research below not only offered us the opportunity to give late medieval ironworking the place it deserves in the broader knowledge of Ireland's past, but it also provided both a base for future research within the discipline, as well as a research model applicable to different time periods, geographical areas and, perhaps, different industries.

Chapter 1

Research framework

1.1 Research aims

The main objective of this thesis is to provide a full and comprehensive analysis of the available knowledge on Irish ironworking in late medieval Ireland (c. AD 1200 to 1600). To this end, three main topics will be addressed. First, an assessment will be made of the types of iron available in Ireland at that time. This includes the ores recorded in the geological literature, for which a new distribution map will be composed. The results of chemical analyses carried out on geological ore samples, along with the analytical data gained from iron ores found on archaeological sites, will be used to characterize the different ore types in Ireland. If certain ore types can be finger-printed, then this will be used to interpret, or re-interpret, the analysis results available for smelting slag. The types of metal used can also be gleaned from the results of analyses results on finished iron objects. In addition, the written sources will be used to provide an overview of the types of iron recorded as used and imported into Ireland in the late medieval period.

Secondly, the available information will be used to elucidate various aspects of ironworking technology in late medieval Ireland. With regard to smelting, this means defining and describing the different types of furnaces in use at that time in Ireland. These types, and their chronological evolution, will be assessed against the background of the technological developments in iron smelting in western Europe during the same time period. Some of the better examples of Irish furnaces from the preceding period are included to evaluate the continuation or import of the technology after the Anglo-Norman invasion. Several other aspects of the Irish iron-smelting technology during that period, such as air supply and production capacity, will also be evaluated. Lastly, an attempt will be made to discern evolutions in the demand for iron during different periods and areas in late medieval Ireland. In regard to smithing, a similar line of enquiry will be employed. This involves comparing several aspects of the late medieval Irish technology, such as the type of hearths used, the fuels employed and the manner in which the bellows were protected, to those from preceding centuries and examples from Britain, and further afield, dated to the same period. Also, the important distinction between bloom smithing and secondary smithing will be characterized and applied to the Irish evidence. It is also intended to assess the information from the various analyses results carried out on late medieval Irish smithing residues and finished artefacts. The former will permit to gain insights into smithing conditions, while the latter offers invaluable information on the forging techniques employed. This will also be considered in a wider context.

The third research aim centres on the place of ironworking in late medieval Irish society. This is approached from the angle of ethnicity and ironworking, on the one hand, and the organization of the industry, on the other. After a discussion on the difficulties regarding the identification and labelling of the different ethnicities in late medieval Ireland, the correlation between the various population groups and ironworking will be examined through a combination of archaeological and written sources. An attempt will be made to establish if certain aspects of late medieval ironworking can be attributed to one or more of these ethnic groups. Several aspects of the organization of the iron industry of late medieval Ireland will be studied. This includes establishing which social groups were behind the technological changes discernable in the record. It is intended to use all of the above information and propose models illustrating the structure of the late medieval Irish iron industry. These models will be based on the correlations between different types of sites and the activities carried out on them. As such, the operational sequence (*chaîne opératoire*) of late medieval Irish ironworking will be vizualized as one or more sequences of site types where the different stages of the *chaîne* are carried out. These models have implications for the trade in iron in its various forms and for the wider economic organization of late medieval Irish society. Finally, the above information will be compared with the available data for the rest of northwestern Europe to illustrate the position of late medieval Irish ironworking in a wider context.

1.2 Previous research

Apart from Brian Scott's publications during the 1970s and 1980s, most of the work on the archaeology of Irish ironworking is of very recent date. In general, the research in this area has experienced a tumultuous history, only recently settling down as important aspects of the technology are becoming agreed upon. As many of the misconceptions in the field go back to the very beginning of archaeology as a discipline, a broader overview is offered here, to locate research undertaken in Ireland in a wider context.

1.2.1 The pioneers

Early histories of the production of iron were based on the available written sources combined with surviving technologies in Europe and beyond, in an attempt to reconstruct the installations and technologies used in the distant past. Travellers and explorers had published descriptions of furnaces used for smelting iron still in use in Ceylon (Knox 1681: 97–98), India (Buchanan 1807 vol. 1: 171–172), Central Africa (Mungo Park 1799: 283–285), Russia (Georgi 1775: 399–401, 875–876) and other regions. The majority of these furnaces were round or square shafts of clay from which the slag was tapped off laterally. Most of the time, some kind of bellows was used, but, in some cases, the bloomery furnaces was blown by natural draught. Other furnace types were also described, such as the large pits without a superstructure in Madagascar described by W. Ellis (1858: 264–265). Smaller furnaces, without slag-removal, were noticed by J. Russegger (1838; 1844: 286–293) during his travels in the Kordofan area in Northern Sudan, but here the iron was smelted in a two-step process, whereby the slag richest in iron from the first smelt was reduced again in the same installation. Also in Europe, iron-smelting furnaces making wrought iron directly from the ore were still in use, and had been described, by the early nineteenth century. Most of these were water-powered bloomeries of the open-hearth type, such as the furnaces in Lancashire (Lister 1694) and on Corsica (Tronson du Coudray 1775) and a similar process was in use in North America (Overman 1855: 541–552; Sterry Hunt 1870). In Scandinavia, until the nineteenth century, bloomery iron was still manufactured in open, funnel-shaped, timber-cased furnaces and their bellows were operated using either water power or treadles (Jensen 1968; Buchwald 2008: 40–43, 413).

The Catalan furnace, used in the Pyrenees, was a large open-hearth furnace with slag-tapping provisions which could produce blooms up to 150kg of various types of iron (Percy 1864: 280). The blowing apparatus was a *trompe*, an installation by which air was pushed into the hearth due to the pressure of falling water. The Catalan furnace or forge was to greatly influence the later archaeology of iron and the term would often be used to describe any kind of bloomery furnace. Rinmann (1785: 317–318), described the *Luppenfeuer*, a hand-blown bloomery furnace with a clay and stone shaft which was still in use in Germany at the time of his writing. More than a decade earlier, von Justi (1771: 323) published what could be the oldest description of an excavated furnace and, if so, can be seen as the beginning of the archaeology of ironworking. The author, having found remains of old iron-smelting furnaces while looking for iron mines, at an unspecified location, in his role as Prussian Inspector for Mines, Glass, and Steel Works, speculated on how these would have looked and functioned. They consisted of heaps of about 1.5 to 2m wherein a cylindrical hollow of about 1m deep and about 0.6m diameter was made. At the base there could have been a hollow for collecting the slag and, higher up, a hole in the furnace wall for admitting the necessary air flow.

According to both von Justi and Rinmann, furnaces like these would have been the earliest to have been used to produce iron. Other authors would also propose early furnace-typologies based on the examples available to them. Hasse (1836: 6) suggested a sequence from *Erdgruben* (pits in the ground, that is to say bowl furnaces) over *Bauernofen* to *Zerrenherden* or *Luppenfeuer*.[1] In the historical sketch at the end of his seminal work, J. Percy (1864: 878) proposed a sequence starting with the Catalan hearth, going through the successive stages of the Osmund furnace and the *Stückofen*[2] before arriving at the blast furnace. Around the time of the publication of Percy's work, more and more members of the growing body of antiquarians had started publishing the results of excavations carried out all over the globe. In many areas in Europe with an iron-mining history, this led to the discovery of the remnants of iron-smelting furnaces. Most of these fitted in with the shaft furnaces known from other continents (the slag-pit furnaces took somewhat longer to be recognized as such), but a few of the sites showed different structures connected with ironworking.

One of the earliest extensive archaeological surveys of ironworking remains was carried out by French mining engineer Auguste Quiquerez in eastern Switzerland. The fieldwork, including excavations, took over 15 years and resulted in several well-illustrated publications. In the first of these, Quiquerez (1866: 35) quoted the occurrence of bowl-shaped furnaces next to more elaborate furnaces set into conical mounds. These last furnaces were shown to operate with natural draft and were dated to the Iron Age. In a later publication (Quiquerez 1870: 77), and after further excavations, the author re-

1 These terms are used to designate different installations by different authors, probably with *Bauernofen* this author means shaft furnace and with *Zerrenherd* and *Luppenfeuer* water-powered bloomeries.

2 Percy (1864: 320–321) uses the term Osmund furnace to describe the open-hearth furnaces which are now usually termed Evenstadt furnaces after one of its earliest describers, a *Stückofen* is a medium-sized water-powered furnace capable of making both wrought and cast iron.

interpreted the bowl-shaped furnaces as bases of more sophisticated models. As we will see, these furnaces were actually of late medieval date (See Chapter 10.1.2). In 1870, during construction works for a railway at Hüttenberg in Austria, two hollows, interpreted as a calcining hearth and a furnace, set in a mortared embankment were uncovered. In the same year, at Lustin (actually in the commune of Godinne) in Belgium, two oval, conical pits, measuring over 4 by 3m, were discovered on the banks of the river Meuse (Berchem 1873a, 1873b). Both had a stone-lined channel set in the side leading down to the centre and contained unfused pieces of iron ore, vitrified material with a very high iron content and "some charcoal fragments". A small piece of this vitrified material was analysed, which gave a percentage of iron of more than 93% iron for the inner part, which led to the pits being seen as iron-smelting furnaces. The author ends the article with the rhetorical question: if these installations, because of their rudimentary character, should not be assigned to a far-removed epoch.

Mushet (1822: 249) had, early on, tentatively proposed a sequence of "air-bloomeries", using natural draft, followed by "blast-bloomeries", using bellows. Swank (1892: 72–73), following the same model, assigned the above example from Lustin to the pre-Roman period on the basis that it did not use a forced blast. Others also adhered to the view that furnaces evolved from simple structures to more complicated ones, implying the continued use of bellows. Ludwig Beck (1891: 779) concurred that the earliest Germanic iron smelting would have taken place in low shaft furnaces or "open hearth fires", while according to Gowland (1899: 311–319) "the shallow hole scraped in the ground" was the earliest furnace type, but stated that it had not yet been found, nor was it likely to be, in Europe. As more advanced installations, the same author put forward the examples of Kordofan and the Catalan furnace, being hollow furnaces fed with oxygen from above. Next, vertical holes were blown from below, which eventually led to the shaft furnace proper. Kluseman (1924) suggested a further evolutionary model comprising several furnace types: pits (*gruben*), furnaces, advanced furnaces, blast furnaces and crucible furnaces. The author found examples of all these types both in Africa and Europe and arrived at the conclusion that iron-smelting technology had originated in Africa, which had then spread to Europe.

1.2.2 The bowl furnace

Oliver Davies (1935: 42–44), lecturer at Queen's University Belfast, using a similar model to Gowland's, introduced the term “bowl-furnace” into the English language to describe dug features interpreted as iron-smelting furnaces. These consisted of clay-lined hearths with the blast being delivered from above. Davies quotes numerous examples from all over Europe, including Hüttenberg, dating from the Iron Age until the medieval period. Other types of furnaces for smelting iron included the pot furnace, the ditch furnace and the shaft furnace. Two years later, in an excavation report of a cairn by Estyn Evans (1937: 14), Davies interpreted three pieces of slag as originating from a bowl furnace and at the same time suggested one of them could be termed a “furnace bottom”. Clearly under the influence of Davies, both terms would become commonplace in Irish archaeology during the rest of the 1930s and the 1940s (Hencken 1939: 54–55; Ó Ríordáin 1942: 105–107; Mogey 1946: 133). Forbes (1950: 127–128) would more or less take over Davies' definition, examples and furnace-typology, including the bowl furnace, and Coghlan (1956: 87–89) simplified the technology to bowl furnaces, domed (“pot”) and shaft furnaces. In defining the bowl-furnace, the author accepted air supply both from above and lower down in the furnace, and stated that it is doubtful that the slag was tapped in these installations. The seminal work by Schubert, *History of the British Iron and Steel Industry from c. 450 B.C. to A.D. 1775* (1957: 28), included many new examples of bowl furnaces excavated in Britain, including the recently published Iron Age ironworking remains at Kestor (Fox 1954) and the older results from the cave at Chelm's Combe (Palmer et al. 1926).

Whereas the working of the shaft furnace could still be readily studied in some communities in Asia and Africa, the bowl furnace could best be understood and/or validated through the reconstruction of the process. In what must be one of the earliest experiments in archaeometallurgy[3], Wurmbrand (1877: 152), using the Hüttenberg pits as an example, managed to roast and smelt an unspecified amount of iron ore into nearly 5.5kg (12 *pfund*) of good quality wrought iron in 26 hours. The author did remark on the large amounts of charcoal that had to be used. Coghlan (1941: 77) tried, in a series of experiments, to smelt iron ore using the “camp-fire model”, but found that it had merely been roasted or turned into a cindery material which crumbled under hammering. Sadzot (1956), using different models of a *bas-foyer*, in this case shaft furnaces without slag-tapping, did manage to produce blooms up to 5kg. Around the same time O'Kelly (1961) was conducting experimental iron smelting in Ireland based on the examples

3 Before 1785, a Mr. Garney had built some *Bauernofen* 'of the very oldest smelting method' in Daland, Sweden to produce bloomery iron. Interestingly, the argument was that there was more demand for high-quality wrought iron than there was for steel (Rinmann 1785: 319).

found at Kestor and Chelm's Combe. This author came to the conclusion that using a clay-lined, hemispherical hollow with a clay covering and measuring 0.3m diameter by 0.3m deep, led to the production of residues closest resembling the ones known from the archaeological record. An earlier experiment using the bowl furnace (Wynne and Tylecote 1958) indicated that these installations gave poor results if uncovered and that pre-packing the fuel in front of the air blast improved the yield.

A metallurgist by training, Tylecote would turn his attention to the excavation of ironworking remains, and was soon publishing the results of a 1ate medieval site in Weardale (1959) and a Roman site at Ashwicken (Tylecote and Owles 1960). Both articles describe bowl hearths being used for reducing iron ore next to shaft furnaces. The slag from one of the furnaces at Weardale had been tapped. Shortly after, the same author would also publish a general work on archaeometallurgy of the British Isles (Tylecote 1962), in which he discusses numerous examples of bowl furnaces, while also accepting the possibility of slag being tapped from these kinds of installations (ibid: 226, 229 and 266). Three years later, Tylecote (1965b) in an article attempting to classify iron-smelting furnaces known from the anthropological record, divided the installations according to the method of air supply (natural draft and induced draft) and the absence/occurrence of slag-tapping. In this paper, the author states that "[v]ery few recent pre-industrial furnaces seem to be what the archaeologist has been tending to call bowl furnaces in which the bloom is withdrawn through the top" (ibid.: 341). In his next overview on early metalworking, *A History of Metallurgy*, Tylecote (1976: 41–42) again gives the bowl furnace more prominence. This time it is defined as a hollow without slag-tapping and with a short clay superstructure. This type of installation was seen as the typical furnace used for reducing iron during the Iron Age and was only superseded by the slag-tapping "developed bowl-furnace" during Roman times. The same arguments were used by Tylecote in an article four years later (Tylecote 1980: 210–211), but a year after that, West Brandon and a newly excavated site at Roxby, Cleveland were quoted as the only British examples of bowl furnaces (Tylecote 1981a: 21–22). Also the strict "Iron Age = non-slag-tapping, Roman = slag-tapping" distinction was dropped.

Next, in his influential *The Prehistory of Metallurgy in the British Isles*, Tylecote (1986: 133), defined the true bowl furnace as an installation with a height about equal to its diameter. Three types were distinguished: furnaces where the fuel is packed in front of the tuyere (Catalan principle); with layered or mixed addition of fuel and ore and finally open furnaces wherein the mixture is manipulated to prevent re-oxidization. Furnace bottoms from bowl furnaces could be distinguished from smithing residues based on their larger size. Examples of bowl furnaces given were Chelm's Combe and Kestor, while West Brandon was re-interpreted as a low shaft furnace. In Tylecote's last overview work on archaeometallurgy (1987: 152–154), the bowl furnace was described as an installation that functioned with the fuel in front of the blast and the ore packed on the opposite side. As examples, the author gave the Catalan furnace, the nineteenth-century Scandinavian ones and “its African counterparts”. No archaeological examples were given.

In a final article (Tylecote and Merkel 1992), the Catalan, Scandinavian and Burundi furnaces (see below) were used as examples of the bowl furnace, either working with vertically packed charges or manipulation during smelting. In Germany, the discovery of large domed furnaces seemingly using natural draught and dated to the Iron Age, excavated in the 1930s (Gilles 1936), would lead to less emphasis being put on the bowl furnace as a potential “primitive” furnace type and a renewed interest in the German-speaking world in the use of induced draught by early furnaces (Gilles 1952; Osann 1971: 9–16; Pelet 1976). Cleere (1972) had also taken into account the factor of natural draught in his influential classification and Bielenin (1973) would successfully use natural draught in his experiments on early bloomery technology in Poland.

1.2.3 Smithing hearth cakes and new furnace typologies

That not all slag relating to early ironworking was produced in furnaces was already appreciated early on, for example at two Roman sites at Warrington where May (1904: 18–33) distinguished not only various furnaces, but also “refining furnaces or smithy hearths” with accompanying slag. Both Coghlan (1956: 50), who quoted May, Schubert (1957: 23) and Gilles (1957: 182) accepted the bloom-refining hearth with associated slag. Gilles distinguished between iron-rich slag deriving from bloom smithing and iron-poor slag from steel making, when sand and manganese were added. Tylecote (1962: 232–233) acknowledged that slag is produced during bloom refining, but specifically stated that further smithing only left hammerscale. In the same work (ibid.: 193), the author also points to the difficulty in distinguishing “forging cinder” from early smelting slag. In the 1960s and early 1970s, several authors, led by researchers in Central Europe, started to realize that early blacksmithing did indeed result in the formation of slag (Pleiner 1963; Bartuška and Pleiner 1968; Pleiner et al. 1971; Jones and Grealey 1974: 156). At first, Tylecote had started calling these residues “smithing furnace bottoms” (Tylecote 1975; 1981b: 43) and later terms such as “plano-convex bottoms”, “smithing hearth bottoms”, and “smithing hearth cakes” would be applied to the same material, as it also became clear that these bun-shaped lumps of slag were the dominant form of smithing residue (McDonnell 1983: 83).

It was not only the “furnace bottoms”, but also the installations themselves which came to be seen in a different light. Before the First World War, de Tryon-d'Alembert had already realized that small hollows with limited slag were more likely to be the result of smithing than smelting, without discarding the possibility of smelting in small “Catalan hearths”, but his work would only see publication some 40 years later (de Tryon-Montalambert 1955: 71; 1956). Cleere (1972: 8–11), although retaining the bowl furnace in his classification of early iron-smelting furnaces, pointed to problems with both the uncovered and the covered variety. The first was unlikely to produce iron due to the lack of heat insulation and reducing conditions, the second would only produce very limited amounts because of the problem of replenishing the process with fuel and ore. The author also states that larger, potentially covered “bowl-furnaces”, such as at Hüttenberg or Great Casterton, were more likely to have functioned as roasting or smithing hearths. Further discussion about the typology of iron-smelting furnaces would be based on the preference of differing criteria, but consensus would never be reached (See for example the discussion in *Norwegian Archaeology* between Martens 1978b, 1978a; Pleiner 1978 and Serning 1978).

Based on the study of slag and experiments with bowl and shaft furnaces, Clough (1985) argued for a re-evaluation of sites producing plano-convex slag cakes accompanied by shallow hollows. The installations at the sites of Kestor and West Brandon were considered more likely to be the bases of shaft furnaces (ibid.: 183–184). In a later work, the same author stated that bowl furnaces could be used to reduce iron ores, but only with very rich ores and producing limited blooms (Clough 1988). Around the same period Peter Crew was excavating several iron-smelting sites in Wales. At first these furnaces were interpreted as bowl furnaces, but after several experiments it was concluded that these furnaces should be interpreted as low-shaft furnaces, albeit without the slag being tapped (Crew 1991).

Meanwhile, Brian G. Scott of Queen's University Belfast had been studying a wide range of aspects of early metallurgy in Ireland since the early 1970s. In his overview publication *Early Irish Ironworking* (Scott 1990), the author argued that the lack of tap slag combined with the consistent occurrence of hollows, clay-lined or otherwise, on sites producing ironworking residues, "makes it certain" that, at least before late medieval times, iron in Ireland was smelted using bowl furnaces (ibid.: 155, 158–167). The evidence, however, was often too scant to be able to establish if these furnaces had a clay superstructure or not. With regard to the plano-convex slag cakes found on these sites, the author stated that a general European consensus accepted that the larger ones (more than 0.3m diameter) could be seen as furnace bottoms (produced in a bowl furnace), while smaller ones (0.1–0.15m) should be seen as smithing hearth bottoms (ibid.: 155–156). This still meant that positive identification of Irish sites was often a difficult process. Scott also claimed that liquid iron could be produced in a bowl furnace, citing that cast iron rather than blooms were produced during O'Kelly's experiments (ibid.: 33, 39).

One of the earliest criticisms of this model was published as a specialist report on metalworking residues excavated at Tara Hill, Co. Meath, where the "myth of Irish iron-smelting in the so-called bowl furnaces" was opposed (Crew and Rehren 2002: 96). Instead it was suggested that the smelting occurred in shaft furnaces. As this was referenced to earlier experimental and excavation work by Peter Crew, this implied that the furnaces were interpreted as being non-slag-tapping[4]. When Radomir Pleiner (2000: 144–149) published his seminal *Iron in archaeology. The European bloomery smelters*, he defined the bowl furnace as open hollows in the earth lined with refractory clay, and saw them as the simplest and likely the oldest type of iron-smelting furnace (2000: 144–149). The examples, however, include furnaces from the Republic of Georgia, which were about one metre deep with the upper half consisting of a stone-lined funnel leading into the lower hearth (ibid.: 144). Another example, this time from Langenbach, Nord-Rhein/Westphalen, Germany, was a 0.50m-deep pit with facilities for slag-tapping (ibid.: 148). Apart from older and newer examples of Eastern European furnaces, those from Kestor in Devon and various Irish sites are also quoted as bowl furnaces.

But, by this time, more and more archaeologists were distancing themselves from the concept of the bowl furnace and fewer furnaces would be described as such. Two recent works, giving an overview of the current knowledge of early ironworking in France, did not include the bowl furnace in their furnace-typology (Leroy and Merluzzo 2004; Fabre and Coustures 2005: 295). However, archaeologists working in Africa have

4 It is important to remember that slag-pit furnaces are generally considered as non-slag-tapping by English researchers.

recorded features which could classify as bowl furnaces. The furnaces from Rwanda and Burundi described by Celis (1989: 35–46) all operate without slag-tapping, while some have, and some do not have, a superstructure. The iron ore is reduced in pits with a diameter of about 0.6 to 0.7m and a depth varying from 0.1 to about 0.4m. Each furnace type had its own specific way of packing the ore-fuel charge. The ore used was haematite and the slag was described as adhering to the pieces of bloom recovered after the smelt. Also some furnaces from Kenya, using exceptionally rich magnetite sands as ore, have been described as bowl furnaces (Iles and Martinón-Torres 2009), but here, due to the limited amount of slag produced, the bowl can be seen as a small slag-collecting pit.

1.2.4 Ireland

In Ireland, although the highly influential work by Brian Scott (1990: 155–156) did differentiate between smaller bun-shaped slag cakes as originating from smithing and larger ones as “furnace bottoms”, in the years following this publication, most excavators would interpret any plano-convex slag lump as the result of iron smelting (See for example McMahon 2002: 103; Comber et al. 2006: 121–122). This led to the situation where, even if potential confusion with smithing sites was accepted, it was generally believed that early iron smelting in Ireland was undertaken in small hearths in a wide variety of settings (Edwards 1996: 86–87; Barry 2004: 108–110). It was only after excavations were carried out in non-settlement contexts as a result of infrastructural works, and specialists with training in archaeometallurgy were engaged in those projects, that a different picture started to emerge. The first of these, Effie Photos-Jones, was approached to study the archaeometallurgical residues excavated along the N8 in 2001 (Photos-Jones 2005). In the townland of Ballinvinny North, Co. Cork a pit, radiocarbon dated to the Iron Age, with vertical sides and a flat base was uncovered. The slag was dense and drippy with pieces up to nearly 0.2m long and weighing more than 2kg. These slag pieces were interpreted as waste, but “also resemble blooms and […] assessed on that basis by the early Irish smith” (ibid.: 75). In conclusion, the feature was seen as both allowing space for slag to run and as a repository for this slag (ibid.: 87).

Around the same time, Tim Young, a geologist by training, wrote reports on furnaces of the same type from Tullyallen, Co. Louth, Cherryville, Co. Kildare and

Carrickmines, Co. Dublin [22] (Young 2003). This author interpreted these features as pits under the actual furnace, which would have had a shaft, and suggested dropping the term "bowl furnace" for these kinds of features and considered them a type of slag-pit furnace, albeit of a smaller type, with less slag, than examples of this furnace type known from abroad (ibid.: 3). The drippy slag showed impressions of relatively large pieces of wood, interpreted as stacking material in the furnace pit before firing. This theory was re-enforced by the survival of a "furnace cake" (11.2kg) with partial slag flow at the upper part of the Tullyallen furnace. No less than 21 additional features were interpreted as the basal pits of iron-smelting furnaces, all of which were uncovered in 2003 during the excavation on the N7-Motorway trajectory (Young 2005). Next to slag with wood impressions and fragments of furnace cake, furnace-wall fragments and indications of an arch in the walls to facilitate slag- and bloom-removal were observed.

Photos-Jones (2008g), on the other hand, would interpret similar features (vertically sided pits c. 0.4m diameter, drippy slag) found along the trajectory of the M4 motorway excavated in 2002 unequivocally as "bowl furnaces". Vitrified ceramic material associated with the furnaces was interpreted as the remains of clay ridges for protecting the bellow-ends (Photos-Jones 2008f: 17). Oxidization at the sides of the features pointed to the limited reducing conditions inside these installations (Photos-Jones 2008g: 8). In the report on the material found at Killickaweeny, Co. Kildare, the same author stated that slag from different furnace types is difficult to distinguish visually (dripped vs. dropped) and that furnace bottoms are indicative of "largely unsuccessful smelts" (Photos-Jones 2008h: 15). Photos-Jones also reported on an area of intensive ironworking uncovered at Derrinsallagh 4, Co. Laois (Photos-Jones and Wilson 2009a). Here again the author dismisses the dense drippy slag as smelting slag and instead suggests that the material represents "slag accumulation clogging the furnace" while no bloom would have formed (ibid.: 426). Ceramic rims about 40 to 50mm high, well finished according to the author and hence not furnace shafts, were interpreted as lips for containing the charcoal (ibid.: 429).

One of the furnaces from this site was lifted after it was partially excavated and further examined and described by Tim Young (2009c), who interpreted the feature as a slag-pit furnace with an arch and working hollow in front to facilitate slag- and bloom-removal. The outspoken negative view of the skills of Irish ironworkers held by Photos-Jones, however, is rarely substantiated by the many analyses carried out by this author. Moreover, statements in these reports concerning the identification of the processes through chemical analyses and mineralogical examinations are sometimes contradicted in other reports. For example, in one report slag was interpreted as representing the result of smelting because of its large proportion of interstitial glass (Photos-Jones 2010b: ccxxviii). In an earlier reports, however, smelting slag was identified with small amounts of the same material (Photos-Jones 2008a: 11) and, in another, slag from a post-medieval forge was shown to have similar amounts of interstitial glass (Photos-Jones 2005: 47).

In the meantime, other specialists had also begun making reports on Irish ironworking remains. Neil Fairburn (Dowd and Fairburn 2005) was the first to publish an account differing from the traditional bowl furnace model. A relatively small amount of slag recovered from a shallow depression during gas-pipeline construction at Farranastack, Co. Kerry [61] was identified as tap slag and deemed the result of iron smelting in a shaft furnace. At Cappakeel, Co. Laois more tap slag was identified, but again without a furnace (Fairburn 2005b: 34). At Lisnagar Demesne 1, Co. Cork, tap slag was found in a pit from which an Iron Age radiocarbon date was retrieved (Fairburn 2006: 56–57). Although the slag was seen as originating from a shaft furnace, the pit, which measured 0.46 by 0.41 by 0.12m and had steep sides (Murphy 2006: 44), had all the characteristics of a pit under a slag-pit furnace. Fairburn (2007) would recognize the occurrence of slag-pit furnaces in Ireland shortly after this and identified features as such at Monganstown, Co. Westmeath but, confusingly, still classified them as shaft furnaces (2009a: 35).

Angela Wallace, sometimes in cooperation with Lorna Anguilano, has also reported on the metalworking remains from various infrastructures projects. The sites studied included a stone-lined furnace pit at Tonybaun, Co. Mayo (Wallace and Anguilano 2010a) and a small furnace with lateral slag-tapping built against one end of an oval pit at Grange 2, Co. Meath (Wallace and Anguilano 2011). Barry Cosham has, since 2008, been involved in writing specialist reports on archaeometallurgical residues from Irish sites and has identified the furnaces encountered near-exclusively as slag-pit furnaces or shaft furnaces (see for example Cosham 2009b: 159 and 2011: 377). Lynne Keys, influenced by Young, also regularly identified smelting installations as slag-pit furnaces (Keys 2010a: 27; 2012b: 299). Very recently, doctoral research was carried into the technological and social aspects of Irish ironworking during the Iron Age and Early Medieval period (Dolan 2012). Here, again, it was concluded that the majority of the furnaces excavated belonged to the slag-pit furnace type (ibid.: 197).

The idea of slag-pit furnaces being the dominant furnace type in use in early Irish iron ore smelting has recently been adopted by non-specialists, although remnants of the “bowl furnace” model are still in evidence (Carlin 2008: 91–93; O'Sullivan et al. 2010: 108–109). As a result of the misidentification of the bun-shaped smithing slag as “furnace bottoms”, late medieval iron smithing had not received a lot of attention in Ireland before 2000. Since then, as a result of these slag cakes being seen as the result of forging activities by all the above specialists, smithing sites are more frequently being recognized and described as such. Most of the information from the infrastructure projects, however, remains unpublished. Various types of smithing sites were identified in Brian Dolan's (2012: 198–199) doctoral study on early Irish ironworking.

Systematic research into the available written sources on late medieval ironworking in Ireland has not been carried out to date, although some archaeological publications did incorporate references to trade and smithing (Barry 2004: 108; Murphy and Potterton 2010: 444). The only aspect of ironworking in late medieval Ireland that has been studied by historians to any extent is the organization of the urban guilds, some of which catered for ironworkers and merchants (for example Le Fanu 1930). Information on the position of Ireland in the late medieval trade networks, however, has been extensively researched, including the information on iron (Touchard 1967; Bernard 1980; Childs 1982; O'Brien 1995; Childs 2000; Lyons 2000). A recent extensive study on the trade between Bristol and Ireland in the sixteenth century has also provided valuable information on the iron trade (Flavin 2004; Flavin and Jones 2009), with further research concentrating specifically on the material culture in Ireland at that time (Flavin 2011).

1.3 The sources

1.3.1 The documentary sources

The use of late medieval written sources to help answer archaeological questions has a long tradition in Ireland, including an important cooperative project in the early 1980s, when both phospate analysis and documentary evidence was combined to understand the nature of the Anglo-Norman settlement at Newcastle Lyons, Co. Dublin (Edwards et al. 1983). More recently, *The Dublin region in the Middle Ages* (Murphy and Potterton 2010) is an excellent example on the use of both archaeological and historical sources to describe the material world during the late medieval period. Although many late medieval sources were lost during the fire at the Public Records Office in 1922, several important series had been calendared and published in full previously, such as the *Calendars of Documents relating to Ireland* (Sweetman 1875–1886), the *Accounts in the Pipe Rolls of the Irish Exchequer* (as Appendices to the Reports of the Deputy Keeper of Public Records in Ireland, vols. 36–47) and the *Account Roll of the Priory of the Holy Trinity, Dublin 1337–1346* (Mills 1891). Much other material is preserved in different archives, including the most extensive surviving manor accounts for late medieval Ireland: the accounts for the Bigod manors in the south-east of the island. Regrettably, only a small part of these has been published to date. Much more late medieval source material was, and continues to be, published, either as papers or monographs.

The documentary sources used were limited to those those present in the UCC library, which has near complete collections of the various Calendars and other Public Records Office series, supplemented with additional material available through the Internet. Together, these accounted for the vast majority of published primary sources for late medieval Ireland. However, some potentially important information, such as that contained in the fourth volume of the Calendar of Justiciary Rolls for example, was not included as it was not present in either of the above repositories. Surprisingly few references to ironworking were found in the late medieval Gaelic-Irish literature. A general review of the evidence by Nicholls (1987: 417–418) and another, more specifically on the information contained in the surviving Bardic poetry, by Simms (2004: 153–157), provided only a handful of examples. Many of the early Irish laws, which Brian Scott has mined so succesfully for information on early medieval ironworking (1983; 1988b; 1990: 171–212), were still in use in late medieval times (Patterson 1989), but it would appear unwise to conclude that the technological and other information in those early texts is of relevance for the understanding of the later situation. Additionally, a handful of unpublished manuscript sources relating to the smelting of iron in Ireland in the sixteenth and early seventeenth centuries were transcribed and their information incorporated into this thesis.

1.3.2 The archaeological evidence

By far the most relevant results of excavations are as yet unavailable in published form and in many cases where they are, the information is insufficient to allow it to be meaningfully interpreted. For this reason, where possible, the excavation reports[5] themselves were used for interpreting the remains relating to late medieval iron smelting and smithing in Ireland. The main reference sources to these reports were the yearly-compiled *Excavation Bulletins*[6] and the archaeological database of the National Roads Authority (NRA).[7] One of the archaeological companies, Eachtra Archaeological Projects Ltd., have put the majority of their excavation reports in their online *Eachtra Journal.*[8] Reports of the two most proficient specialists who worked on Irish ironworking remains, Tim Young and to a lesser extent Effie Photos-Jones, are also available on their company web sites.[9] Since recently, the NRA provides full access to all their excavation reports finalized to date. Several reports on excavations not carried out by the NRA were obtained directly either from the directors or the companies responsible, while for others again, permission was received to take copies and notes from the paper versions held in the National Monument Service in Dublin.

As most of the information on Irish iron ores was published before 1900, much of it was found in digital collections of out-of-copyright publications, such as *Archive.org*. Further information on iron ore occurrences was found in online newspaper archives[10] and, especially, on the online map of the Geological Survey of Ireland, which includes a database of minerals in the Irish Republic.[11] The information on ironworking technology, the material on the European background of the industry and that on the more general information on late medieval Ireland were mostly found through the various online content providers such as JSTOR and several publishers.[12] The latest volumes of the Irish archaeological journals not in JSTOR, such as the *Journal of the Cork Historial and Archaeological Society*, *Old Kilkenny Review*, *Tipperary Historial Journal* and many more, were consulted in the University College Cork library. The archaeological monographs on late medieval sites in Ireland were similarly checked in the same repository. Much additional information was retrieved by using the Google search-engine to find both out-of-copyright source material and more

5 Several of these excavation reports have no pagination either in part or in full. In these cases, the page referred to is the page number of the document.
6 Published in hard cover, but text searchable version online at www.excavations.ie
7 Visible at www.nra.ie/archaeology/nra-archaeological-database/
8 eachtra.ie/index.php/journal/
9 Respectively archaeometallurgy.co.uk/report_static_index.aspx and www.sasaa.co.uk/sasaa%20projects.htm
10 At www.irishtimes.com/archive and http://www.irishnewsarchive.com, accessed through the Boole Library interface
11 Visible at http://spatial.dcenr.gov.ie/imf/imf.jsp?site=GSI_Simple
12 Accessed through the University College Cork online collections.

recent publications put online by the authors themselves. *Academia.edu*, for example, was very useful for finding recently generated works. These then often contained references to valuable older material. Of the online bibliographies, the *British and Irish Archaeological Bibliography*[13] proved the most relevant and productive, while much information was retrieved from the various collections accessible through the Archaeological Data Service.[14]

1.4 Research methods

1.4.1 Research timeframe

This research project commenced in the autumn of 2009 and ran up until the submission of the thesis in December 2013. The first year (2009–2010) was mostly devoted to collecting and processing of the published material on various aspects of the research: excavated remains of late medieval ironworking in Ireland and northwestern Europe, Irish iron ore occurrences, documentary evidence of iron trade and ironworking in Ireland and the archaeometallurgy of iron in general. A start was also made in locating and studying the available unpublished excavation reports and initial contacts were made with specialists in the field, mainly members of the Historical Metallurgy Society. All the above activities were continued in the second year of research (2010–2011) and supplemented with the initial writing up of the chapter on the archaeometallurgy of iron in Europe. The first visual examination of an assemblage of late medieval Irish ironworking residues, from Aghmanister, Co. Cork [1], was also undertaking in that period. By the end of the third year (2011–2012), the vast majority of published and unpublished material had been collected and processed. Most of the information on excavated Irish remains was also written up in the form of the thesis catalogue. Much of this third year was dedicated to the examination of additional assemblages of ironworking remains. The fourth and final year (2012–2013) was then primarily used to synthesise and write up the data collected. Throughout the four years, information on late medieval Irish ironworking was presented at seven conferences, both in Ireland and abroad.

13 www.biab.ac.uk
14 archaeologydataservice.ac.uk

1.4.2 Data analysis and source criticism

The body of information relating to late medieval ironworking in Ireland has increased exponentially during the last decade and a half, as a result of the many infrastructure works carried out during this period. Our knowledge about the techniques involved has reached the point where we can, in most cases, confidently distinguish between the various stages in the production of iron, different furnace types and various smithing techniques. This is especially the case where *in situ* ironworking features are found with associated slag which was not extensively weathered. As a first step these recent insights will be applied, when enough detail is present, to the available archaeological data, both published and unpublished.

For nearly one third (32.6%) of the late medieval Irish sites with ironworking the assemblages had, before this research, been subjected to visual examination, while only 4.6% saw metallographic and chemical analysis of iron objects. There was a large discrepancy between the types of sites and the study of their ironworking assemblages and the sixteen collections on which visual examination was undertaken as part of this doctoral research, were selected to partially balance this situation (Table 1.1).[15] As very little material from the large urban sites (8.8%) had been visually examined before this research, most assemblages choosen were from this type of site. Three collections from Cork (Phillips' Lane [35], 35–39 South Main Street [36] and Tuckey Street [39]) and four from Kilkenny (The Parade [82], 33 Patrick Street [84], Robing Room [85] and Talbot's Tower [86]) were examined, as to distinguish between a pre-Anglo-Norman town and one of their new creations. Ironworking assemblages from military and monastic sites were similarly understudied (8.3%) and examinations of material from five of these (Aghmanister, Co. Cork [1], Bridgetown Priory, Co. Cork [14], Jerpoint Abbey, Co. Kilkenny [72], Kilcoe Castle, Co. Cork [76] and the Dominican Priory at Mullingar, Blackhall Place, Co. Westmeath [108]) were carried out in function of this doctoral research. Ironworking residues from small urban centres had been studied more often (26.7%), which was complemented with two additional collections from Athenry, Abbey Row/Bridge Street, Co. Galway [4] and Thomastown, Chapel Lane, Co. Kilkenny [118]. Finally, rural sites are the only type of site whereof more than half of the assemblages (58.9%) had been examined, and only two examinations were carried

15 Material from two more sites was also examined, but for one, Ballyman, Co. Dublin, the dating evidence was considered unconvincing, while at the other, Moore Abbey, Co. Kildare, the material turned out to be non-metallurgical modern industrial residues (see Appendix 7).

out on collections from Dysart, Co. Kilkenny [60] and Shandon, Co. Waterford [115]. The Dysart assemblage was of particular interest as the site was a documented monastic manor, while material from Shandon [115], which included both smelting and smithing residues, had been previously studied by Neil Fairburn, but this did not constitute the full assemblage.

	Site information		Ironworking analysis				Total
Site type	Published [a]	Unpublished	Slag, etc. analysis/ examination [b]	Object analysis/ examination [b]	Own visual examination	None	
Large urban	23	11	3	2	7	22	34
Small urban	6	9	4	2	2	7	15
Rural	12	44	33	1	2	21	56
Military/ monastic	15	10	2	1	5	17	24
Total	56	73	42	6	17	66	129

Table 1.1 Specialist analyses on late medieval ironworking sites per site type. [a] Final excavation reports available on CD appended to some of the National Roads Authority monographs are considered published, online reports and excavation notices are not, [b] at two sites both slag and objects were examined/analysed.

As will be argued, much of the information currently available on late medieval ironworking in Ireland is based on erroneous premises. Because of this, a full re-evaluation of the data was necessary. This was done by applying the recent insights on the interpretation of ironworking remains to the body of information relating to late medieval iron smelting and smithing in Ireland. Wherever possible, this information was sourced in its most primary form. In most cases, this meant the excavation reports, which in many instances had appended specialist reports. Of exceptional value was the work by Tim Young, who carried out detailed visual analysis on large amounts, and a wide range, of remains of Irish ironworking. His research has, for example, led to the identification of the slag-pit furnace as the most important smelting installation in early medieval Ireland and of the large bun-shaped slag cakes as related to bloom smithing. The methodology and style adopted by the same author was also used for the visual examination of the additional assemblages of ironworking debris as part of this thesis. In some cases, where the material was difficult to identify or classify, advice was received from the same specialist through email exchanges.

This archaeological information was complemented with insights which could be gleaned from the available written sources relating to late medieval Ireland. To put any evolutions and patterns observed regarding late medieval ironworking into context, overviews were compiled of both iron smelting and smithing in western Europe. The other information, relating to late medieval ironworking further afield, trade and so on, was subjected to a degree of scrutiny proportional to its relevance to late medieval Irish ironworking. Ethnographical data was primarily used to find comparative material relation to different aspects of technology, such as furnace types, bellows protectors and bloom size. While the contribution of ethnography to the social and organizational aspects of ironworking is certainly recognized, it was deemed that selective quoting from this huge body of data would not do justice to, and possibly misrepresent, the potential it has in relation to the findings related to Ireland.

1.4.2 Dating conventions and methods

Defining the late medieval period

Various criteria have been used to delineate the date-span of the late medieval period in Ireland. The start-date is generally seen as coinciding with the Anglo-Norman invasion in 1169. However, as we will see, Ireland was evolving into a feudal society before this event and many areas in the island would remain unaffected by the new economic and political order for several decades, or even longer. The start date for the late medieval period in this thesis, then, was choosen as c. AD 1200, which incorporates the many sites and artefacts dated to the late twelfth to early thirteenth centuries. As an end date, c. AD 1600 was choosen, as it is broadly the end date of the Tudor conquest of Ireland, after which the island became fully controlled by the English Crown and its subjects, both politically and economically. This period after AD 1600 is then regarded as the Early Modern period. The Plantation period, a term also used in this thesis, was very much part of the Tudor conquest mentioned above and colonization attempts took place from the mid-1550s onwards. This Plantation period continues into the seventeenth century, when the various projects were more succesful due to the enhanced stability on the island.

Dating methods

The ironworking remains discussed in this thesis were almost exclusively dated to the late medieval period based on either pottery typologies and/or radiocarbon analysis. Both have their own methodological issues in respect of dating.

Pottery

Pottery in Ireland during the late medieval period is characterized by various types of both imported and locally-produced types. The non-native pottery was mainly imported from either Bordeaux (Saintonge Ware) or Bristol (first Ham Green and later Redcliffe Ware) (McCutcheon and Meenan 2010: 96–99), the production dates for which are known. In the south of Ireland, the local pottery types typically consist of Coarse Wares, pottery types named after the urban centre where they were first identified in quantity and a type often found over a large area in the east and south-east of the island: Leinster Cooking Ware. This latter type of pottery was first extensively described in late 1980s and considered to have potentially been manufactured into the early fifteenth century (Ó Floinn 1988: 337). Later, the production of all the local pottery types in the south of Ireland was considered to have ended by AD 1400 (see all specialist reports by McCutcheon and various others). Reasons regularly offered for this are the disruptions of the fourteenth century after which mostly organic (wood, leather) and metal vessels were used (O'Donovan 2003: 167; McCutcheon and Meenan 2010: 96). However, locally produced pottery was available throughout the late medieval period and into the seventeenth century in the Province of Ulster (McSparron 2009b: 14). Recently, a new type of pottery, so-called Transition-type Ware has been identified in minimal quantities in the south of the country and appears to date between the late fourteenth and sixteenth centuries (McCutcheon and Meenan 2010: 100).

However, evidence from a variety of sites recently published, or still awaiting publication, appears to point to possible production of pottery as late as the sixteenth century outside of Ulster. The find of a fractured but near complete pot of Leinster Cooking Ware at Portmarnock, Co. Dublin [112] in a pit, charcoal of which returned a radiocarbon date of AD 1450–1631 (2σ), would at least imply an exceptionally long period of use of this pot (Moriarty 2011: 271). Further sherds of local wares, Leinster Cooking Ware and Dublin-type Ware, were recovered at Portmarnock [112] from a well and a floor organic material from which returned slightly later radiocarbon dates. The same article mentions two further sites where this extended use of local wares was suggested, one in Ashbourne, Co. Meath[16], the other at Dublin, Thomas Street [55]. At

16 The information on the Ashbourne site is only available as an unpublished excavation report which

the latter site, a similar problem was encountered where an apparent lack of occupation was noted in the fifteenth and sixteenth centuries, based on the dates provided through pottery analysis, in an area with historically recorded activity (O'Donovan 2003: 167). The author made a strong point for re-evaluating the date ranges of Irish late medieval pottery. Also at the site of Nobber, Bridge Park, Co. Meath [111], 350 sherds of medieval pottery, 342 of which were Dublin-type and Drogheda-type Wares, were found in a ditch from which radiocarbon analysis on charcoal gave a date range between AD 1437 and 1634 (2σ) (Seaver 2010 vol. 2: 140; McCutcheon 2010c: 155). This again more likely points to later production of these pottery types, rather than large scale redeposition.

Finally, at Carrickmines Castle [22], a house gully (C.921) preserved over a length of about two metres contained 57 or 65 pieces of pottery (mostly Leinster Cooking Ware with three sherds of Dublin-type Ware) (Breen 2012: 107; McCutcheon 2012c: 470). Organic material from this gully was radiocarbon dated to the mid-fifteenth to seventeenth centuries (Breen 2012: 1445). More similar dates for features with the same types of pottery occur at Carrickmines. This led the author of the report to suggest that Leinster Cooking Ware was produced into the fifteenth century (ibid.: 273). A potter is also recorded in St. James' parish, along the road leading west out of Dublin, in AD 1469 (McCutcheon 2000a: 119). Whereas a *terminus post quem* date for the production of a type of pottery is falsifiable, by the secure find of a sherd in a layer of a known and earlier date for example, a *terminus ante quem* date is much more difficult to establish, as the pottery can always be redeposited. While further research is urgently required to clarify these late dates associated with locally produced pottery outside of Ulster, it is deemed prudent to accept a wider date range until the issue is resolved. As such, sites or features with only locally produced pottery will be regarded as potentially dating between the late twelfth to sixteenth centuries, while imported wares, when present, are then used to refine the dates.

Radiocarbon dates

Radiocarbon dates are statistical approximations of the time of death of organisms. For most organisms, such as animals and smaller plants, the dates received will indeed indicate when they died, although this does not automatically mean when their remains, such as bones or grains, were deposited in the relevant features. Other organisms, such

was not consulted for this PhD research.

as trees, can be more problematic. First of all, timber can have a very long period of use and is often reused, so the time between the original cutting of the tree and its deposition can be considerable. Secondly, as only the outer layers of sap-wood are alive, the heart-wood of long-living trees, such as oak and yew, can have been dead for a long time before the tree is cut. Both phenomena are known as the "old wood effect" and are the reason why oak wood, for example, is often avoided for radiocarbon analysis. In the case of metallurgical contexts, however, where oak charcoal was often used as fuel, this caution might be somewhat exaggerated. In many cases, the wood used for charcoal production would have come from coppiced trees, meaning only the branches were used. A recent study on charcoal-production kilns in Belgium has demonstrated that small-diameter wood was used even in the case of complete deforestation of an area, in this case of coppiced woods (Deforce et al. 2013: 688). Also, in seventeenth-century Ireland, when large volumes of charcoal were required for the blast furnaces and fineries, the trees were primarily cut for timber after which the "moots and roots" were converted to fuel (Grosart 1886 vol. 3: 198).

For consistency, all radiocarbon dates used in this thesis were recalibrated using the Calib Rev 6.1.0 programme. In archaeology, the results are usually given as confidence intervals of one sigma (68.3%) and two sigma (95.4%). Both of these will be used when discussing the Irish evidence. The two-sigma ranges give a broad time-span with a high probability, while the one-sigma ranges give a lower probability within a narrower date range. As such, a one-sigma value of 74% equals an overall probability of more than 50%.

1.5 Thesis structure

After this chapter outlining the research aims, the previous research on the subject and the methods and frameworks applied to the sources, the first volume of this thesis follows with an chapter giving an overview of the various uses of iron in the different parts and periods within late medieval Ireland. This chapter culminates in an broad overview estimating when and where most iron (and steel) would have been required in Ireland during that period. Next, the current knowledge on the technology, installations, waste products and tools for each step of early iron production are outlined. This is followed by a revized overview of the known iron ore occurrences in Ireland, primarily based on geological accounts, but also including the analyses of iron ores retrieved from archaeological excavations. The next two chapters give overviews of the available evidence for iron ore smelting in late medieval Ireland, respectively derived from the written and archaeological sources. This is followed by two chapters outlining the evidence for iron smithing in the same period and using the same source criteria. Next, an overview is presented on the trade in iron and steel in northwestern Europe within the research timeframe, with particular concern for that trade in Ireland, both internationally and domestic. Chapter 10, then, presents, for the first time, an overview of the current knowledge of iron smelting in western Europe using both archaeological and documentary sources. This followed by a similar treatment of the evidence for smithing, this time concentrated on Britain, both because of its higher relevance to Ireland and as a result of the available documentation. All the above information is then summarized in the final chapter and used to answer the three main research questions as well as proposing suggestions for further research.

The second volume of this thesis commences with the site catalogue which provides detailed accounts, and (re-)interpretations, of all 129 excavated Irish sites with evidence for late medieval ironworking. This is followed by appendices listing iron mines in the Desmond Survey, references to smiths in the Fiants, in documents relating to medieval Dublin in general and the Dublin Franchise Rolls in particular. Dimensions of late medieval smithing hearths are listed, as well as the references to iron in the various murage grants. The last appendix lists the sites not included in the research, and the reasons why, and is followed by the bibliography.

When sites are mentioned withing the text body of this thesis, a reference to the relevant Catalogue entry is given in square brackets. Urban sites are described first by the relevant town or city followed by the site name, often a street. Next comes the county name, except when the name of the town in question is the same as the county name. Most rural sites consist of the site name, and number if applicable, followed by the county name. In some cases, such as castles and monasteries, the name of the monument was used instead of the townland. Within the original reports and publications many different feature annotations are used, that is to say c.123, F123, (123), and so forth. Within both the text and the Catalogue, these annotions were standardized to the form C.123.

Chapter 2

Historical background: the use of iron in late medieval Ireland

In this chapter a broad overview is offered of the developments that shaped late medieval Ireland. The aim is to provide insights into which activities, mainly the economic ones but also including warfare and day-to-day domestic life, required which type of iron objects. On top of this, an attempt will be made to quantify the amounts of iron needed for the different types of activity. Based on this, then, the levels of ironworking in late medieval Ireland can be estimated and the location of the concentrations predicted. The activities are divided into those relating to rural life, the urban environment, warfare and transport.

The two main source types for late medieval Ireland, however, do not provide a full picture of iron consumption although they are broadly complementary. As the bulk of the documentary sources available consists of records produced by, and for, the government, they give us only a partial view of the use of iron between AD 1200 and 1600. This means that we have information regarding the construction of castles, iron in warfare and iron on which taxes were levied in the market centres. Of other activities which would have needed substantial amounts of iron, such as shipbuilding and forestry, the information is very scant at best. The same applies to iron objects found on archaeological excavations. These only represent a fraction of the iron around at the time and their deposition is likely to have been selective: smaller objects are both easily lost and less likely to be re-worked into other objects. Large pieces of structural iron, for example, are virtually unknown from the archaeological record and hardly any are reported from architectural studies of upstanding late medieval Irish buildings. To date, the study of late medieval iron objects in Ireland has been limited to typological finds catalogued as part of excavations, with large bodies of information composed as part of overview publications of the research in various urban centres.

2.1 Iron in the rural landscape

2.1.1 Agriculture

Arable farming was already practised in Ireland when the Anglo-Normans arrived, with several monastic enterprises prospering on the back of large agricultural estates (Down 1987: 440–441). These, however, were still anomalies in a world where wealth was mainly counted in cattle. With the coming of the Anglo-Normans, came also full-blown feudalism, which meant that all the land belonged to the king which he then granted to trusted underlings. The establishment of manors proceeded unevenly, as shown by the study on early thirteenth-century south County Tipperary (Hennessy 1996). Here, the impression is that income was initially mostly generated from mills built within what were, in essence, castle-territories (ibid.: 121). By AD 1243, manors proper were present, with the bulk of the income generated by rent from largely Gaelic-Irish tenants, supplemented with that derived from the mill (ibid.: 123–124). Land for pasture on many of the Anglo-Norman manors constituted only a limited area, estimated at an average of about 10% or just big enough for the upkeep of the animals that pulled the plough and provided manure (Down 1987: 476). Other manors concentrated on producing wool, so coveted by the Italian merchants who would control important sections of the economy by the end of the thirteenth century (O'Sullivan 1962). A well documented estate is that of the Earl of Norfolk in the south-east of Ireland where different animals were bred, with Ballysax specializing in sheep, Fennagh in pigs, Forth in pigs and later cattle, and Old Ross in cattle and horses together with more sheep (Down 1987: 478). Some of the land on the Ballysax manor, however, was also subjected to ploughing (Lyons 1981: 41).

From the beginning of the fourteenth century onwards, like much of Europe, Ireland saw a rise in rebellions and epidemics, the worst of which were, respectively, the Bruce invasion (AD 1315 to 1318) and the Black Death (reaching Ireland in AD 1348). The central government reacted in horror, and the following period is, depending on the political inclination of the historian in question, either seen as a "Gaelic Revival" or as a descent into Celtic chaos (McNeill 1997: 173). It is, however, easy to exaggerate the impact of the those events. Large surpluses of wheat could still be sent to the armies fighting in Scotland and Wales up until AD 1324, that is to say after the Bruce invasion (Down 1987: 472). A quick glance, on the other hand, at the customs revenues for the period between AD 1275 and 1335 (McNeill 1980: 134), clearly shows the loosening grasp of the Crown by the end of that period. The resulting power vacuum was filled by several powerful Anglo-Norman families in the south of the country and a mixture of similar nobles and remnants of Gaelic-Irish power elsewhere. Little in-depth research has been carried out regarding the agrarian economy of the fifteenth and sixteenth centuries in Ireland, but it seems generally agreed that many areas had reverted to pastoral agriculture, while the land in the Pale was still largely ploughed in that period (Down 1987: 472–473).

Ploughing required a lot of iron, and references to making, mending and replacing ploughs are commonplace in the accounts of manors with arable farming (Mills 1891: passim; Lyons 1982). The most common plough in late medieval Ireland would have been a heavy plough consisting of two shares and a coulter for cutting the ground, all made out of iron (Fig. 2.1). The cutting part of the ploughshare was often made of steel (see for example Mills 1891: 30, Murphy and Potterton 2010: 302–303). Single-bladed ards, cheaper and more suitable for smaller holdings, are mentioned in the murage grant for Thomastown, dated to AD 1375 (CPI: 68). Smaller, but not insignificant, amounts of iron were necessary for shoeing the beasts of burden. The rearing of cattle, for milk or hides, and pigs would require only a minimal amount of iron, such as knives and pitchforks. Sheep farming requires slightly higher quantities of that metal for shearing the wool. Any grain produced which was not exported ended up

Fig. 2.1 Early 16th-century plough and coulter from Massereene, Co. Tyrone (length 48cm) (Hamlin and Lynn 1988: 77).

converted into flour. Hand-mills are recorded in the murage grants, but invariable together with millstones (Vallency 1786: 550–553; CPI: 40, 76, 79, 87). In mechanical milling, substantial amounts of iron, and sometimes steel, were needed for the mill building (nails), bearings and bands to reinforce the millstones (Rynne 1998: 83). Other tools, such as pick-axes, shovels and spades, were regularly employed in agricultural activities, but were also used for other purposes (Figs. 2.2 and 2.3).

Fig. 2.2 Iron-tipped spade in a 15th-century Irish manuscript, King's Inn (Dublin) MS 17, fo. 5V (Kelly 1997: 464)

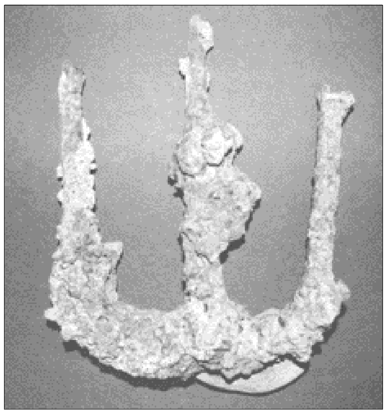


Fig. 2.3 Iron pitchfork from a 13th- to 14th-century ditch at Trim, Co. Meath (Seaver 2009: 162)

2.1.2 Forestry, quarrying and mining

Before the new agricultural lands could be either ploughed or grazed, the existing forest had to be cleared. This required an intensive use of iron tools, such as axes, saws, and so forth, but would have, in most cases, represented a single event. Some woods, on the other hand, would have been preserved as a reservoir of timber, some in the form of coppices (Slattery 2009: 64). The same kind of tools would then be employed on a more regular basis. The products of these woods, the timber, would have needed similar and additional iron tools for its further processing. These consisted of adzes, planes, files, wedges and many others (Goodall 2012: 21–27).

The extractive industries were not only exacting on the people who worked in them, but also the tools they used. Both mines and quarries would need such a high rate of repair and replacement of the tools that the building of a forge would be justified. At Clonmines, Co. Wexford, where German miners were employed in AD 1551 and 1552, there was a forge run by English smiths (PRO SP 61/4 f.199–). At the quarries, along the Dodder River and at Clontarf, where stone was extracted for the repair of Christ Church Cathedral in Dublin in AD 1564 and 1565 (Gillespie 1996: 24, 51), no forges are mentioned, probably because the works were relatively short-lived. The heavy wear on the tools, however, is illustrated by the frequent payments to smiths. At one point, one of the smiths remarks that “the stone is so hard it eats the steel” (ibid.: 95). Another commodity that falls under the extractive industries, salt, would not see such wear on the tools used. However, evaporation of salt in northern latitudes was often carried out using salt pans, as is recorded in Ulster in AD 1211/12 (Davies and Quinn 1941). These pans could either be made of lead or iron, and judging by the price of the Ulster example, 41s 8d, it must have been quite substantial. The salt industry in Ireland could have been substantial in the early part of the late medieval period, as it is mentioned in the foundation grants to the Cistercian monastery at Mellifont, Co. Louth in AD 1142 and likely relating to Salterstown in the same county (Dugdale 1846 [1664]: 1132–1133) and the Benedictine monastery at Nendrum, Co. Down in AD 1177 (ibid.: 1127) and the Cistercian abbey at Dunbrody, Co. Wexford in Ad 1182 (ibid.: 1130). The Cistercians of Baltinglass Abbey, Co. Wicklow were still winning salt at Arklow in AD 1264 (ibid.: 1128), as were those of Mellifont in AD 1258 (CDRI 1252–1284: 95) and we hear of the destruction of the salt pans at Lerges[17], likely on Dundrum Inner Bay, Co. Down in AD 1282 (ibid.: 388).

2.1.3 Rural building and domestic activities

The vast majority of the population of late medieval Ireland lived in the countryside. Little is known about rural houses when the Anglo-Normans arrived, but these appear to have been circular wattle or post-and-wattle structures often leaving little trace (O'Connor 2002: 203), although rectangular structures have also been noted (ibid.: 204; Bradley 2002: 214). Circular domestic structures are famously illustrated in several late sixteenth- and seventeenth-century maps and drawings and it is tentatively assumed that these represent the continuation of a former tradition (O'Connor 2002: 201–203; Horning 2001: 377). From the thirteenth century onwards, rectangular-shaped buildings appear in the Anglo-Norman controlled areas of Ireland, closely resembling the cruck-built structures of England and Wales (O'Connor 2002: 205). Nails were found in association with both circular structures, for example at Ballysimon, Co. Limerick [11] (Collins and Cummings 2001: 43–44), and rectangular ones, like those at Portmuck, Co.

17 Lerges, identified as Lerkes in the parish of Loughlinisland (Orpen 1913: 40)

Antrim (Dunne 2004: 94). More substantial stone buildings, possibly manor houses, are also known, as for example at Jerpointchurch, Co. Kilkenny (Foley 1989). Several nails were found during the excavations at the site, but, as the largest amount of these (nineteen) came from a well (ibid.: 93), it is unclear whether these were used in construction.

General domestic activities required further iron (Fig. 2.4). The frequent occurrence of knives on archaeological sites, testify to their common usage, mostly in relation to food preparation but also in various trades. The murage grants include levies on tripods in the early fourteenth century and cooking pots from the mid-fourteenth century onwards (for example CARD I: 12–13, ibid.: 14–16), but many of these could have been made from copper-based metals. The gridirons, probably more common than the murage grants suggest, constitute a another use of iron in cooking. Further iron in the domestic environment was employed in providing lighting in the shape of candleholders. Finally, minimal quantities of that metal were used in clothing (buckles), music (for example in Jew's harps), hunting (arrows) and fishing (hooks). Interestingly, an iron barrel padlock was also found during excavations of a thirteenth to early fourteenth-century Gaelic-Irish palace at Clonmore Road, Co. Clare (Hunt 1946: 206).

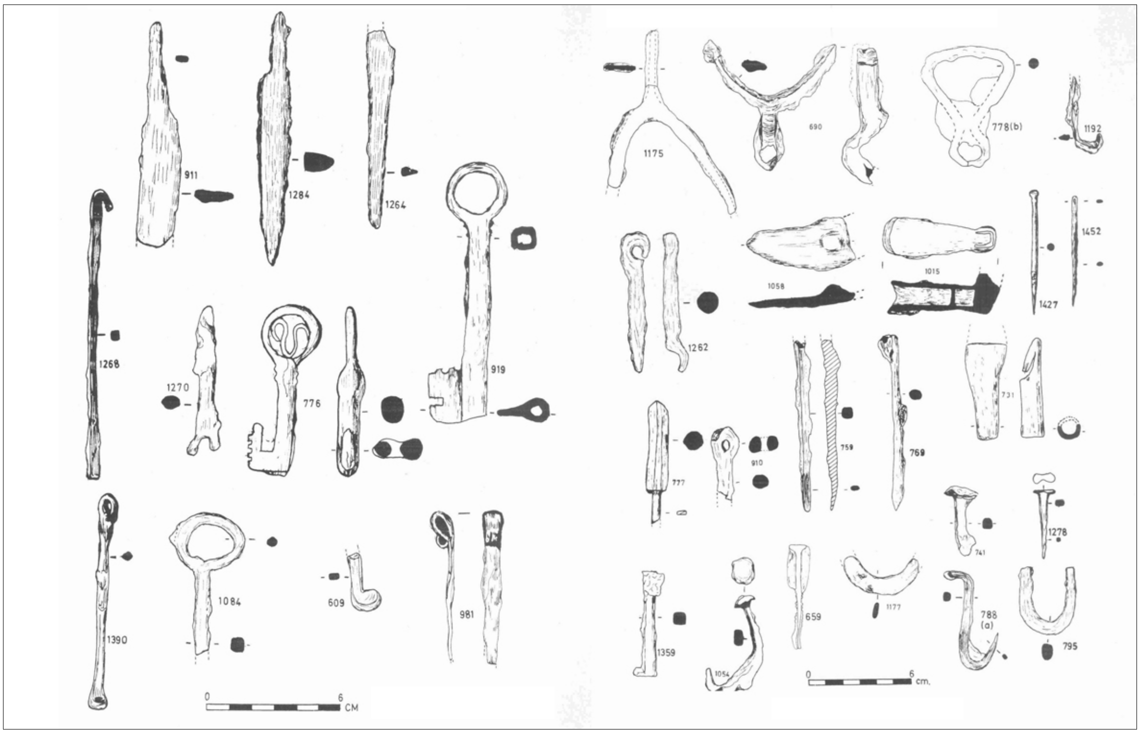


Fig. 2.4 Late medieval iron objects from Loughgur, Co. Limerick, Car Park Area II (Cleary 1983: 56, 58)

Monasteries can be seen as agrarian production units with extensive stone buildings at their centres. Iron tools would have been needed for the quarrying of the stone as well in their construction, but information on structural iron in Irish monastic buildings is scant. Iron grills are recorded in the small windows providing light for the crypt under the church of Mellifont Abbey, Co. Louth (de Paor et al. 1969: 130), which might have been late medieval, while we know from the documents relating to the dissolution of the monasteries, around the mid-sixteenth century, that iron was often listed under the materials removed (White 1943: passim). The use of iron in monasteries, however, might have been more widespread than the literature suggests (Mooney 1956: 129). It has also been suggested that the use of harder types of stone for decorative elements in monastic buildings from the fourteenth century onwards could be the result of the use of better chisels (McNeill 1997: 173).

2.2 Iron in the urban environment

On arrival, the Anglo-Normans would have encountered urban centres only along the coast. These were inhabited by the descendants of the Scandinavians who founded them, mixed with Irish inhabitants. Inland, only at Killaloe, Co. Clare had an early example of a borough probably been established by that time (Bradley 1994). During the Anglo-Norman period many of the older urban centres saw significant expansion, while numerous new towns, large and small, were established in the interior of the country as both marketplaces and administrative centres. After the loosening of Royal control from the early fourteenth century onwards, many of the market towns would lose much of their former importance. The coastal towns and cities would see many of the houses, formerly built of timber, replaced by stone structures, from the thirteenth century onwards in Dublin (Simpson 2011: 100), in the fourteenth century in Cork (O'Brien 1993: 105) and sporadically during the fifteenth in Waterford (Hurley and Scully 1997: 18). By that time, the coastal towns in the south and west of Ireland had become virtual independent states (O'Neill 1987: 130). The sixteenth century, in Ireland as elsewhere, saw a gradual improvement in the economic climate resulting in a continued importance of the Irish port-towns.

2.2.1 Construction

Like those in the rural areas, structural iron was employed in the houses in the urban centres, both those of timber and those in stone. The roof nails "for houses" frequently mentioned in the murage grants (for example CDRI 1285–1292: 107, 277–278) were likely used locally. Perhaps more so than in the countryside, fittings would have been used in urban houses. Hinges and nails, either for furniture or structural use in buildings, appear very frequently both in the archaeological and the written record. The overview publications of the excavations on three of the main urban centres of late medieval Ireland, Waterford, Cork and Galway, all include copious amounts of iron objects with a structural function (Scully 1997; Carroll and Quinn 2003; Scully 2004). The added wealth in urban centres required more security, and this is reflected in the keys and locks often found during excavations (ibid.). All in all, apart from general assumptions, we are poorly informed of the full scope, and potential evolutions, of the use of iron in the Irish late medieval urban environments. This is exacerbated by the near-complete lack of building accounts for late medieval Ireland. Although not fully representative, as it relates to the repair of a church, a fifteenth-century account for Dublin includes two gemels or bars (*gemmelys*) for the window (4s), fifty *syngylbord* nails (2d), two new locks and keys (10d) and a thousand slat pins (*sclat pynnys*) (3d) (Lydon 1982: 75).

2.2.2 Urban economic and domestic activities

The range of iron objects used in urban domestic activities would have been comparable to that described above for the rural settings, but in larger amounts. Knives, buckles, Jew's harps and other iron domestic articles feature prominently in the late medieval assemblages recovered during urban excavations (see for example Scully 1997; Carroll and Quinn 2003; Scully 2004). Many trades, on the other hand, would have been concentrated in the towns, although the total amount of iron used for these, in the form of tools, would have been limited (Fig. 2.5). Leather-workers and tanners used punches and specialized knives (Goodall 2012: 67–69), while textile workers used heckles, a variety of combs and needles (ibid.: 59–61). Carpenters and masons needed a wide variety of tools, detailed above, for the many wood- and stone-working needs of the urban centres. Finally, the metalworkers themselves employed a multitude of iron tools and implements for processing both the iron and the other metals required for urban life.

These included anvils, hammers, tongs and a variety of tools for the finishing of the metal objects. Detailed analysis of the chronological evolution of the types of iron objects used in late medieval York has clearly demonstrated the diminishing role of tools and knives against the growing importance of structural ironwork (Ottaway and Rogers 2002: 2984), but it is unclear if this model would be applicable to the contemporary Irish towns and cities.

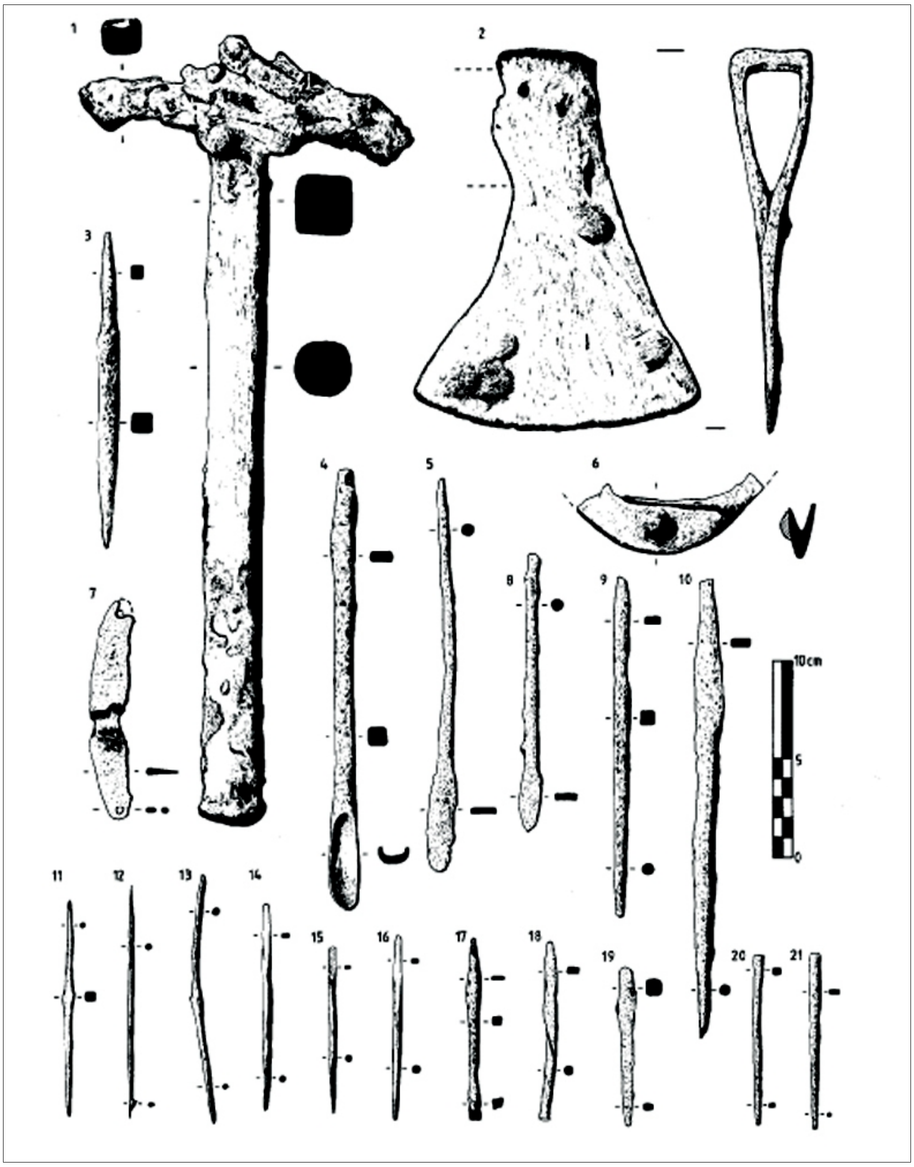


Fig. 2.5 Late medieval iron tools from the excavations in Waterford (Scully 1997: 471)

2.3 Iron in warfare

The Anglo-Norman invasion was successful because of superior military might, for a large part based on iron and steel. This is poignantly captured in a poem written after the

Battle of Downpatrick in AD 1260 (O'Donovan 1849: 153):

Unequal they engaged in the battle
The foreigners and the Gaeidhil of Teamhair
Fine linen shirts on the Race of Conn
And the foreigners in one mass of iron

That the battles were not all that unequal is shown by Giraldus Cambrensis' description of the Danes of Dublin having breastplates, shirts of mail and iron-bound shields at the time of the Anglo-Norman conquest (Forester 2001: 30). The same author, in a different work, also noted the use of battle-axes by the Irish, which they had copied from the Norwegians and Ostmen (Forester 2000: 69). These were described as tempered, so must have been made of steel. The accounts of money spent for the invasion of Ireland in Waterford in AD 1171 give some idea of the amount of iron that was shipped over for that occasion: 3140 spades, 2140 pickaxes, 1000 shovels, 930 axes and 67000 nails (CDRI 1171–1251: 1–7). This does not include the weapons and body armour, which would have been the private property of the knights.

Iron was also employed in defence against the invasion, as is witnessed by the spectacular feat by the inhabitants of Waterford of forging three chains and stretching them across the harbour of that town, to prevent the landing of the invading fleet in that same year (Gilbert 1865: 25). Very soon after the invasion, some of the knights, in particular the de Lacys of Meath, started expressing dangerously independent behaviour. This eventually led to King John landing in Ireland with an army in AD 1210 to restore royal authority. The types of iron shipped over for this campaign, and the period immediately after, are markedly different from those for the original conquest and included 2940 horseshoes with nails, irons for prisoners and 176 *esperduci* of iron[18] (CDRI 1171–1251: 68–69). After the initial military successes, Anglo-Norman power was consolidated by the erection of strategically-placed castles. The more important were built of stone, such as at Trim, Co. Meath, while others consisted of wooden structures built on mounds (mottes). Most of these mottes were constructed by the knights themselves, or their tenants, but in AD 1212 three of them were built by the justiciar in Dublin (McNeill 1997: 57–58). The accounts for the costs of the motte and bailey built at Clones show that while arrows and horseshoe nails were brought over from Dublin, smiths were paid for at Clones (ibid.; Davies and Quinn 1941).

18 *Esperductis* were masses of iron similar to the 'piece' (see Chapter 11.1).

No detailed building accounts for late medieval stone castles in Ireland survive, but examples from England show that iron was used extensively. The accounts for Dover Castle, for AD 1220/21 and 1227, when major repair works were carried out, show that tens of thousands of nails were purchased, next to iron for bars, hinges and other structural uses (Colvin 1971: 31–79). Some moneys expended on tools are included, but mostly the iron used for quarrying, carpentry, and so forth, are not. While there is some evidence for Gaelic-Irish mottes (McNeill 1997: 72–74), native warfare was not based on territorial expansion, but on forcing loyalty of the defeated, with the added bonus of the spoils of war (Simms 1975). This led to the Irish, traditionally, did not engage in large-scale fortification.

The waning of royal power from the early fourteenth century onwards resulted in a decentralization of military power across most of the country. In most of the northern parts, on the other hand, cattle-raiding continued to be the most common form of warfare (Simms 1975: 102–106). The new overlords of the south, notable are the Earls of Kildare, Ormonde and Desmond, still occupied the major castles, while their most powerful tenants now built tower houses (McNeill 1997: 209, 233). These tower houses would have had their entrances defended by either a wooden door enforced with iron or an iron grill or gate (*yett*) (see for example COD 1547–1584: 22–23) (Fig. 2.6). In AD 1583, the Desmond Castle at Askeaton, Co. Limerick even had iron-clad bedroom doors (Westropp 1904: 119). As an added defence, some tower houses had a wooden pounder coated in iron located in the ceiling of the doorway (Hore 1949: 19).

Each of the more powerful gentry would have kept a militia of foot soldiers (*kern*) and horsemen, supplemented with mercenary fighters (*galloglass*) when the occasion arose. These would have been armed with swords, axes and bows and arrows (Fig. 2.7). Archery is a characteristic aspect of late medieval warfare, in Ireland and abroad, and its archaeology and history was summarized by Halpin (1997). In AD 1611, Sir Thomas Phillips, when reporting on iron being made in Ulster by the local population, mentions that this is used for manufacturing “skeynes and darts” (swords and arrows or spears) (CCM 1603–1623: 138).

One of the great revolutions in medieval European warfare was the introduction of gunpowder. And while cannons are recorded in Ireland early on, the first reference dates to AD 1394 at Carlow Castle, their use appears to have been very limited before the sixteenth century (de hÓir 1983: 80–81). In that century, in AD 1534, cannons were used during the siege of Dublin Castle by Thomas Fitzgerald, Lord Offaly (Clarke 2002:

9). Handguns are mentioned from the end of the fifteenth century onwards and seem to have been fairly common by the next century (ibid.: 82–84).

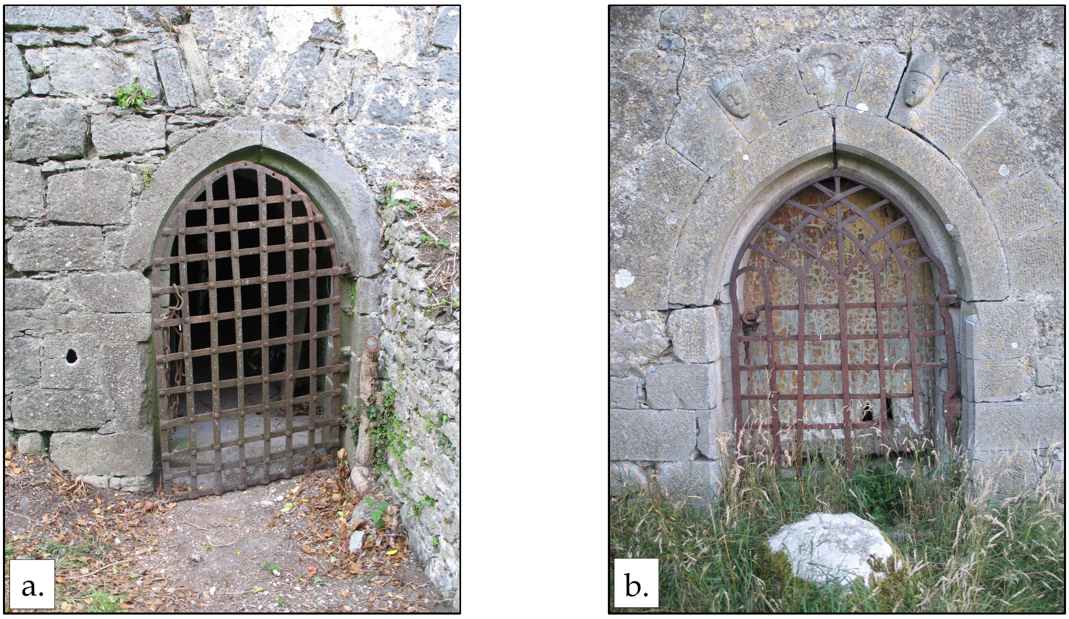


Fig. 2.6 Irish 15th to 16th century *yetts.* a) Clonbrock towerhouse, Co. Galway, b) Donore towerhouse, Co. Westmeath (Both courtesy of Rory Sherlock)

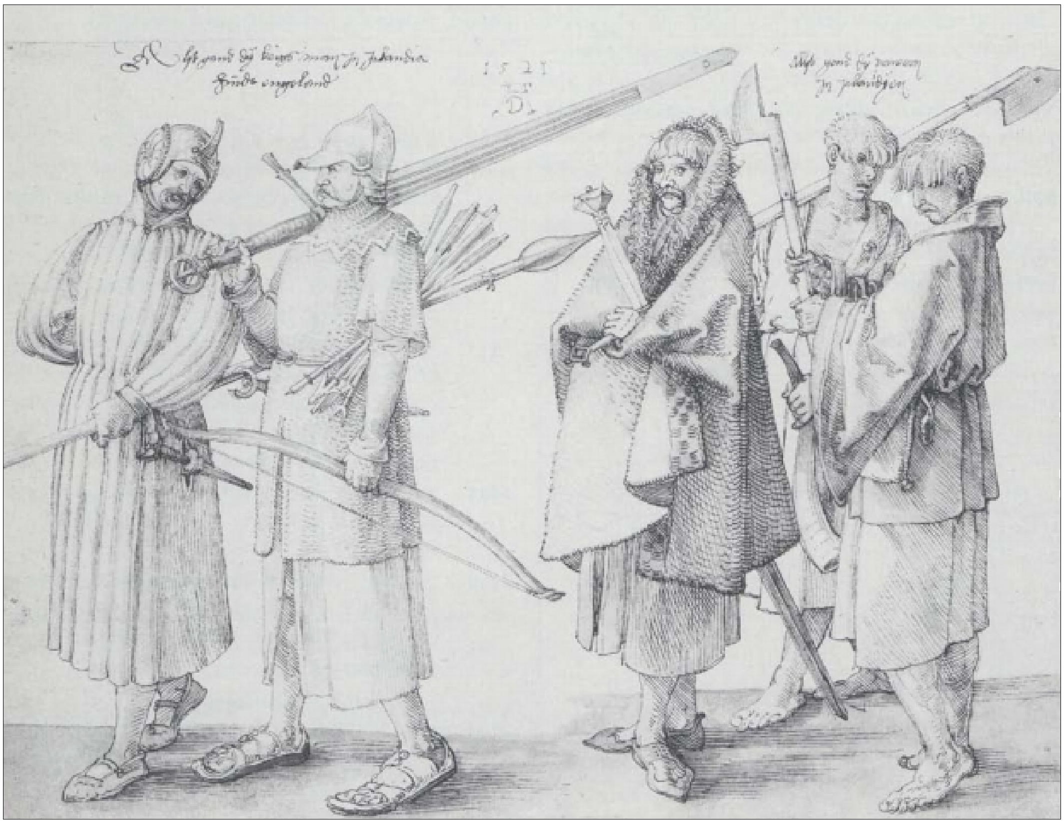


Fig. 2.7 Weaponry of 16th-century Irish *galloglass* and *kern* (A. Dürer 1521)

2.4 Iron for transport

Horseshoes, both for transport and for farm work, had to be replaced on a regular basis. In most cases, this involved the so-called “remove”, or the taking off of the shoe to cut back the hoof (Clark 2004: 83). This led to the need for new nails, but not the iron shoe itself. The latter could, if not worn too much, be reused several times (ibid.). Next to shoes, some of the furnishings, such as bits and stirrups, could be made out of iron. Larger quantities of material to be moved required carts. Some of the more elaborate of these had extensive iron fittings, such as clouts, hinges, hooks, nails, and so forth (ibid.: 2). In some, but not all cases, iron bands were fitted on the tyres (Lay 1992: 39).

All the transport of goods and people to and from Ireland, and a large part of the internal traffic, was done by ship. Very little or no information on the building of ships in late medieval Ireland exists, but if an account of the construction and repair of several galleys at Newcastle in AD 1295 is somehow representative, the amounts of iron expended were very substantial indeed (Whitwell and Johnson 1926; Johnson 1927). Some industry related to shipping is implied by the purchase of four anchors with chains (“cables”), together with victuals for the wars in Wales, in Ireland in AD 1282/83 (CDRI 1252–1284: 471). A final use for iron in transport is recorded in the contract for building a bridge at Enniscorthy, Co. Wexford in AD 1581 (Anonymous 1868: 15–16). Apart from the nails, and so forth, which are not mentioned in the contract, each of the forty-two pillars of the bridge was expected to be shod with an iron shoe weighing two stones (ibid.: 15). An annexed “Square Castell or Tower of Lyme and Stone” required further “crossebarres of yron, greate spikes and cheines of yron” (ibid.: 16).

2.5 Conclusions

The requirements for iron were determined by the demands of the activities carried out. While military campaigns were, in essence, movements of flesh and iron, and the quantities of the latter substantial, after the battle most of this iron would be brought back and kept for another day. Similarly, building projects required a lot of iron, both in their fabric and in their construction tools, but again these would have been relatively short-lived activities. This also applies to the quarrying which would have accompanied the larger building campaigns on castles, monasteries and town walls. Subsequent repairs and remodelling of buildings would have required additional amounts of iron.

Only in denser populated, urban areas, would this amount to a constant requirement of substantial volumes of that metal. Agriculture can also require an ongoing replenishment of iron. Ploughs required fixing or replacing on a regular basis. Very little of that same metal would be required in areas where the raising of cattle, or other animals, were the mainstay of the economy. Additionally, limited volumes were needed for most trades and everyday activities.

This implies that the demand for iron would have fluctuated in different areas through time. Urban areas would have been pools of more or less constant, relatively high iron requirements, while in the rural areas large amounts of that metal would have been needed when arable agriculture was practised. Convincing evidence for long-term and/or intensive ironworking in a rural setting would then very probably point to arable agriculture being carried out. Both military and large building campaigns constituted short bursts of high demand for iron and steel, while everyday activities and transport would generally have needed a limited, but continuous, supply of that metal.

Chapter 3

Technology and archaeology of early iron production

In this chapter, an overview will be presented of the current knowledge concerning the archaeological remains of the various stages of ironworking in late medieval Europe. The literature on this subject is voluminous, but while there is now increasing confidence in many important aspects, there is still uncertainty in many fundamental ones. The main objective of this chapter is to bring together the information from this literature, which will then be applied to the Irish material.

The different iron minerals are strictly defined, although the classification of the actual ores has changed over time and there is still no consensus on this subject. Regarding the transformation processes of iron, the discipline has long suffered from the misidentification early on in its history of smithing hearth cakes as resulting from smelting in a so-called "bowl furnace" (see Chapter 1.2). Even though this error is now generally recognized, its legacy is only slowly disappearing from the literature. Moreover, there are important differences in the terminology applied to the various installations and their (waste) products. These differences are not only geographical, but have also evolved over time.

Furthermore, various scientific methods, such as chemical analysis and mineralogical and metallographic examination, have been applied to the residues from ironworking. The various implications of the results of these will be explained and an overview presented on the relevant insights currently available on early ironworking techniques.

3.1 Iron ore mining

3.1.2 Iron ore extraction

Advanced technologies for mining were developed long before the late medieval period and applied to iron ores, non-ferrous ores and non-metallic substances. In certain cases, iron ores could be collected in stream beds or other deposits. Examples of this are nodules of iron ores weathered out of softer rock and iron-rich sands collected from streams and beaches. Other low-impact ore gathering could include removing the outer occurrences of visible outcrops or the harvesting of bog iron ores. A rarely reported “mining technique”, the ploughing of fields solely for the purpose of iron ore collecting, is recorded in China in AD 1637 (Wagner 2008: 340–341). If the scarcity and quality of the ore in question justified the extra efforts expended, it could be mined through the digging of trenches, pits and, in some cases, galleries and adits. From seventeenth-century Ireland, we have a reference in the Lismore Papers to a pond being made for washing away the earth before opening up a new mine on the Earl of Cork's land (Schubert 1957: 215).

3.1.3 Iron ore preparation

After the ore is collected or removed from the bedrock, it is sometimes washed and often further selected on purity or other qualities, such as specific composition. On several sites, evidence has been found for the use of more than one type of ore, for example at the late fourteenth- to early fifteenth-century bloomery at Llwyn Du, Merionethshire (Charlton et al. 2010: 360) and the thirteenth- to fourteenth-century blast furnace at Lapphyttan, Västmanland in Sweden (Björkenstam and Fornander 1986: 192–193). The ore seems to have been generally broken into pieces measuring a few centimetres before it was fed into the furnace (Serneels 2004: 43).

Stones with hollowed-out cavities have been found on smelting sites appears to have been connected to ore preparation, as, for example, at the thirteenth- to fourteenth-century site of Trécélien, Brittany, France (Vivet and Girault 2009: 45–46) and on several early medieval sites in Ireland (Dolan 2009). It is, however, generally believed that small-sized iron ore particles would be detrimental to the smelting process (Overbeck 2011: 309) and pulverising is more commonly applied to non-ferrous metals (Serneels 2004: 43).

Different iron ores are roasted for different reasons: hydroxides (including bog ores) and carbonates to remove respectively water and carbon compounds and haematite and magnetite to fracture the ore (Maréchal 1992: 36). Archaeological excavations have revealed a wide variety of types of roasting hearths, ranging from simple circular depressions to long stone-lined roasting trenches, in which the ore was moved up as it reached different degrees of burning (Pleiner 2000: 109–113). Historical sources also mention the roasting and hammering of iron ore, as for example at mid-fourteenth-century Tudeley (Kent) and early fifteenth-century Kyrkeknott/Byrkeknott, Durham (Schubert 1957: 124). Excavations at Minepit Wood, Sussex, less than 20km to the west of Tudeley, uncovered a fourteenth- to fifteenth-century iron-smelting site with a three-sided stone-built roasting hearth (Money 1971: 92). Some vitrification could occur during roasting but the temperatures used (200 to 800ºC) would normally not lead to the formation of actual slag (Maréchal 1992: 38). When the identification of a feature connected to ironworking is unclear, then the occurrence of reddish, magnetic iron oxides could indicate roasting (Buchwald 2005: 150). Stone-lined pits known as *hellegryte*, found in Norway and dated to the sixth to eighth centuries, have been interpreted as installations for pre-treating bog ore into a more concentrated product which was subsequently smelted (Espelund 2006).

3.2 Iron ore smelting

3.2.1 Principles of iron ore smelting

Various parameters will determine the character of both the product and the waste of a smelting operation. The chemistry and morphology of the ore, the type of fuel, the shape of the furnace, the blowing regime and the duration of the operation will all have an influence on the resulting iron and slag produced.

Iron ores, in the majority of cases, enter the furnace as iron oxides, where they are reduced to iron. Depending on the smelting process, the resulting iron will contain varying amounts of carbon (Fig. 3.1). In the bloomery process, which uses operating temperatures between 1050 and 1250ºC (Kronz and Keesmann 2003: 273, Tite et al. 1985: 51), solid forgeable blooms with a low carbon content (0.1 to 0.25%) are produced. The slag produced in bloomery furnaces is typically iron-rich. Furnaces worked at higher temperatures, and with higher charcoal ratios, produce iron with carbon contents between 2.1 to 4%, which leaves the furnace as liquid iron (Rehren and Ganzelewski 1996: 175, Crew et al. 2011: 242). This liquid iron can either be cast in the desired shape, but is unworkeable afterwards, or re-oxidized to remove excess carbon to produce wrought, forgeable iron. The low-carbon products of both processes can then be further converted into steel, which contains a mid-range carbon-content (0.25 to 2.1%) (see below).

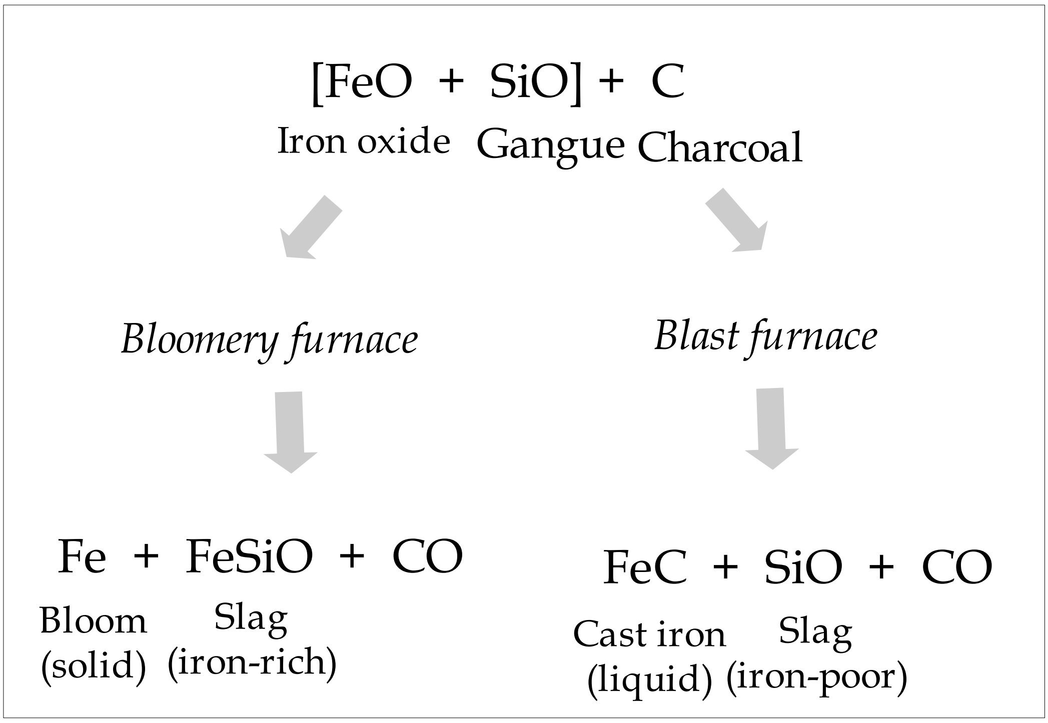


Fig. 3.1 Bloomery vs. blast furnace iron ore smelting

Early experimental iron smelts in bloomery furnaces used low-volume blowing regimes, hence the long operating times. An important paper by experimentalists Sauder and Williams (2002) described their experiences with air rates 1.2 and 1.5l/min/cm^2 (about two to three times the “old” rate). This led to a larger hot zone encompassing the entire internal diameter of the furnace. As a result the bloom formed lower down in the furnace and the slag above this zone offered better protection from re-oxidization to the descending iron particles. The bloom then settled centrally in the furnace and was not attached to the furnace wall under the blowhole as was often postulated based on the results of older experiments. A higher air rate also led to a lower carbon content of the bloom (Sauder 2011: 2). A similar regime was subsequently successfully adopted for other experimental smelts (Crew and Charlton 2007: 222).

Buchwald (2005: 97), after extensive analysis of bloomery-ironworking remains, found no evidence for the adding of fluxes during smelting. On the contrary, other researchers have noted a marked discrepancy between the calcium content of slag from prehistoric furnaces at various sites in eastern Germany, near the Polish border, and the available ores, some of which were found on one of the smelting sites (Heimann et al. 2001). The higher amount of calcium in the slag was seen as the result of the deliberate addition of this material to the ore. More recently, however, it was shown that the calcium content in the smelting slag can be significantly higher than it is in the ore due to contributions from the fuel ash, which implies the that deliberate use of calcium-rich fluxes would be difficult to recognize (Crew 2007).

3.2.2 Steel production

A very important alloy of iron is steel. It was, in medieval times, the best material available for making cutting edges, which were needed in ploughs, swords and many other kinds of tools. Steel has a carbon content higher than wrought iron, but lower than cast iron and the dificulty was to have the carbon homogeneously distributed throughout the iron. The different steel-making processes available in medieval Europe are shown in Fig. 3.2. Manganese oxides are not reduced inside a bloomery furnace, but will replace iron oxides in the slag. As a consequence, the use of manganese-rich ores will lead to a lower iron oxide content of the slag and hence a greater carbon absorption by the iron not incorporated into this slag (Kronz and Keesmann 2005: 453). This is the basis of the production of natural steel from manganese-rich ores. This type of ore was sometimes referred to as steel ore, such as in Hundersfield on the Lancashire and Yorkshire border in AD 1235 (Farrer 1899: 69) and at Château-Verdun in Ariège, France in AD 1293 and later on in the same area (Verna 2001: 65). Steel cakes were still made directly from the ore in Arrasate/Mondragón in the Spanish Basque region till the eighteenth century (Manès 1848: 68).

Analysis of a bloom fragment, recovered from a thirteenth- to fourteenth-century smelting site of Castel-Minier (Ariège) operating within the famous steel-producing district of the central French Pyrenees, showed an almost uniform steel structure (0.8% C) and a high-manganese content of the slag inclusions between 4 and 25% (Dillmann et al. 2006: 8). Truffaut (2008) has recently suggested that first- to fourth-century furnaces at Semlach-Eisner, Kärnten, Austria used high-manganese ores which led to the production of manganese-rich cast iron which was subsequently, and lower down in the furnace, re-oxidized into low-manganese but high-carbon steel. The furnaces, each with two or three air inlets, were specifically designed for this purpose and would have produced the famous *ferrum Noricum* steel of the Roman empire. Natural steel is also more frequently recognized in finished objects, for example by recent research in Sweden (Grandin and Hjärthner-Holdar 2008). At temperatures higher than 1400ºC, however, manganese oxides will become reduced and some of this metal can end up in the bloom, as shown by experimental smelts (Crew et al. 2011: 256).

Smelting product	Secondary process	Description	Comments
Steel bloom		Production of blooms with high carbon content	Manganese-rich ore
Mixed bloom	Natural steel	Production of blooms with variable carbon content	Steely parts are separated manually
Gromps		Production of carbon-rich gromps under the bloom	Forged together into a steel *dul*
	Carburisation	Heating of an object in a carbon-rich environment	Only affects the outer surface
Wrought iron	Crucible steel	Heating of particles of iron in a carbon-rich environment	
	Brescian process	Submerging the iron in a bath of liquid iron	
Cast iron	Osemund process	Resmelting and submerging the iron in a slag bath	Also for wrought iron production (i.e. fining)

Fig. 3.2 Steel production processes used in late medieval western Europe

Other experiments have indicated that, apart from adding manganese, using a higher fuel ratio will also lead to a higher carbon content of the resulting iron (Tylecote et al. 1971: 362). This is probably the basis for the recorded instances where steel was produced together with “normal” iron. This was observed in Finland in the seventeenth century, where the partially steely blooms were also interpreted as the result of the ore used or the iron-master using less ore than charcoal by weight (Buchwald 2008: 69). Similarly, the *merlaria* traded in the thirteenth and fourteenth centuries in the Comté de Foix, Ariège, France, are interpreted as blooms of both iron and steel (Verna 2001: 106–110). After this period, the same area produced steel, this time seemingly the result of consecutive heating and cooling of “purged” iron (ibid.: 110–112).

A third way to produce steel direct from the furnace is described by Walenty Roździeński in the poem *Officina Ferraria* of AD 1612 (Różański and Smith 1976).

One of the by-products formed in the water-powered bloomery were the *grąpie* (pronounced “grompie”) which either formed under the bloom or as a harder part of the bloom which broke off during further refining or forging (ibid.: 86, 89). These *grąpie* were then forged together into a *dul* of steel (ibid.: 72). The *greynes* sold at the fourteenth-century ironworks at Tudeley in Kent are likely to be products similar to the *grąpie*, rather than evidence for cast-iron production as proposed by Craddock (1999). If this interpretation is correct then this manner of steel production was also possible in non-water-powered bloomeries.

In other areas, steel was being produced from low-carbon blooms. In the Brescian process (after Brescia, Lombardia, Italy), described by Biringuccio in AD 1540, pieces of bar iron were submerged into a bath of liquid iron for four to six hours (Buchwald 2008: 474–475). Georgius Agricola, in his *De Re Metallica* (1556), described how small fragments of bloom were converted to steel in crucibles in mid-sixteenth-century Bohemia (Agricola et al. 1912 [1556]: 423–426). The fining of cast iron into wrought iron or steel following the Osemund process in Germany, and possibly to make Osmund steel or iron in Sweden, involved submerging the iron in a bath of liquid slag, presumably finery slag (Knau et al. 2003: 179).

At elevated temperatures, any phosphorus present in the ore will be reduced and migrate into the iron (Neff and Dillmann 2001: 675). At lower, that is to say bloomery-operating temperatures, the situation is more complex. While some researchers agree that at least some phosphorus present in the ore will end up in the iron, often up to considerable amounts (Piaskowski 1965: 84; Leroy et al. 2007: 7), other studies have come to the conclusion that even when using ores with a high phosphorus content, due to the low operating temperatures, the resulting products will be nearly phosphorus-free blooms (Bauermeister and Kronz 2006: 57). Other research has pointed to the fact that different phosphorus-containing minerals in the ores will have their phosphorus taken up by the iron at varying rates (Vizcaino et al. 1998). From a practical point of view, phosphorus-rich iron, although dense and tough (and brittle) when cooled, makes for easily forgeable iron which is both hard and corrosion resistant (Sauder 2011: 4–5). Small amounts of copper included in the iron will also make it more resistant to corrosion (Kronz and Keesmann 2005: 442). Agricola mentioned that hard iron, for hammers and other high-use tools, could be made by leaving the bloom in the furnace after re-smelting it in an open-hearth furnace (Agricola et al. 1912 [1556]: 423).

3.2.2 Furnace types

The most common shape of the iron-smelting furnace is the shaft or chimney, which is known to have been used from the beginning of iron production up until today's blast furnaces. Archaeologically, two types are distinguished based on how the slag is removed from the furnace. If the slag flows vertically into a specially constructed pit under the furnace they are known as slag-pit furnaces. If the slag is removed laterally through a hole at the base of the furnace these are traditionally designated shaft furnaces. This term is misleading, the slag-pit furnaces also have a shaft, but is accepted for historical reasons and the current lack of a better alternative.

There is also disagreement as to whether slag-pit furnaces should be considered as slag-tapping or not. Martens (1978b, 1978a) and Serning (1978) argued for accepting the formation of the slag blocks at the base of the slag-pit furnace as the result of slag-tapping, in this case below the furnace as opposed to laterally. The latter view is now accepted by many (see for example Serneels et al. 2000: 105; de Rijk 2003: 17; Leroy and Merluzzo 2004: 64–65), while others, mostly British researchers, regard the slag-pit furnace as non-slag tapping (Pleiner 2000: 149, 152; Bayley et al. 2001: 11; Young 2003: 3). In this study the slag-pit furnace is considered slag-tapping, be it vertically instead of laterally as in the shaft furnace.

Many other furnace varieties are known. A type of furnace, of some importance to this study, is regularly termed the Catalan furnace or forge, like the variety existing in the Pyrenees in the late eighteenth century which was one the first bloomery installations to be extensively studied (Tronson du Coudray 1775; Picot de Lapeyrouse 1786). This type of furnace, without a superstructure and with slag-tapping at the base, had a long history before that time, with a well-known example illustrated by Georgius Agricola (1912 [1556]: 422). The latter is a square bloomery furnace about 1m high and with a side length of about 1.5m (Fig. 3.3). The hearth itself is described as being 0.45m diameter and 0.3m deep and the furnace as being operated by water-powered bellows. Another early description of these installations was published in Gerard Boate's *Irelands Naturall History* (Boate 1652: 132):

> There is another and lesser sort of Ironworks, much different from the former [blast furnaces]: For instead of a Furnace they use a Hearth therein, altogether of the fashion of a Smiths Hearth, whereon the Oare being layd in a great heap,

> it is covered over with abundance of Charcoal, the which being kindled, is continually blown by Bellows that are moved by Wheeles and Water-courses, in the same manner as in the other Works.

These furnaces appear indistinguishable from contemporary finery hearths, or installations for the re-oxidization of sow iron (see below). In this study, this type of installation will be termed open-hearth bloomery furnaces.

Fig. 3.3 Water-powered open hearth furnace, Bohemia, mid-16th century (Agricola et al. 1912 [1556]: 421)

That this furnace type is under-researched is not helped by the fact that iron ores can also be reduced in a blacksmith's forge. Pleiner (1995) mentions the case of forge-hearths in late nineteenth-century Bohemia, which were used as bloomeries to reduce limonite when the usual scrap iron was unavailable. Throughout the historical record there are more dispersed accounts of smiths being able to produce wrought iron in their forges. Early examples include short notices from Wiltshire (Grew 1681: 331) and Staffordshire (1686) (Jones and Harrison 1978: 798). Later, nineteenth-century, accounts still mention smiths smelting iron ore without details of the installations used, but these seem to have been occasional, experimental activities. In the 1840s, a County Antrim blacksmith managed to make iron from the newly discovered haematite deposits of Glenravel by “imitating the ancient Irish ironworkers” (Hodges 1882: 53–54). Several years later, Dublin historian John d'Alton entered a piece of iron made from clay ironstone from County Mayo in the Great Exhibition of London (Anonymous 1851:

145). This had been reduced using turf “in a common smith's forge”. And, finally, Bleekrode (1858: 345) mentions that he had no problem producing a small bar of iron in a smith's forge using exclusively early medieval tap slag as ore, but did remark that the amount of charcoal needed would make larger-scale production uneconomical.

Some slag-pit furnaces had thin-walled, mobile shafts which could be used several times over different pits, such as the near-complete example from Scharmbeck in Northern Germany dated to the second century AD (Pleiner 2000: 159). Other furnaces have been calculated as having been used over a hundred times, as at the fourth-century site at Storbekken in Nordland, Norway (Buchwald 2005: 231). If tuyeres were not used, one or more holes through the furnace wall were made to insert the bellows or to allow for air to enter the furnace by natural draught. At an eighth- to ninth-century site in Nemeskér, Hungary, so-called tuyere-panels were found (Gömöri 2006: 187). These were clay slabs with tuyere-holes, functioning as door-like features at the front of the furnace, thus allowing the removal of slag and/or blooms without damaging the actual furnace. At an eleventh- to thirteenth-century site in Belkenscheid, Sauerland, Germany, a U-shaped band of iron was used to line the rim of the furnace arch (Sönnecken 1971: 90).

Examples are known of gullies dug around the furnace to keep the underlying ground dry, like at the eleventh- to thirteenth-century site at Neuenloh, Sauerland in Germany) (Sönnecken 1971: 47). Although most furnaces seem to stand unprotected, some have been found inside purpose-built structures such as the circular building around the Iron Age furnaces at Crawcwellt in Wales (Crew 2002) or inside sunken-floor workshops in Moravia (Pleiner 2000: 67). Written sources point to late medieval ironworks often being located inside buildings (Schubert 1957: 125–126).

3.2.3 Blooms and sows

The products of the furnaces are, by their nature, rare finds on archaeological excavations and it should be remembered that the pieces found might have been discarded due to their inferiority. In the late medieval period, only fragments of blooms are known, such as the twelfth- to fourteenth-century bloom (fragment) from Hohenlimburg, Nordrhein-Westphalen, Germany (Schulz and Bornefeld 1952), the thirteenth-century piece from Downpatrick, Co. Armagh (Tylecote 1977) and several fragments from Poland (Piaskowski 1961: 268), all weighing under one kilogram.

Earlier examples of blooms and billets are often rounded or loaf-shaped and are regularly split into multiple “fingers”, presumably for quality control either for the producer or the user, or both (Pleiner 2003). Semi-finished iron bars, often formed into specific shapes, are found somewhat more often and can have a wide variety of shapes and sizes, ranging from pointed bars to small lumps (de Rijk 2003: 82–83), but none are known from the late medieval period. No references were found to archaeological finds of sows of iron. The weights of blooms and sows will be studied in more detail below.

3.2.4 Smelting slag

In the past, the high iron content of the slag resulting from bloomery-iron smelting was often seen as an indication of the inefficiency of the process, but through experiments it is becoming increasingly clear that a high iron content in the smelting slag was not only unavoidable, but was a prerequisite for a high-quality bloom (Sauder 2011: 2). In the bloomery furnace, the material that does not become part of the bloom will form as slag (Crew 1995). Mineralogically, this slag is typically made up of the iron silicate fayalite (Fe_2SiO_4) and the iron oxide wüstite (FeO). Depending on the occurrence and levels of aluminium, magnesium, calcium and other elements in the ore (or the furnace wall) many other silicates and oxides can be present (Kronz and Keesmann 2005: 426–439). The identification of smelting slag based on the occurrence of hercynite ($FeAl_2O_4$) by Photos-Jones and Atkinson (Photos-Jones and Atkinson 1998: 894), who used this argument to state that iron smelting was carried out in the medieval burgh of Perth, Perthshire is untenable as this mineral has been encountered in both secondary smithing slag (Andersson 2007: 4–5) and hammerscale (Young 2009b: 3).

The slag that leaves the furnace will exhibit, after cooling and solidifying, a flow-pattern, which sometimes indicates the direction of the slag flow: from vertical (slag pit furnace) to horizontal (shaft furnace). A portion of the bloomery furnace slag, which is generally lighter and sometimes called “fuel ash slag”, will form in the hottest, oxidizing zones of the furnace, that is to say under the air inlets. The clay on the inside of the furnace wall and/or the tuyeres can also become heavily vitrified. There is still no consensus as to the amount of slag resulting from a single smelting operation. It is generally thought that the slag produced is in the region of three to five times the amount of (unconsolidated) bloom, but ratios as high as 20:1 have been put forward (Crew and Crew 1996: 48–50).

Slag-pit furnaces which are used multiple times can lead to the formation of large (up to 400kg) slag blocks, which are often preserved in the underlying pit. As this pit below the furnace is filled with organic material, the slag blocks can retain impressions of the filling material, that is to say grass or, more commonly, pieces of wood (Mikkelsen 2003; Henriksen 2002). In shaft furnaces, the solidified slag which left the furnace shows a ropey lava-like structure on its upper face. If the base of the hearth of a lateral-tapping furnace is lower than the base of the tapping-hole, slag can cool at the base of the furnace and form so-called “furnace bottoms”. The slag derived from the water-powered bloomery is less clearly understood, but seems to be similar to tap slag with a characteristic honeycomb structure on the lower side (Dungworth 2010: 19). blast furnace slag has a very low iron content, a glassy appearance and comes in a wide variety of colours, including blue, green, white and brown.

Another factor determining the chemistry of smelting slag is the contribution of the furnace wall. This has been calculated as high as 25% of the weight of the ore when producing a 2kg bloom from high-grade ore (Thomas and Young 1999: 225), while others have concluded that the contribution of the clay lining of the furnace is negligible (Kresten et al. 1997; Buchwald 2005: 97). The low contribution of the walls of the large Roman-age dome-shaped furnaces at Laxton, Northamptonshire was seen as functional, as the furnace would have been expected to withstand high temperatures over long campaigns (Crew et al. 2008). Elevated amounts of some elements present in the clay of the furnace wall, such as aluminium, can result in slag inclusions in the metal which make it difficult to weld. This led experimental iron-smelter Sauder (2011: 3) to resort to building thin-walled furnaces, which resulted in higher heat loss through the wall, hence less reaction and influence of its constituent parts.

3.3 Further processing of the iron

3.3.1 Fining and refining

It is frequently stated that, after smelting, the slag remaining in the bloom needed to be removed, leading to the formation of refining slag (see for example Crew 1996: 1; Pleiner 2000: 215). Larger examples of bun-shaped slag are generally seen as connected to the refining process, and that their size can be very substantial is shown by the 93kg Roman-period piece found at Les Martys, Aude, France (Fabre and Coustures 2005:

311). This type of slag has proven difficult to characterize because of the closeness of its chemistry to that of smelting slag and its shape to that of furnace bottoms and smithing hearth cakes (Fluzin et al. 2004: 163; Pleiner 2000: 255).

We know from written sources that blooms from some water-powered works were purified in so-called string-hearths, as is recorded for Byrkeknott, Co. Durham in AD 1408/09 (Lapsley 1899: 510), and in AD 1541, at the Rievaulx and Bilsdale bloomeries in Yorkshire, where the stringing of the blooms led to a weight loss of 34% (Schubert 1957: 396). In Middleton, Staffordshire around AD 1577 the estimated loss in weight after "burning" was 25% (Smith 1967: 131). But this bloom refining does not appear to have been universal. No further processing of the blooms, for example, is mentioned at the non-water-powered fourteenth-century bloomeries at Tudeley in Kent (Guiseppi 1913; Hodgkinson and Whittick 1998). Georgius Agricola, in his description of iron smelting in Bohemia around the middle of the sixteenth century (Agricola et al. 1912 [1556]: 421–422), does not mention any further bloom processing before it reached the blacksmith.

Perhaps the best-studied site which included bloom-processing remains is the Merovingian settlement at Develier-Courtételle, Jura, Switzerland, which yielded over four tons of ironworking remains (Eschenlohr et al. 2007: 9). The residues connected to bloom smithing were identified on the basis of their chemical composition and the occurrence of bloom inclusions within the slag (ibid.: 34–35, 55). Smelting slag, however, made up only a small part of its composition. This was partially explained by proposing that the actual refining of the bloom took place on the smelting sites, so this slag then represented bloom-working, rather than bloom-refining, slag.

On the other hand, several extensively excavated non-water-powered bloomery smelting sites revealed only limited amounts of slag which could potentially be attributed to bloom processing. This was the case at the late thirteenth- to early fourteenth-century bloomery smelting site of Genoeserbusch in Luxembourg where only two smithing hearth cakes (4.95 and 1.12kg, both complete, very flat cakes) were recovered (Overbeck 2011: 129–131). In the publication on the excavation of dozens of medieval smelting sites in the Sauerland, Nordrhein-Westphalen in Germany mention is only made of occasional medium-sized bun-shaped pieces of slag (1971: 65, 68, 76, 92). Also, extensive analysis of the residues from slag-pit furnaces from sites in Poland led the researchers to believe that the blooms produced needed no further purification (Bielenin and Suliga 2008: 65; Bielenin 2011) and recent analysis of an undated bloom from Austria showed no sign of post-reduction forging (Strobl et al. 2010). Detailed chemical and mineralogical examination of large amounts of slag from the site at Develier-Courtételle, Jura, Switzerland showed that steel blooms contained less slag than ordinary iron blooms (Eschenlohr et al. 2007: 55). There then appear to be three situatuations concerning bloom refining: it can take place at the smelting sites, elsewhere or not be necessary because of the lack of slag in the bloom.

If the liquid iron produced in a blast furnace was not cast into an object, it was further refined into bar iron. The sow (later called pig), a block of iron cast for this purpose, was brought to a separate installation, the finery. Here, the sow was again liquefied, this time under oxidizing conditions, which depleted the iron of carbon. The resulting product, confusingly sometimes called a bloom (see for example Lower 1849: 202), was then hammered into bars or plates of iron. In the Walloon blast furnace, this hammering was done after a second reheating in the chafery (from French *chauferie*, heating place) (Schubert 1957: 273). Fineries, which always used water-powered bellows, were forge-like structures with slag-tapping facilities (Fig. 3.4). As a result, finery slag is dense, iron-rich slag displaying a clear flow-pattern and is often confused with tap slag produced in the bloomery furnace (Horstmann 2003: 232). Chaferies seem to have been similar installations to fineries, but without slag-tapping facilities. Large saucer-shaped dense slag cakes, not dissimilar to the larger smithing hearth cakes, are known as “mossers” and are the typical waste product of the chafery plants (Morton 1963: 266–267).

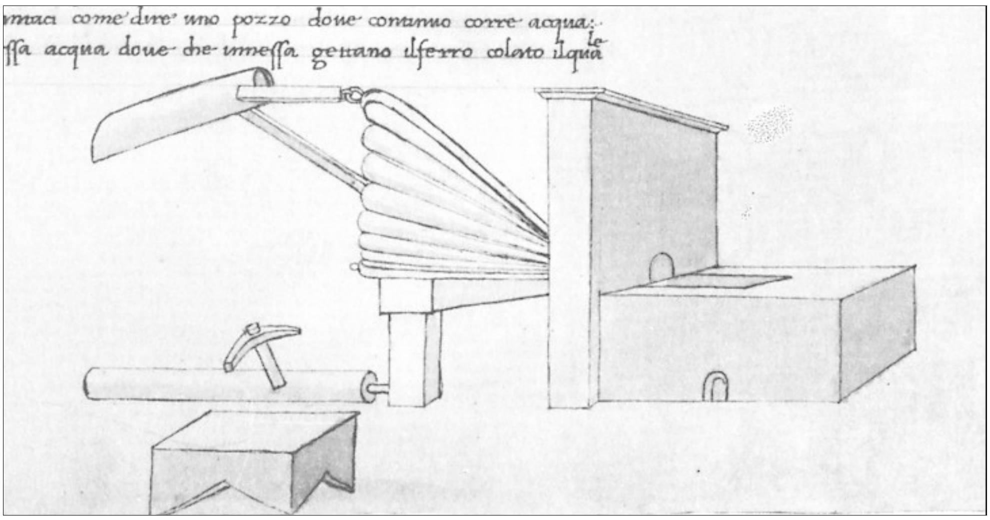


Fig. 3.4 Finery, between AD 1433 and 1447 (Grottaferrata, Roma). Antonio di Piero Averlino, alias Filarete, AD 1465 (Spencer 1963: 202). Note the opening for slag-tapping at its base.

3.3.2 Smithing hearths

Early smithing was carried out at ground level and was characterized by pits of varying sizes, shapes and burnt surfaces. These smithing hearths were sometimes accompanied by wind-brakes or other more substantial structures. Ground-level smithing hearths could be (partially) lined with a clay or stone wall to control the internal environment. From the twelfth to the thirteenth centuries onwards, smithing was more frequently conducted in specially constructed buildings (Astill 1996). There is evidence that during Roman times, smithing was also carried out at waist level (ibid. 1986: 163). This manner of smithing then disappeared from the historical and archaeological record and reappears around the fourteenth century. These waist-high forges will be dealt with in more detail later (see Chapter 11.4).

3.3.3 Smithing slag

Smithing slag forms during the heat-related smithing processes, especially during object manufacture. It is made up of iron lost from the object/bloom, clay from smithing hearth walls and tuyeres and materials added (fluxes). The typical slag formed in the charcoal-fired smithing hearth is the smithing hearth cake: a bun-shaped lump of slag of varying density and appearance. These cakes formed below the tuyere/blowhole and were composed of iron and slag lost from the object, charcoal ash, hearth-lining and materials added during forging (welding sand, and so forth). Mineralogically, however, they contain the same phases as smelting slag which has led, and still leads, to difficulties distinguishing between smelting, bloom-smithing and smithing slag (Pleiner 2006: 119).

The waste produced in a smithy also includes hammerscale, small magnetic globules or flakes of magnetic slag-like material which forms as a result of, respectively, forge-welding and the striking of hot iron/bloom (Dungworth and Wilkes 2009; Young 2011e). Large layered cakes, containing scattered particles of hammerscale, have recently been identified as the result of quenching (Rehren 2008).

In general, little research has been done on understanding the relationship between smithing residues and the techniques which led to their formation, mainly because the residues were seen as too heterogeneous. Recent work, however, on the nature of both smithing waste and weld-line slag inclusions in knives from the same site, found that a connection did exist between the composition of the objects and that of the waste produced in their manufacture (Daoust and McDonnell 2008). An elevated level of manganese (or arsenic) in the smithing slag could point to the use of this mineral in forge-welding, and if phosphorus was indeed added during the smithing stage, this would lead to elevated levels of this element in the slag (see above).

3.3.4 Smithing techniques

Blacksmithing is the physical and chemical alteration of iron alloys. This is carried out in the smithing hearth, a shallow hollow which is either at ground or waist level. Smithing can be carried out using both charcoal and coal. The temperature required can be anything between 900 and 1400 ºC (Schubert 1957: 131, Tylecote 1981b: 45). The standard tools of the smiths are the hammer, anvil tongs, used to handle and shape the iron. Many more were used to fashion the and finish the objects, such as chisels, punches and files (Scott 1990: 21–23). in some cases, such as nails or rods, the iron needed to be drawn out and for this specialized tools with purposely made hollows were used or the anvil was equipped with the same.

During smithing, sand is often added to form a coat of iron oxide around the object and during forge-welding (see below). There are indications that sometimes calcined flint was used for this purpose (Buchwald 2005: 218). Pre-modern iron, which still had a certain slag content, would only require a welding flux if its carbon content was elevated (steel). The use of high-manganese welding sand in an early medieval sax has been demonstrated (Joosten et al. 1996).

Depending on the processes used, the bloom will consist of iron with a variable content of other elements, the most important being carbon. When no or very little carbon is present, we talk about wrought iron. This material is easy to work and durable, and as such is most suitable for structural purposes, from nails to beams over the non-cutting parts of knife- and axe-blades. When the iron contains more carbon it will be a harder and tougher material, suitable for cutting edges and hard-wearing objects, such as hammers. If an object requires additional carbon after completion it can be carburized or case-hardened. This will result from the heating of the object in a carbon-rich environment which will lead to the uptake of (additional) carbon. This is famously described by Theophilus in his *De Diversis Artibus* (Dodwell 1986: 93–94). Due to the limited depth of carbon uptake in the object, this is reserved for objects which need very hard outer surfaces, such as files.

As we have seen, phosphorus can enter the iron in the smelting stage and is generally advantageous to the nature of the iron. Because it will inhibit the distribution of carbon, it will also be preferred for pattern-welding as it will preserve the carbon in the steel component (Rubinson and McDonnell 2008). No information was found on the possibility of adding phosphorus during the smithing stage. The occurrence of enriched arsenic along welding lines in iron objects has been seen as the possible, or even probably, result of the use of an arsenic rich flux (Castignino and McDonnell 2008; Daoust and Castignino 2008).

Welding will be carried out if composite objects are required, either larger ones consisting of several pieces or to combine iron alloys with different properties into one object. The most common technique is to add a high-carbon piece of iron to a lower carbon body to produce cutting edges on axes, knives and ploughs. This can be done by welding the steely part directly unto the body (edge-welding) or by first splitting the body and inserting the edge (fork-welding) (Fig. 3.5).

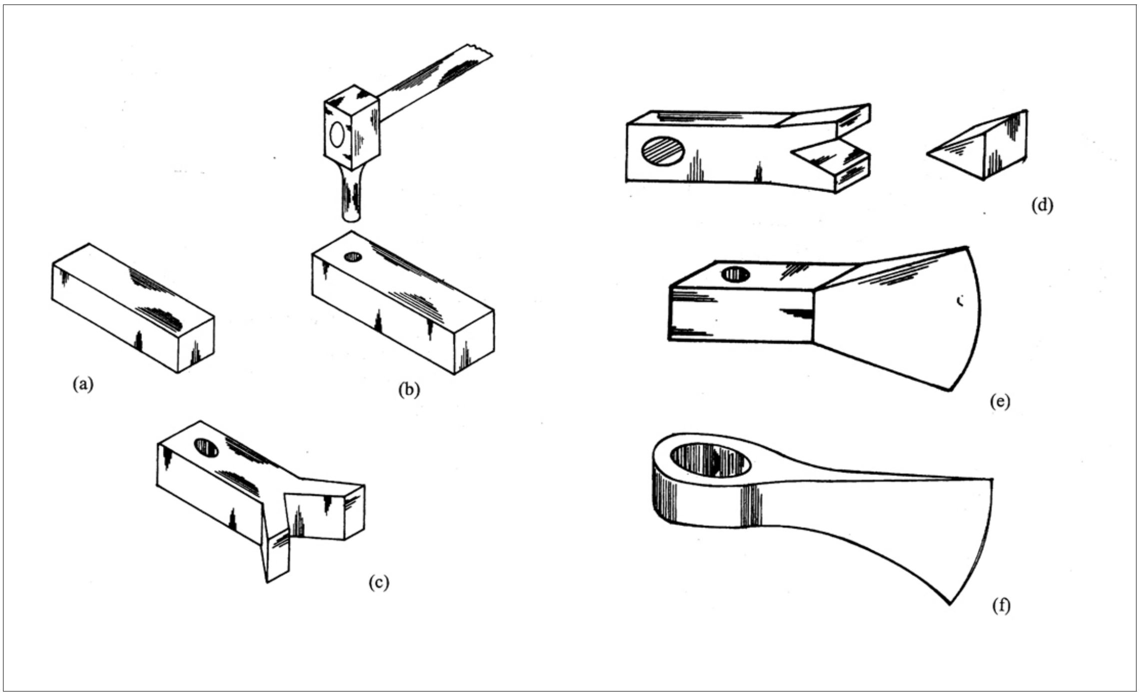


Fig. 3.5 Stages of the manufacturing of an axe (after Sim 2012: 115)

Pattern-welding is an intricate and demanding technique whereby small strips of iron with different properties is joined and twisted to produce, after additition of a steel edge, high-quality swords and knives (Fig. 3.6). This technique not only resulted in superior properties, but also an esthetic pattern on the blade after polishing.

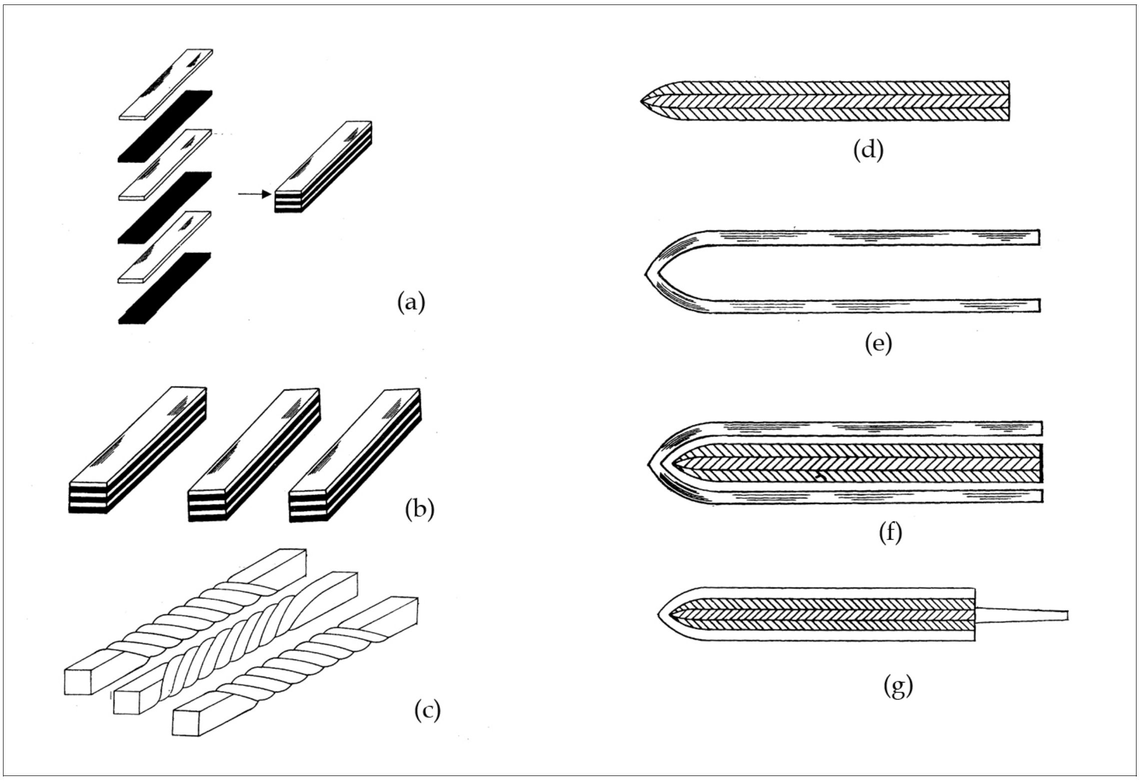


Fig. 3.6 The stages of pattern-welding (after Sim 2012: 105)

Further heat-treaments to the finished object include quenching, which is the sudden submerging of a hot, high-carbon object in a liquid will lead to a more even distribution of this carbon. Quenching is occasionally performed in combination with carburization. Sometimes exotic liquids are noted in the written sources as appropriate for quenching: the urine of a small red-headed boy (Dodwell 1986: 95) or a concoction based on earthworm and onion juice (Johannsen 1941: 118). Quenching is typically followed by tempering to reduce hardness. In the modern sense, the re-heating of steel to reduce hardness. In earlier times, the term was used to describe the initial quenching in steel production (Williams 2012a: 26–27). Brittleness introduced into the object after cold hammering or over-heating can be removed through annealing, or re-heating of the object (Pleiner 2006: 66; Sim 2012: 136). this is often carried on sheet iron which has become brittle by the frequent hammering down. Slack-quenching is the same operation carried out with slower cooling rates (Williams 2012a: 22). The metal will then be less hard, less brittle and will not need to be tempered.

3.4 Tools, implements and air supply

3.4.1 Hand tools

As very few iron mines have been archaeologically excavated, little is known about the tools used in the early mining of iron and Pleiner (2000: 103), in the most recent overview publication on the subject, only refers to a few picks, some shovels and a few lamps retrieved from pre-modern European iron mines. In the nineteenth century an assemblage of mining equipment was found in an abandoned iron mine in Ludres in Lorraine, France. The material included picks, hammers, chisels, a shovel and a wooden sledge on iron bands for transporting the ore (Leroy 1997: 80–82). A complete pot dating to the eighth to ninth centuries was among the finds. The further breaking of the ore would have required at least some type of hammer, either stone or iron, but hardly any examples are known.

The most commonly quoted tools from smelting sites, both from excavations and the written record, are iron bars. Various functions have been assigned to these. Schubert (1957: 129–130) mentions them in connection with the manipulation of the ore mixture during smelting, Overbeck (2011: 153–154) interpreted a rounded iron point found on the late thirteenth- to early fourteenth-century bloomery-smelting site of Genoeserbusch in Luxembourg as part of a tool to break through the furnace wall to allow slag-tapping. Impressions of tools were also observed in pieces of solidified slag from the same site, but were difficult to characterize (ibid.: 110). More bar fragments were recovered during the many excavation campaigns undertaken by Sönnecken (1971: 121) on late medieval smelting sites in the south-east of Nordrhein-Westphalen in Germany. As impressions of iron bars are also known from blooms (Schubert 1957: 130), they would have had some function in bloom removal.

Axes are also recorded, both for cutting up the hot blooms into smaller units and for splitting the bloom to expose the inside, presumably for quality control (Schubert 1957: 131–132). An axe fragment was recovered from the Genoeserbusch site, mentioned above, possibly for splitting blooms (Overbeck 2011: 153). The occurrence of clearly raked slag (Bayley et al. 2001: 11) would imply the use of rakes on smelting sites.

Smithing tools are much better known, both from graves (Mehofer 2004), from caches (Goustard 1997; Lønborg 1996) and found discarded on smithing sites. They are also regularly depicted in manuscripts or sculptures. The tools consist of tongs for holding the object/bloom, hammers, whetstones, chisels, files, punches and various other tools to shape the object (Pleiner 2006: 71–108).

3.4.2 Anvils and troughs

Anvils are among the most important implements in the repertoire of the smith. Simple anvils consisted of no more than blocks of stone, while iron anvils came in various forms dependent on work carried out on them (ibid. : 93–96). Pre-modern iron anvils were generally small and had a pointed base to be inserted in a wooden support block (Coghlan 1956: 117–122). Isolated "postholes" inside forge buildings and around smithing hearths often represent the place of the wooden anvil-block in which the actual iron anvil was inserted (Crew 1996: 2). Larger anvils were either the products of the blast furnace and would have been cast in one piece at the furnace, or were made from wrought iron in specialized anvil forges (Schubert 1957: 312).

Troughs near furnaces could be used for cooling blooms or tools, while the author of *Officia Ferraria*, the poem describing the working of a water-powered bloomery, mentions a trough at the hammer-forge containing clay mixed with water which would be sprinkled over the charcoal (Różański and Smith 1976: 84, 89). Various pits and supports for troughs found in conjunction with smithing activities, especially in the later medieval period, have been interpreted as indicating quenching activities (Astill 1993: 279; Pleiner 2006: 133–134). A trough "for the forge" is mentioned in the accounts for Winchester Castle in AD 1222 (Colvin 1971: 132–133).

3.4.3 Tuyeres and air supply

Tuyeres are ceramic, stone or metal implements to protect the wooden bellow-ends against the heat from the furnace or the smithy (Pleiner 2000: 196–212). The shape of tuyeres can vary widely: conical, cylindrical or rectangular. The use of multiple tuyeres in smelting furnaces is often encountered and some block tuyeres are constructed to channel the air of two tuyeres. Iron tuyeres are known from the written sources from the fourteenth century onwards (Guiseppi 1913: 158; Arnoux 1993: 117–118) and several late medieval examples are known from the archaeological record: from the late thirteenth- to early fourteenth-century bloomery at Genoeserbusch, Luxembourg

(Overbeck 2011: 157–158) and the blast furnace of similar age at Lapphyttan, Västmanland, Sweden (Magnusson 1986b: 42).

Next to various types of tuyeres connected with smithing, there are also known in Scandinavia and Northern Germany, clay or stone heat shields (*Essesteinen*) with holes for air supply into the hearth (de Rijk 2003: 76, 79; Smith 2005: 191). These were often made out of soapstone, but ceramic and basalt examples are known, which had flat bases for support and were occasionally decorated with human faces on the outer side. An additional way in which the bellows can be protected is through the construction of a clay hearth wall in which a blow-hole is made. This would seem to have been the predominant technique used in early, including late medieval, Britain (Young 2009a: 82; McCullough and Young in press: 17).

In many cases the bellows would have been operated manually, but these, and smiths' hammers, are also known to have been operated by foot (Percy 1864: 321; Schubert 1957: 138). Alternatively, furnaces could be worked successfully using natural draught. Pellequer (2008), based on archaeological and ethnographical research, listed several criteria as indications for the use of natural draught in furnaces: no tuyeres, multiple tuyeres, large blow-hole diameters, placed in a wind-served location, and so forth. The argument of the lack of tuyeres is complicated when iron tuyeres are used, which would rarely be lost or left on a site. Such iron tuyeres, and bellows, are regularly recorded in the accounts for the fourteenth-century non-water-powered furnaces at Tudeley (Kent) (Hodgkinson and Whittick 1998: passim). An iron tuyere was found at the late thirteenth- to early fourteenth-century site of Genoeserbusch in Luxembourg. This tuyere was regarded as used in the smelting process in the publication, but as it was found together with two partially refined bloom-fragments and part of an axe (Overbeck 2011: 157), it might have been used in bloom refining.

Water-power could be applied to every stage of the iron production process: for draining mines, breaking the ore, driving the bellows, powering hammers and turning sharpening stones (Lohrmann 1995). The water supply was either a natural or man-made stream connected to a dammed water reservoir. Both would have had some mechanism for regulating the water supply. The wheels either directly turned the device for continuous action (rag-and-chain pump, grinding-stone) or the power was transferred via a camshaft for intermittent power (bellows, hammer).

3.5 Conclusions

Early iron-smelters knew of a large variety of techniques to obtain different products. The type of ore, the furnace used and the fuel ratio would all influence the carbon content of the iron, producing wrought iron, steel or liquid iron. The properties of these products could later on be further altered. In theory, if the archaeological remains are reasonably well preserved, the type of features and residues should indicate if smelting or smithing is represented. Smelting sites will be characterized by slag showing flow-structure, indicating either vertically-flown (slag-pit furnace) or almost horizontally-flown slag (shaft furnaces). The evacuation of slag in both processes is regarded here as tapping. The volume of slag will be dependent on the richness of the ore, the proportion of the slag left in the bloom and the number of times the furnace was used. Frequently, some slag will solidify in the hearth area of the furnace resulting in furnace bottoms (shaft furnaces) or furnace cake (slag-pit furnaces). Smithing sites, on the other hand, are typified by bun-shaped slag cakes produced in shallow hearths. Hammerscale also invariably points to forging activities.

In reality, however, determining the processes involved is not always straightforward. Furnace bottoms can be confused with (bloom) smithing hearth cakes, but the former should always occur together with tap slag. The nature of the pit, however, together with aspects of the slag itself, should indicate the process involved. Some smithing slag can have a very similar structure to drippy smelting slag, but will nearly invariably be accompanied by smithing hearth cakes, while the lack of a furnace base or pit would confirm the activity as smithing.

Chemical analysis on smelting slag can provide indications of the types of ores used, but caution is necessary as the composition of ores can vary widely. Ideally, samples of locally occurring ores should be analysed concurrently. A high manganese content of smelting slag implies that the product would have been high-carbon iron, that is to say natural steel. There is no consensus on the behaviour, origin or function of elements such as phosphorus, calcium and arsenic. Mineralogical examination can provide information on the conditions in the furnace, but generally cannot distinguish between the different production stages. The occurrence of unaltered quartz being an exception and points to it being added during smithing activities. The data from chemical analysis of smithing slag has only slowly resulted in meaningful advances in our knowledge, as both the complexity and the chaotic nature of the processes involved in iron smithing are becoming better understood. Some very initial research has been carried out regarding the relationship between the composition of smithing slag and the resulting objects and substantial advances have been made in understanding hammerscale. The implications of the results of the metallographical examinations are well understood and have led to important insights into early smithing technology.

Chapter 4

Irish iron ores

The map showing the distribution of Irish iron ores published in Brian Scott's seminal work *Early Irish Ironworking* (1990: 153) is still widely used today (Rynne 2006: 106; Photos-Jones and Wilson 2007: 92; Photos-Jones 2008d: 188; Comber 2008: 114). There are, however, some problems with this map. Laterites, pyrites and bog ores are represented as separate groups, while haematites, siderites and so forth, are classed as another. However, while the category pyrite may be omitted, as these are unlikely to have been used as an ore, the haematites, siderites and others are better differentiated. Scott (1990: 153) does mention references to bog ores in the Geological Survey memoirs, but these are only partially incorporated on the map. A quick glance at the map also shows empty areas where known, and important, iron ore occurrences are recorded, such as Richard Boyle's iron mines around Tallow, Co. Waterford. Other areas where the occurrences of ore are strongly under-represented, include the Leinster Coal Field area. Because of the easy accessibility of the sources, mostly nineteenth-century publications nearly all of which can be readily found on the Internet, it was decided to compile all the known references on a new map of iron ore occurrences in Ireland. An early version of this map was used by Brian Dolan in his recently completed doctoral thesis (Dolan 2012 vol. 2: 96).

Apart from the published sources, a lot of information is also noted down on 6-inch Ordnance Survey maps. This information has been incorporated into the online map/database by the Geological Survey of Ireland[19] and is referenced in the following discussion as (GSI). A request for data from the Geological Service of Northern Ireland produced an Excel document containing location and elemental information for Northern Irish metal occurrences. As the type of iron was not specified, this information was not incorporated into the following discussion. In some cases, bright orange patches of bog ore are visible on the aerial photographic layers of the Ordnance Survey of Ireland website.[20] Brian Dolan (2012 vol. 1: 204) confirmed these to be occurrences of bog ore by checking on the ground and using the ore in his experimental smelt.[21] These

19 http://spatial.dcenr.gov.ie/imf/imf.jsp?site=GSI_Simple
20 www.osi.ie
21 See http://smelt.seandalaiocht.com/

locations are referred to as (OSI), followed by the relevant year of the aerial photograph. Some placenames in Ireland refer to iron, and although this does not always necessarily mean that iron would have occurred in mineable quantities, these are included in the text and on the map. Most unpublished references to these placenames were found in the online Placenames Database of Ireland[22] and are referenced as (Logainm). This same website also has some of the information from the handwritten Field Name Books of the Ordnance Survey which occasionally contained information on iron occurrences.

The categories used on the maps produced are oxy-hydroxide ores (eagle stones, limonitic ores, haematites and magnetites), siderites, pisolitic ores, bog ores and unspecified ores (See Chapter 3.1.1). Some limited occurrences of iron compounds, which were presumably recorded by the GSI for scientific rather than economic reasons, are also not represented on the maps. Bog ore, recorded as extracted for gas purification, is listed as an occurrence and not a mine. Several iron mines are on record which have no precise information regarding their location. These mines were not represented on the maps, but the relevant information is given in the text.

4.1 Iron ore classification

Iron is the fourth most abundant element in the earth's crust, amounting to about five percent in weight, after oxygen, silicium and aluminium. Small amounts of nearly pure iron have also reached the earth in the form of iron meteorites. Over time, physical, chemical and biological forces have created the multitude of iron compounds found in nature today.

The classification of natural iron compounds has always been problematic. Firstly, the element iron not only has two oxidization states (+2 and +3), but also comes in three natural varieties in their crystal structure (allotropes: α, β and γ). Fe^{+2}, or Fe(II), is found in siderite ($Fe^{2+}CO_3$) in pyrite (FeS_2) and in magnetite (Fe_3O_4) which also contains Fe^{+3}. Fe^{+2} also occurs in compounds which are formed through heating, such as wüstite (FeO) and fayalite ($Fe_2{}^{2+}SiO_4$), which are major components of iron slag. Fe^{+3}, or Fe(III), is encountered in most naturally occurring oxides and oxy-hydroxides of iron, which are then distinguished by the type of allotrope they contain. The most common of these are haematite (α-Fe_2O_3), maghemite (γ-Fe_2O_3), goethite (α-$Fe^{3+}O(OH)$, akaganéite (β-$Fe^{3+}O(OH,Cl)$) and lepidocrocite (γ-$Fe^{3+}O(OH)$).

Some of the above iron compounds, such as haematite, pyrite, magnetite and

22 www.logainm.ie

siderite, occur naturally as more or less homogeneous accumulations, but most iron ores are difficult to standardize and consist of complex combinations of oxides and oxide-hydroxides. Sometimes, the term limonite is used to describe certain types of these iron mixtures, but limonite is not a recognized iron mineral. Because of this, Cole (1922: 67) preferred the term "limonitic ore" for these types of Irish ores. Other iron mixtures have traditionally been given names based on their formation processes, such as "bog ore", because of its morphology, such as pisolitic ore ("bean ore") and, based on folklore, aetites or eagle stones, which were thought to be found in eagles' nests.

It is also important to keep in mind that "iron ore" is an economic, not a scientific term, indicating an iron compound suitable for smelting. As such, the iron content of a mineralogical compound will be one factor which will termine if it is considered an ore, but others such as the local demand for iron, the technology used, impurities within the same compound and availability of fuel will also play a role. In other cases, an iron compound will only be suitable for smelting if another, with a different composition, can be obtained to be smelted together.

Different types of ore consist mainly of a single mineral and are designated by the name of that mineral:

Magnetite (Fe_3O_4)

As the name implies this iron mineral is naturally magnetic and, in pure form contains 72.4% iron. Magnetite occurs in huge quantities in Banded Iron Formations, witnesses of the early oxidization of the earth's atmosphere, as "black sands" which have been transformed into metal since antiquity (Photos et al. 1988) and as ore bodies associated with non-ferrous mineralizations.

Haematite (Fe_2O_3)

Haematite means "blood stone" because of its use as a red pigment, but most of the material found in nature will appear brown or black. Pure haematite contains 69.9% iron. Large ore bodies of haematite are often sedimentary in origin. Today it is the most important ore for iron.

Goethite (FeO(OH))

Goethite often forms as through weathering of other iron-rich compounds. As such it is mostly encountered in soils and muds and is one of the main constituents of iron ores such as bog ores and gossans (see below).

Siderite ($FeCO_3$)

Siderite takes its name from *sideros*, Greek for iron. Pure siderite contains 48.2% iron and is found as veins and concretions often associated with coal formations. In the latter form it is commonly known as "clay iron-stone", which, historically, was an important iron ore.

Other types of iron ore are named after their formation processes and are often made up of multiple minerals and sometimes have substantially varying compositions:

Limonitic ores

The poorly defined group of limonitic ores consists of any compound made up of oxides and/or hydroxides of iron. The main constituent minerals are goethite and lepidocrocite (both FeOOH), which contain 62.9% iron in pure form. Confusingly, the word "limonite" comes from the Greek *leimon*, meaning meadow, and refers to a type of bog ore, and in the older literature is known as "brown hematite". Limonite is generally amorphous and is found as concretions and earthy masses. Weathered outcrops or gossans, where iron sulphide has turned into oxide are also a type of limonitic ore.

Bog ores

Bog ore is a broad term used for a wide variety of substances. Early mineralogists defined various categories of the material, with Robert Jameson (1805: 334–338), for example, suggesting three categories: morass ore, swamp ore and meadow ore. The lake ores of Sweden and Finland can be included in this category, although an eighteenth-century description of bloomery-iron smelting in Finland distinguishes between several types of lake ore and bog ore, the latter generally being avoided for smelting (Buchwald

2008: 68). Bog iron ores from Denmark were mineralogically investigated by Tim Young (2009i) and shown to be complex compounds containing goethite, haematite, magnetite and maghemite. Due to their potentially high phosphorus content, bog ores have generally not been exploited by modern smelters, but bog ore did play an important role in the early iron industry of the United States of America (see for example Hartley 1957: 100).

Pisolitic ores

Pisolite derives its name from *pisos*, Greek for pea and is also known as “bean iron ore”. This ore consists of small, rounded and highly iron-rich nodules of iron ore formed as a result of weathering. Their composition varies because different origin material can lead to pisolite formation. If available in sufficient quantities, pisolitic iron ore is of great value to the modern iron industry.

Aetite or eagle stone

Aetites are a rare type of iron ore which was believed to originate in eagles' nests. They are layered concretions of different mineral types with a hard outer layer and are often hollow. Inside this hollow, aetites sometimes contain a hard kernel, which is why they are also known as *klapperstenen* or *Klappersteine* (rattle stones), respectively in Dutch and German. In the Netherlands, aetites were smelted on a large scale between the seventh and the twelfth centuries (Heidinga and van Nie 1993).

Gossans

A gossan is the part of a metallic ore body located closest to the earth surface and which is therefore oxidized. Typically, it consists mainly of iron-rich compounds, the non-ferrous metals being concentrated lower down.

Iron sulphides

Iron sulphides (pyrite and marcasite, both FeS_2) would have generally been avoided as an iron ore due to the detrimental effect of sulphur on the iron. Heavily weathered nodules may, however, have been used (Tylecote and Clough 1983).

Iron slag as ore

The reuse of slag from bloomery furnaces as ore in blast furnaces is well documented throughout Europe up until the twentieth century, but poorly researched (Butler 1973). Early references include ore and slag (*laitier*) which was collected "to make iron ore (*pour faire mine à fer*)" and brought to the ironworks at Croisy, Cher, France in AD 1480 (Quantin 1835: 36), and the large amounts of "cinders" reused in local furnaces and exported, also to Ireland, from the Forest of Dean in the seventeenth century (Schubert 1957: 185–186, 229). But there is also evidence that slag, presumably from non-water-powered bloomeries, was also used in water-powered bloomeries. In AD 1407 *sindres* were brought to the Byrkeknott, Co. Durham bloomery for "new iron or to temper it" (Lapsley 1899: 518) and about thirty years later, in AD 1438, an "Irynbrenner" was given permission by the Bishop of Durham to collect *sinders* for his forge (Louis and Vellacott 1907: 354).

The evidence for the reuse of slag in hand-powered bloomeries in Europe is less clear. Values and payments for cinders are recorded in the third quarter of the thirteenth century for the Forest of Dean (Hart 2002: 146) and purchases of iron and cinders are mentioned in the accounts of the manor of Honiton, Co. Devon in AD 1288 (Griffith and Weddell 1996: 33). These references very likely pre-date the introduction of water-powered bloomeries in England (see Chapter 10.3.1), but the slag could have been used for reasons other than smelting, for example road construction. We do, however, have clear evidence of slag being used in bloomery-iron smelting from Cameroon, where the Bikom tribe used it as an addition when smelting in an open-hearth type furnace (Jeffreys 1952: 49). Also, one of the possible explanations for the occurrence of multiple tuyere fragments near slag-pit furnaces in the west of Tanzania, but very little slag, was that the latter had been re-smelted elsewhere (Mapunda 1995: 50).

Initially, experimental iron smelting had shown that adding the "gromps" (mixtures of slag and reduced iron) back into the furnace at the end of the smelting campaign led to a greater density of the bloom (Sauder and Williams 2002: 134–135), but after more trials it was decided to abandon the practice as the resulting iron was too "nasty and recalcitrant" (Sauder 2011: 3). A complaint from the smiths of Nürnberg, Bayern in Germany around AD 1400 about the low quality of the local iron because it was made with re-used slag (Oelsen and Schurmann 1954: 514), which was presumably made in bloomeries, possibly water-powered ones, also suggests that adding slag to the smelting mixture was often detrimental to the iron.

4.2 Iron ore occurrences in Ireland

On the one hand, the iron ore occurrences in Ireland are many and varied, while on the other only certain have been recorded in detail. Below is a listing, per province, of all the references found on iron ore occurrences in Ireland. Each province listing begins with a brief overview of the geology and its relation to the main iron ore occurrences.

4.2.1 Leinster

There are three main concentrations of iron ores in Leinster. The first is located in the Carboniferous sandstones and shales of the so-called Leinster coalfields on the Counties Kilkenny and Loais border and mainly consists of sideritic ores. Various other types of ore, including heamatites and magnetites, are found around the volcanic intrusions through the Wicklow Ordovician. The third group are bog ores, of Quarterny age, occur in several locations, with a concentration on the Meath, Westmeath and Offaly borders.

County Carlow

No occurrences of iron ore were found for Co. Carlow.

County Dublin

The references to mined iron deposits in Co. Dublin are limited. From the beginning of the nineteenth century onwards, large amounts of manganese and limonite (“brown ironstone”) were quarried on the south side of Howth Peninsula (Fitton and Stephens 1812: 42). Further north, poor quality siderite (“clay ironstone”) was encountered at Baldongan and Donabate (Kinahan 1887: 239). On Lambay Island abundant lumps of haematite were observed to the south-west of Raven's Well (Hull et al. 1875: 50).

County Kildare

Bog ore is recorded at Ballyneagh (Ambularius 1794: 5), while veins of haematite were noted at Watergrange (GSI). Unspecified iron ore found on the Hill of Allen was assayed and found to contain just under 30% of iron (*Freeman's Journal* 13/12/1787: 3). South of Kildare town, there is a townland called Ironhills (Logainm).

County Kilkenny

In Co. Kilkenny, most of the iron mines and occurrences, invariably siderite ("ironstone"), are located in the Castlecomer coalfield. At Aghamucky, a road cut through a layer of ironstone which was formerly smelted at Mountrath (Tighe 1802: 73) and ore from Moyhora was smelted at a furnace along the Clohogue river (ibid.: 74). Ironstone was also present as thick rich veins in coal pits at Massford Bridge, in Moneenroe townland, and ancient workings for ironstone were seen at Coolbaun Hill (Kinahan and Jukes 1859: 51). Thomas Molyneux, writing in 1709, mentions iron ore being raised at coal pits one mile north of Castlecomer, these might be the Massford Bridge or Coolbaun pits, and another at "Donane" on the Kilkenny and Laois County boundary, which must have been somewhere near Doonane bridge in Clooneen townland (Prendergast and Graves 1861: 301–302). The ore from both places was smelted locally. Ironstone was also encountered at a colliery in the townland of Crutt (Tighe 1802: 74). Iron was mined at several other places in Co. Kilkenny, but the nature of the ore is not stated; on the higher hills of the parish of Coolcashin "deep pits and large excavations" were assumed to have been the result of iron ore extraction (ibid.: 39), workable ore was raised at Ballytarsney (ibid.: 88), several tons of iron were raised at Parkstown and exported to Cardiff (*Freeman's Journal* 2/6/1824: 2) and the calendar of the De Vesci Papers mentions an iron-mining venture at Glenballyvally in the early eighteenth century (Malcomson 2005: 61–62). Red haematite was noted in the townland of Grenan near Thomastown (Kinahan 1887: 243).

County Laois

The northern and eastern part of the Leinster coalfield extends into Co. Laois and ironstone was mined and observed there at several localities. Ancient works for ironstone were observed in Graiguenahown, Knockardagur and Moyadd, where they were particularly extensive (Kinahan and Jukes 1859: 51). Thick layers of shale rich in iron occur on the north of Garrendenny Hill (ibid.) and mines, presumably of iron, in the townland of Ballylehane (North/South) are mentioned in a lease of 1912.[23] Part of the Gracefield demesne was known as Iron Park (Brewer 1826: 108) and there was previously a mine on the same estate (Coote 1801b: 129). Further north, pits around the summit of Cullenagh mountain are interpreted as workings for siderite ("clay ironstone") (Hardman 1881: 29–30, GSI). Around Dunamase Castle, limonite mixed with haematite was mined in the seventeenth century (and possibly earlier) in the townlands of Dunamase and Dysart (Kinahan 1885: 314; 1887: 244), and another iron mine, the ore not specified, is noted in the adjoining townland of Aghnahilly (GSI). Bog ore was known to occur in the townlands of Aghaboe (Ledwich 1803: 270), Brockagh, Cush Upper and Rushin (GSI). In the latter, it was raised as iron ore.

County Longford

Co. Longford contains two mines where haematite was raised, in Cleenrah and Enaghan. According to Kinahan (1887: 244) these were exploited during the sixteenth or seventeenth centuries and again in the nineteenth century.

County Louth

In Co. Louth, Kinahan (1887: 244) noted a vein of limonite at Clogher Head and three occurrences of magnetite are known on the western side of the mountains on the Carlingford peninsula at Jenkinstown, Ravensdale Park and Rockmarshal (GSI).

County Meath

Kinahan (1889: 48) records tumblers and fragments of haematite two miles south east of Kingscourt. There is a reference to bog ore at Coolroonan in an online calendar of the Earls of Darnley Papers.[24] The reference is dated to the early twentieth century and the

23 http://www.nationalarchives.ie/PDF/SmallPrivateAccessions.pdf: 851
24 http://cityark.medway.gov.uk/query/results/?Mode=Search&SearchMode=explorer&SearchWords=bog+ore&DateList=&.submit=Submit+Query&Boolean=AND&Results=25&PathList=&.cgifields=Verbose&.cgifields=Exact

bog ore was undoubtedly intended to be exploited for gas purification.

County Offaly

The most common iron ores known in Co. Offaly are bog ores. These are known from Derryiron (OSI 2005), Derrygreenagh (GSI, OSI 2005), Derryarkin (OSI 2005) and Derrycoffey (GSI). The placename of Derryiron is taken as meaning “oak wood of the iron” (Logainm). Further west, bog ore is recorded at Tumbeagh (O'Carroll 1999: 51) and Turraun by Brian Dolan, who visited the site in connection with his doctoral research on early Irish ironworking.[25] Haematite is known to be present as small veins at Killoneen (GSI).

County Westmeath

Co. Westmeath's iron deposits are exclusively bog ores. These are known to exist at Drumman, Farthingstown, Rathgarrett (OSI 2005), Annaskinnan (*Irish Independent* 15/3/1922: 89), Killucan (Report Select Comm. Transp. 1918: 30) and Pallasboy (*Irish Independent* 27/9/1957: 8). In the townland of Cullenhugh there is a lake known as Lough Iarainn, that is to say “Iron Lake”.

County Wexford

The only potential iron mine recorded for Co. Wexford is located in the townland Ballybrennan. Here limonite and “underground stones” next to hollows in a hill were interpreted by Kinahan (1878: 354; 1882: 30) as the remains of “very ancient workings”. Kinahan (1889: 43) also notes poor-quality clay ironstone at Woarwoy Bay near Hook Head and a thick vein of siderite is noted at nearby Lambstown (GSI). The other iron ore occurrences in this county are rather scattered (GSI): haematite in Forties and Kildavin, bog ore at Kilmallock, an unspecified iron oxide deposit at Richfield and two gossans at Curraghmore and Ballyhackbeg. Killinierin (Coill an Iarainn, “Wood of the Iron”) is a townland close to the Wicklow border.

25 http://www.ucd.ie/t4cms/early_irish_ironworking_bd_2007.pdf

County Wicklow

Co. Wicklow is substantially more iron-rich. Several occurrences of magnetite are known on Croghan Kinsella. Very rich magnetite was recorded at Ballycoog where old pits, locally said to have been "worked by the Danes", were still visible (Steward 1800: 121; Cole 1922: 86). These works were reopened around 1850, when both chalcopyrite and magnetite were extracted (Hull 1888: 30). Further south-east, more old workings on magnetite were found at the boundary of the townlands Moneyteige Middle and South, which, according to Kinahan, were the oldest in the region (Cole 1922: 86). Other magnetite occurrences are recorded at Moneyteige North (Hull 1888: 30), Middle and South (GSI). On the eastern slope of the mountain, a shaft on iron and sulphur was noted at Ballinvally and further east veins of siderite are recorded at Monaglogh (GSI). In the Vale of Avoca, to the north, several of the mines better known for copper and sulphur also contained bodies of iron ore. The South West Avoca mines at Ballymoneen and Knocknamohill both produced magnetite as well as chalcopyrite (Cole 1922: 85–86). At Ballymurtagh both limonite ("brown hematite") and ochre were extracted in the nineteenth century while at Ballygahan Lower ochre was also found (Cole 1922: 84–85). On the eastern side of the river, the East Avoca Mines at Connary Upper, Cronebane and Tigroney East had ochres and limonite (Cole 1922). The upper parts of these largely sulphurous non-ferrous mineral veins would have originally consisted of iron oxides and in the nineteenth century these were considered to have been worked out "long ago" (Smyth 1853: 373). More ochre occurs in the townland of Sroughmore (GSI). East of the Avoca mines, rich magnetite ore with manganese is known at Ballard Upper, Ballycapple Hill and Kilbride. These were mined in the nineteenth century, but older works known as "Clash Pits" in Ballard Upper were considered to have been worked in the seventeenth century (Argall 1879: 224). Around Arklow, a shaft was sunk on siderite ("ironstone") at Rock Big, bog ore was found at Pollahoney and unspecified iron was noted at Mongan (GSI). At Ballycullen, near Rathnew, haematite was found while digging a well (GSI). On the western side of the Wicklow Mountains, at Cloghleagh and Knockatillane, mines were wrought on iron ore containing haematite, limonite and manganese (Kinahan 1887: 246; Cole 1922: 80). Bog ore occurs in the townland of Aghowle (GSI). The townland name Fananierin is interpreted as meaning "slope of the iron" (Logainm).

4.2.2 Munster

The main concentration of known iron ores in Munster is located in the Carboniferous Munster Coalfields on the Counties Limerick and Kerry Borders, and consist mainly of sideritic ores. Further, smaller, concentrations are located in south Co. Waterford, southeast Co. Clare and north Co. Tipperary, where limonitic and heamatitic ores are mainly to the Devonian bedrock.

County Clare

Several iron ore occurrences, none of them worked, are located on the northern side of the Shannon in Co. Clare, most of which are siderite; at two places in Cahiracon (Kinahan et al. 1860A: 29), Mountshannon East (ibid.: 30), Carrowniska South (ibid.: 31), Knockerry West and Tullagower (ibid.: 33). Other iron ore occurrences in this area are of unspecified iron ore; at Truskylieve (Dutton 1808: 19), Mutton Island and Seafield (ibid.: 18). In the area south-east of Ennis, haematite was noted as occurring at Heathmount, Coolshamroge and Mooghaun North (GSI). “Heavy blackish iron-stone” was noted in Dromoland (Dutton 1808: 18) and unspecified iron ores at Cullaun (Steward 1800: 28). Further north, just south of the Burren, bog ore (“meadow ore”) was recorded at Clifden (“Riverston”) (Giesecke 1832: 247) and iron ore and coal at Rathbaun (Lewis 1837 vol. 2: 183). All the known iron mines in Clare, however, are located in the east of the county, in the Tuamgraney area. Several mines, two in Bealkelly, three in Ballymalone and one in Ballyvannan (GSI) yielded haematite (“peroxide”) (Kinahan et al. 1861: 43). The nearby townland of Callahy also contained bog ore, which was mixed with the former in local furnaces operating in the seventeenth century (Kinahan 1870: 461). Further west, an old adit, possibly for haematite was recorded in Glendree (Kinahan 1863: 24), open-cast working for (iron) ore at Cloonnagro, bog ore raised at Corracloonbeg and limonite worked for local furnaces at Kildavin (GSI).

County Cork

In Co. Cork, near to the borders of the Counties Tipperary and Waterford, old workings of iron were found at Gortnaskehy and nearby, a deposit of iron oxide was noted at Lyre

(GSI). Near Mallow, in the townland of Spaglen, are the remnants of iron mines, probably those mentioned in a lease between Sir Thomas Norris and Conogher O'Kallaghan (Crowley 2004). A specimen of haematite from Ironstone Hill near Mallow was donated to the Museum of Irish Industry in 1854 (Robinson 1855: 189). Around Dromagh and Drominagh (North/South), further west, unspecified iron ore was recorded as raised here in the late eighteenth century (Beaufort 1792: 97). Haematite was found at the western end of Beara Island (Kinahan 1885: 315), in the Glandore manganese mines at Rouryglen and the copper mines at Coosheen (Kane 1845: 126). On Castle Island, a lode of sparry iron (siderite) was recorded (GSI). Also in West Cork, iron was mined near Kil[na]managh (Allihies) around 1700 (Lunham 1909: 164) and near Aghadown (Cole 1922: 88). Close to the latter place, at Cunnamore, a nodular band of siderite ("clay ironstone") was noted (GSI). Further iron occurs in East Cork as limonite ("brown hematite") at Loughane (GSI) and Rostellan (Lamplugh et al. 1905: 112) and an unspecified iron ore is mentioned at Rathcallan (Smith 1750 vol. 1: 156). Bog ore is recorded in North Cork at Aghacunna (GSI). Iron mines are also mentioned near Bandonbridge (Bandon) in AD 1626 on the lands of John Roche and Lieutenant Jacques (PRO SP 63/268 f.24). These mines could not be more precisely located.

County Kerry

In Co. Kerry two occurrences of siderite ("ironstone") are recorded at Tarbert Island (Kinahan et al. 1860A: 33) and Tarmon East (Jukes and Kinahan 1860: 19). The placename Skehanierin (East/West) means "the bush of the iron" (Logainm). Iron was mined at undisclosed locations in the Kenmare/Ardtully area (CCM 1601–1603: 222; CSPI 1669–1670 Addenda: 663) and on the sea coast on the Cork and Kerry counties border (CSPI 1633–1647: 85).

County Limerick

The largest concentration of iron mines and occurrences in Co. Limerick is situated in the Slieve Lougher mountains in the west of the county. The most important source is the so-called Desmond Survey of AD 1586, the text of which has been put online as part of the Corpus of Electronic Texts[26], and mentions no less than 47 "iron mines of iron stone", 34 of which could be located to a modern townland. Although the term

26 http://www.ucc.ie/celt/published/E580000-001/index.html

"ironstone" is generally used to designate siderite from the seventeenth century onwards, for mines in the Desmond Survey it will be considered as an unspecified ore. The localized mines, with their map numbers, are listed in Appendix 1. In the same area, haematite was mined at Knockbweeheen in the seventeenth, and again in the nineteenth centuries (Kinahan 1887: 243). Haematite was also noted at nearby Lisgordan (GSI). Siderite ironstone has been observed at Ballyine and Knocknagornagh (GSI) and bog ore at Glenastar (Jukes and Kinahan 1860: 28). Further north, on the southern side of the river Shannon, siderite ("clay ironstone") was worked at Carrowbane More and Kilteery (Kinahan et al. 1860A: 35–36, 37). Haematite was found in various localities in this county, at Ballyvorneen, Drombane, Knockroe (Mason) and Ballycormick (GSI). Bog ore was noted at Gleno and Glenosheen and a breciated gossan at Gannavane Upper (GSI). Finally, Lewis (1837 vol. 2: 121) mentions abundant ironstone in the parish of Killagholehane.

County Tipperary

The three mines specifically worked for iron in Co. Tipperary, are situated on the eastern slopes of the hills to the west of Thurles. Haematite was mined at Craiguedarg (GSI) and an unspecified iron ore at Crumlin Big was worked in the eighteenth century (Coote 1801a: 65). A mine at Gortnahalla was stated as being worked for limonite (Kinahan 1887: 245), which was smelted locally, but later the same author (1905: 274) describes it as an ancient copper mine. The GSI website describes this as an iron mine, possibly with copper (GSI). Haematite occurs as a thick bed at Foilaclug, as layers in limestone at Kilcurkree (GSI) and as veins at Lackenacoombe (Kinahan et al. 1860b: 36). Veins of siderite associated with copper sulphide ores were found at Knocknaharney, Rathcardan, Barnabaun, Bunkimalta, and Killeen (GSI). Bog ore occurs at Drum and, as flakes in gravelly limestone, at Inchadrinagh (GSI). Iron mines were referenced in the late 1620s as occurring north of the Araglin River, in the very south of the county (see for example CPCRI James I: 304) and these are probably the same mines referred to as near Ballyporeen by Arthur Young (1785: 393) and as "having been idle many years past".

County Waterford

In Co. Waterford, the iron mines and occurrences are mostly concentrated in two areas, around the Bride and Blackwater rivers and in the area between Youghal and Dungarvan. In this latter area, haematite was mined in the seventeenth and nineteenth centuries at Drumslig, Grallagh (Kinahan 1887: 145) and Grallagh Upper (GSI), while trials were made on veins of the same mineral around 1860 at Monagilleeny, Moyng and Moyng Little (Wynne and Jukes 1861: 21). Siderite and limonite were noted in the spoil of a mine in the townland of Pulla (GSI) and limonite was mined, probably in the seventeenth century, at Mine head in the townland of Monagoush (Kinahan 1887: 245). An iron mine at Rathnameneenagh was the subject of a dispute between the Earl of Cork and John Fitzgerald in AD 1625 (Grosart 1886 vol. 2: 151, 156–157). The same Earl of Cork had mines at Ballyregan and Balligarren (see for example ibid.: 297). The first mine is located in the townland of Deerparkhill, where traces of the water-powered water-pump infrastructure can still be seen. The second mine was traced by the author to an open-cast mine at the northern extremity of Knockroe townland. It was positively identified as Balligarren mine as remnants of a water-supply system were also noted here.[27] The cost of this water-supply system at Balligarren mine was disputed by Richard Boyle and his lessee Thomas Ball in an unpublished document in the Irish Lismore Papers collection (NLI Lismore Papers 43.297/2a). It is unclear which type of iron ore was extracted at these mines. Other mines of unspecified iron ore were worked, in the seventeenth century, in the townlands of Salterbridge (Power 1978: 35) and Ballymulalla (East/West) (Grosart 1886 vol. 2: 8). Two toponyms in the same area could also point to iron ore extraction: Clasheenanierin means “the small trench of the iron” (Logainm), while Glanasaggart was better known locally as Gleann Iarainn or “Glen of the Iron” (Power 1952: 24). Further afield, haematite was noted as occurring at Killerguile (Kinahan 1878: 371) and Lauragh (GSI), while an area of the townland of Killowen is known as Móin an Iarainn (“Bog of the Iron”) (Power 1952: 191).

4.2.3 Connacht

The largest concentration of iron ore occurrences in Connaught is located in the coalfield of Carboniferous age on the borders of Counties Leitrim and Cavan. Another

27 Thanks is due to Colin Rynne who helped with this identification during a visit to the site on 18/03/2012.

major group of occurrences is found in Connemara, Co. Galway where the bog ores are of Quarternary age.

County Galway

Pits and heaps of limestone containing both haematite and limonite at Kylemore, interpreted as possible former iron workings (Kinahan et al. 1878: 162), are the only located potential iron mines found in Co. Galway. Magnetite veins occur at two locations in Golam and at another two in Lettermullan Island (GSI). It has also been found further west at Derroogh South and Cloghmore South (GSI). Minor occurrences of haematite were found in Teernakill South and Garraunmeetagh (GSI). Bog ore occurs in widely dispersed localities in Co. Galway. In Connemara it is recorded at Pollacappul (Kinahan et al. 1878: 162), Derravonniff, Glencoh, Gortmore, Turlough (Cole 1922: 89), Knockadav, Annaghvaan Island, Cornarona, Inishnee and Lettercaumus (GSI). In the east of the county, bog ore occurs at Derryvunlam (Kinahan 1863: 48), Woodlawn (Fourth Rep. Comm. Bogs 1814: 113–114), Kilcreevanty and Derrybrien East (GSI). Bog ore was also abundant around Woodford near Lough Derg, where it was smelted locally (Cole 1922: 89). This county also has eight placenames referring to iron, all in Connemara. The townland of Ironpool or Pholl an Iarainn means “the hole (or cave) of iron” (Logainm). Loch an Iarainn/Loghaun (“Iron Lake”) is found in the townlands of Derrennagusfoor, Lugganaffrin, Callowfinnish and Loughawee, while the toponym Ciarriag/Carrig an Iarainn (“Iron rock”) is found on both Mason Island and Mweenish Island (ibid.). A place known as Ros Iarainn (“Grove of the Iron”) is located in the townland of Mountross (ibid.).

County Leitrim

Several iron mines are recorded for Co. Leitrim. A mine at Gortinee was said, by Kinahan (1887: 243), to have yielded limonite during the sixteenth or seventeenth centuries and another nearby at Derrycarn Demesne was worked for an unspecified ore (Atkinson 1833: 384). Veins of haematite were also observed at Gortinee (GSI). Further mines, or potential mines, of unspecified iron ore are mentioned by the same author (Atkinson 1833: 368) at Derreens, Aghacashel, Gortnawaun (“Gurtnewayne”) and Knockacullion (“Knockacullen”). More mines in the same area are stated as worked in

Mullghmorrow, Auskinamuck, Clarenmore, Clarenbeg and Colliery Mountain (ibid.), the location of which could not be positively identified. Another mine, again of unspecified ore, is recorded as having been worked at Prabagh and used in the furnace in Castlefore (Journal of the House of Lords of Ireland 1707: 216–217). Numerous occurrences of siderite ironstone nodules were observed in the hills north of Lough Allen: at Boleymaguire, Glackaundarragh, Glassalt, Gortnasillagh West, Kilnagarns Lower, Seltan, Shass, Stangaun, Corrasra, Dergvone, Gowlaun, Lisgavneen, Tullinwannia, Tullynacross, Tullynamoyle and Greaghnaguillaun (GSI). The main mountain here is called Sliabh an Iarainn ("Iron Mountain") and is recorded as such from early medieval times onwards (Scott 1982: 116; 1988b: 111). Bog ore was noted at Carrickleitrim and Corchuill Lower (GSI), while Lewis (1837 vol. 1: 352) mentions a vein of good-quality iron ore at Glenfarne.

County Mayo

The only reference to an iron mine which contained information on the locality in Co. Mayo was found in the calendar of the Westport Papers (Clesham and Geddis 2005: 318) which mentions copper, sulphur and iron mines at Curraun Hill ("Corraun") in Bollinglanna townland. Mitchel (1879: 21) mentions a rich vein of haematite at this location, while Kinahan (1887: 244) cites limonite was found here. Near Burrishoole was the rich iron mine, as yet unlocated, encountered by Nicholas Malby in the 1580s (see Chapter 5.2). Haematite was noted at Derrassa and magnetite ore at Cloonalison (GSI). Several localities in Cuillalea had siderite ("ironstone") with coal (GSI), while unspecified iron was recorded at Clydagh (Lewis 1837 vol. 2: 95) and Cross (Boyd/Wallace) (McParlan 1802b: 19). Bog ore was noted at Gortnahurra Lower, Bellagelly South, Tawnaghmore and Atticloghy (GSI). In 1860, the sale of the estate of John W. Burmester mentions bog iron ore at Ballintadder, Barroe, Bottiny and Corragooly (*Irish Times* 14/11/1860: 1). Specimens of siderite ("clay ironstone") and bog ore from Cloonmore were exhibited at the Royal Dublin Society in 1851 (*Freeman's Journal* 7/6/1851: 2) and heaps of bog ore, probably extracted for gas purification, were noted along the road at Dooega on Achil Island (Murray 1866: 196). Some placenames in Mayo are possibly relayed to iron ores: Gortanierin ("Field of the Iron"), Moneynierin ("Brake of the Iron"), Muinganierin ("Marsh of the Iron"), Cloonierin ("Meadow of the Iron") and Bellanierin ("Mouth of the Iron Ford") (Logainm).

County Roscommon

Three mines in the very north of Co. Roscommon were worked for siderite ("ironstone"): at Altagowlan (Griffith 1818: 22, 69), Cornagee and Rover Lower (GSI). Occurrences of siderite ironstone, in the same area, were noted at Bolarry and Tullynahaw (GSI). Three occurrences of "iron ore/iron mine" recorded in the Ordnance Survey Field Name Books (Logainm) at Derreenavoggy, Srananooan and Timpaun probably also represent siderite ironstone. The same source also records iron ore in the townland of Ballyfeeny. Numerous veins of baryte and haematite were seen at Cooltacker (GSI). The townland name of Fawnanierin means "Slope of the Iron", but local information suggested the place was named after smoothing irons (sic.) (Logainm).

County Sligo

For Co. Sligo, Kinahan (1887: 245) mentions old iron mines at Ballintogher and at undisclosed locations at the base of the Ox Mountains. Haematite was recorded at Ballynakill with a furnace nearby (ibid.: 244) and Corhawnagh (GSI). At the eastern extremity of the county, siderite bands and nodules in shale were found at three locations in Straduff, in Tullynure and in Carrowmore (GSI). Small pockets of bog ore were seen in Carrownacreevy and Carrownalecky (GSI), while an interpretation of the meaning of the townland name of Curraghaniron is "Moor of the Iron" (Logainm).

4.2.4 Ulster

Ulster has three major concentrations of iron ore occurrences. The first, the pisolithic ores related to the Tertiary Co. Antrim basalts, were worked extensively in the nineteenth and twentieth century. Co. Donegal has widespread localities where Quarternary bog ore was extracted for gas purification during the nineteenth century. A variety of ore, including the rich and rare 'eagle stones', were found to west of Lough Neagh, in Counties Tyrone and Derry.

County Antrim

More than forty mines, and several occurrences, of pisolitic iron ore are recorded along the east and north coast of Co. Antrim. These are neither elaborated on nor numbered on the map, and the interested reader is referred to the relevant Geological Survey Memoirs (Egan 1882, 1884; Symes 1886; Symes and McHenry 1886; Symes et al. 1888) and the works by Cole (1922; Cole et al. 1912). Although these pisolitic ores were regarded as a new discovery in the early 1860s (Cole 1922: 70), Slievanee, one of the higher mountains in this area, was still referred to by the older inhabitants as Slieve-an-Eerin, or "Mountain of Iron" by the 1880s (O'Laverty 1884: 476). Siderite ironstone was mined at collieries at Ballyreagh Lower, Ballyvoy and Tornaroan (Symes et al. 1888: 15). Similar ore was noted at Ballynagard and Torglass (Griffith 1854: 288). Water-worn nodules of clay ironstone were also observed at Ballynamullan, along the eastern shore of Lough Neagh (Egan 1881: 36). Steward (1800: 4) mentions "very large balls of iron ore […] more rich in iron than in Sleave-iron [Sliabh an Iarainn] and other mountains on each side of Lough Allen" along the Lough Neagh shore between Portmore Park [Deer Park] and Longford Lodge [Gartree]. Clearly some type of siderite ironstone is referred to here. Unspecified iron ore was unsuccessfully mined in the parish of Derryaghy (Lewis 1837 vol. 1: 451) and, according to Pilson (1846: 84), iron occurred at Willmount, Dunmurry and New Forge, Malone Upper near Belfast.

County Armagh

The only iron occurrence found for Co. Armagh is a reference to bog ore in Aghinlig (Egan 1873: 55).

County Cavan

The only mine worked for iron in Co. Cavan, at Claragh, was worked for limonite ("brown haematite") (Hull 1875: 218). Lewis (1837 vol. 1: 307) mentions an "iron mine which was never worked" nearby at Carrickmore. Haematite, together with manganese, was observed at Cornasaus (GSI) and Tievenanass (Leonard 1878: 23). Bog ore occurs at Cornaslieve (Leonard and Cruise 1873: 40), Knocktaggart and Correagh Glebe (GSI). The *Field Name Books of the Ordnance Survey* (Logainm) record unspecified iron ore at

Bellavally Lower, Bellavally Upper, Bursan, Moneensauran and Tullyminister. Two townland placenames potentially refer to iron occurrences: Tullanierin ("Hill of the Iron") and Annaghierin ("Morass of the Iron") (Logainm).

County Derry

Iron was extracted in no less than thirteen places in Co. Derry. According to Kinahan (1887: 243–244) haematite was mined in the early seventeenth century by Rennie[28] at Tullybrick, Carndaisy and Tirgan. The same ore was mined in the nineteenth century at Cranny (ibid.: 244) and Ballylagan South ("Ballylaggin") (Hunt 1879: 68). Siderite ("clay-ironstone") was also wrought by Rennie at Drumard, Brackaghlislea and Mormeal and smelted in local furnaces (Kinahan 1887: 239). The same ore was found near Ballymultrea, along the shore of Lough Neagh (Egan 1881: 34) and pisolitic ores were extracted at Islandmore Lower, Islandmore Upper and Killygreen Lower in the early twentieth century (Cole 1922: 73). Mines of unspecified iron ore were worked in Boveagh (Day and McWilliams 1995: 113) and Fallagloon (Day and McWilliams 1993: 74). An extensive bed of limonite was observed at Moydamlaght (Kinahan 1873), "iron stone" was recorded in Agivey parish (Lewis 1837 vol. 1: 20) and iron ore was said by the same author (ibid. vol. 2: 327) to be abundant in the townland of Drumcroon. The discovery and mining of a vein of iron oxide was announced in the *Donegal News* (3/10/1908: 8) in Drumraighland and an unworked occurrence of bog ore at "Camon Wood".[29] More bog ore is recorded in Feenan More, Tullynure (Egan 1881: 43), Inishrush (ibid. 1882: 20) and Templemoyle (Portlock 1843: 225). There is the curious note of iron occurring in a near-metallic state which causes the compass to vary at Ballyhacket (Sampson 1802: 103).

County Donegal

In Co. Donegal, unspecified iron ore was mined at the lead mine at Carrickahorna (Kinahan 1887: 211), at Lismonaghan and Pluck, where it was smelted in the Tully ironworks in the eighteenth century (Stokes 1891: 23) and in the parish of Templecarn

28 Many of the early seventeenth century ironworks in Ulster are said by Kinahan to have been worked by this 'Rennie'. No other reference to this character was found. In the late eighteenth century, however, a Robert Rainey was involved in ironworks around Castledawson, Co. Derry (Gribbon 1969: 264) and it seems possible an error in date was made.

29 Today this is known as Ballykelly Forest, formerly known as Caman or Walworth Wood (McDonald 1997: 57).

before 1814 (Gallachair 1975: 325). At Kilcar/Glebelands, bog ore was extracted for the production of magenta (*Belfast Newsletter* 29/04/1861). This is possibly the same bog ore from Trabane Bay which was mined to be smelted in a small furnace at Carrick in the nineteenth century (Hull et al. 1891A: 57). In 1946 bog ore was still mined around Killynure (*Ulster Herald* 13/07/1946). Limonite with slag nearby was observed by Kinahan (1887: 241) at Skreen Lower, unspecified iron ore was described as abundantly occurring in the parish of Desertegny (Lewis 1837 vol. 1: 456) and McParlan (1802a: 25) mentions large lumps of iron ore found while digging a road in Tullaghobegly (Scotch/Irish). Numerous locations where bog ore occurs have been recorded in Co. Donegal. Hull et al. mention bog ore at Knockybrin, Slatehill, Ballygreen ("Ballygreer"), Carnhill, Carrowcashel, Glenleary, Glancar Irish, Glancar Scotch, Creeve Glebe, Letterleague (1891b: 117) and Devlinmore (ibid.: 61). Further occurrences of bog ore were noted around the village of Glen (*Donegal News* 5/3/1910: 2), at Portlough (ibid. 22/3/1930: 4), Faltybanes (ibid. 22/4/1933: 1), Glack (ibid. 30/5/1953: 3), Derryreel (GSI), Glenfad and Carrickmaquigley (Giesecke 1826: 20), Ballyliffen (*Irish Times* 3/10/1931: 5), Dunaff and Killygordon (Hall 1885: 833), Corradooey (Egan et al. 1888: 45), Fintown (PRONI D3451/1/1/3)[30], Kilcar (Murray 1866: 83), Aught (Hull et al. 1890: 36), Three Trees (Royal Comm. Congest. Irel. 1907: 225), Blackrepentance and Mondooey Upper (Kinahan et al. 1889: 31, 33), Annagary and Dunglow (Giesecke 1832: 247) and on the Heathfield Park Estate (Falcarragh) (*Irish Times* 11/7/1877). Two placenames potentially refer to iron occurring: Altinierin ("Hill or Glen-Side of the Iron") and Bruach an Iarainn ("Edge/Cliff of the Iron") in the townland of Meenaclady (Logainm).

County Down

The only iron mine recorded for Co. Down is located at Deehommed, where haematite was raised in the nineteenth century (Cole 1922: 76). Unspecified iron is recorded at Carnreagh, Begny, Gransha, Moneybane and Legananny (Kinahan 1878: 365). Bog iron ore was recorded at Lisnasliggan (Egan 1872: 42).

30 Hamilton of Brownhall in Donegal Papers. Online calendar at Public Records of Northern Ireland website http://applications.proni.gov.uk/LL_DCAL_PRONI_ECATNI/BrowseSearchResults.aspx

County Fermanagh

The three recorded iron occurrences in Co. Fermanagh are all situated near to Belleek, in the west of the county. Cole (1922: 76) mentions haematite in Leggs and Magheramenagh. In the latter locality it is associated with copper and was worked in the nineteenth century. Griffith (1854: 292) also mentions an unspecified iron ore with copper at Rossbeg.

County Monaghan

Apart from "ironstone" having been raised at Glaslough (Coote 1801c: 151–152) and "manganese rich iron" noted at Calliagh and Tattinlieve ("Tattin Hieve") (Kinahan 1890: 345–346), all iron occurrences of iron in Co. Monaghan are of bog ore. This type of iron ore was observed in Carrickaslane, Tullycaghny (Egan 1877: 25), Drumhawan, Tullycarragh, Corduff and Corratanty (GSI).

County Tyrone

A mine at Unagh, in Co. Tyrone, was worked in the seventeenth century and yielded haematite, limonite and ochre (Kinahan 1887: 245). Kane (1845: 127) interestingly states that the ore from the Tyrone coalfields is popularly called "eagle stone", which is equivalent to "adelaarssteen" in Dutch, "Arendstein" in German and "pierre d'aigle" in French. All these names refer to a type of ore consisting of a hollow nodule of iron oxide, often containing a loose iron rich kernel inside. This type of ore does not occur in Britain. The ore from this locality was illustrated in an article by Hardman (1873: 153). Similar ore was extensively tried at nearby Kildress (Nolan 1884: 24). Siderite ("clay-ironstone") was mined at Anagher (Griffith 1854: 328) and magnetite was unsuccessfully extracted at Bardahessiagh (Kinahan 1887: 245). Bog ore from Pigeon Top (Dressoge) was used in the Gas Works of Omagh in 1947 (*Ulster Herald* 28/6/1947). Siderite ironstone was found at Derry, Gortnaskea and Baltiboy (unlocated) collieries near Dungannon (Hardman 1877: 87). Bog ore was recorded at Lanaglug (Egan 1881: 43) and as tubular "meadow ore" at Hollyhill (Giesecke 1832: 247). Bog ore from Donaghey was shown at the Irish Exhibition in London of 1888 (*Belfast Newsletter* 25/06/1888).

4.2.5 Distribution and geology of Irish iron ores

From the distribution map based on the above information several areas emerge with concentrations of iron ores (Fig. 4.1). Widespread occurrences of siderite, or ironstone, are found in the Laois/Kilkenny border area, in Leitrim around Sliabh an Iarann (Mountain of Iron) and north of the Shannon estuary and possibly south of it. Concentrations of bog ore occurrences can be seen in Co. Donegal, the east of Co. Westmeath, in Connemara in the west of Co. Galway and to a lesser extent in the south of Counties Cavan and Monaghan. Other areas with concentrated occurrences of iron ores include west Waterford, where mostly limonitic ores and haematites were mined in the seventeenth century; the Wicklow mountains, often as gossans of non-ferrous ores, but also important haematite deposits; south Co. Derry, where a wide variety of ore types are known, and Co. Antrim, where the pisolites were mined extensively in the nineteenth century.

This is, however, not the full picture. It is obvious from the different Geological Survey Memoirs that various authors were more inclined to report iron ores than others. Especially George H. Kinahan was instrumental in recording even the smallest occurrence of iron ore. It is also apparent from the constant accumulation through time of references to these occurrences in Kinahan's publications that many others are likely to have been missed. This is clearly demonstrated by the discovery of Iron Age and early medieval iron smelting furnaces in areas with no, or limited amounts of, known ores, such as Counties Dublin/Meath, East Cork and Kerry.[31] In the case of Kerry and Cork, the lack of geological research would seem to be at least partly to blame, while in the Counties Dublin and Meath this could be the result of the subsequent draining of the marshier areas where bog ores would have occurred.

4.3 Chemical analyses of Irish iron ores

Multiple analyses on Irish iron ores were carried out in the nineteenth and early twentieth centuries, mostly on the pisolitic ores. Since then, analyses were conducted in

31 For Co. Dublin see, for example, the sites at Carrickmines (Ó Drisceoil 2005b, 2007) and Steelstown (Young 2010f), for Meath the sites at Lagavooren (Young and Kearns 2010c), Rath (Schweitzer 2009) and Grange 2 (Kelly 2011), for Co. Cork see Curraheen (Danaher and Cagney 2004), Barrafohona (Gilligan 2012), Ballynamona 2 (Hegarty 2011) and Ballinvinny North (Sherlock 2005). For Kerry see Chapter 6.2.2.

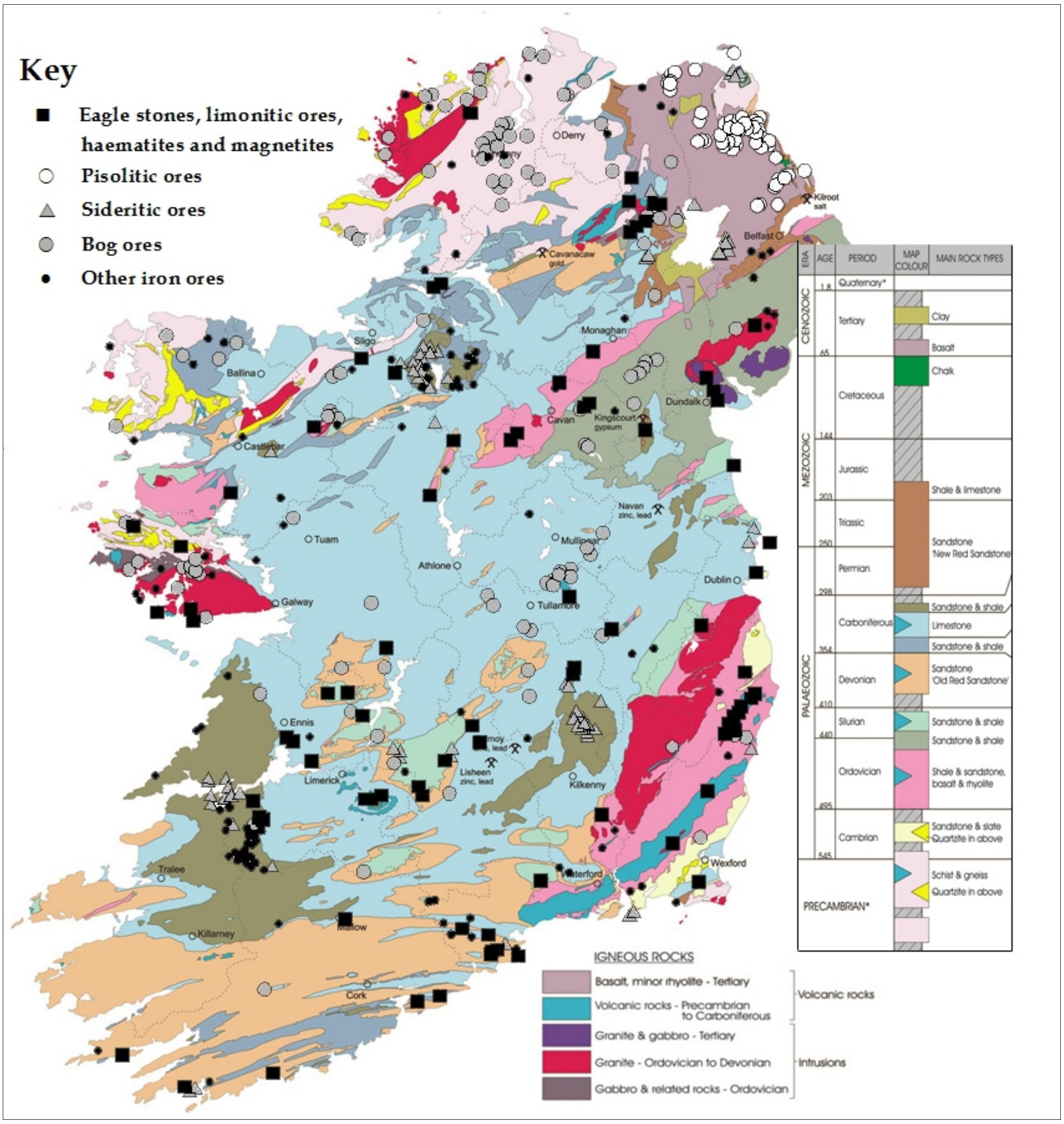


Fig. 4.1 Distribution map of Irish iron ores

order to understand metalworking residues on archaeological sites. These involved natural iron compounds found on excavations and interpreted as ores, but more recently, due to the advances in microscopy and analysing technology, this also included inclusions in slag interpreted as iron ore. But several aspects inherent in chemical analysis have to be borne in mind when using these results. First of all, the choice of samples is important; because the early analyses were carried as part of the then blossoming iron industry, which was based on the reduction of ores low in phosphorus, ores with elevated levels of that element are heavily under-represented in these analyses. One should also be mindful that the content of iron in an ore will depend on the size of the sample; the bulk analysis of a large specimen of ore will give lower iron content than the analysis of a small piece of near-pure haematite extracted from the same specimen. This is clearly shown by the analysis of the magnetite from Kilbride, Co. Wicklow. For various reasons, certain elements are not recorded in the published analyses.[32] Note, for example, the virtual absence of potassium (K) and sodium (Na) from the earlier publications, whereas the same elements appear prominently in the modern ones, albeit in relatively small amounts.

4.3.1 Mined ores

Eagle stones, limonitic ores, haematites and magnetites

The Tyrone eagle stones are generally rich iron ores (Table 4.1). Sample 1 was nearly pure iron oxide/hydroxide and contained manganese as the second most common element. Another high value for manganese is seen in sample 4, which also had relatively high phosphorus content. Magnesium has moderate values, while calcium seems generally absent. The analyses on Irish limonitic ores are of limited value, but do point towards potential high phosphorus levels, as in the case of Cloghleagh, Co. Wicklow. The analysed haematite ores show varying levels of manganese (high in the Cavan/Monaghan ores, low at Deehommed) and generally very low amounts of phosphorus. The relatively high levels of calcium and, to a lesser extent magnesium, in analysis 12 are partially the result of the low iron content of this sample. The magnetite ores from Kilbride, Co. Wicklow show low manganese content although these were often recorded as manganese-rich. They contain some amount of phosphorus, but especially the elevated sulphur content would have been prohibitive for using these ores in early smelting without extensive roasting.

	Eagle stones				Limonitic ores			Haematites					Magnetites	
	1	2	3	4	5[33]	6	7	8[14]	9	10	11	12	13	14
Fe	58.49	52.12	67.48	47.85	34–36	51.98	53.93	32.79	40.30	61.30	51.00	36.05	44.43	63.48
Fe_2O_3	83.68	74.56	95.44	68.45		74.37	77.15	46.91	57.57	87.70	72.67	51.44	22.03	15.30
SiO_2		9.42[34]	1.00	14.62			0.30	29.51	22.80	8.34	18.20	28.09	4.01	3.64
Al_2O_3		3.51	0.28	1.88			tr.	7.55	8.93		4.22	2.78	6.70	3.33
CaO		tr.	tr.	nd				0.35	0.28[35]	tr.	0.19	4.83		tr.
MgO	0.27	0.04	tr.	0.53				0.21			0.72	1.69	2.60	

32 As the reasons for these omissions are unclear, the relevant boxes were left empty.
33 Samples 5 and 8 were deemed poor (Griffith 1854: 327; Cole 1922: 79)
34 Soluble silica together with insolubles containing a small amount of aluminium
35 Carbonate of lime 0.50%

MnO	1.16	tr.	tr.	1.07				6.24	6.20		0.05	0.59	2.05	tr.
P_2O_5		tr.	0.06	0.86			1.60	0.03		tr.	0.05	0.05	1.20	0.20
CO_2		tr.												
TiO_2				0.24				tr.						
Co/NiO								0.03			0.24	0.26		
As													tr.	0.01
Cu														tr.
SO_3										tr.			1.40	0.62
H_2O	11.97	13.14				14.12	20.43	3.21	3.00				19.91	3.58

Table 4.1 Chemical analysis results of Irish eagle stones, limonitic ores, haematites and magnetites

1 Eagle stone. Tyrone Coal district (Kane 1845: 127)
2 Goethite (eagle stone). Unagh, Co. Tyrone (Hardman 1873: 153)[36]
3–4 Haematite (eagle stone). Barrow Mine, Unagh, Co. Tyrone (Scott 1990: 154)
5 Brown haematite. Dysart, Co. Laois (Jukes et al. 1859: 30)
6 Brown haematite. Ballymurtagh, Co. Wicklow (Haughton 1851: 281)
7 Pitchy iron ore. Cloghleagh, Co. Wicklow (Haughton 1866: 2 20)
8 Iron and manganese ore (haematite). Calliagh, Co. Monaghan (O'Reilly 1889: 449–450)
9 Haematite. Redhills, Co. Cavan (Leonard 1878: 22)
10 Haematite. Carndaisy/Tirgan, Co. Derry (Lloyd et al. 1918: 36)
11–12 Haematite. Deehommed, Co. Down (Scott 1990: 154)
13 Magnetic oxide of iron. Kilbride, Co. Wicklow (Tichborne 1876: 220)
14 Magnetic oxide of iron. Id. (ibid.) [pure ore]

Pisolitic ores

Typical of the pisolitic ores is the often high levels of titanium, but some varieties have only trace elements of it (Table 4.2). Phosphorus and sulphur amounts are consistently small, and low values for manganese and calcium seem to be the norm, although exceptions occur. The low amounts of the two first elements was the primary reason for their large-scale exploitation in late nineteenth and early twentieth centuries.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Fe	31.50	31.85	44.53	45.99	44.45	41.58	54.05	63.70	65.20	47.54	60.00	46.72	51.52	47.21	30.25	23.50
Fe_2O_3	45.06[37]	45.56	63.70	65.42	51.37	59.40	77.22	71.00	81.50	68.01	83.33	62.43	71.64	67.54	43.28	33.62
SiO_2		4.00	6.30	7.08		10.40	20.65	9.00	8.50	8.15	1.55	8.40	5.05	10.93	9.75	9.87
Al_2O_3		35.50	12.75	12.54					4.20	7.76	3.50	10.19	4.25	1.75	27.95	34.57
CaO	0.56	0.35	0.10	0.20					0.93	2.53	0.40	2.80	0.81	0	0.60	0.91
MgO	2.44		0.05	0.08						1.10	0.55	0.59	0.61	tr.	0.20	0.62
K_2O					36.89										0.49	
MnO_2	tr.	tr.		tr.				tr.	2.57	0.23	0.22	0.28	0.27	0.17	0.05	tr.
P_2O_5			0.06	0.02						0.02	0.13	0	0.20	0	0	tr.
TiO_2		2.00	4.60	5.28			tr.		tr.	8.50	4.85		8.89	10.80		3.51

36 The sample was taken from the spoil heap and the proper ore was considered richer, up to 60% Fe.
37 The values for analyses 1 to 3 are given as pure iron and peroxide of iron in the publications. The latter signifies Fe_2O_3, but the conversion does not add up. Here the oxides were recalculated from the pure iron.

CuO											0.01					
SO_2			0.02	tr.						0.03		0	0	0	tr.	
CO										2.16		tr.	tr.	0		
H_2O	18.00	12.65	12.70	8.82		8.40	2.13		1.96	0.92		10.36	6.40	7.87	18.60	19.36

Table 4.2 Chemical analysis results of Irish pisolithic ores

1 Pisolitic ore. Kilwaughter, Co. Antrim (Holden and Tate 1870: 159)
2 Pisolitic ore. Tully, Co. Antrim (ibid.)
3 Pisolitic ore. Knockboy (Correen), Co. Antrim (Birkinbine 1896: 81)
4 Iron ore (pisolitic). Broughshane, Co. Antrim (Symes 1886: 30)
5 Pisolitic ore. Red Bay, Drumnacur, Co. Antrim (Holden and Tate 1870: 158)
6–7 Pisolitic ore. Red Bay, Drumnacur, Co. Antrim (ibid.: 159)
8–9 Pisolitic ore. Glenravel Mines, Slieveanee, Co. Antrim (ibid.)
10 Iron ore (pisolitic). Glenravel Mines (Cole et al. 1912: 115)
11 Laterite (pisolitic). Glenravel, Co. Antrim (Scott 1990: 154)
12 Pisolitic red ore. Glenariff, Co. Antrim (Argall 1883: 157)
13 Pisolitic black ore. Glenariff, Co. Antrim (ibid.)
14 Pisolitic black ore. Glenariff, Co. Antrim (ibid.)
15–16 Brown haematite. Exported from Belfast (Percy 1864: 207, 225), and according to Holden and Tate (1870: 162) from Ballypalady. This ore is not pisolitic in nature but is, geological and chemically, similar to the pisolites).

Clay ironstones

The interpretation of the composition of the Irish siderite ironstone is hindered by the large proportion of iron(carbonate) compared to the other elements (Table 4.3). Calcium and magnesium are relatively abundant elements, while analyses 4 and 5 show that manganese and phosphorus can also occur in relatively high levels. Analysis 5 also shows elevated levels of sulphur.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fe	39.70	37.60	21.7–35.5	30.24	63.84[38]	41.69	42.28	40.03	36.74	38.80	35.44	38.00	28.46	22.97	39.62
Fe_2O_3	56.80	53.79		43.26	91.33	59.64	60.49	57.27	52.56	55.51	50.70	54.36	40.72	32.86	56.68
SiO_2					1.40										
Al_2O_3	1.86	1.45				1.00	1.43		1.59	0.87	1.40	1.40	3.00		1.40
CaO	0.16	1.51			2.49		2.23	0.69	1.26	3.75				13.05	4.13
MgO	1.05	4.24			3.06		2.02	1.55	2.23	3.79	11.92	5.88	11.61		tr.
MnO					1.65										
P_2O_5			0	0.94	0.35										
S			0	0.02	0.42										
CO	31.93	28.60		33.80		32.92	31.25	30.74	29.18	32.57	38.09	40.92	30.58	23.68	42.51

Table 4.3 Chemical analysis results of Irish clay-ironstones

1–2 Clay ironstone. Castlecomer, Co. Kilkenny (Kane 1845: 132)
3 Clay ironstone. Dungannon, Co. Tyrone (Hardman 1875: 538)
4 Blackband ironstone. Ballycastle, Co. Antrim (Cole 1922: 68)

38 This value is too high for metallic iron in iron carbonate, possibly the amount of $FeCO_3$ was intended.

5 Blackband ironstone (calcined). North coast of Co. Antrim (Lloyd et al. 1918: 35)
6–8 Clay ironstone nodules. Arigna, Co. Roscommon (Kane 1845: 135)
9–10 Vein ironstone. Arigna, Co. Roscommon (ibid.)
11–15 Nodular ironstone. Creevelea, Co. Leitrim (Buchan 1859: 16–18)

4.3.2 Ores from excavations

Iron ore fragments

Iron compounds are very common in most subsoils and in Ireland it is common for foreign, stony material to be found far from its point of origin due to past glacial activity. The author recalls coming across rich iron compounds, unrelated to metallurgy, on many excavations across Ireland; a fist-sized piece of very pure haematite found on the late mesolithic/early neolithic site of Gortore, Co. Cork, being just one example. The occurrence of plentiful weathered rock iron ore specimens in a Bronze-Age ditch at Sheepstown 3, Co. Louth, being another (Young and Kearns 2010d). Positive identification of an iron ore should be confined to concentrations of pieces with a high iron content and/or clear signs of ore treatment (roasting). The analyses of iron ores from Irish archaeological excavations are given in Table 4.4.

	1	2	3	4	5	6	7	8	9	10	11	12	13
Fe	50.71	56.04	46.98	59.63	62.28	49.32	14.06	54.62	13.97	34.60	20.65	31.47	14.78
Fe_2O_3	72.55	80.18	67.21	85.31	89.10	70.56	20.11	78.14	19.98	49.50	29.54	45.02	21.14
SiO_2	10.27	5.21	14.11	6.33	0.49	1.92	20.10	2.75	60.68		14.28		2.06
Al_2O_3	2.54	1.23	8.71	1.50	0.13		7.29	0.13	4.63		3.08		8.94
CaO	0.10	0.04	5.09	0.76	0.16	1.25		1.69	1.53	6.11	8.95	11.50	0.42
MgO	0.18	0.01	5.14	0.46	0.20			0.22	0.35		0.46		0.57
K_2O	0.44	0.06	0.41		0.05			0.01	0.75	0.59	0.70	0.89	0.17
Na_2O	0.11	0.11	3.88		0.04			0.11	0.45		0.16		0.09
MnO_2	0.05	0.28	2.90	1.13	0.02	0.36	22.70	0.32	0.72	1.50	0.10	2.38	0.70
P_2O_5	0.33	0.16	2.78	0.34	0.14			1.94	1.80		0.98		
TiO_2	0.32	0.03	nd	0.12	0.02		0.36	0.01	0.31				0.10

	14	15	16	17	18	19	20	21	22
Fe	21.83	25.01	59.76	25.28	19.57	19.45	19.43	19.33	40.18
Fe_2O_3	31.23	35.78	85.49	36.16	28.00	27.82	27.80	27.65	57.48
SiO_2	49.26	40.11	7.72	15.27	51.29	50.97	54.73	54.45	29.36
Al_2O_3	7.12	7.97	0.29	10.90	2.59	2.58	2.71	2.70	4.10
CaO	0.20	0.43	0.50	1.42	19.31	18.80	15.44	16.60	2.13
MgO	0.37	0.27	0.04	1.38	0.80	0.80	0.92	0.96	0.98
K_2O	1.47	1.41	0.21	0.96					0.70

Na_2O	0.21	0.21	0.31	1.11	0.38	0.42	0.49	0.40	0.39
MnO_2	0.80	3.57	1.39	0.24	0.27	0.34	0.26	0.20	3.60
P_2O_5	0.82	2.31	3.12	5.04	0.16	0.16	0.11	0.10	0.86
SO_3			0.38	0.34					0
TiO_2	0.45	0.42	0.36						0.35

Table 4.4 Chemical analysis results of iron ores from Irish excavations
1–2 Goethite. Adamstown 3, Co. Waterford (Young 2009j: 4) [XRF, fused beads]
3 Siderite. Dun Emer, Lusk, Co. Dublin (Photos-Jones and Wilson 2007: 89) [SEM, area analysis]
4 Haematite. Ballyhenry, Co. Antrim (Scott 1990: 154) [not stated]
5 Magnetite. High Island, Co. Galway (Young 2006: 5) [XRF, fused beads]
6 Bog ore. Derryarkin, Co. Offaly (Dolan 2012 vol. 2: 23) [not stated]
7 Bog ore. Ballyvourney, Co. Cork (Tylecote 1986: 126) [not stated]
8 Bog ore. Ballykilmore, Co. Westmeath [7], Sample BYK26 (Young 2012c: 19) [XRF, fused beads]
9 Secondary bog ore. Clonfad, Co. Westmeath, Sample CFD29 (Young 2008a: 25) [XRF, fused beads]
10 Bog ore. Derrinsallagh 4, Co. Laois, Sample 12 (Photos-Jones and Wilson 2009b: 307) [portable XRF]
11 Same sample (ibid.) [ICP-MS]
12 Bog ore. Derrinsallagh 4, Co. Laois, Sample 12 (ibid.) [portable XRF]
13 Same sample (ibid.) [ICP-MS]
14 Bog ore. Woodstown 6, Co. Waterford, Sample WTN 19 (Young 2009h: 32) [XRF, fused beads]
15 Bog ore. Woodstown 6, Co. Waterford, Sample WTN 22 (ibid.) [XRF, fused beads]
16 Bog ore. Rath, Co. Meath, SASAA 261.04 (Photos-Jones 2009a: 391) [SEM, area analysis]
17 Iron pan. High Island, Co. Galway (ibid.) [id.]
18 Iron pan. Drumbaun, Co. Mayo, Sample 1 (Grant 2004: 193–194) [AAS]
19 Idem, Sample 2 (ibid.) [AAS]
20 Idem, Sample 3 (ibid.) [AAS]
21 Idem, Sample 4 (ibid.) [AAS]
22 Ochre. Cookstown, Co. Meath [30] (Photos-Jones 2009b: 176) [SEM, average of two area analyses]

A recent publication on the material from Derrinsalagh 4, Co. Laois suggests that semi-liquid iron seepages were used as an ore in early Irish and Scottish furnaces (Photos-Jones and Hall 2011). These seepages are described as a powdery and clay-like paste (ibid.: 329). The argument put forward was that, in contrast to the two latter countries, early furnaces for smelting bog ores, in "many places (outside of Ireland and Scotland)", still contain remnants of solid bog ore in various stages of reduction. The site at Snorup in Denmark is given as an example. Contrary to what is suggested, however, several early Irish furnaces do have residual ore fragments at the base of the slag pit, for example at Nangor, Co. Dublin (6th to 5th century BC) (Rondelez 2014), Cherryville, Co. Kildare (4th to 3rd century BC) (Young 2007b) and Ballykeoghan 10, Co. Kilkenny (AD 9th to 10th century) (Young 2010d). Conversely, in many early continental furnaces, ore is not present. For example, the lack of ore finds at the famed pit-furnace fields of the Świętokrzyskie Mountains in Poland was so acute that, even after twenty years of intensive research, the exact nature of the ore used was still unknown (Orzechowski 1994: 351–352).

Further arguments for the same idea were put forward based on the XRF-analyses of soils from eight furnace fills from the same site (Photos-Jones and Hall 2011: 633–634). The context descriptions in the original excavation report (Lennon 2009b), however, make clear that two of these eight fills had no slag (ibid.: 69, 48), five had frequent slag (ibid.: 48, 52, 59, 60, 75) and one context was described as non-archaeological (ibid.: 20). High values of iron, manganese and nickel were recorded through portable XRF analysis of these soils; the abundance of the first two of these elements was seen as suggesting iron seepages were used, while the nickel pointed to the use of a different ore. It would seem that the strong over-representation of the manganese, to a lesser extent the iron and potentially the nickel in the XRF analyses, together with an acceptance that iron (and manganese) will diffuse through archaeological layers on a biologically/chemically active site, could be a more straightforward explanation for the obtained results. As stated above, the lack of ore fragments in a used furnace is the rule rather than the exception and should not be used as an argument for the use of non-solid ores.

Ore inclusions in slag

During metallographic examination of slag from various sites across Ireland, Effie Photos-Jones regularly encountered iron-rich inclusions embedded in the material and interpreted these as iron ore particles (Table 4.5). Several of these, however, show up as hollow irregular spheres on the electron microscope photographs. This is clearly the case for the material from Derrinsallagh 4, Co. Laois (Photos-Jones and Wilson 2009b: 295, 344) (Figs. 4.2a and b). A further inclusion interpreted as iron ore was recorded from Cappydonnell Big, Co. Offaly [16] (Photos-Jones 2010b: ccxxiii) (Fig. 4.2c), which is a similar hollow sphere. Particles of 'iron ore' embedded in slag was also reported from the site at Bricketstown, Co. Wexford (Photos-Jones 2009e: 70) (Fig. 4.2d). It is unclear which part of the relevant picture depicts the particle (the black area?), but an irregular, hollow material is visible in the bottom left of the same picture.

Based on the above evidence, it is argued that these small hollow spheres are likely better interpreted as globular hammerscale trapped inside the still liquid smithing slag during forging. Their irregular appearance can be explained as deformation due to the heat of this liquid slag. The analysis of these particles was not included in the current study. Other 'iron ore' particles in slag from different, and the same, sites appear as solid inclusions. The material from only one site, Kinnegad II, with strong indications that it is connected to smelting, is very poor in iron (less than 5%) and rich in silica (42.08%) and manganese oxide (37.08%) (Photos-Jones 2008b: 17)). This sample is described as manganese ore and could represent material added to the charge.

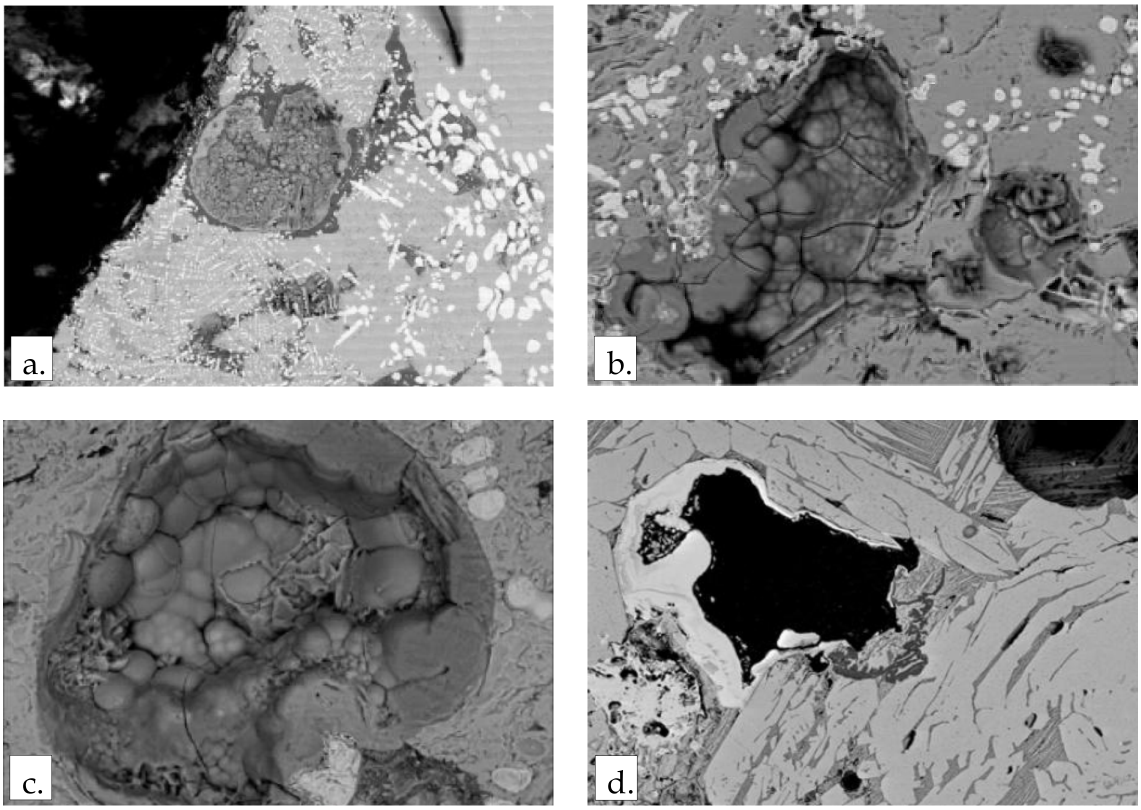


Fig. 4.2 SEM-EDAX images of globular “iron ore” inclusions in slag from Irish sites. a. Derrinsallagh 4, Co. Laois (SASAA 271.041) (Photos-Jones and Wilson 2009b: 309), b. Same site (SASAA 271.351) (ibid.: 295), c. Cappydonnell Big, Co. Offaly [16] (SASAA 323.18) (Photos-Jones 2010b: ccxxiii), d. Bricketstown, Co. Wexford (SASAA 245.02) (Photos-Jones 2009e: 70).

4.3.3 Composition of Irish iron ores

Based on the above several important observations can be made regarding the composition of Irish iron ores. Every type of ore has provided examples with an iron content above 50%[39], while some, such as eagle stone and magnetite, do seem to be generally richer ores. No element proportion can be stated as definitely distinguishing for a certain ore type, although high phosphorus and manganese levels are sometimes claimed as typical of bog ores. By 1845, no analysis had yet been carried out on Irish bog ores, and results from German bog ores, which showed high phosphorus and

39 The siderite ores have a lower iron content, but have large proportions of CO which would escape as gas during smelting.

manganese levels, were seen as also representative for the Irish ones (Kane 1845: 128). Seemingly, no further analysis was undertaken and a high level of phosphorus was still assumed by the beginning of the twentieth century (Turner 1908: 64). That bog ores from Ireland, or in general, have high phosphorus and manganese levels was, and still is, assumed in some of the archaeological literature (Scott 1976: 166; 1990: 153; Pleiner 2000: 88; Photos-Jones 2010b: ccxxviii). It is clear, however, from the analysis results above, that the content of both phosphorus and manganese can vary widely in bog ores and that similar high and low values can be encountered in other ore types (Fig. 4.3). High values, that is to say above 5%, for calcium, on the other hand, do seem to be typical for Irish bog ores.

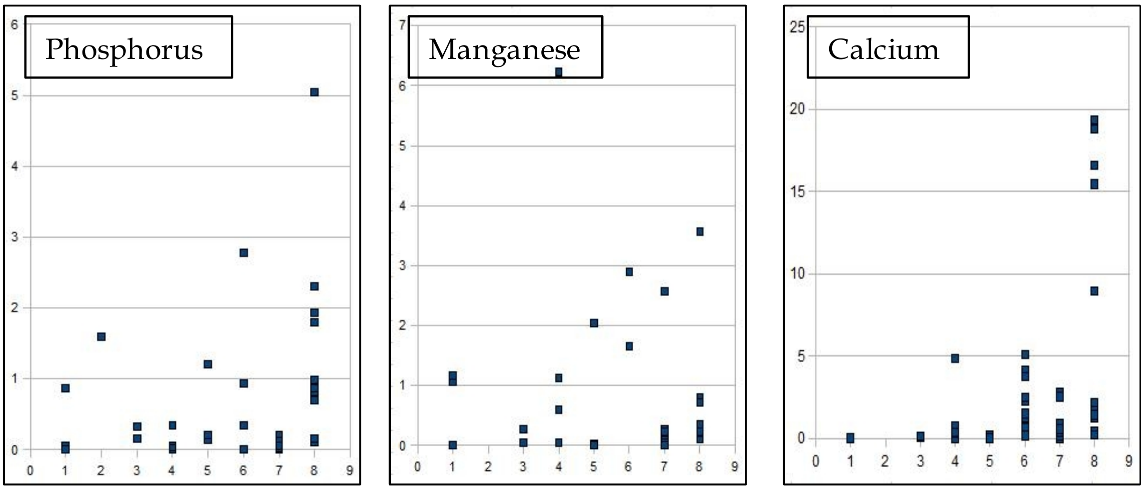


Fig. 4.3 Phosporus, manganese and calcium contents of Irish iron ores. Y-Axis: percentage. X-Axis: 1. Eagles stones, 2. Limonitic ores, 3. Goethites, 4. Haematites, 5. Magnetites, 6. Siderites, 7. Pisolithic ores, 8. Bog ores.

If certain types of iron ores were preferred for smelting in Irish bloomery furnaces is hard to say based on the current knowledge. First, it is not always clear if the iron-rich compounds found during excavations were indeed intended to be used in smelting. Second, the limited available evidence does not show any patterns suggesting ores were selected with either high or low levels of certain elements. Finally, it is unclear if the high ratios of elements in some of the samples would have been selected specifically for this reason. Only for bog ores do we have evidence they were used, both directly through analysis and based on the location of some of the furnaces in areas were no other types of ore can reasonably be expected to occur.

4.4 Conclusions

Because of the geological build-up of the island, Irish iron ores are varied and widespread. Moreover, from the available chemical analysis data, there appears to be a considerable difference in composition between different samples of the same ore-types. It is also clear that our knowledge of Irish iron ores is both limited and biased toward ores which were of economic interest during the nineteenth and early twentieth centuries.

As such we are well informed on the pisolitic ores associated with the basalts of Co. Antrim, as well as sideritic ores occurring in the Leinster, Munster and Connaught coalfields. Some dispersed locations of rich bodies of haematite and magntite ores are also well known. Other types of ore, goethites and especially bog ores, as well as smaller bodies of the previously mentioned ore types were only recorded in early historical documents or as local curiosities.

In several cases, at Ballykilmore, Co. Westmeath [7] and Woodstown, Co. Waterford for example, chemical analysis pointed to bog ores being used for smelting. In other cases, the location of the furnaces in low-lying wetland areas would suggest the use of similar ores. The contention, however, that Irish bog ores are typified by high contents of phosphorus and manganese can, based on the available analysis results, not be withheld. It appears that in actual fact high amounts of calcium is the distinguishing characteristic of these bog ores.

Chapter 5

Documentary sources for iron mining and smelting in late medieval Ireland

In this chapter, an overview will be presented of the evidence for the mining and smelting of iron ores from the written sources relating to late medieval Ireland. These will be used to gain insights in when and where iron ores were mined and which types of ores were used. These written sources can also provide valuable information on the techniques and technologies used to smelt these iron ores. Often, these aspects of ironworking can be difficult to understand based on archaeological sources alone.

For the first three centuries of the late medieval period, the written sources are practically silent on the mining and smelting of iron. The little information we do have, however, is tantalizing as it seems to include references to the export of iron from Ireland during those centuries. From the sixteenth century onwards, the documentary sources become both more voluminous and detailed and give insights not provided by the archaeological sources. They offer us rare glimpses of the technologies used in bloomery smelting and into the nature of its products, and also indirect indications that water-powered bloomeries might have operated in Ireland in the third quarter of the sixteenth century.

The later sixteenth century also sees the introduction of the blast furnace in Ireland. Even an approximate date of this is uncertain, as many of the early relevant sources are vague on the exact technology employed. The early Irish blast furnace has been referred to in several works on the late sixteenth-century plantation attempts in the south of the country (MacCarthy-Morrogh 1986: passim; Breen 2007a: 179–180), while its technological and broader economic aspects have been extensively researched by Colin Rynne (2001, 2006, 2007, 2009).

5.1 Thirteenth-century sources

According to a local tradition surviving into the nineteenth century (Kinahan 1887: 305), the iron mines at Ballycoog and Moneyteige (between Arklow and Aughrim in

Co. Wicklow) were worked by the native Irish before the Anglo-Norman conquest and subsequently by Shillary and Raymond, two knights of Strongbow, one of the leading figures in that conquest. Also according to Kinahan (ibid.: 306), the trails between Wicklow and Shillelagh used for bringing iron ore to the seventeenth-century Chamney works were old because they passed the sites of Sillery's and Raymond's Castles. No information was found on Shillary/Sillery's castle, but Raymond's castle, in the townland of Killaveny and on the route described by Kinahan was, according to O'Donovan (1856b: 2018), named after Raymond O'Byrne who owned the castle in the first half of the seventeenth century. It is clear there is some confusion about this tradition.

The earliest surviving Irish murage charter, granted to the town of Waterford in AD 1225, seems to imply that iron was produced in Ireland at that time, as the iron is listed under the export products (PRHen. III 1216–1225: 433; CDRI 1171–1251: 177). It is worth quoting the translated charter in full:

> Grant to the citizens of Waterford of customs to enable them to enclose the King's town of Waterford, as follows:
>
> For every hogshead of wine coming to the city for sale, 3d,
> From the merchant who buys the wine, 2d,
> For the ship's freight, 1d,
> Every hogshead of honey coming to the city for sale, 5d,
> From the merchant who buys the honey, 4d,
> For the ship's freight, 1d,
> For every sack of wool exported, 4d,
> Every dicker of hides, ½d,
> Every 100 ells of cloth, 3d,
> A weigh of iron (*pisa ferrum*), 3d.
>
> This grant to last for 4 years from the feast of John the Baptist [24 June]. Bristol.

The designation of *pisa* as a trade unit for iron, or any other commodity, was not found elsewhere. The *weigh*, also recorded in other early thirteenth-century murage grants (see Appendix 6), was used as a weight in England, but not for iron (Zupko 1985: 434–438).

A weigh of both lead and wool was about 80kg, but could vary substantially for other commodities. The levy of 3d in the grant, though, would suggest a substantial quantity of iron was being taxed.

Around the middle of the thirteenth century, the foundation charter for the only Carthusian monastery ever established in Ireland, at Kinaleghin, Co. Galway, mentions that "should they find a quarry in the hills or millstones or a marlpit or iron-ore (*minam ferri*), they have licence to dig for them and transport them to their house freely" (Gray 1959: 53). Although permission is given in the conditional sense, the fact that for example no non-ferrous metals are mentioned, could indicate that the finding of iron ore was expected.

The accounts of the Earl of Norfolk's estates in the south-east of the country, for Old Ross in AD 1283/84 and 1284/85, mention *ferro proprio* or own iron (see Chapter 7.2.1). This own iron is used for making plough shares, coulters and agricultural implement. No expenses are recorded for this iron, only the stipends of the smith making the objects, in contrast to iron for structural parts of the ploughs, which is always purchased. As no excess iron appears in the accounts which could have been carried over from one year to the next, it is suggested this own iron might have been produced, that is to say smelted, on the estate.

In September AD 1289, King Edward I gave a mandate to Nicholas de Clere, treasurer of Ireland, to work or lease "the king's mine of silver, copper, lead, iron or other metal reported to be recently discovered in Ireland" and to provide funds out of the treasury to fund this venture (CPR 1281–1292: 322). A mine, presumably for silver, was already being worked in Tipperary since at least AD 1277 (PRIE 1272–1284: 39), but in AD 1289 a new mine was opened in that county (CDRI 1285–1292: 232) and in the same year mines in the Counties Kerry and Limerick are mentioned for the first time (CDRI 1285–1292: 224; PRIE 1287–1294: 51). The possibility is great that these mines only produced silver and lead, and that the iron in the mandate was mentioned generically. It has recently been suggested that the references to four miners and a smelter being employed near Waterford in AD 1296 and 1297 (PRIE 1295–1304: 33) were working mines of iron (Murphy 2011: 230). A recent study of the evidence, however, argues that these were silver mines (Claughton and Rondelez 2013: 3–5).

No documentary sources dating to the fourteenth century referring to iron mining or smelting were found.

5.2 Fifteenth- to early seventeenth-century sources

The next reference to potential iron mining dates from about a century and a half later, when, at the Parliament of Drogheda of AD 1450, provisions were made to levy taxes on wheat and malt, to be spent by a certain Richard Ingrame on developing mines of "silver, lead, iron, coal, plaster of Paris and millstone" which he had discovered within the Pale (Berry 1910: 285). The iron could have been just a commodity added to Ingram's list of achievements, but only 25 years later, in *The Noumbre of weightes*, a manual for English merchants, iron, possibly in the form of finished products, is listed under the export products of Ireland, "Also there is lynnone [linnen] clothe and jrone..." (Jenks 1992: 308).

The *Red Book of the Earls of Kildare* (1503) lists several mines in the south of Ireland and on the subject of iron it is stated that "There beth so many mynes of yron that Irishmen do occupy noo yron but suche as they make themselves" (Mac Niocaill 1964b: 13). Although the "mynes of yron" do not necessarily imply adits or even open cast mining, even bog ore collecting could conceivably be seen as a "myne", it does clearly indicate the self-sufficiency of the Irish in their iron production at the turn of the sixteenth century. As Garret Fitzgerald, the Earl for whom the Red Book was composed, was of Anglo-Irish ethnicity, it is not fully clear if the Irishmen referred to in the text were Gaelic-Irish or the Old-English. Shortly after his appointment as Lord Deputy of Ireland, Anthony St. Leger mentioned to King Henry, in AD 1541, that Ireland had mines of lead, tin, copper and iron, "whiche we thinke wolde be a greate ryches, if it mought be quyetely labored for" (SPHen. VIII: 343), indicating not only the growing interest in the country's mineral wealth by the English state, but also of the secrecy surrounding these enterprises.

A very interesting, and as yet unpublished, document is the account written by John Denton, agent for the Company of Mines Royal, of his experiences in Ireland (BL Cotton MSS Titus B/XII f.4–15). Denton was initially sent to Ireland to procure wood for the copper-works at Keswick, Cumbria and returned in AD 1567 (CSPD 1547–1580: 289). He had set off in AD 1565, originally to try to source the timber in Ulster but, because of troubles there with Shane O'Neill, he was sent further (south) west to investigate possibilities for exploiting both timber and minerals (PRO SP 63/20 f.29). In his account of his travels, written at an uncertain date and also including events after his return from Ireland, Denton, after enumerating the potential for using timber in shipbuilding and exporting it to Spain, talks about mining and smelting iron ore (BL Cotton Titus B/XII f.1):

> Being in the weast parte with mr. Henrye Davell, mr. James Heydon and mr. W[illia]m Apslye and the Lord Barrymore, Sir Waran Selinge[40] send for us to kepe him companye conserninge of the stait of the Contrie of Munster one all parts. Hit was agreed with the manuringe of the land by the bredinge of oxen calves, the fellinge of wods, squaring and hewing them for bewlding tymbe[r] in cartting and sawyng them into planks and bords, joysts, quarters, laths and clap bord for making of small carvells, shippbotts & wheries and small clappbord for all kynd of vessells as the crokes, peeces, quares for bewldinge of shipps and lycence to be had to carrie of them into Spane. The bowes to be cutt for colling as all other underwoods, hollye, white and Blake thorne and other bramble into small coale and great. And with the same for that there is plentie of Iron ower to have men bothe Frence for Collong and Spaniards that cold Skill of the making of Iron and Irishe men that cold bothe cole and mak Iron. For that bothe in the weast in Munster as in the northe in Ulster there is gret plentie of Iron Stone and ower and if some Dushemen that cold make Iron potts and suche Englishemen as cold caste and make gonne. Upon these speches Sir Warran said he wold mak choyse of a place and put the premises in practyze which for the next yeare put the premises in practize to his good proffet but ill Servants and worsher neghbors did gretlye hynder the worshipfull gentillmen.

Up to the part where the making of coal (charcoal) is mentioned, the text seems to be a list of activities planned by the group with Sir Warham St. Leger. This was likely part of the latter's plan at that stage to begin the plantation of Kerrycurrihy, which was started in AD 1568 and lasted until the following year (Piveronus 1979). The sentence referring to Frenchmen making charcoal, the Spanish making iron and the Irish doing both, can be read as a proposal, but it is unlikely that Denton was suggesting that the Irish becoming (more) involved in ironworking, let alone the Spanish, at this turbulent time. Sir Henry Sidney, upon his appointment as Lord Deputy, had already stated that his presidency would counter the activities of the Spanish and French in Ireland and also promote the exploitation of the mineral resources of the south-west of the island (Canny 1976: 98):

40 Sir Warham St. leger.

> By this [the Munster presidency] the fisshing now used by the Spaniards and ffrenchmen may be converted to the comen-welth of that realme and fermid to the Queen's advantage. By this rich mines now hidde and lost may be lokid into and gainfully usid to the Quenis use.

And Denton himself, in a letter to William Cecil in AD 1566 (PRO SP 63/20 f.29):

> In the said boke shall apere unto your honor bothe what woodds there be as also menerall and mettall owers as the countres there dothe yuld with the great plentie of ffishe and the great comoditie the Spaniards there have as what beniffit the prince lostethe yerelie of here yeares costome.

If, on the other hand, this sentence is a description of the situation at that time in Munster, as seems likely, it would confirm that the local population was making iron (and charcoal), but also a unique testimony to foreigners being involved in ironworking at this early stage. Potential foreign interest in Irish metals, including iron, is also apparent in the letter sent by Allesandro Fidel, an Italian merchant working out of Waterford (Izon 1956: 93), to Pope Pius V in AD 1571 wherein the author talks about additional reasons why an invasion of Ireland by Italian troops would be of benefit to the Holy See (CSPV 1558–1571: 391).

> The mines of gold, silver, lead, tin and iron are of recent discovery: a mine of alum is of extraordinary richness. These mines are owned by Irish gentlemen who do no sort of obedience to Elizabeth, and will hear of no name but that of your Holiness, to whom they do all obedience and service, as our duty is much rather to your Holiness.

Again an indication that Catholic landowners in Ireland had access to its mineral wealth and probably the means to exploit it.

Another document, written in AD 1574 by David Wolf, Jesuit, papal nuncio to Ireland and native of Limerick, entitled *Description of the Realm of Ireland, its Maritime Ports and Cities, with the Names of the Bishoprics, Lords, Counts and Nobles of that Realm made at the Instance of His Illustrious Lordship Don John Borgia,* *Ambassador of his Catholic Majesty in the Kingdom of Portugal* states: “There are mines of silver, tin, lead and copper in that island, but the mines of iron are such as might suffice for other realms” (CSPV 1572–1578: 160). Here, not only is Ireland stated as being rich in iron ore, but it is suggested that the export of that metal might be feasible. The idea that Ireland was rich in iron became widespread during this period and led to several historians, at that time, to believe that Ireland got its name from its abundance of that metal:

> Of whom at the same time the countrie (as some hold) was named *Hibernia,* as in the description further appeareth: although some rather hold, that it tooke the name of iron, of the plentifull mines of that kind of mettall wherewith that land aboundeth: and so those ancient writers which name it Ierna, named it more aptlie after the speech of the inhabitants than others, which name it *Hibernia.*
>
> *Chronicles England, Scotland, and Ireland* (Holinshed 1587: 49)
>
> Irlanda los mesmos abitadores la nombran Erin, que sinifica tierra de hierro, por que se faca della.
> [The inhabitants of Ireland call it Erin, which means land of iron, because it is made there]
>
> *Second Eclogue* (de la Vega 1580: 623)

That iron extraction in Ireland around that time was not merely hearsay is shown by events at Burrishoole, Co. Mayo. This was the main residence of Richard Bourke or Richard an Iarainn, “of the Iron”, when Sir Nicholas Malby, recently promoted to Lord President of Connaught in AD 1579, was sent to Mayo to subdue Richard. Malby's description of Burrishoole, sent the 29th of February 1580, which was planned as the future shire town for Mayo, mentions both mining and smelting of iron ore (PRO SP 63/71 f.140):

> There ys a great myne of yron, a fayre ryver for mylles and
> wood ynoughe, great store of tymber to make
> shipping. […]

> The myne of yron ys very riche. I fownd mouche
> yrin made there by the rude cuntry people of w[hi]ch
> I do send your honur a lyttell pece for an example
> and have a pec of 40lb waight w[hi]ch I will
> send you shurtly to make triall of there. I think
> yt ys more steele then yrun: yt ys very plentyfull
> and a great mountayne of yt.

The reference to the great mine of iron indicates that the ore mined was not bog ore, but instead a type of rock ore. The weight of the *pec*[41] obtained by Sir Nicholas Malby, 40lb or about 20kg, possibly refers to a (refined) bloom. Malby's description also contains the earliest reference to the steely character of Irish bloomery iron (see Chapter 9.4).

Further interest in the iron resources of Ireland was expressed by Henry Sidney, then retired as Lord Deputy, in his *Discourse for the Reformation of Ireland* (1583) wherein he states: "there is plenty of iron in some places [...] the mines to be searched" (CCM 1575–1588: 370) and by the current Lord Deputy, Sir John Perrot, who, in his *Project for Ireland* (1585) wrote: "Good store of iron will probably be found in Munster or else may be had out of Spain" (CCM 1575–1588: 416). Also in AD 1583, a certain Richard Speart proposed a large-scale plantation project in Munster which included the setting up of ironworks (PRO SP 63/106 f18):

> Item we meane if we maie plant o[u]rselves where myne &
> water is to sett up an Iron worke then the w[hi]ch there is
> no one thing in o[u]r opynions more fytter to brydell that ydell
> and fillching people then the cutting downe of theire woods
> w[hi]ch are ther chieffest succo[u]r and strenghes.

The reference to water indicates that either a blast furnace or a water-powered bloomery was envisaged. The text is also an early reference to the establishing of ironworks with an eye on depriving the Irish of the cover of woods.

In AD 1584, Robert Fowle, provost marshal of the province of Connaght, together with John Browne, had proposed to settle the recently acquired town of Athenry, Co. Galway, with "sundry laborers and artyficers" (CPCRI II: 74). They intended to export not only copper, lead, timber, woad, hops, oil and salt, but also iron

41 This could be a piece or a wedge (Oxford English Dictionary).

and steel (PRO SP 63/155 f.39). In AD 1586, they received a warrant to proceed with their venture (PRO SP 63/161 f.95) and in the same year mention is made that advice on this project was received from "divers workmen, and one Mr Morley, a gentleman of Sussex, that hathe had to deale theise twenty years in Iron workes" (PRO SP 63/122 f.177). This was likely Anthony Morley who owned a blast furnace and a forge in the Sussex Weald in AD 1574 (Teesdale 1986: 32–33), who entered a bond not to make or sell ordnance without permission of the Crown in the same year (CSPD 1547–1580: 477), held a blast furnace in Glamorganshire, Wales from at least AD 1583 (Wilkins 1903: 16; Schubert 1957: 374) and, around the time of his advice concerning Ireland, was encountering legal issues surrounding his Welsh ironworks (Llewellin 1863: 94–103). Although it is unclear what the exact nature of the ironworks at Athenry was, the possible involvement of Anthony Morley could mean that cast-iron production was planned. It is unclear if the Athenry venture did produce results, but certainly "men … for myneral causes" had been brought over before AD 1591 (PRO SP 63/161 f.95).

In the south of the country, the second rebellion of the Earl of Desmond had resulted in his lands being forfeited after his death in AD 1582. To accommodate the distribution of the lands, the so-called Desmond Surveys were carried out in various parts of Munster. The published portion for Co. Limerick, finalized in AD 1586, contains at least[42] forty-six references to iron mines (Purcell 2009), referred to as "an iron mine of iron stone", of which thirty-five can be located (see Chapter 4.1.2). The majority of these mines are concentrated along the eastern slopes of the Slieve Lougher mountains to the west of Newcastle West, with others lying further west, around Athea, and north, around Glin on the Shannon. The term "iron stone", at least from the seventeenth century onwards, was normally reserved to designate siderite, or the carbonate of iron, but was earlier also used as a synonym for iron ore in general (see below). Several modern references do exist to siderite occurring in the same area, and even the same townlands, but both bog ore and haematite are also known to occur there (see Appendix 1).

A large part of the attained Desmond lands in Counties Cork and Waterford was granted to Sir Walter Raleigh in AD 1586 (Ball 2007: 47–48). When, in AD 1588, Raleigh leases the manor of Mogeely, Co. Cork to Denys Fisher, the list of lands included the placename Forgepoole (IPRI: 81, 93). This term would suggest some kind of water-powered ironworking, and it would seem likely that the name was given to the place during or before the survey of the lands.

42 In some cases more than one mine is implied per townland.

In the same year of AD 1588, the neighbouring plantation of Kinalmeaky, Co. Cork was awarded to Phane Beecher, who assigned Robert Payne/Pyne as his steward (Ó Ríordáin 1930: 60; Smith 1961: 34). Robert Payne was at the time involved in an unsuccessful project concerning woad production in Nottingham financed by Sir Francis Willoughby (ibid.: passim). In AD 1589, Payne wrote his *Brife description of Ireland*, a pamphlet describing the situation on the ground in Ireland which was designed to convince settlers to move to Ireland (Payne 1589). In all likelihood the information in the tract relates to the area in or around Kinalmeaky. Concerning the natural resources available, Payne notes that (ibid.: 9):

> There is verie rich and greate plentie of Iron stone, and one sort more then we have in England, which they call Bogge myne, of which a Smith there will make at his forge Iron presently. Also there is great store of Lead Ore, & Wood sufficiente to mayntayne diuers Iron and lead workes (with good husbandrie) for euer.

Several other documents, although dating later than the period under study, give us additional insights into aspects of Irish ironworking in earlier times. Peter Lombard, an important Irish Counter-Reformation figure, states in his *De regno Hiberniae* (1600) that "iron as well is dug up easily and even melted by those who are insufficiently skilled in metals, and none the less it proves so outstanding that no other [iron] in Europe is more durable" (Moran 1868: 47)[43], again touching on the quality of the ores and the products. The same was also confirmed by Sir Thomas Phillips, agent for the Corporation of London, when surveying the lands of Co. Derry. Even before Phillips' survey was carried out, the abundance of iron and copper ores was used as an incentive to convince the Corporation of London to take on the plantation of Ulster (CPCRI James I: 619). In a letter sent during the survey, on the 18th of September 1609, Sir Thomas relates how they went to the south-east of the said county (ibid.: 636):

> to make some experience of the iron ore which is said to be there in greater abundance than elsewhere, though in these parts there is sufficient store to be found, almost in every mountain and bog, which the native take only for their necessary uses, and not for profit and enrich themselves by it, as other people would do.

43 Translation kindly provided by Vicky Janssens (Department of Classics, UCC).

Less than a week later, Sir Thomas sent a letter containing the following (CSPI 1608–1610: 290):

> From Thence [Coleraine] through part of Tyrone and so to Toome [on the Derry/Antrim border at the northern end of Lough Neagh], within which circuit he showed them good land, very fair woods, and rivers. At Toome caused some of the ore to be sent for, of which he caused a smith to make iron before their faces, and of the iron he made steel within less than one hour. Mr. Broad [John Brode/Broade], one of the agents for the city [of London], who has skill in such things, says, that this poor smith has better satisfied him than Jarmaynes [Germans], and others that presume much of their skill. Has sent a sample of each to his lordship. The ore is rich, for they judge by what they see wrought, that very near the sixth part will be iron.

The actual report from this expedition, written in October 1609, specifies the occurrence of the ores (ibid.: 317):

> Of minerals there is no certainty, except of iron ore, and of that in sundry places some four miles from the main woods, and in the mountains of Slewgallen [Slieve Gallion] further distant yet not far from the river Mayola [Moyola] which divides the woods of Glenkankeyn [Glenconkeyne] and Killetrough [Killetra].

In AD 1611, Sir Thomas proposed an ambitious scheme for the plantation of "the county of Colrane and the Derry", which included potential for ironworks (CCM 1603–1623: 153):

> I am in good hope there will be found such store of iron ore that it shall bring a great commodity into the land, for the Irish of themselves wil take the ore, and in short time make iron; and it proves to be very good of which they make their skeynes and darts [short swords and arrowheads or spikes[44]].

Another seventeenth-century source providing insights into bloomery-iron production is the royal grant to Teige O'Hara in AD 1612 of lands in Co. Sligo (CPR 1603–1619:

44 Oxford English Dictionary

259). This included the right to receive thirty wooden dishes and six stone of iron out of Coylemore. If the stones represents the weight of the iron, this would amount to about 38kg. Coylemore is an unlocated place in the barony of Leyny (Nicholls 1987: 418). This is undoubtedly locally produced iron which would either be used by O'Hara, redistributed or sold on. As late as the early nineteenth century, unconfirmed rumours told of iron stone being smelted in common forges in the Munterloney Mountains in the Strabane area of Co. Tyrone (McEvoy 1802: 25).

Other information in the seventeenth-century sources could also relate to earlier, possibly late medieval, iron smelting. As we have seen (see Chapter 3.1.1), the iron-rich slag from the bloomery furnaces was often re-used in the later blast furnaces. In Ireland, this was the case, for example, at the Earl of Cork's ironworks in Co. Waterford in the early seventeenth century (NLI Lismore Papers 43.297/1d) and at the Wexford ironworks later on in the same century (Barnard 1985: 111), when the "cinders" were imported from the Forest of Dean. At other works, however, there are indications that these cinders were sourced locally. Barnard (1982: 16) noted the low cost Sir William Petty expended on both his ore and cinders at his ironworks in Co. Kerry and suggested these were sourced locally. In AD 1662, it was contemplated to use the cinders from a nearby, disused furnace in the newly constructed blast furnaces near Enniscorthy, Co. Wexford (Barnard 1985: 111). There are no recorded earlier furnaces in that area. More information is available from the unpublished Emmerton Papers. John Emmerton owned blast furnaces in Scarriff, Co. Clare and Woodsford, Co. Galway during the last decade of the seventeenth century and the lease for the Woodsford works included the right to raise cinders within three miles of the furnace (Brown and Colles 1789: 460). In AD 1694, Emmerton's agent writes that the Woodstown works had collected about 400 tons of cinders, while at Scarriff, 80 tons a week were being brought in (Nott. Arch. Emmerton Papers, DDSY 156/3). As the many slag-pit furnaces we know of in Ireland, dated to the Iron Age or early medieval period, are never associated with slag heaps, these large amounts of bloomery slag, which the cinders are likely to represent, were probably produced in shaft furnaces and as such could represent late medieval material.

5.3 The introduction of the blast furnace in Ireland

The earliest reference to a blast furnace in Ireland could be contained in the Denton document dating to the mid-1560s, quoted above. The suggestion was made to bring over Dutchmen to cast pots and English to cast ordinance in Ulster and Munster; clearly an intention to use blast furnaces. Neither the Denton text, nor other material available on the same scheme, suggests that this was put into practice. Interestingly, Sir Henry Sidney, Lord Deputy of Ireland since AD 1565, patron of Sir Warham St. Leger and son of iron-master William Sidney, was previously Lord President of the Marches of Wales where he was involved in setting up the earliest-known blast furnace in Wales, in Glamorganshire, before AD 1564 (Schubert 1957: 176–179; Crossley 1975b: 32).

That the passage on iron in Payne's *Briefe description* (see above) was not mere propaganda is shown by that author's involvement in early plans to set up ironworks on lands which Sir Francis Willoughby had purchased in Ireland, an agreement of which survives and was written in AD 1589 (NUL Mi 5/165/75). This contract was drawn up between Sir Francis and Lawrence Loggyn who were jointly to erect an ironworks on Sir Francis' lands. The venture was going to be financed either by both parties or by Loggyn and his partners, depending on advice from Robert Payne and two others. This advice concerned the “vallewe & connvyencye of the woods, Ieron stone mynes & wattres for the ereackttinge of suche work”. If Loggyn and partners were to bear the cost of the ironworks, Sir Francis was to provide “Iron stone within v miles dystantt of the woods at the works” and was going to receive every tenth ton of iron made. Although Sir Francis did already possess ironworks when he got involved in the Irish venture, these were all water-powered bloomeries (Smith 1967). The reference, however, of the tenth of every ton as part of the agreement possibly indicates that a blast furnace was planned; Sir Francis' bloomeries produced a total of around 40 tons of iron per year (ibid.: 97), whereas his later blast furnaces were calculated to produce from 150 to 240 tons (ibid.: 101, 108, 112). Loggyn was also a self-proclaimed specialist in the building and operating of blast furnaces and went on, after the Irish project, to do just this for Sir Francis in Middleton, Warwickshire, Oakamore, Staffordshire and Duffield in Derbyshire (ibid.: 98, 104, 138–139).

Two years later, in AD 1591, another “iron workes” is mentioned as operating in Co. Waterford (APC 1591: 213–214). Robert Robins and William Carter, from Kent, had a lease from the Bishop of Lismore “of certaine lands and woods neere to that place” for the upkeep of the works. Nothing more is known about these works. In the same year another ironworks was envisaged at Castleisland Co. Kerry by Sir William Herbert, but it is unknown if it was ever constructed (MacCarthy-Morrogh 1983: 339–341; 1986: 225).

Two years later again, in AD 1593, the President of Munster, Sir Thomas Norris, started up ironworks in Mallow. The earliest document relating to this venture is “a lease of woods from Conor O'Callaghan to Sir Thomas Norreys of Moyallo” dated to AD 1593 (Grosart 1887 vol. 1: 4–7). Moyallo was interpreted by Schubert (1957: 189) as being Mogeely near Tallow, but both Thomas Norreys, President of Munster, and Conor O'Callaghan are connected to Mallow, not Mogeely (see for example O'Clery 1846 vol. 2: 581). Moyallo is also consistently used as an old name for Mallow in that period.[45] According to this document, Sir Thomas Norreys received permission to cut wood and dig iron ore for his ironworks, next to other privileges, for 21 years. The next document is a chronicle of Ireland mentioning, under November 1598, that the “castell and house of Mallowe was well defended by the ward, but …. the iron milles were throwne downe spoyled and burned that weare theare” (Falkiner 1907: 110).

Further, we have a document entitled *Note of what Lands are to be procured in the p[ro]vince of Munster to build forges upon*, wherein is stated: “Mayallo a convenient place for that purpose. S[i]r Jhon Jepson is to lease the land wheruppon the old forge and furnace stoode. And on O Calagan hath great store of wods adioyning nere that land” (PRO SP 63/196 f.145). This document is dated in the Calendar of State Papers Ireland to AD 1596 (CSPI 1596–1597: 197) but from the naming of John Jephson in connection with Mallow it is clear this document dates to the years after AD 1607.[46] The document is more likely connected to the project that a certain Tokefield had suggested to start up ironworks in Ireland in AD 1610 (CSPI 1608–1610: 686, 687, 712). The reference to a furnace and forge is the first positive indication of both a blast furnace and its accompanying finery in Ireland. We also have an eighteenth-century description of what was found by a farmer in 1759 while laying out a potato field “on the south bank of the Blackwater, a mile west of Mallow” (Crowley 2004: 26–29). He discovered several lumps of pig iron, parts of a possible mill shaft and pieces of wrought iron, confirming that the furnace was indeed a blast furnace. That this was correctly identified as the location of Norris' ironworks, or at least the finery part of it, was later confirmed by the finds of probable finery slag by the author just south of the former Mallow Flour Mills in Quartertown [98] (see Chapter 6.2.2).

On the 13th of June 1596, help from the Privy Council was solicited by Herbert Pelham and George Goring who had been brought over to start up “iron mylles” on the lands of Sir Walter Raleigh (APC 1595–1596: 453–454). Settlers had been brought over,

45 See Logainm at http://www.logainm.ie/Viewer.aspx?text=mallow&streets=yes
46 c. AD 1609 is suggested by MacCarthy-Murrough (1986: 225)

but the lands for settlement and the ironworks could not be occupied because of the “obstinacie and forward dealinges” of Sir Walter's tenants and “borderers” and “imperfect grants” made by Sir Walter's officers. Both Pelham and Goringe are recorded as lessees of Raleigh in AD 1594 (MacCarthy-Morrogh 1983: 364–365). Herbert Pelham was the brother-in-law of Anthony Morley who was likely involved in the Athenry project (see above) (Hasler 1981: 193) and Pelham had a lease of an ironworks in Sussex in AD 1577 (Cleere and Crossley 1995: 312).

5.4 Conclusions

The number of sources for late medieval bloomery-iron production in Ireland is limited, but they nonetheless provide us with valuable insights into topics such as the ores used, the different technologies and the resulting products. Also, the distribution map of the known and potential locations in the written sources (Fig. 5.1) shows a notable absence of sites in the east of the country, exactly the area best covered by these sources; this could imply that no or very limited production took place here.

The likely reference to the export of iron in the Waterford charter of AD 1225 would suggest that there was either a large production unit in its hinterland or a network connecting many smaller ones, while *The noumbre of weightes* of AD 1475 either indicates the same or the presence of superior products. The “cinders” recorded as used in several seventeenth-century Irish blast furnaces, then, could represent the locations of these large production units. The manor accounts for Old Ross, on the other hand, potentially testify to part of the iron used on a manor being locally produced in relatively small amounts at the end of the thirteenth century. The mention of iron ore in the foundation charter of the monastery of Kinaleghin in County Galway, dated to the mid-thirteenth century, indicates at a minimum that this was hoped to be found.

Although some of the sixteenth-century sources extolling the richness of Ireland in iron ore are likely to be either propagandistic or based on little real knowledge, others are more convincing. For example, the statement in the *Red Book of Kildare* claiming that Irishmen are self-sufficient in iron is an important indication of the ubiquity of both the ores and the technology to smelt them. The references in Denton's tract and in Phillips' letters to the Irish making iron, respectively in Munster and Ulster, together with that to levies paid in iron in Co. Sligo, all point to that metal being produced on an ongoing basis in different parts of the country.

We learn that rock iron was extracted at Burrishoole, Co. Mayo, where there are also indications of sub-surface mining, although the nature of the latter is unclear, and in Kinalmeaky, Co. Cork, bog iron was smelted next to other ore types.

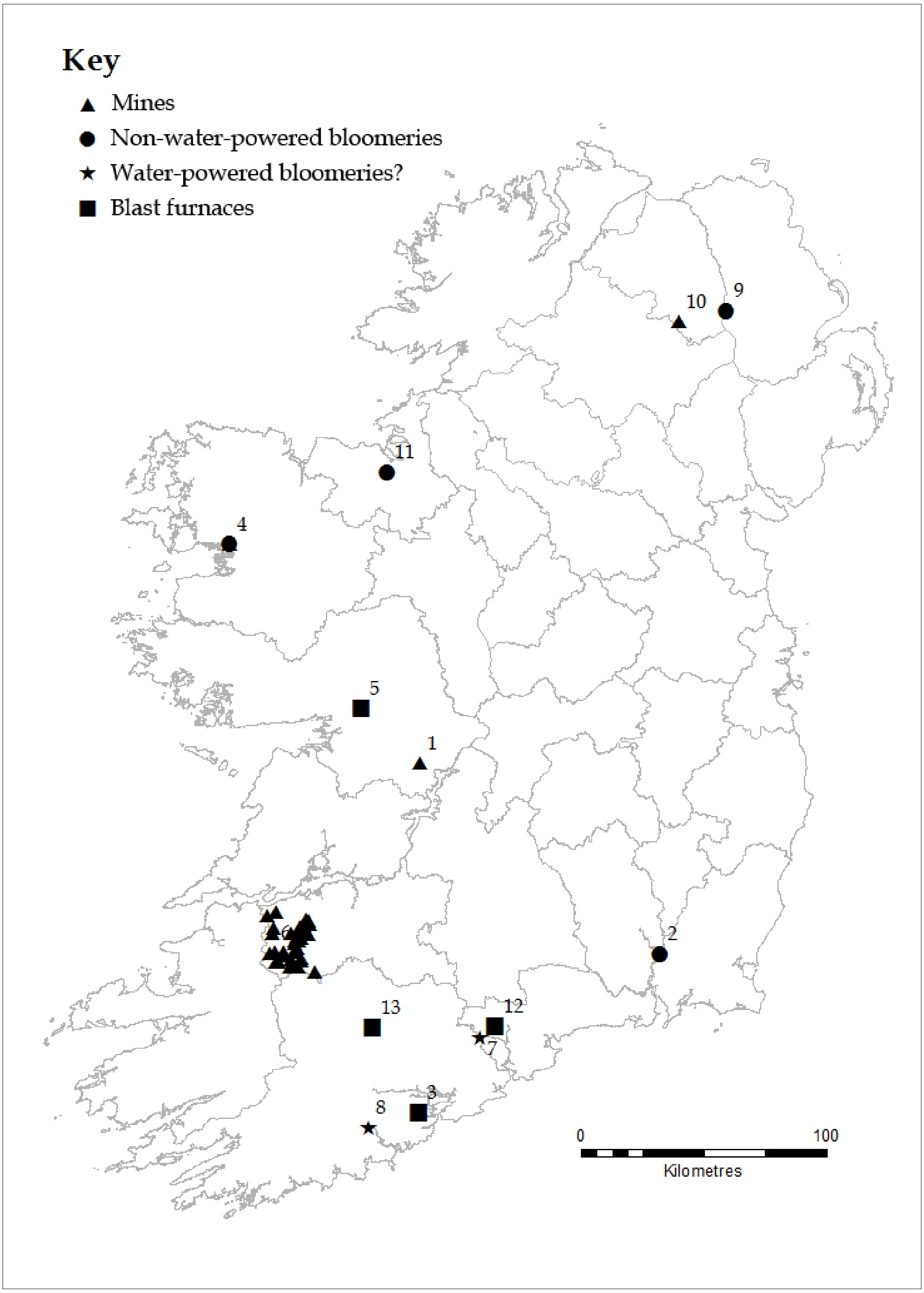


Fig. 5.1 Map of late medieval mines and furnaces in Ireland mentioned in the written sources. 1. Kinaleghin, Co. Galway, 2. Old Ross, Co. Galway, 3. Kerrycurrihy, Co. Cork, 4. Burrishoole, Co. Mayo, 5. Athenry, Co. Galway, 6. Mines in the Desmond Survey (see Appendix 1), 7. Forgepool, Co. Waterford, 8. Kinalmeaky, Co. Cork, 9. Toome, Co. Antrim, 10. Slieve Gallion, Co. Derry, 11. Coylemore, Co. Sligo, 12. Lismore, Co. Waterford, 13. Mallow, Co. Cork

The percentage of iron in the ore at Toome, on the Co. Tyrone and Co. Antrim border, was about 16.6%, somewhat higher than the few values we have for ores used in contemporary bloomeries (see Chapter 10.6.3). At the same place, the iron was subsequently converted into steel in less than an hour. The most likely explanation for this is that the iron produced was actually natural steel, and that the hour was spent on refining the bloom. Steely iron is also recorded as produced at Burrishoole, Co. Mayo, where we might have information on the weight of the blooms produced, or around 20kg. Peter Lombard likewise commented on the durability of iron produced in Ireland, undoubtedly the product of bloomeries. Curiously, the only source with information on the installations used, that of Payne's description of the smith making iron "at his forge", is at odds with what is known archaeologically in Ireland for that period. The only known likely sixteenth-century Irish bloomery furnaces, excavated at Borris, Co. Tipperary [13], are of the shaft-furnace variety, as are the ones known from the preceding centuries (see Chapter 6.2.2). These furnaces are not known to have been placed inside a building, and hardly amount to what would be termed a forge. The majority of sixteenth-century Irish smithing hearths, on the other hand, are simple hollows in the ground and operated at ground level (see Chapter 8.2.1). There is no evidence of smelting in these types of installations, nor would this appear possible. Waist-level smithing hearths will be shown to be correlated with stone-walled buildings (see Chapter 11.4), and this would have been the type of forge that Payne was familiar with. It would thus seem possible that Payne was describing iron smelting in a waist-high installation, which would then appear to refer to some type of open-hearth furnace, water-powered or otherwise.

The reference to Spanish ironworkers in Ireland in the mid-1560s also deserves closer scrutiny. The possibility that they were operating a blast furnace is highly unlikely as only two of these are recorded in Spain by that date and both were used for military purposes (see Chapter 10.5.1). A blast furnace operated by Spanish workers, even for other purposes, is unlikely to have been tolerated in Ireland by the English Crown. That they were operating non-water-powered bloomeries is somewhat more likely. But, as we know from both the same text and the *Red Book*, iron was already being made by the native Irish, undoubtedly in those kind of installations, and bringing over artisans from Spain would only appear to be justified if they were making a special product. This leaves the water-powered bloomery as the technology most likely to have been employed by them. At this period, this type of furnace had already been in use for at least a century and a half in the Basque country (see Chapter 10.3.1). The placename Forgepoole in Co. Cork further potentially alludes to water-powered ironworking in Munster, predating the English take-over of that area.

We are poorly informed about the products made, only in Co. Derry is the fabrication of arms recorded. The comment by Sir Thomas Phillips, that the Irish only make iron to fulfil their own needs and did not consider making a profit “as other people would do” is highly informative. If the same mentality prevailed in Co. Sligo at the same time, the iron levied by O'Hara would then be used by himself and/or distributed among his tenants.

The blast furnace, in contrast, was brought in specifically as part of the development of newly acquired lands (Rynne 2001: 102; 2006: 109–110). The profits which could be made from establishing an iron industry were already alluded to in AD 1541 by the Lord Deputy for Ireland. Profit was also the expressed motive in the Kerrycurrihy and Kinalmeaky plantations and undoubtedly the main reason behind the others. Both land, infrastructure and especially fuel were in good supply and at low cost. In the 1580s, another argument put forward for the setting up of blast furnaces was the removal of woodland cover from the Irish. Where we are informed about the origins of the iron-masters, such as at Athenry, Lismore and on Raleigh's lands, these are invariably from the Weald Counties of Sussex, Surrey and Kent. Anthony Morley, although having Wealden roots, had already set up ironworks elsewhere, much like Lord President Henry Sidney himself. The increase of planned ironworks from the late 1580s onwards is likely to be at least partially the result of the act forbidding the erection of new ironworks in the Weald in AD 1585 (Herbert 1837: 571). As such, the introduction of the blast furnace into Ireland can be seen as part of the broader expansion of the English liquid-iron industry out of the Weald (Schubert 1957: 188–189) (and see Chapter 10.5.1). This new technology appears to have been introduced initially in the province of Munster, where we have evidence of an already established iron industry, possibly using water-power. Elsewhere, iron was likely most commonly produced using non-water-powered bloomeries up till AD 1600.

Chapter 6

The archaeology of iron mining and smelting in late medieval Ireland

Nearly all the references to late medieval iron smelting in Ireland in the published literature describe an industry based on simple “bowl furnaces”, suggesting an activity carried out on an occasional basis, often wasteful and producing inferior products. This model is the result of the identification of bun-shaped slag cakes, small and large, as “furnace bottoms” and associated shallow scoops and pits as the primitive furnaces which produced them (see for example Barry 2004: 108–110; Murphy and Potterton 2010: 445–447). These slag cakes, even the large ones, are now generally accepted as the products of smithing activities (see Chapter 1.2.3). The publication in 2005 of the site at Farranastack in Co. Kerry [61] (Dowd and Fairburn 2005) was important for providing evidence of iron smelting in furnaces which were not bowl furnaces. Around the same time, slag-pit furnaces, shafts of clay built above a pit functioning as a slag receptacle, were beginning to be confidently identified as such and are now seen as the predominant furnace type used in Ireland during the Iron Age and the early medieval period (Carlin 2008: 106–107; Young 2012b: 7). Although several late medieval iron-smelting furnaces have been described as such, this was exclusively in the form of excavation reports on single sites, the majority of which remain unpublished.

As we shall see, no excavated evidence for late medieval iron ore mining is known from Ireland. Some information on the types of ores used can be gleaned from the analysis results of smelting slag. The available information on late medieval smelting sites will be used here to examine the different types of furnaces which were used during that period. Aspects discussed include their physical properties, their waste products, the likely modes of air supply and the wood species employed as fuel. Further insights into the smelting technology will be elucidated from the available analyses of both smelting slag and blooms. It will also be examined if chronological variations can be discerned. The numbers in square brackets refer to the site numbers in the Site Catalogue.

6.1 Mining and ore preparation

There is no archaeological evidence from Irish sites for either mining of iron ore or its preparation before smelting, dated to the late medieval period. The exploitation of bog ore would have left little traces, while the mining of other ore types has to date received no archaeological attention. Somewhat more surprising is the complete lack of evidence for pre-treatment of the ore on the various sites. The same scarcity of convincing finds of ores is also characteristic of earlier Irish smelting sites, the reference to "stocks of ore" at Garryduff, Co. Cork being a rare exception (O'Kelly 1964: 99). One explanation could be offered by Boate (1652: 126), who stated that Irish bog ore would turn to dust or sand after exposure to air. Other reasons could be that ore pre-treatment was carried out elsewhere or that this was not required for the ore types used.

6.1.1 Ore composition

Some indications about the ores used can be gained from the results of the chemical analyses carried out on smelting slag. This, however, has only been carried out on material from six sites of late medieval date (Table 6.1), and in three of those cases the attribution to smelting is unsure. While the slag from Ballyonan, Co. Kildare [9] and Rossan, Co. Meath [114] could have resulted from smelting, the material from Johnstown, Co. Meath [73] is poorly described and its high manganese content can be related to as yet not understood smithing activities. Neither have associated smelting installations recorded.

A high percentage of the same element (Mn) was also observed in slag from two furnaces and an associated dump of probable smelting slag at Borris in Co. Tipperary [13]. The activity at this site was tentatively dated to the late fifteenth to sixteenth centuries based on a radiocarbon date taken on a (bloom?)-smithing hearth located between the two near identical furnaces. Similar high-manganese contents are rare, but were encountered on two sites (1 and 3) in the same townland of Camlin, Co. Tipperary. At both sites, the ironworking was considered early medieval and the slag interpreted as related to smelting (Young 2011c: 1–2; 2011d: 3, 6). Two samples from site 1 contained 13.7 to 22.8% MnO, depending on the sample and the method of analysis (Young 2011c: 14–15). A smithing hearth cake from the same site also had an elevated manganese content, that is to say 10 to 12.3% MnO. Two samples from the second site contained 11.8 to 15.7% MnO (Young 2011d: 25–26). When we look at the available analysis data for Irish iron ores, the only two with elevated manganese levels are the haematite ores from Calliagh, Co. Monaghan and Co. Cavan and the bog ore recovered during the excavations at Ballyvourney (6.24%, 6.20% and 22.70% respectively) (see Chapters 4.1.4 and 4.2.2). As the manganese would have fully entered the slag by the end of the smelting stage, the levels of this metal in the haematites could perceivably result in the observed levels in the Borris [13] slag. The Ballyvourney ore would lead to a much higher manganese content in the slag if smelted purely. So, either an as yet unidentified iron ore with elevated manganese was used at Borris [13], or a low manganese ore was smelted together with very manganese-rich bog ore. The low manganese content of the smelting slag from Ballykilmore, Co. Westmeath [7] was seen as an indication of the use of manganese-poor bog ore.

Based on the high titanium content (up to 0.60% TiO_2) of some of the objects in the Carrickfergus [19 and 20] material, Scott (1976: 203) suggested a link with the nearby laterite ores, which contained a high amount of the latter metal (between near zero and 10.80% TiO_2) (see Chapter 4.1.4). But neither the bloom from the same site (0.03% TiO_2) (see below) nor the slag inside it (0.17% TiO_2), that is to say smelting slag, showed above-average titanium levels. The smithing slag from the same site (see Chapter 8.2.10) had mostly 0.17% TiO_2, with only two examples of high levels (0.67% and 0.83%). The Carrickfergus [20] smithing slag values were also very average compared to the analysis results from the same type of material from elsewhere. A possible explanation for the high titanium levels in some Carrickfergus [19 and 20] objects might lie in the wide date range of the material. As this includes the seventeenth century, the objects might have been produced through the indirect (blast furnace) process, during which any titanium in the ore would migrate into the iron (Buchwald 2008: 304).

Sites	P_2O_5	CaO	TiO_2	MnO
Ballykilmore, Co. Westmeath [7]	0.59	6.04	0.10	0.53
Ballyonan, Co. Kildare [9]	n.d.	14.64	0.42	9.29
Borris, Co. Tipperary [13]	0.44	2.41	0.16	11.26
Carrickfergus, Co. Antrim [19/20]	0.39	0.14	0.17	0.13
Johnstown, Co. Meath [73]	4.08	5.47	n.d.	9.13
Rossan, Co. Meath [114]	0.34	6.19	n.d.	5.45

Table 6.1 Chemical analysis results of late medieval Irish smelting slag

The phosphorus levels are generally low for all samples, except Johnstown [73] which had a high content of that element (4.08% P_2O_5). The calcium content of the samples varied from low (Borris [13] and Carrickfergus [20]), over medium (Ballykilmore [7] and Rossan [114]), through variable (Johnstown [73]), to high (Ballyonan [9]). Both these elements can indicate the use of bog ore for smelting, but can occur in high quantities in other ore types (see Chapter 4.3). Opinions about the behaviour of phosphorus in bloomery smelting vary widely, while calcium, to a certain extent, can also be derived from the fuel (see Chapter 3.2.1).

6.2 Smelting

6.2.1 Site distribution

Despite the fact that the number of late medieval smelting sites is limited, their distribution can provide some insights (Fig. 6.1). Although the area with the highest concentration of excavations, no smelting sites dating to the late medieval period were recorded with certainty within the Pale, that is to say the region around Dublin with the strongest Anglo-Norman influence. This would suggest a low level of iron smelting in this area. The lack of sites in the north of the country, on the other hand, is probably the result of the dearth of excavations carried out in non-settlement environments. On the rest of the island, two apparent concentrations stand out. The first is located in the midlands around the borders of Counties Meath, Westmeath and Kildare. Here, four sites dated to the late medieval period were recorded, Ballyonan, Co. Kildare [9], Johnstown, Co. Meath [73], Rossan, Co. Meath [114] and Ballykilmore, Co. Westmeath [7]. The exact process leading to the slag from the first two sites however, is not fully clear. A fifth site in the same area, in the townland of Kiltotan and Collinstown, Co. Westmeath, belonged to the centuries before the late medieval period. The second possible concentration is located in the north-east of Co. Kerry, where two smelting sites were excavated in the adjoining townlands of Dooneen [45] and Mullaghmarky (AR016) [105]. A third furnace (AR024) [106], located in the latter townland and similar in technology to the one found at Dooneen [45], but not in size or construction details, was not directly dated.

6.2.2 The furnaces

It is now generally accepted that the most common, and near-exclusive, type of furnace used for smelting iron ores in Ireland from the Iron Age until the tenth century was the slag-pit furnace (Carlin 2008: 107; Young 2009h: 7; Dolan 2012: 197). The slag-pit furnace consists of a clay shaft constructed above a circular pit which is filled with organic material, mostly pieces of wood. Around the first century BC, evidence for arches at the bases of these furnaces appear (Young 2010c: 40). After the furnace is charged with ore and fuel, the smelting process results in the formation of bloom and slag. The bloom will form at the base of the clay shaft, while some of the slag will run into the underlying pit and char the organic fill, which often results in large rectangular hollows being visible in the slag. Other slag will solidify below the bloom at the top of the pit as a spongy mass (furnace cake).

The slag-pit furnace, which before the tenth century was nearly exclusively employed, seems to slowly disappear from the archaeological record. One of the latest example at Ballykeoghan, Co. Kilkenny was dated to the tenth century. Here, an isolated pit was uncovered yielding ironworking residues (Wren 2010a). This pit measured 0.4 by 0.23m and was 80mm deep (ibid.: 17). It contained a small amount (236g) of fine-grained smelting slag typical of slag-pit furnaces, suggesting that this was the remains of a furnace pit of which the upper part was truncated (Young 2010d: 81). This feature was not dated, but the fill of a pit located further east, containing a small piece of slag (56g) with clear flow-structure and the impression of a large fragment of wood, was dated by radiocarbon analysis on an oat grain to the late ninth to late tenth centuries (Wren 2010a: 84). Another potential example of the same type of furnace, at Kiltotan and Collinstown, Co. Westmeath, was dated to the tenth to eleventh centuries (Richardson 2009). One of the features on this site, a circular pit measuring 0.47m diameter by 0.15m deep, had a heat-affected base and sides (ibid.: 6). The slag it contained consisted of small pieces of fluid slag, furnace lining, amorphous slag and two broken smithing hearth cakes, some 635g in total (Fairburn 2009b: 32). Radiocarbon analysis on a fragment of oak charcoal returned a likely late tenth- to early eleventh-century date (Richardson 2009: 6, 29). Although both the fluid and the cake-shaped slag were seen as the result of smithing, the shape of the feature resembled more closely a furnace pit than a smithing hearth. The cake-shaped slag could then either represent furnace cake or bloom-smithing debris.

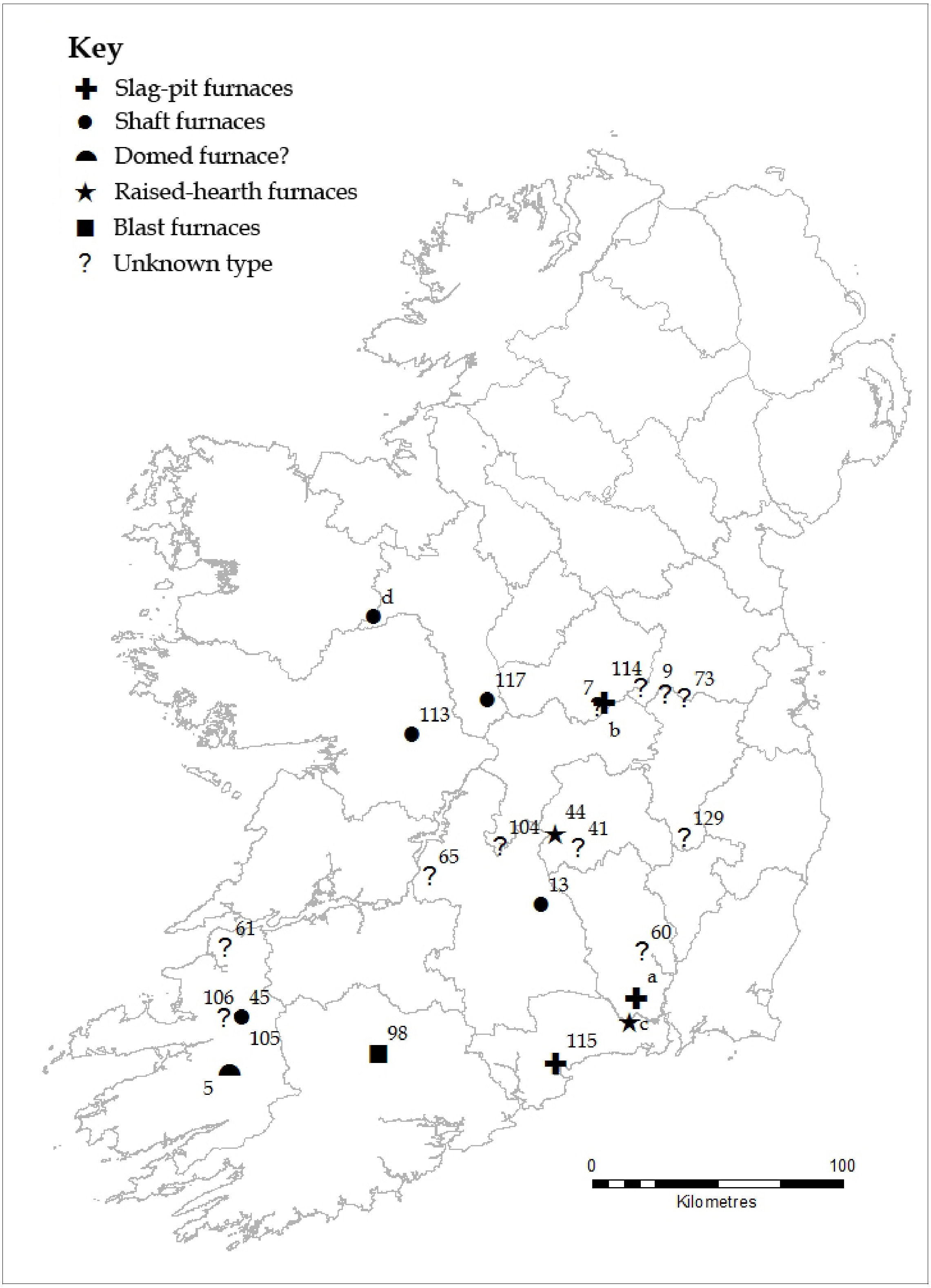


Fig. 6.1 Map of Irish archaeological sites with evidence for late medieval iron smelting. a. Ballykeoghan, Co. Kilkenny, b. Kiltotan and Collinstown, Co. Westmeath, c. Woodstown, Co. Waterford, d. Cuilmore, Co. Mayo. The numbers refer to those in the Site Catalogue

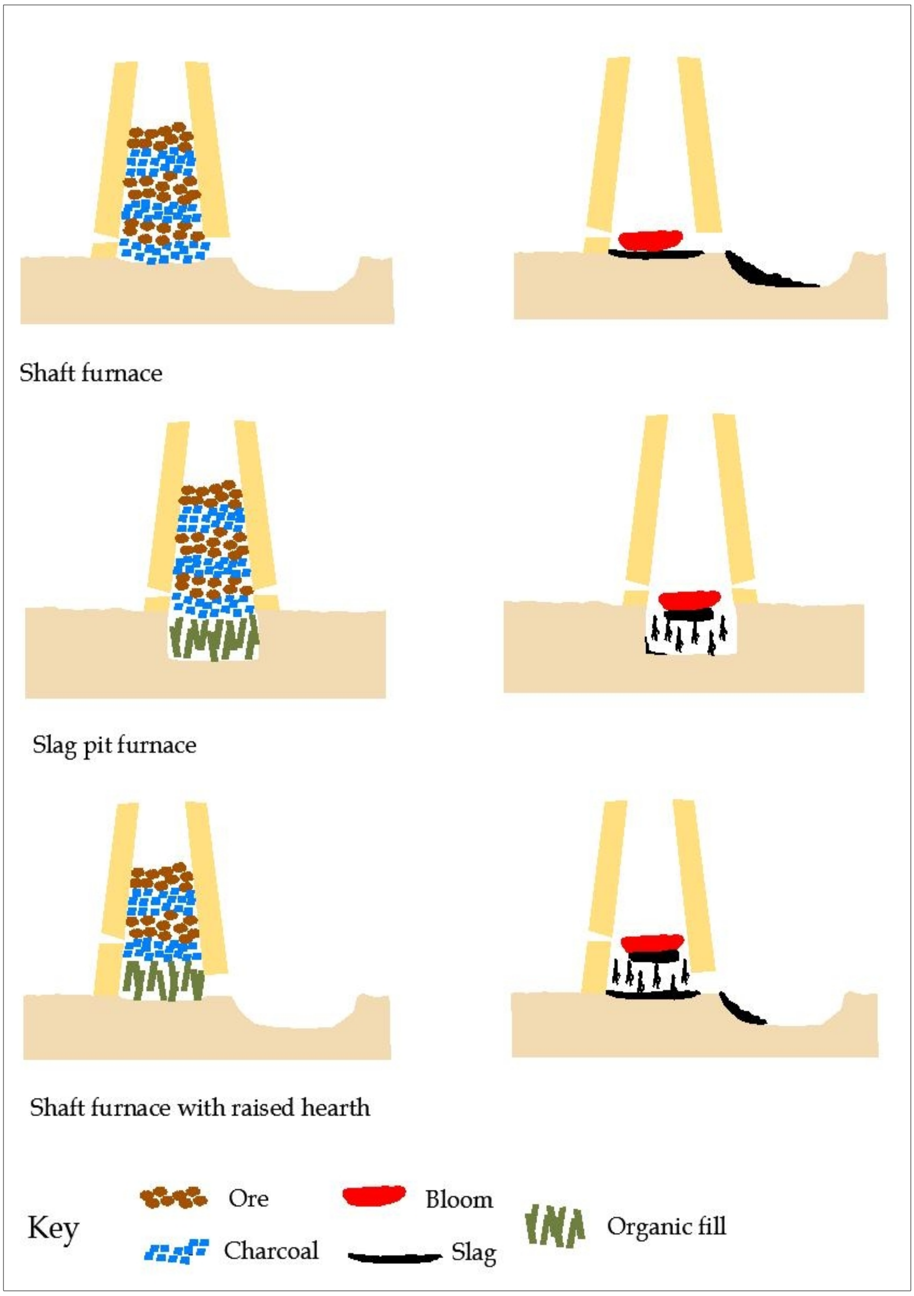


Fig. 6.2 Irish late medieval bloomery furnace types, before and after firing. The Ballydowny [5] furnace is not represented due to the lack of technical evidence.

The slag-pit furnace at Shandon, Co. Waterford [115] (Fig. 6.3a) could represent the use of this type of installation into the late medieval period, but here the dating evidence is circumstantial. The smelting slag from this site was typical for slag-pit furnaces: small drippy pieces of dense slag, often showing impressions of large pieces of wood (Fig. 6.3b) The lack of this kind of furnace from the thirteenth to sixteenth centuries is even more striking as, due to having a slag-tapping pit, they have a better chance of being preserved and found than furnaces predominantly built on the ground surface.

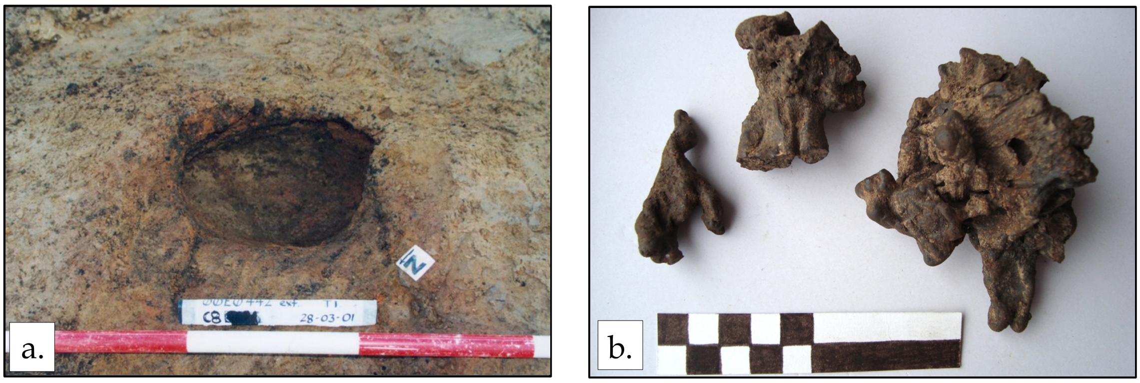


Fig. 6.3 Slag-pit furnace, Shandon, Co. Waterford [115]. a. Furnace C. 2008 (Elder et al. 2012: 108), b. Drippy furnace pit slag from the same furnace

A different type of furnace was excavated at Woodstown in Co. Waterford, which was located in the partially silted-up terminus of the enclosing ditch of a Viking longphort (O'Brien et al. 2005: 45). Detailed analysis of this feature led to the conclusion that it was most probably a shaft furnace with lateral slag-tapping facilities, possibly re-organized as a smithing hearth after use (Young 2009h: 3, 8). At its base, the furnace measured 0.55m externally and 0.3m internally. The slag, which resembled tap slag, seems to have solidified on the base of the furnace, and not in an external tapping-pit. No wood impressions were noted on the *in situ* slag within the furnace, but they were present in slag deposited elsewhere in the same ditch, and in one case the impressions were potentially located at the top of the slag (ibid.: 2, 19, 24). This would seem to imply that the furnace hearth was located higher than its base and the space in between these was filled with wood pieces, as in the slag-pit furnace. The furnace also had evidence of an arch at its base (ibid.: 3). The date of the enclosing ditch, and the furnace, was first believed to be situated between the fifth and seventh centuries, based on several radiocarbon dates taken on material from fills of the ditch, including one of the furnace fills (O'Brien et al. 2005: 15).[47] Subsequent research, aided by additional radiocarbon dates, has convincingly argued that the early radiocarbon dates, which were taken from oak charcoal, were the result of “old wood-effect” and that the site, including the ironworking in the ditch, should be seen as dating to the ninth and tenth centuries (Russell et al. 2007: 18–22).

A similar, relatively well-preserved furnace was excavated at Derrinsallagh 1, Co. Laois [44] (Fig. 6.4). Likewise, no slag-pit was present, while the slag showed clear flow-structure and impressions of large wood fragments. The furnace was built around

47 Confusingly, in the introduction to the article, the furnace is described as 'Viking-type' (O'Brien et al. 2005: 17).

two protruding pieces of natural limestone on top of which an arc-shaped structure of limestone blocks with an external diameter of c. 1.2 by 1.2m was constructed. The internal diameter was calculated at around 0.7m. In front of the furnace, a circular tapping pit was constructed.

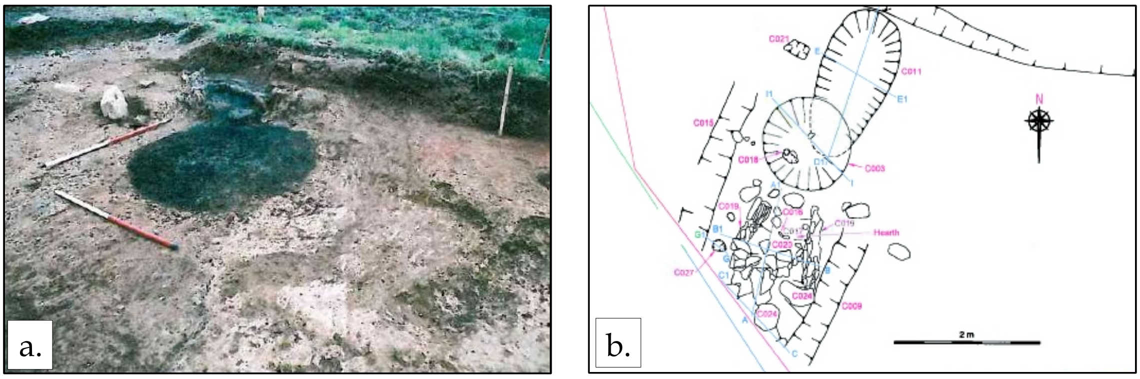


Fig. 6.4 Shaft furnace with raised hearth, Derrinsallagh 1, Co. Laois [44]. a. Furnace C.025, b. Post-ex. plan of the same (Lennon 2009a: 81, 84)

The same type of slag, showing flow structure and large wood impressions, was also recovered from Taduff East, Co. Roscommon [117], but the evidence for a furnace base was slight and the material could have been brought in from elsewhere. This type of furnace is seemingly unique in Europe, but a similar principle was recently described from northern Cameroon (David 2010). Here, a horseshoe-shaped clay ledge was constructed on the inside of the furnace about 0.3m above ground level (ibid.: 43). A tuyere about a metre long was inserted vertically into the furnace down to the level of the clay ledge. This led to the formation of a ring-shaped bloom and drippy slag prills (ibid.: 43–44). The difference with the Irish furnaces is that the space between the elevated hearth and the base of the latter was filled with organic material (wood fragments), in a similar way to the slag-pit furnaces. These would also probably not have had an internal clay rim, nor the long tuyeres. It is suggested to use the term "shaft furnaces with raised hearth" for the Irish examples of this type of installations.

Several other examples, at Cuilmore, Co. Mayo, Dooneen, Co. Kerry [45], Mullaghmarky AR024, Co. Kerry [106], Rathglass, Co. Galway [113] and Borris, Co. Tipperary [13], were interpreted as examples of classic shaft furnaces with lateral slag-removal. The earliest of these, at Cuilmore, probably dates to the eleventh century, and clearly testifies to this type of furnace being in use before the arrival of the Anglo-Normans. At Cuilmore, Co. Mayo the furnace was uncovered during sand-removal for a golf course (Grant 2004: 143). The feature, according to an observer, was pear-shaped and about one metre maximum length. The wider end consisted of a clay-lined, bowl-shaped pit which contained slag and charcoal. Several pieces of this slag were retained by the landowner and consisted of large pieces broken off even large blocks, were dense and had characteristic ropey upper surfaces (ibid.: 154). Four pieces weighed respectively 3000, 2700, 2500 and 952g, the smallest of which was described as very brittle and fragile with frequent charcoal inclusions. These inclusions from within this slag were subjected to radiocarbon analysis, which returned a late tenth- to early twelfth-century date (ibid.: 155). Charcoal retrieved from another nearby feature, without metal-working residues, returned a similar date (ibid.: 143, 155). Both the description of the feature and especially the slag suggest that this feature was a shaft furnace with lateral slag-tapping.

In the case of Dooneen, Co. Kerry [45], the residues pointed to lateral slag-removal, and the lack of a tapping pit suggests that the badly truncated remains (C.1/2) represent the base of a shaft furnace (Fig. 6.5). The activity was dated to the mid-thirteenth century by radiocarbon analysis.

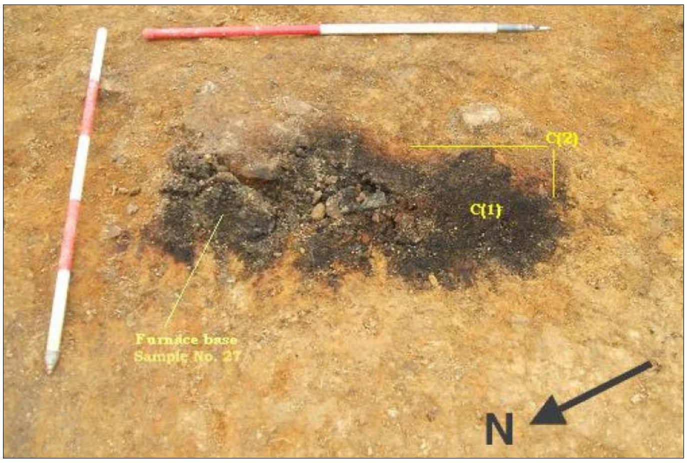


Fig. 6.5 Likely shaft furnace, Dooneen, Co. Kerry

The furnace at Mullaghmarky AR024, Co. Kerry [106] was a convincing shaft furnace, but was not directly dated. A nearby charcoal-production pit returned a fifteenth- to seventeenth-century radiocarbon date. The Rathglass [113] furnaces were relatively convincing examples of furnaces with lateral slag-removal, both equipped with elongated tapping-hollows (Fig. 6.6). The largest furnace had a slightly earlier radiocarbon date, late thirteenth to fourteenth centuries, than the smaller one, which dated to the fourteenth century.

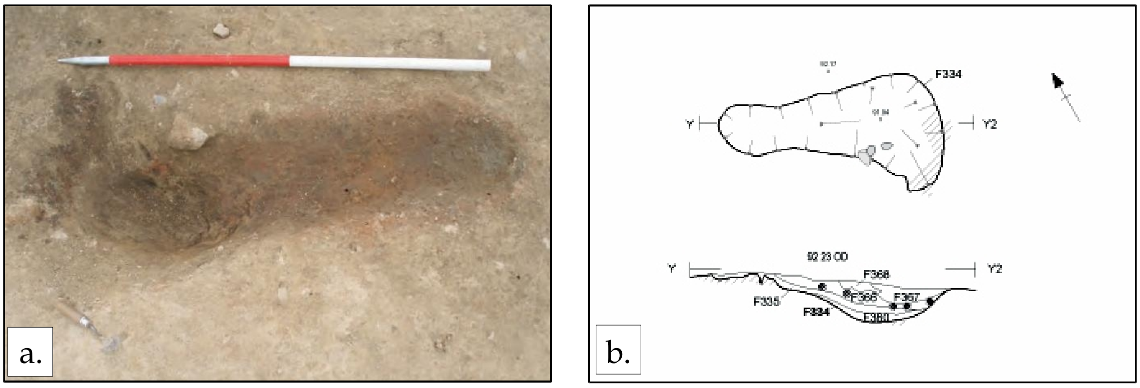


Fig. 6.6 Shaft furnace, Rathglass, Co. Galway [113]. a. Post-ex photograph of furnace C.334, b. Plan and section of the same (Pétervåry 2009: 186, 198)

Two clear examples of shaft furnaces, although originally interpreted as smithing hearths, were excavated at Borris, Co. Tipperary [13]. Both were very similar, although differing in hearth-size, with sunken oval furnace bases and large pieces of tap slag in their respective tapping-pits (Fig. 6.7). The furnaces were (re-)dated, based on their likely connection to nearby activity which potentially represents bloom smithing, to the late fifteenth to sixteenth centuries.

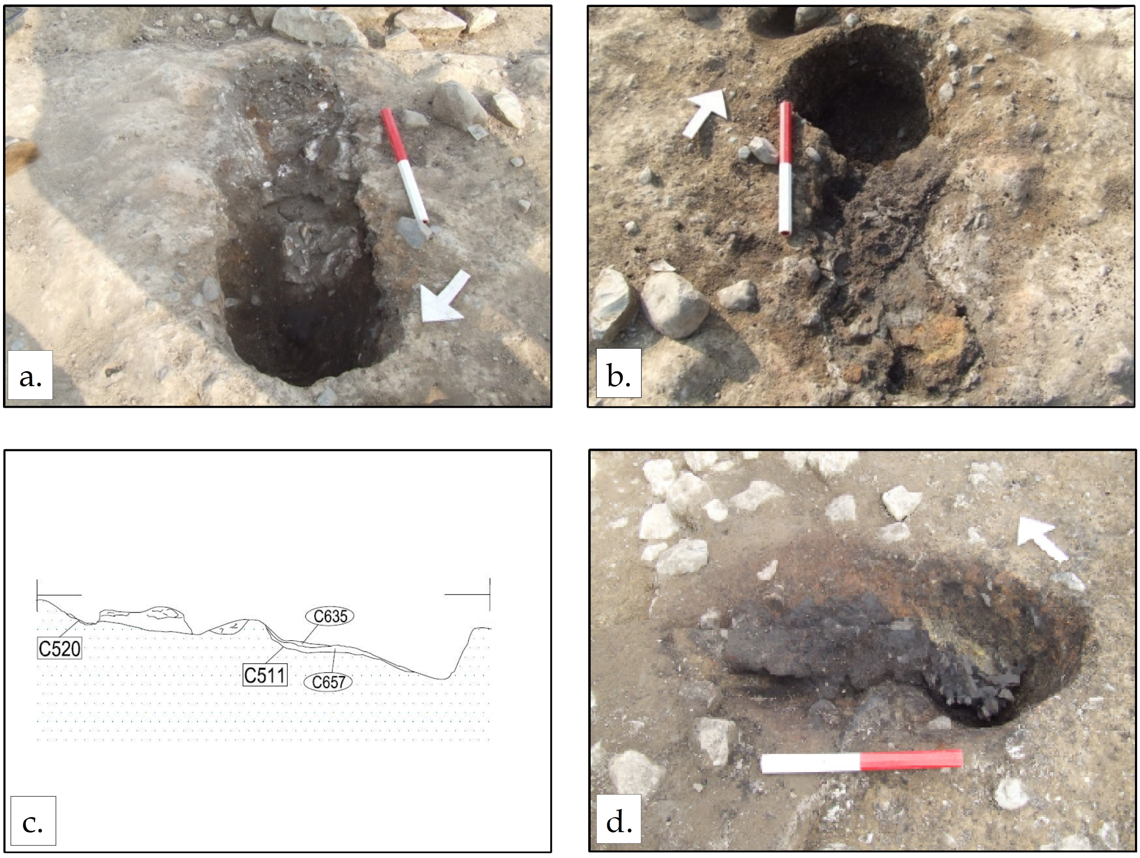


Fig. 6.7 Shaft furnaces, Borris, Co. Tipperary [13]. a. Furnace C.511, from the north-east, b. Same furnace from the south, c. North-east facing section of the same furnace, d. Furnace C.306 from the south-west,(Wallace and Anguilano 2010b: 379, 381, Stevens 2010: 275)

The mid-thirteenth-century furnace at Garraun, Co. Tipperary [65] and the fourteenth-, likely early fourteenth-, century furnace at Mullaghmarky AR016, Co. Kerry [105] were possibly also shaft furnaces, but the remains were too poorly preserved to allow positive identification. In some cases, for example at Mullaghmarky AR024 [106], the back of the furnace was dug into the natural subsoil, while at others, like at Mullaghmarky AR016 [105], Rathglass [113] and Borris [13], the furnaces would have been free-standing. Comparable examples of the deep tapping-pits in front of the Borris [13] furnaces were not found outside of Ireland. Smelting slag from Carrickmines Castle, Co. Dublin [22] was interpreted as originating in a shaft furnace, but dating evidence was lacking, while the presence of a shaft furnace was claimed at the site at Farranastack, Co. Kerry [61], but the available evidence was inconclusive. At several other sites at Curragh, Co. Laois [41], Dysart, Co. Kilkenny [60] (Fig. 6.8), Ballykilmore, Co. Westmeath [7] (Fig. 6.9), Woodlands West, Co. Kildare [129] and Moneygall, Co. Offaly [104], which produced smelting slag, it is also unclear which type of furnace was used.

Fig. 6.8 Smelting slag, Dysart, Co. Kilkenny [60]

Fig. 6.9 Smelting slag, Ballykilmore, Co. Westmeath (scale: 100mm) (Young 2012c: 420)

The furnace at Ballydowny, Co. Kerry [5], with an oval base measuring 1.17 by 0.65 by 0.18m (Fig. 6.10a) and containing a large piece of slag weighing about 20kg (Fig. 6.10b), has no known comparisons. It is here tentatively interpreted as a domed furnace, which is not recorded as being used in this period anywhere in Europe, while the large slag block would set it apart from the earlier British and continental European domed furnaces.

Clearly recognisable furnace-wall fragments were recorded in conjunction with the slag-pit furnaces at Shandon, Co. Waterford [115], while the vitrified lining recovered at Derrinsallagh, Co. Laois [44] is very likely similar material. A review of

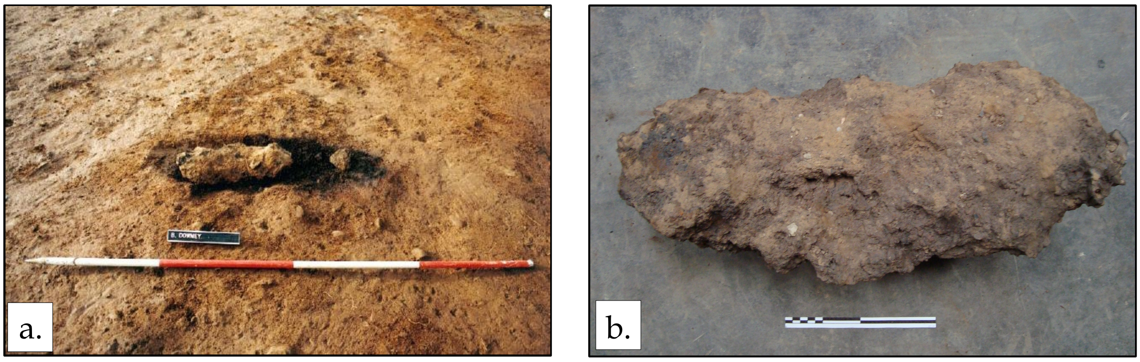


Fig. 6.10 Domed (?) furnace, Ballydowny, Co. Kerry [5]. a. Furnace C.28 (Kiely and O'Callaghan 2010: 35), b. Large piece of slag from the same furnace.

the remaining residues would be necessary to establish if the other sites did indeed not have furnace wall fragments. If these are absent from these later sites the explanation cloud lie, partially, in the methods of discovery, i.e. by mechanical digger, or possibly indicate that the furnace was left standing during bloom removal and subsequently decayed.

At only one site, at Mallow, Quartertown, Co. Cork [98], were remains found related to blast furnace iron smelting predating AD 1600. Here, several fragments of dense slag adhering to clay-luted stone-work (Fig. 6.11) were found at the location of Sir Thomas Norris' ironworks which operated in the 1590s (see Chapter 5.3). Subsequent excavation at the spot revealed a large dump of cinders originating from the nearby nineteenth-century flour-mills, but no further remains of the earlier ironworking venture.

Fig. 6.11 Finery slag with adhering clay-luted stone-work, Mallow, Quartertown, Co. Cork [98].

When we consider the internal diametres of the Irish late medieval ironsmelting furnaces, even if many of the measurements are approximate values, we see a clear evolution towards larger internal diameters (Table 6.2). Internal diameter of the furnaces up to the mid-thirteenth century average around 0.3 to 0.4m diameter, while after this period the average is around 0.5 to 0.7m. This would seem to imply a larger bloom being produced in the more recent installations. Similarly, again allowing for imperfect structural and dating evidence, an evolution away from the classic shaft furnace can be noted during the late medieval period. The four furnaces likely to be the most recent are either shaft furnaces with raised hearths (one clear example at Derrinsallagh [44] and one less so at Taduff East [117]), the Ballydowny [5] domed furnace and the shaft furnaces with steep tapping-hollows at Borris [13]. The contemporary corn-drying kilns at Rathglass [113] and Borris [13] could indicate at least part of the iron was destined for agricultural use.

Sites	Furnace type	Internal dimensions	Approximate date
Woodstown, Co. Waterford	Shaft furnace (raised hearth)	0.3m diam.	9th to 10th centuries
Ballykeoghan, Co. Kilkenny	Slag-pit furnace	0.4 by 0.23m	10th century
Kiltotan and Collinstown, Co. Westmeath	Slag-pit furnace?	0.47m diam.	10th–E11th centuries
Cuilmore, Co. Mayo	Shaft furnace	?	L10th–E12th [11th] centuries
Shandon, Co. Waterford [115]	Slag-pit furnace Slag-pit furnace	0.28 by 0.23m 0.46 by 0.4m	12th–13th centuries? 12th–13th centuries?
Garraun, Co. Tipperary [65]	Shaft furnace?	0.47 by 0.39m	M13th century
Dooneen, Co. Kerry [45]	Shaft furnace	c. 0.44m diam?	M13th century
Mullaghmarky 016, Co. Kerry [105]	Shaft furnace?	0.54 by 0.45m?	14th [E14th]century
Mullaghmarky 024, Co. Kerry [106]	Shaft furnace	0.75 by 0.7m diam.	?
Rathglass, Co. Galway [113]	Shaft furnace Shaft furnace	c. 0.8 by 0.6m c. 0.5m diam.	L13th–14th centuries 14th century
Ballydowny, Co. Kerry [5]	Domed furnace?	1.17 by 0.65m	M13th–L14th centuries
Taduff East, Co. Roscommon [117]	Shaft furnace (raised hearth)?	c. 0.57m diam?	14th [E–M14th] century
Derrinsallagh, Co. Laois [44]	Shaft furnace (raised hearth)	c. 0.7m diam.	E15th century
Borris, Co. Tipperary [13]	Shaft furnace Shaft furnace	c. 0.8m diam. c. 0.58m diam.	L15th–16th centuries? L15th–16th centuries?

Table 6.2 Excavated Irish iron-smelting furnaces (10th to 16th centuries). Sources for the sites without Catalogue number, see text.

6.2.3 Air supply

The lack of tuyeres, according to Pellequer, is one of the indications that a furnace was operated with natural draught (see Chapter 3.4.3). Alternatively, however, this could also imply that iron tuyeres were used, which would be much rarer in the archaeological record in comparison to their ceramic counterparts. At both late medieval Irish smelting sites where ceramic tuyeres were recovered, Shandon, Co. Waterford [115] and Ballykilmore, Co. Westmeath [7], these were of the same type as is usually found on smithing sites, although the examples from the latter site were much larger. It is highly unlikely that these would have been inserted in a furnace wall and are regarded as connected to bloom-smithing activities (see Chapter 8.1.10). It would then appear that the late medieval iron-smelting furnaces in Ireland either operated using natural draught or bellows with iron tuyeres.

6.2.4 Fuel

At only two sites, Garraun, Co. Tipperary [65] and Dooneen, Co. Kerry [45], was the charcoal directly related to the furnaces identified (Table 6.3). In both cases the most common species was oak, while the smaller amounts of other species or porous diffuse wood could represent tinder used for starting the fire.

Site	Date	Wood species
Garraun, Co. Tipperary [65]	M13th C	Oak (74 frag.), hazel/alder (4 frag.), alder and willow (1 frag.).
Dooneen, Co. Kerry [45]	M13th C	Predominantly oak, some porous diffuse wood.

Table 6.3 Identification of charcoal from late medieval Irish iron-smelting furnaces

6.2.5 Blooms

To date, two blooms of a late medieval date have been chemically analysed and metallographically examined. A small piece of iron bloom was recovered from thirteenth-century levels during the excavations at Cathedral Hill, Downpatrick in Co. Down [26] (Schubert 1957: 140) (Fig. 6.12). Metallographic examination of the bloom showed it consisted of ferrite (Tylecote 1977). The examination of a bloom fragment found at 11–17 Market Place, Carrickfergus, Co. Antrim [20], dated to between the twelfth and seventeenth centuries, revealed this to be made up of ferrite and pearlite, with uneven carburization and random carbon distribution. Chemical analysis of these blooms show very similar low values for carbon (both 0.08%, the value for the latter is an average between 0 and 0.15%), phosphorus (respectively 0.061% and 0.06% P) and manganese (0.02% and 0.03% Mn respectively). Particles of bloom material inside a piece of slag from Ballykilmore, Co. Westmeath [7], contained 0.42% of calcium.

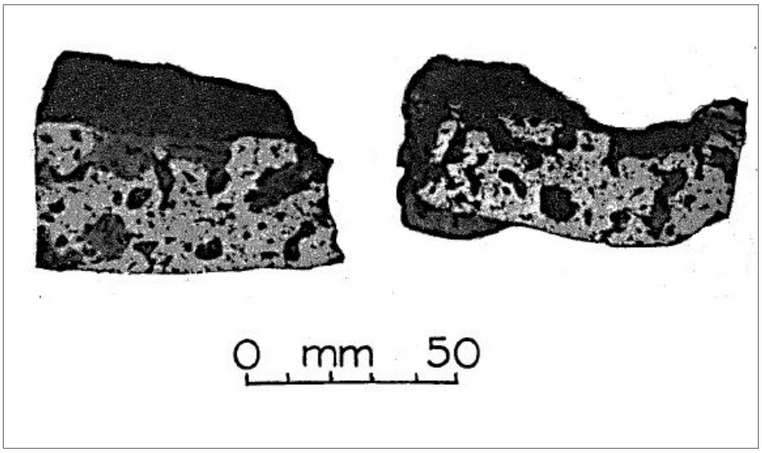


Fig. 6.12 Bloom fragment from Cathedral Hill, Co. Down [26] (Tylecote 1977: 83)

We have seen that the use of high-manganese ores is one of the more successful ways to produce natural steel and the values from the smelting slag from Borris, Co. Tipperary [13] at 10.6 to 11.8% MnO are very similar to the manganese oxide content of the slag trapped inside a natural steel bloom at Castel-Minier, Ariège in France which varied between 4 and 25% (see Chapter 3.2.1). High levels of manganese were also encountered at Ballyonan, Co. Kildare [9] (9.29% MnO), Johnstown, Co. Meath [73] (9.13% MnO), where the late medieval date is uncertain, and to a lesser extent at Rossan, Co. Meath [114] (5.45% MnO), where it is not established if the slag is the result of smelting.

6.3 Conclusions

Due to the paucity of excavated sites and the uneven scope of specialist analysis carried out on the sites, our knowledge of late medieval iron smelting in Ireland remains limited. Several points of interest, however, can be made.

There were at least three different types of furnaces used in that period: traditional shaft furnaces, shaft furnaces with raised hearth and the Ballydowny [5] furnace, possibly a domed furnace. The first category seems to have been the most prevalent type, but in many cases only the slightest remains of the furnaces themselves were preserved. As such, they were often recognized by the associated tap slag and their tapping-pits. The latter vary from shallow hollows, such as at Dooneen, Co. Kerry [45], to substantial vertical-sided pits at Borris, Co. Tipperary [13]. The installations described as shaft furnaces with raised hearths remain poorly understood. The raised hearth is suggested because of the lack of a tapping-pit under the furnaces, while the associated drippy slag shows signs of having flowed over large pieces of wood. Examples of both these varieties of shaft furnaces are known from the period preceding the Anglo-Norman invasion; at the Viking longphort at Woodstown, Co. Waterford for the raised hearth version and at Cuilmore, Co. Mayo for the classic shaft furnace. The possible example of the domed furnace from Ballydowny, Co Kerry [5], with its slag piece of 20kg is unique for Ireland. Striking is the lack of slag-pit furnaces in the records, with only one potential example known from the very beginning of the research period at Shandon, Co. Waterford [115]. This type of furnace would have been near-ubiquitous in early medieval times, and before, and would be expected to be encountered more frequently in the archaeological record due to the chance of survival of the underlying pit.

Several observations concerning the technology used can be made. What is clear from the available dimensions of the furnaces is that their internal diameters become larger as the late medieval period progresses. This would appear to imply the production of larger blooms in the fifteenth and sixteenth centuries compared to the two previous centuries. The lack of finds of tuyeres, which could have been used in the smelting process, would suggest that the furnaces were operated either with natural draught or with iron tuyeres. Concerning the type of fuel used, little can be said due to the limited sites where charcoal from the actual furnaces was examined. At the two sites where this happened, the species was near-exclusively oak. Of particular importance is the smelting site at Borris, Co. Tipperary [13], where analysis on three assemblages of smelting slag showed a very high content of manganese, that is to say over 10%. The use of high-manganese ores is now recognized as the main method of producing natural steel blooms and will indeed result in a high content of that metal in the smelting slag. At several other sites a similar high-manganese content was observed, but here neither the designation as smelting slag nor the dating were unclear. The late medieval bloom fragments analysed from Ireland showed these to be wrought iron, low in carbon, phosphorus and manganese. Finally, the pieces of likely finery slag from Quartertown, Mallow, Co. Cork [98] represent the only known material remains relating to the smelting of iron in the blast furnace in Ireland before the seventeenth century.

Chapter 7

The written sources relating to late medieval smithing in Ireland

Although smiths themselves, and other references to smithing, are often recorded in late medieval documents, this information, in Ireland or elsewhere, has not been studied in any detail to date. As will become clear, the late medieval sources for Ireland contain only minimal information on the technologies used. They do, on the other hand, give us information on the position of the smiths in late medieval society, an aspect often difficult to grasp by using only archaeological sources. This includes their status in society, specialization of craft and, of special interest to late medieval Ireland, the ethnicity of the smiths. The problems involved with identifying smiths, and their ethnicity, in the documentary sources is elaborated upon in the first sub-chapter. After this, the relevant information on iron smithing in non-urban settings will be presented in a chronological fashion, followed by the sources for the cities. Finally, the limited information on military smithing will be discussed.

7.1 Ethnicity and trades

The deduction of ethnicity from names in late medieval Ireland is problematic. Many examples show that shortly after the coming of the Anglo-Normans, English first names were taken by the Irish, while English surnames were also adopted, for legal reasons, certainly as early as the late thirteenth century (Otway-Ruthven 1965: 79). Later on, the adoption of English surnames by the Irish, at least in the Pale, became a legal requirement, as witnessed by an act from AD 1465 (Vesey 1765: 29). Intermarriage between Irish and English (Foley 2011: 206) and the evidence of many immigrants from further afield (see below) further obscures this picture.

The usual designation in medieval Latin for a smith was *faber*, literally “maker”. In some cases, this term was also used to denote carpenters, but then normally always followed by *lignarius*. A different version of the occupational surname *faber* is *le Fevre*/*Feure*/*Fevere*/*Feuere* (*fèvre*, smith). William Faber, rent collector at Saggart, is also recorded as William le Feuere (see below), Peter Faber, owner of 25 acres on the manor of Swords, is known as Peter Feure in AD 1331 (Crooks 2012: 5 Edw III/13) and Robert Faber from Old Leighlin (see below) is called Robert le Fevere in another document, together with the same defendants (CJR 1308–1314: 85). On the other hand, the goods of Peter le Fevere at Drogheda in AD 1305 included his house and a workshop, but the mention of four stone of lead, and no iron, might suggest that he was predominantly working non-ferrous metals (CJR 1304–1307: 82). The occupational surname le Kopersmith does appear in the Dublin Guild Merchant Roll for the year AD 1263/64 (Connolly and Martin 1992: 109). These occupational surnames start to become hereditary, and no longer designate a person's trade, from around the beginning of the late medieval period, but do still occur until the end of it. It is important to remember that the designation as smith also applies both to somebody involved in secondary blacksmithing, as well as a smelter of iron ores, while a smithy could be either a forge or a furnace (Moorehouse 1981: 774).

The fact that families involved in ironworking became part of the Norman nobility before their invasion of England, further complicates matters. It is impossible to know if people with surnames like le Marescallus, and so forth, (*maréchal*, farrier) or Ferrours (*ferrière*, iron worker) were family members of the powerful Marshal or Ferrers families or just humble smiths. To complicate matters even further, a marshal was also an official present on certain manors, such as those of the Bishop of Cloyne (MacCotter and Nicholls 1996: passim). Undoubtedly, a number of the people named le Marescal(lus) recorded in the Dublin Guild Merchant Roll would have been farriers (Connolly and Martin 1992: passim), but it would be impossible to distinguish them from the non-metalworkers. Several of the recorded smiths are connected to two locations, for example William of Corc who joins the Dublin Guild Merchant. As this research is mainly concerned with occurrences of smithing activities taking place, these smiths will be counted twice (once as smithing in Cork and once in Dublin). Sons of smiths, regularly appearing in the written documentation, although in many cases probably smiths themselves, were not included in the discussion below, except when it was clear where the son himself was active as a smith.

7.2 Sources for rural smithing

7.2.1 Thirteenth-century sources

Several smiths listed in the Dublin Guild Merchant Roll came from outside the city (see below). We have Walterus Lorimar of Kilmainham and William the smith from Carrickfergus (*Crofergus*), both before AD 1222, Nicholas the Lorimer, or maker of bits, bridles, and so forth, of Castledermot (*Tristledermot*) (AD 1239/40) and Patrick the smith from Clontarf (AD 1243/44) joining the guild (Connolly and Martin 1992: 36, 49, 75, 80). After AD 1250, Nicholas the smith from Cellbridge (*Kildroth*), Co. Kildare (AD 1250/51), John the smith from Finglass (1259/60) and Walhinius the smith from Downpatrick (*Doune*) (AD 1263/64) also join the same organization (ibid: 90, 95, 101, 108).

From other sources we hear of Willelmus de Galetrim [= Galtrim, Co. Meath] son of Symonis the smith, around AD 1220 (St John Brooks 1936: 174) and in AD 1224 the canons of St. Thomas' Abbey of Dublin granted two carucates of land in Grenan in Odoth [= Grenan, Co. Laois] to Richard the smith at the yearly rent of one mark, or two-thirds of a pound (Archdall and Moran 1876: 43). In the sheriff's accounts for the Honor of Dungarvan for the years AD 1262/63, two smithies and fisheries are included in the rent of the town itself, which amounted to £13 14s (Curtis 1931: 2). A further £8 6d was received from Rosmyr [= Rossmire parish, Co. Waterford] with a smithy and two mills per the English there (ibid.: 3). It is unclear if the English held only the mills or the smithy as well. An inquisition at Tristledermot [= Castledermot, Co. Kildare] in AD 1264 heard that Ricardus faber, living outside the manor of St. Sepulchre [or Colonia] near Dublin city had stolen cloth and cheese (HMDI: 145) and in AD 1269, Petrum le Feure and his wife are said to have held half an acre and a sixth of an acre, with dependencies in the manor of Cottrelstown, Co. Dublin (St John Brooks 1936: 153–154). We also hear of Henry the smith of Swords, who was witness to legal proceedings in Dublin around AD 1280 (St John Brooks 1936: 159). From this period onwards we have more references to smiths and smithing on the Anglo-Norman manors.

The best set of manorial records for this period, although only partially published to date, are those for the Bigod manors in the south-east of the country. In the accounts for the manor of Old Ross for AD 1280/81, the provost was compensated for paying 9s for the keep of the smiths, who are listed as servants (Hore 1900: 17). In the same accounts, moneys disbursed for iron are recorded and a newly bought plough-coulter cost 5d (ibid.: 15, 17). In the next transcribed account for the same manor, for AD 1282/83, iron is again purchased and the smith is paid wages for repairing the ironwork on the plough (4s) and shoeing heifers (6d) (ibid.: 23). In the account for the next year, AD 1283/84, the wages of the smith amount to 8s for making the ironwork for four ploughs and 4s 1d for shoeing the ploughing heifers (ibid.: 30).[48] The same account also has 11s 1d expended on iron for repairing four ploughs, but also a coulter and two ploughshares made from "home iron" at the very low cost of 8 ½d. It also includes a pick (2d), a hammer (1d) and three agricultural forks (2d), all made of home iron. The servants of the manor are dealt with separately in the same account. The Old Ross account for AD 1284/85, was published both by Hore (1900) and Lyons (1982), who give differing transcriptions:

Hore 1900: 34	Lyons 1982: 20	Lyons 1982: 21
Iron for the repair of 5 ploughs, 10s	*In ferro empto in sustenacione [cancelled: iiii] v carucarum per predictum tempus*	In iron bought for the maintenance [cancelled of four] of five ploughs during the aforesaid time
Making 1 coulter and 2 ploughshares, 8 ½d	*In j cultro et ij vomeribus de ferro proprio faciendo viij d. ob.*	In the making of one coulter and two plough shares of iron 8 ½d.
For one "lirelig"[49] made of the home iron ¾d	*In j berleg' de ferro proprio faciendo ob. quart.*	In making one pole/shaft? of iron ¾d.
	In stipendio fabri fabricantis ferramenta dictarum carucarum per predictum tempua v s. iiij d.	In the stipend of the smith making the aforesaid irons of the said ploughs for the aforesaid time 5s 4d.
	In ferrura v affrorum per predictum tempus xxij d. quart.	In the shoeing of 5 affers for the aforesaid time 22 ¼d.

Table 7.1 Comparison between transcriptions by Hore and Lyons of the Bigod manor account for Old Ross AD 1284/85.

It is clear from the above that the "home iron" mentioned by Hore is recorded as *ferro proprio* in the accounts, which can also be rendered as "own iron". In the Old Ross accounts, all iron bought appears to be for the ironwork of the ploughs, while the shares, coulters, lireligs and various tools were made from the *ferro proprio*. Although the two earliest accounts are vague, the *ferro proprio* does not seem to be left-over iron from

48 A half-yearly account within the same year records a slightly higher amount paid to the smith for making the ploughs (8s 1d), while only 16d had been paid for shoeing the heifers.

49 Although there is a difference of opinion on the transcription of this word, it is probably the same as the lezerlegges [small iron fittings] mentioned in the Priory of Holy Trinity Accounts. These lezerlegges cost 2d apiece.

earlier purchases. If this is correct, it would be a strong indication that the *ferro proprio* did not have to be accounted for and therefore likely produced on the estate. Lyons (1981) published a transcript of the account for AD 1285/86 of the manor of Ballysax, also owned by the Bigods, wherein moneys expended for both iron and finished implements are recorded (see Table 7.2). The difference in cost between buying new implements at Ballysax and having them made by the smith from *ferro proprio* at Old Ross was around twice the amount: two ploughshares and a coulter, 14d vs. 8.5d and a lirelig, 1.66d vs. 0.75d. Although expenses for shoeing heifers are included, the Ballysax account does not mention wages for smiths.

Year (source)	Iron bought	Implements bought	Smith's stipends	*Ferro proprio*
AD 1280/81 Old Ross (Hore 1900: 15, 17)	For supporting 2 ploughs, 12d., for the waggons, 2s.	5 forks for the sheepfold, 10d., repairs to the same, 4d., 400 nails, 10d. , 1 coulter, 5d., nails, 22d.	9s ("the smiths")	
AD 1282/83 Old Ross (ibid.: 23)	[unspecified] 6s		For repairing the iron work of the plough, 4s ("the smith"), for shoeing heifers, 6d.	
AD 1283/84 (half a year) Old Ross (ibid.: 27)	For 4 ploughs, 8s 1d	A lock, 2d, another lock, 2 ½d, another lock 5d	For repairing the iron work of the aforesaid ploughs, 4s ("the smith"), for shoeing heifers, 16d	2 forks, 2d
AD 1283/84 Old Ross (ibid.: 30)	For the reparation of 4 ploughs 11s 1d	3 hoops for binding the plough 2d.	For making the iron work of 4 ploughs, 8s ("the smith"), for shoeing heifers, 4s 1d.	1 coulter and 2 plough shares 8 ½d., a pick, 2d., a hammer, 1d., 2 agricultural forks, 2d.
AD 1284/85 Old Ross (ibid.: 34, Lyons 1982: 20–21)	For the repair of 5 ploughs, 10s.		For making the aforesaid irons of the said ploughs 5s 4d. ("the smith"), for shoeing 5 heifers, 22d.	1 coulter and 2 plough shares, 8 ½d, 1 lirelig ¾d.
AD 1285/86 Ballysax (Lyons 1981: 46)	16 ½ stone, 7s 2d.	14 plough shares, 4s 2d. [4 ½d per plough share], 13 lerleggis 21 ½d. [1.66d per lerleg], 1 garb of steel, 7d.	For shoeing heifers, 3s.	

Table 7.2 References to iron and smiths in the published Bigod accounts for Ireland

The accounts for the Old Ross manor for AD 1287 records a smith named Kerr at Kylcolman[50] and another at Baliconhuer[51] (Hore 1900: 36). The name Kerr is potentially Irish and a Ralph Ker is recorded as a cottar at Cloncurry, Co. Kildare among near exclusively Irish names (Murphy and Potterton 2010: 190), but could also be from Scotland where the name is common. A Robert Kerd from Ayr is recorded in Dublin in AD 1260/61 (Connolly and Martin 1992: 102). An inquisition in AD 1307 into the Bigod manors, records that the burgesses at Fothered, Co. Carlow[52] paid 4 horseshoes or 4d in rent per year for what is variably translated as each/a smith's house (CJR 1304–1307: 346; CDRI 1302–1307: 174), each smithy (CIPM 1300–1307: 305; Dryburgh and Smith 2007: 70) and a smith's workshop (Mills 1892: 54).

Around the same period, smiths, or their offspring, were responsible for collecting rents of two of the four royal manors within the Pale. William the smith paid the farm of the manor of Taxagard [= Saggart, Co. Dublin] into the Treasury on several occasions between AD 1284 and 1293 (PRIE 1272–1284: 77 (le Fevere); CDRI 1285–1292: 86, 105; PRIE 1287–1294: 25; CDRI 1293–1301: 24–26, 29), while John, son of the smith, paid £24 worth of rent from the manor of Newcastle Lyons in AD 1289 (CDRI 1285–1292: 233). In the extent of Old Coillath [= Coolaghmore][53], Co. Kilkenny of AD 1287/8, Reginald Faber is stated as formerly possessing two burgages and twelve acres, but now only holding two and a half acres and a stang for which he yearly pays 5 ½d (Dryburgh and Smith 2005: 284).

From AD 1297, we have the interesting agreement between the King of Oriel, Brian macMathghamhna and his chieftains with Bishop of Armagh, Matthew MacCathassaigh. The former concluded that the leaders of the kerne would not exact "from shoemakers, smiths, weavers or other persons practising the mechanical arts who dwell on church lands on the pretext of any customs which have been wrongfully used up to now" (Nicholls 1971: 417). From around this time onwards, many smiths are also recorded as renting land on geographically widely dispersed manors. In AD 1298/99, on the manor of Senede [= Shanid Upper/Lower, Co. Limerick], listed under the land of the Irish, five acres near the castle are held by the smith at 2s per year (CDRI 1293–1301: 258). Ph[ilip?] le Feure is recorded as tenant in Ballymacduflyn, Co. Tipperary[54] in AD

50 Tentatively identified as near Ballylane, Co. Wexford (Orpen and St John Brooks 1934: 58).
51 Unidentified.
52 Or Castlemore, in the current parish of Grangeford (Lyons 1984: 54).
53 See (Williams 2007: 99).
54 Probably related to Foilmacduff, Co. Tipperary. One of the co-defendants, William son of Roger de la Sale is charged with drunkeness and agression in Cashel, relatively closeby, eight years later (CJR 1304–1307: 116).

1297 (CJR 1295–1303: 12) and William le Feure, of Kil [= Kill, Co. Kildare] is charged with being in the company of robbers the following year (ibid.: 195). Finally, we have a few rare Gaelic-Irish sources mentioning smiths in the thirteenth century. The *Book of Fenagh*, generally dated to the thirteenth century, mentions a smith at the church settlement of Fenagh, Co. Leitrim, while in Co. Cavan, chieftain Brian Mag Shamhradháin, at the end of that century, had smiths fashioning tall spears for him (Simms 2004: 154).

7.2.2 Fourteenth-century sources

At a hearing at Tristledermot [= Castledermot, Co. Kildare] in AD 1305, Roger the smith, together with others including a tailor, two crockers, two fishermen and two masons, are recorded as having been confiscated of twenty acres of wheat and oats worth 40d per acre in the town of Leghlyn [= Oldleighlin, Co. Carlow] (CJR 1304–1307: 110–111). In the same year, the extent of the manor of Donkeryn in King's County [= Dunkerrin, Co. Offaly], the land of Andre the smith is valued at 8s per year (White 1932: 150) and a year later, in AD 1306, a court case concerning Clondalkin in Co. Dublin, reveals that Robert the smith held eight acres of land sown with wheat of the Prior of Christ Church Cathedral, valued at 16s (CJR 1304–1307: 254). Again in AD 1305, Walter le Feure of Lyouns [= Newcastle Lyons, Co. Dublin] is one of many people arrested for diverse felonies (ibid.: 484). David Faber is recorded as holding 6 acres at Davyiston, part of the manor of Dunfert [= Danesfort, Co. Kilkenny] in AD 1307 (Dryburgh and Smith 2007: 80). The following year, Richard le Feure of Rathcoul [= Rathcoole, Co. Dublin] is on record as possessing a cauldron of another worth 20s (CJR 1308–1314: 38).

The extent of the lands of the barony of Kilka [= Kilkea, Co. Kildare] taken in AD 1311, records Gilvino, smith and lorimer (*lorimar*), paying 6s 6d for a house called the Tolselde, or the tholsel, at Tristeldermot [= Castledermot, Co. Kildare] (ibid.: 13). In the same year, Reginald the smith, a free tenant, is recorded as holding three and a half acres for 2s 4d in the manor of Coureduff [= Corduff, Co. Dublin] (ibid.: 26) and a William le Feure had a chest, kept in St Micheal's Church in Athy for safekeeping, broken into (CJR 1308–1314: 227). The Archbishop of Dublin had given twenty-five acres of land, in the manor of Swords, to Peter the smith, who held it between AD 1314 and 1320 (PRIE 1307–1317: 65; 1319–1327: 15, 22; CPR 1317–1321: 204). Similarly, the rental of the manors of Holy Trinity Church, dated c. AD 1326, has a Hugh Faber holding at Glasnevin in Co. Dublin one messuage and one croft and sixteen acres and a half stang, for which he yearly paid 18s (Mills 1891: 190), while at the town of Kill of the Grange in Co. Dublin, Thomas Faber held property for which 14s was paid per year, next to services in kind or 3d and Patrick Faber held property for which 18s was paid annually, next to work or 4 ½d (ibid.: 196–197).

Laurence Faber is recorded as a witness at the manor of Lucan in both AD 1316 and 1334 (COD 1172–1350: 210; CCCD Vol. 2: 99). From the 1320s, we have two records of the contents of a smithy and its value. The first is included in an inventory of the possessions of Richard Bagod of the manor of Baggotrath, the castle of which was located near present-day Baggotstreet in Dublin, where an anvil, two small hammers and two tongs were valued at 4s (Connolly 1976: 72). From the year 1326, we have the inventory of the possessions of the Knights Templar in Ireland, where at the manor Kilcloggan in Co. Wexford, smith's tools were listed (Mac Niocaill 1967: 200–201; translation Colfer 2004: 56). Next to various iron objects and implements, an anvil is valued at 2s, as well as two large *malholi* (probably hammers) and two *folles* (bellows) at the same price.

In the rental for the manor of Maynooth, Co. Kildare for AD 1328/29, Radulfo fabro paid 6d and is described as a *firmarius*, a customary tenant (Mac Niocaill 1964b: 100). In AD 1333, the manor at Tollogwhan, near Loughrea, Co. Galway, is described as formerly having a hundred and twenty acres and three stangs of arable land which tenants used to hold for a yearly rent of 109s 5d, but which were by then lying uncultivated due to the war and the poverty of the tenants; there were also thirteen acres held by the lord’s smith, paying 13s (Smith 2004; Dryburgh and Smith 2007: 149). In the same year, a Johannes Faber, a cottar, was mentioned at the manor of Lisronagh in County Tipperary (Curtis 1935: 48) and Willelmo faber acquired a messuage with extensions in the manor of Kilmainham owned by the Knights Hospitalers (McNeill 1932: 36). The latter Willelmo is likely the same as Willielmus fabro who got a grant of the office of smith at Kilmainham two years later in 1335 (ibid.: 70). Shortly after, in AD 1339, Johannes Staunton, smith, also received a grant of the office of smith in another house belonging to the Knights Hospitalers at Any [= Knockainy, Co. Limerick] (ibid.: 108). In AD 1349 David le Ferrour is employed at the forge at Kilmainham (ibid.: 133). In the Christ Church accounts for their manor at Gormanstown in Co. Meath for the years AD 1337/39, the expenses included £4 14s 3d for ploughs bought, mending of them, making and mending of plough iron and wages of the servants, presumably including smiths (Mills 1891: 22).

Between AD 1338 and 1341, the escheator for Ireland records the case of a smithy in Kells, Co. Meath, leased by Adam le Mareshal, which was taken into the King's hands because John le Dyer, the owner of the yearly rent of 2s, gave this rent "to provide light" before the Holy Cross of the Church of St. Columba, Kells, without royal licence (PRIE 1338: 47; 1338–1339: 36; 1341–43: 30). In AD 1342, in a document relating to the dividing of an inheritance, Laurence Okachan, William Obrenan, David the smith, and Thomas Oconstyn are listed as the cottagers and betaghs of the manor of Lecdoun[55] (Mills and McEnery 1916: 114).

In the accounts of the Priory of the Holy Trinity (Christ Church) for the year AD 1343/44, which seem to include entries covering all their manors, five bends and sixteen pieces of iron, a small amount of steel, four ploughshares, eighteen "lezerlegges"[56] and other iron items such as nails are purchased (Mills 1891: 29–31, 40–41). Seemingly, three smiths (or the same one was paid multiple times?) were employed for making various pieces of iron, for which they were paid per piece. In AD 1344/45, 6s 8d was paid to a smith to make and forge ploughs at the Christ Church manor of Clonkeen, Co. Dublin, "by fixed agreement" (ibid.: 55). During the same period, sums of money were expended for two bends and a half of iron for maintaining and making ploughs (10s) and four ploughshares were bought new (2s).

John Smythe is recorded as paying 40d a year for a cottage in the town of Cloyne in 1364 (MacCotter and Nicholls 1996: 12–13) and in AD 1351, an inquisition into the manor of Nobber, Co. Meath revealed that a rent of four horseshoes a year was collected from the place (*placia*) of Richard Belmount at Nobber, Co. Meath, described as "a smith's place" (*locus fabri*) (Lawlor 1911: 287–288). William Fraunceys, smith, in AD 1369, received a grant of a premises south of the highway in Lucan (CCCD Vol. 2: 118). It is unclear from the document if this property was used for smithing purposes.

7.2.3 Fifteenth- and sixteenth-century sources

We have references to Thomas Russell, *smyth*, holding a messuage in Kilcock (*Kylcoke*), Co. Kildare in AD 1418 worth 2s 4d per year (RCH: 222), John Walsh,

55 Lecdoun is located somewhere near Kilkeary, Co. Tipperary based on internal evidence and could be the same as Ballinalick, south of Nenagh in the same county.
56 These are undoubtedly the same as the lireligs/lerleggis recorded in the Bigod accounts (see above).

smith, paying rent for a tenure in Grennagh, Co. Kilkenny[57] in AD 1434 (COD 1413–1509: 108) and Janyne O'Cowane, smith, at an unknown location in AD 1442 (ibid.: 133). An overview of the economic activities of the Gaelic Irish by Nicholls (1983: 7; 1987: 417–418) only mentions Irish smiths in the O'Doyne lordship in Co. Laois rendering sixteen horseshoes to O'Doyne and eight to each of his horsemen in the late sixteenth century. In the ordnance accounts for AD 1538, John Ryan, smith, is mentioned at Maynooth (Trainor 1949: 329) and in the proctor accounts for Christ Church Cathedral for AD 1564/65, Morris, smith at Clonkeen and the smith at Clontarf are recorded (Gillespie 1996: 44). Most other smiths referred to in the second half of the sixteenth century, however, are those granted English liberty and pardons as recorded in the fiants[58] of the various rulers (Table A.1)

There is a further interesting reference to a grant of English liberty to John, alias Hans Haws, smith in AD 1561 (CPCRI I: 461). Judging by his name, John, or Hans, is likely German. Earlier, in AD 1558, a similar grant was given to Pier or Peter Perryne and Pier or Peter Trymlett, French travelling smiths (Fiants Philip and Mary: 89). Not only did foreign smiths operate in Ireland in the mid-sixteenth century, but several Irish are recorded as working as apprentices in Bristol to become smiths. In AD 1553, Jarman, son of Edmund Rawlin of Cork in Ireland, a smith, started his apprenticeship under Richard Barry, smith, and Katherine, his wife (Ralph 1992: 10). The next year, John Mathew, smith, and Agnes, his wife, accepted Dennis, son of Dennis Tagan, of Balrodie[59] in Ireland, as an apprentice (ibid.: 28). In AD 1560, Murtock, son of Martin Agamis, from Culmore[60] in Ireland was accepted as apprentice to John Hampton, smith, and Alice, his wife (ibid.: 87).

Finally, we have two records of smiths connected to the hostilities at the end of the sixteenth century. The first concerns Francisco de Cuellar, a captain sailing with the Spanish Armada, whose vessel was wrecked on the County Sligo coast in AD 1588, was, according to his own version of events, held as a slave by a smith and his wife where he was employed in blowing the bellows (O'Reilly and de Cuellar 1896: 207). A researcher on the subject, Francis Kelly (pers. comm.), is of the opinion that the event took place in Glenaniffe valley in Co. Leitrim. The other source is a reference to a

57 In Pollrone parish, as other places mentioned in the rental Dunfenane, Polrothan and Clogagh are recognizable as Doornane (Dún Fhionnáin), Pollrone (Poll Ruáin) and Clogga respectively. Perhaps Grange townland?

58 Fiants were warrants to the Irish Chancery dealing with appointments, grants, etc.

59 In the publication, this is interpreted as Balyronie and can signify Ballyroney, Co. Down, Balruddery, Co. Dublin or another place.

60 This could be any of the numerous places called Kilmore or Cuilmore in Ireland.

certain Spaniard, meeting in AD 1594 with Feagh M'Hugh O'Byrne, who was living in the Wicklow/Wexford border area, and who subsequently set all his smiths to making pike heads (CSPI 1592–1596: 248).

7.3 Sources for urban smithing

7.3.1 Dublin

The Dublin Guild Merchant Roll, the List of Free Citizens and various early deeds give us an idea of the number and variety of smiths then operating in the city (See Appendix 3, Table A.2a). Striking is the frequency, especially early on, of lorimers recorded which would have entailed both copper- and ironworking. Lormery or Lormeria is recorded as lying in Castle Street in AD 1236 (CCCD Vol. 1: 44), and more specifically north of this street in AD 1326 (Berry 1919a), that is to say in the current Temple Bar area. We have further evidence for a sword maker (*sparthax*) (before AD 1222), an arrow-smith (AD 1227–28) and, in the list of free citizens for the city, an armourer (before AD 1234). We also have several references to locksmiths, especially in the second half of the period covered by the Guild Roll, perhaps reflecting more stability and prosperity, and hence requiring the protection of wealth. In that same period, and maybe for the same reason, many of the new member smiths come from abroad from England (Tickhill, Chester, Gloucester, Northampton, Bedwyn, possibly Exeter and Birmingham), Wales (Cardigan), Scotland (Ayr and Newton) and France (Beauvais and Paris). Robert Smethe, the only one not described as Faber, is potentially German, or more likely Flemish in origin. From AD 1285 we have a record of Thomas FitzNorman giving 40d “out of a workshop” towards Christ Church (Lawlor 1909: 40), but it is unclear if this is a smithy.

Very few smiths are recorded in the fourteenth century (Appendix 3, Table A.2b), but we do have a mention of an additionally recorded armourer, Nicholas Hodderode, renting a place in Scarlettislane, now Upper Exchange Street. The situation for the first half of the fifteenth century is similar to the preceding century (Appendix 3, Table A.2c), but thanks to the survival of the Dublin Franchise Rolls, and especially its recent full transcription by Lennon and Murray (1998), we are very well informed about the smiths in Dublin in the second half of that century and beyond (Appendix 4). Interestingly, we have four cases of female smiths, three of whom were either armourers

(Jenet Cornell) or apprentices of armourers (Isabel Brun and Alice White). The other female smith was Anastasia Flemyng. Of specific interest to the question of ethnicity is the career of Maurice Segyn/Sogyn. Together with two family members who were leather workers (cordwainers) he was granted English liberty of the city in AD 1431/32 and is recorded as of the Irish nation (RCH: 253; Berry 1919b: 267). Two smiths are admitted to Franchise after finishing their apprenticeship under Maurice in AD 1468 and 1469 (Lennon and Murray 1998: 1, 3) and in AD 1473, when the Guild of Smiths of St. Eligius was created, Maurice Sogyn is listed among its founding members (Le Fanu 1930: 155).[61] One of the stipulations of the founding charter of that same guild was that apprentices should be of the English nation (ibid.: 157). It is clear that ascribing an ethnicity to Maurice Segyn would be difficult and it is likely to have changed during his lifetime. The latter fifteenth century also witnesses the Cornell family gaining considerable standing, with William, the armourer, recorded as proctor of the parish of St. Werburgh's on several occasions between AD 1454 and 1470 (Berry 1919a: 288, 290, 304; CARD I: 320, 343–344), followed by his son Christopher between AD 1490 and 1500 (Empey 2009: 51, 58, 59; Berry 1919a: 307). In AD 1470, Patrick Ley, father of Jenet who will later marry one of the Cornells and become an armourer herself, is proctor for Thomas Street (CARD I: 343–344).

We are also relatively well informed about Dublin smiths in the sixteenth century (See Appendix 3, Table A.2d). Between AD 1505 and 1507, a John Armorer is proctor for St Werburgh's parish (Empey 2009: 83). One of the few documents informing us in more detail of the activity of smiths are the proctor accounts of Peter Lewis for Christ Church Cathedral for the year 1564/65 (Gillespie 1996). The accounts relate to building work at the church at that time, the smithing component of which was mostly carried out by Thomas Frencheman. Some of the smithing activities include work at the church itself, such as mending a lock (ibid.: 31), and making a buckle for the bell (ibid.: 45–46), window frames (ibid.: 48), spikes for nailing the roof (ibid.: 42, 80) and iron “sperres” for fastening the collection box (ibid.: 97). A Mr. Baranes also made iron bars for the windows (ibid.: 106). Thomas Frencheman further made the teeth for two sand racks (ibid.: 24). Most of the work, however, consisted of making and repairing tools for the quarrymen. Sometimes this consisted of making the tools, such as a pickaxe (ibid.: 31) and spade heads (ibid.: 40, 44), but mostly the work was related to

61 Although there is a considerable time span between this date and the grant of liberty, which might suggest it concerns different people with the same name, evidence in Berry (1919b) and various deeds in the Small Private Accessions of the National Archives (http://www.nationalarchives.ie/PDF/SmallPrivateAccessions.pdf) would suggest otherwise.

the mending, sharpening and steeling of tools. The latter had to be carried out often "because the stone is so hard it eats the steel" (ibid.: 95). The steel was frequently purchased separately and is described as being set into the iron tools (ibid.: 90).

7.3.2 Kilkenny

From c. AD 1264, we have a grant to Rogero de Leon of the plat (*plateam*) next to the Bishop's house, extending from next to St Canices' church, in the Irishtown part of Kilkenny, to the east side of the plat of Padinus, the arrowsmith (*faber sagittarius*) (Berry 1908: 125). In AD 1348, one messuage with appurtenances was granted to Robert "the Whyte", smith, in length from the highway to the great wall of Kilkenny and in breadth between the messuage of William Byford, chaplain, on one side and the messuage of John, son of John Spicer, on the other (COD 1172–1350: 340). Kilkenny is the only town in Ireland where extensive references exist to a forge run by the local authorities. The earliest record referring to this dates from AD 1307 when David le Marshall is stated as holding a forge in Kilkenny at the will of the lord, Joan of Acre, Countess of Gloucester, and paying for this 2s a year (CDRI 1302–1307: 187; CIPM 1300–1307: 328). In the 1380s[62] the *Liber Primus Kilkenniensis* lists Clemens Smith as paying 12d for holding the forge from Kilkenny corporation and Maurice Fleming, dyer, 3d for a messuage next to this forge (*le Forge*) (McNeill 1931: 70). Thomas Exham held the "common forge" in the early fifteenth century at 2s (ibid.: 86, 88), while around the 1430s it was in the hands of Nicholas fitz Henry for the same amount (ibid.: 83). In AD 1448 John White paid 6d for the forge (ibid.: 82) and in AD 1473 Richard Smith paid 2s for the forge that Nicholas Henry held for the community (ibid.: 100).

In AD 1508, Walter Courcy, sovereign of Kilkenny, grants the forge "by Crokker's Corsse" by the assent of the community to Nicholas Oge Smith on lease for 50 years rendering 4s per year (ibid.: 117). "Crokker's Corsse" is undoubtedly Croker's Cross, the market cross previously located in the middle of the junction of The Parade, Patrick Street, High Street and Rose Inn Street (Prim 1853: 220). Ten years later, in AD 1518, an indenture between Peter Butler, Earl of Ormond and two burgesses, wherein the Earl lets a "messuage with appurtenances … in length from the toll-house (*tollenario*) of the town on the north to the common smithy (*fabricam communem*) on

62 The dates are deduced from mayors mentioned together with the quoted events and compared to the list of Kilkenny sovereigns (visible at http://archive.is/kgvu) and other internal evidence from the sources consulted. These should be treated as approximate.

the south, and in breadth from the main street (*magne strata*) of the town on the east to a small lane (*vinellam*) on the west" for ten shillings per year (COD 1509–1547: 54).

The location of the toll-house, or tholsel, of Kilkenny was situated by the mayor-elect of Kilkenny, John Hogan (1880), at what was then the Victoria Hotel, or where today the IAB bank is located, in the row of buildings between the southern end of High Street and Pudding Lane. Although agreeing with local lore and placing the old city goal of Kilkenny at the northern-most end of this row of houses, the author dismisses the claim that this was also the location of the tholsel (ibid.: 239), based on the reference to land north again from the old tholsel in a Kilkenny corporation rental from AD 1624 (Ledwich 1786: 400). The *Liber Primus* is clear though. In AD 1372, an inspeximus of a charter for Kilkenny states that "[any offender] should be imprisoned in the tolsell of that town and not elsewhere" (Otway-Ruthven 1961: 12). In AD 1391 Thomas Knareburgh, burgess of Kilkenny, was arrested and put in the tholsell of the town (ibid.: 49) and in AD 1508 John Archer was arrested and put in "the tolsell" (ibid.: 95). Also, the rate stated for the land north of the tholsell in AD 1624, that is to say 5d, is a very small amount and would not relate to any substantial structure. The above, together with the earlier reference to the common forge being situated across from Croker's Cross, would imply that it was this forge which was located at the current AIB building (Fig. 7.1).

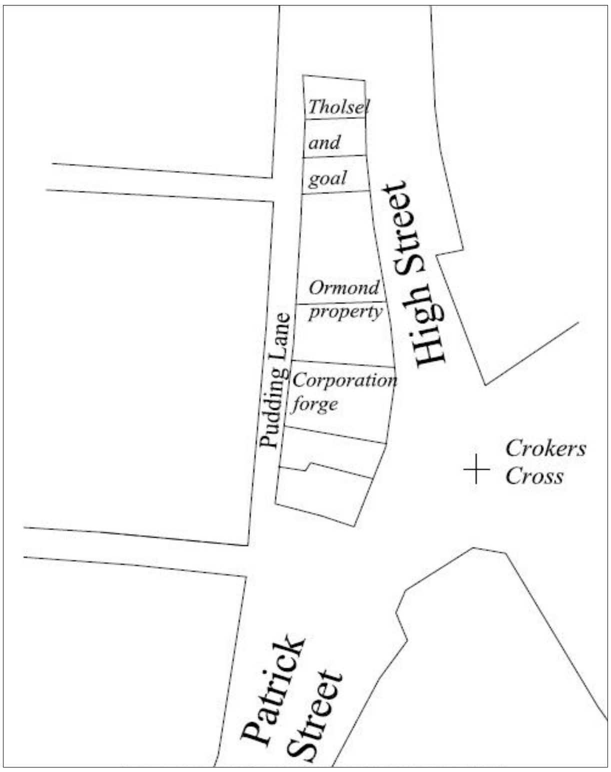


Fig. 7.1 Location of the fourteenth- to sixteenth-century Kilkenny Corporation forge

Although we have a reasonably good idea of the relative position of the properties in question, the main unknown is their size. But, if the town goal/tholsel was at the location of the houses in High Street with numbers 7, 8 and 9 and the forge was at Croker's Cross, this would make the Ormonde property rather extensive, which would conform with the relatively high rent of 10s per year, mentioned in the AD 1518 deed.

We also have records of four smiths being admitted to Kilkenny Corporation between AD 1502 and 1506 (McNeill 1931: 108, 115, 121–123) and in AD 1519 John Raghtone, smith, was exonerated from the office of Portrieve for life, on payment of 6s 8d (McNeill 1931: 139). Interestingly, by the end of the sixteenth century, the Irishtown part of Kilkenny also had its own corporation, for which John Doule, smith, was appointed as "prayser" in AD 1570 and Derby oge, smith, sworn in as collector in AD 1582 (Ainsworth 1978: 35, 42).

7.3.3 Other Irish towns

We have several isolated references to smiths and smithing in other urban centers. In Dundalk, in AD 1310, Peter the smith granted the third part of a messuage built upon (*superedificationam*) in [the New] Town of Dundalk to John the merchant, lying between the land of the vicar of the church of St. Nicholas, S, and the land … Cook, N, … (McNeill 1960: 20). In an indenture dated to AD 1394, two shops (*schoppos*) or houses in the New Town of Dundalk are mentioned, both situated by *le Fleschamlys* [= Flesh shambles or Shambles] called le Forge (ibid.: 133). According to Goslin (1991: 307), this location is probably at the junction of Market Street and Clanbrassil Street, where the eighteenth-century shambles were located. It seems likely that a forge was situated at this location at an earlier date.

In AD 1249/50, the Dublin Guild Merchant Roll records Roger and William, smiths, as being from Drogheda (Connolly and Martin 1992: 89) and in AD 1278 and AD 1279, Ralph le Feure is one of the people accounting for the farm of the Louth side of the same city (PRIE 1272–1284: 45, 49). Next to Peter le Feure (the smith), who might have been a non-ferrous metalworker (see above), we also encounter William le Feure as one of the plaintiffs in a murder case in Drogheda (Louth side) in AD 1311 in the Justiciary Rolls (CJR 1308–1314: 168). Thanks to the survival of some of the Corporation Records of Waterford, we know that here there was also a common forge run by the city corporation. In AD 1446/47, Nicholas Gogh, former mayor of Waterford, rented from the Mayor and Commons of that city a house and forge, which formerly belonged to Wadingretes, for the term of 24 years at the annual rate of 3s 8d, on condition that Nicholas was to repair the house and forge "stiff and strong" (Byrne 2007: 232). We are also informed of a piece of land on the south side of St. Peter's Street, which in AD 1574 is stated as formerly held by Thomas Shuegolde, smith (Fiants Eliz. 1570–1576: 127). In Limerick, we have both John O'Naghtyne, blacksmith, and his wife (AD 1557) and John Y Donyll, smith (AD 1559) being granted English liberty (Fiants Philip and Mary: 73; Fiants Eliz. 1570–1576: 48). And finally for Cork, we have William of Corc becoming a member of the Dublin Guild Merchant before AD 1222 (Connolly and Martin 1992: 13).

7.4 Military smithing

The earliest record of smithing connected to military activity is contained in the Irish Pipe Roll of AD 1211/12, which mentions 12s being paid to the smiths of Clones in Co. Monaghan, by writ of the Bishop of Norwich who had stationed garrisons there (Davies and Quinn 1941: 25). In the same document, reference is made to a smith being paid 20s wages for a year and 8s 8d expended on tools for the smithy at the castle of Dundrum, Co. Down[63] (ibid.: 59). An inventory of Dublin Castle from around AD 1224 mentions a "workshop" containing three great hammers, 2 pairs of pincers [tongs] and an anvil (CDRI 1171–1251: 187). In the early, undated part of the Dublin Guild Merchant Roll, Willelmus Faber de Castello is mentioned (Connolly and Martin 1992: 37), while the Faber de Castello is recorded as a witness at the time when Gilbert de Lyvet was mayor of Dublin, somewhere in the 1230s (Gilbert 1884: 439).

In AD 1241/42, land belonging to Willelmi fabri de Castro Dublinie is described as opposite the cemetery of St. John's (St John Brooks 1936: 17). In the Remembrance Roll of the Irish Exchequer for the years AD 1260/62, a smith is paid 8s 5d to work two bends of iron for repairing the doors of Carlingford Castle in Co. Louth, including the cost of his charcoal (BTR: 59). The next reference, from AD 1394, is to a Richard Gonner, smith, who was to be retained at Carlow Castle with an assistant for a quarter year, and there make guns, armaments and other equipment (RCH: 150). He was to be paid 12d per day for himself and his assistant. More than a century later, in AD 1515, smiths and craftsmen were to be sent to the towns in the Pale to make and forge "gonnes

63 The place is not identified in the text, but was interpreted as Dundrum by Scott (1976: 119) based on deduction.

and saletes”[64] (SPHen. VIII: 26).

An invaluable document is the accounts for small expenses made by the Master of the Irish Ordnance for the years AD 1537 to 1539 (Trainor 1949). From these accounts it is clear that money for both the smith's wages and the rent for forges was only disbursed when needed and, although nowhere stated specifically, all the smithing work was likely carried out in Dublin. There is no indication of a special place for military smithing in Dublin and the work was out-sourced to independent smiths. This situation was to change in AD 1550, when John Morgan was appointed as smith of the Irish ordnance (CPR 1549–1551: 290). He was expected to repair and mend the King's ordnance in Ireland and received a house “built for that purpose” in Dublin Castle. His wages amounted to 12d per day. John Morgan was admitted to the Dublin franchise in AD 1579 after paying a fine (CARD II: 141). In the meantime, in AD 1558/59, Thomas Verdon, a merchant of Dublin, was allowed to have as much Spanish iron as he needed for “*chambers for gonnes*” [= casemates] for the ordnance of the city (CARD I: 482). In AD 1584, John Morgan, then described as chief smith of the great ordinance and artillery [of Ireland], was granted the right to buy iron and coals, forges, tools, and so forth, at reasonable prices (Fiants Eliz. 1583–1586: 33) and in AD 1594 he was one of the proctors of St. John's Church (Robinson and Armstrong 1916: 212). In AD 1597, Edward Hartford, blacksmith, was granted the office of smith of the ordnance for Ireland, at 12d English a day for himself, and 8d Irish for his man (Fiants Eliz. 1596–1601: 53), but the same year he was seemingly replaced by John Miles, on the same conditions (CPCRI II: 435).

7.5 Conclusions

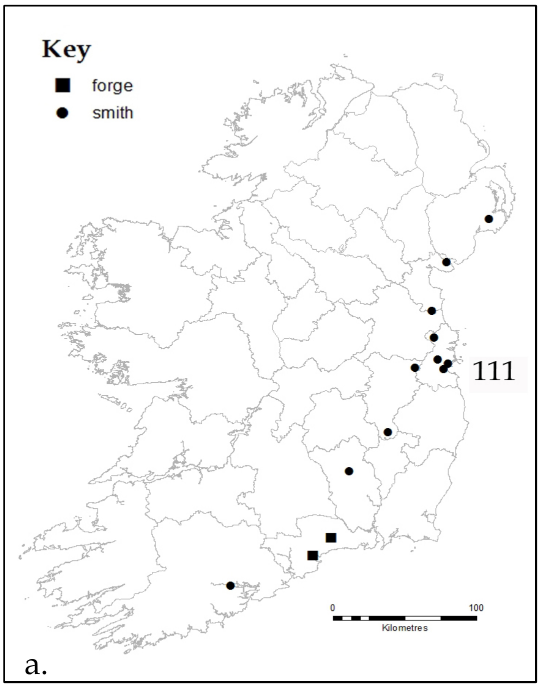
As in most societies, the late medieval smiths known from the Anglo-Norman sources occupy various positions in the social hierarchy. Many of those outside the cities were employed on the manors, where they could be betaghs, free tenants or, in some cases, receivers of the rents of that manor. Most manors seem to have had only one smith, but exceptions, such as Old Ross, Co. Wexford, existed. The relatively small amounts of money earned for smithing work recorded in the detailed accounts of the Bigod and Christ Church manors, on the one hand, and the regular references to smiths paying rent for land, on the other, suggest that the ironworking activities were a part-time

64 These are cannon and helmets.

occupation for the smiths living on many manors. This seems to have been different for the smiths at the Knights of St. John's monasteries at Kilmainham, Co. Dublin and Any, Co. Limerick, where they do appear to have been employed full-time. From the urban centres we have frequent records of smiths, and armourers, filling positions of some importance (proctors, portreeves, and so forth), and although we have no direct evidence for this, smiths lower down on the social ladder undoubtedly existed within the same environment. Apart from armourers, we are informed about other specialist smiths, mainly in Dublin: locksmiths, lorimers, swordmakers and arrow-smiths.

We are hardly informed at all about the smiths outside of the Anglo-Norman influence sphere, but the near-complete lack of them in the Gaelic-Irish literature of the time is striking. The only references we have to Gaelic-Irish ironworkers outside of the Anglo-Norman areas are almost exclusively through pardons extended by different rulers in the late sixteenth century. Interestingly, some of these, like those in Cavan and north-east Kerry, lived in areas with known iron ore sources, and could have been iron-smelters (as well as blacksmiths). Only in a few cases, where smiths were specifically designated as Irish or when they were betaghs, can we be sure that a smith on an Anglo-Norman manor, or in one of the urban areas, was Irish. That the question of ethnicity of late medieval smiths was not just a case of Irish, English and Ostman, is shown by several references to Welsh, Scottish, probably German and Flemish, and especially French smiths operating in Ireland during the late medieval period. Some Irish smiths, at least in the sixteenth century, also went abroad to fulfil their apprenticeships. The complexity of the question of ethnicity is well illustrated by the case of the Irish smith Maurice Segyn/Sogyn, who was granted English citizenship in Dublin in the 1430s, and later was one of the founders of the Smiths' Guild of St. Eligius in that city, which did not allow apprentices of the Irish nation.

The sources on military smithing are rather limited and only really inform us of the situation in Dublin, where a smith was employed, seemingly full-time, at the castle in the thirteenth century. This situation changed at an unknown time and until AD 1550 smithing for the royal army in Ireland was either carried out in castles further inland or out-sourced to non-military smiths. After this date, the office for smith of the Irish Ordnance was created and a forge (re-)established at Dublin Castle. The limited references to smithing at castles probably represent a more common practice than that reflected in the sources. Dublin is the only city where we have sufficient documentation to look in detail at the smiths within the community. One remarkable observation is the relative lack of smiths in Dublin between AD 1275 and 1349, exactly when most smiths are recorded in the rural areas (Fig. 7.2).



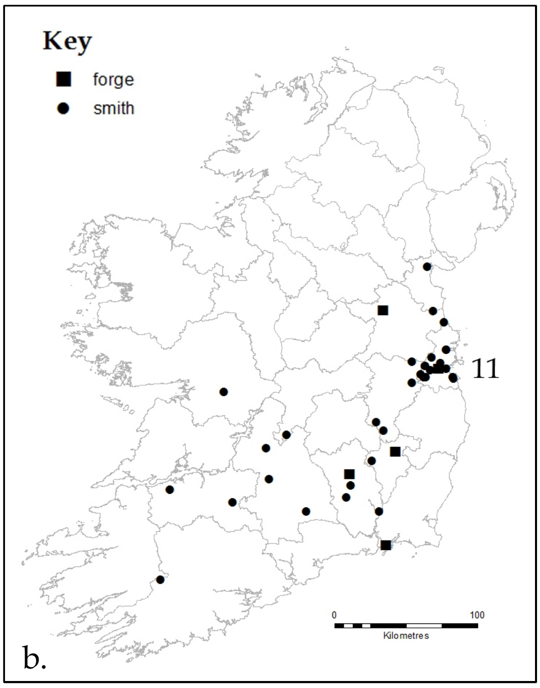


Fig. 7.2 Maps of smiths and forges recorded in Ireland between AD 1200 and 1349. a. From AD 1200 to 1274, b. From AD 1275 to 1349. Values are the number of smiths recorded in Dublin.

The large amount of smiths in Dublin recorded in the period between AD 1200 and 1274 is directly due to the survival of the Dublin Guild Merchant Roll covering this period. The actual number is probably lower, as several names appear more than once indifferent sources and could refer to the same person. This, however, does not explain the dearth of smiths mentioned as active in Dublin in the following 75 years. Documents such as the Justiciary Rolls, covering both rural and urban cases and mentioning only two smiths in Dublin, would suggest that there were indeed few smiths in that city at that time. Interestingly, while we have the list of smiths joining the Dublin Guild Merchant of the thirteenth century and those finishing their apprenticeship recorded in the Dublin Franchise Roll of the late fifteenth and sixteenth centuries, during both periods smiths are mentioned in other documents which do not appear in either of those lists.[65] This would imply that the not all smiths were members of the professional organizations at that time.

What is especially striking is the near-complete lack of references to forges in Dublin over the whole period. Next to the workhouse in Dublin Castle, both in the

65 Some form of guilds, for smiths and various other trades, was present in New Ross in AD 1265 (Orpen 1911: 17–18), well before the establishment of a Guild Merchant in the reign of Edward III (AD 1327–1377) (Hoffman 2011: 228).

thirteenth and late sixteenth centuries, which was clearly a forge but hardly representative, we only know of the workshop out of which money was paid in AD 1285, which was only possibly a smithy. This presents a major difficulty for the interpretation of the available documentation, as the references nearly exclusively refer to where smiths are from and where they own property. The case of the smith at Dublin Castle holding land at St. John's cemetery shows that, at least in some cases, the workplace could be different from property rented. Additionally, it is clear from the thirteenth-century sources that smiths from Ostmanstown [Oxmantown] were specifically singled out for mentioning their location within the city. In all, the distribution of located references to smiths in Dublin does show a clear movement from the west and north-west of the city in the thirteenth and fourteenth centuries to more dispersed in the next two centuries (Fig. 7.3). This, however, will need to be tested against the archaeological data for further analysis.

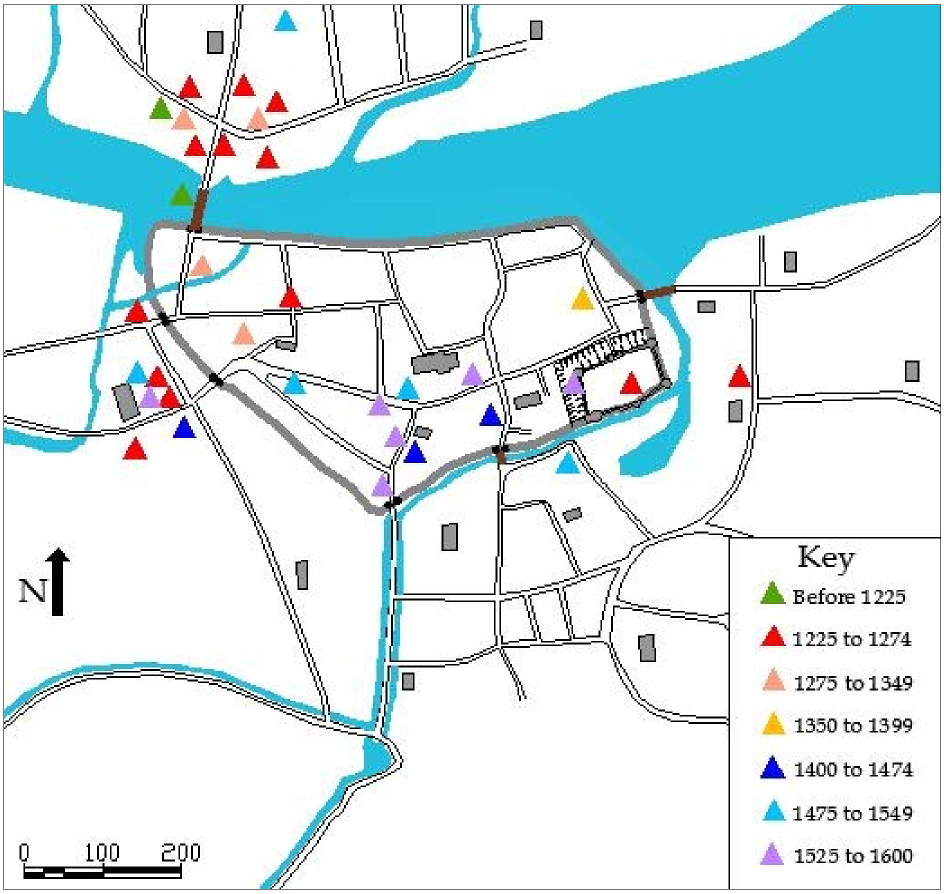


Fig. 7.3 Map of smiths recorded in late medieval Dublin

Although the information on the tools and technology used is limited and not particularly informative, the sources do reveal interesting information on the structures used. Forges, which are rented out for a year or longer, and sub-let to smiths are recorded from Kilkenny, Waterford and Kells. This undoubtedly implies that these were seigneural forges which would have had a monopoly on iron smithing and as such were comparable to the feudal mills. The yearly rent in Kells (1330s) amounted to 2s, in Kilkenny (late fourteenth to early sixteenth centuries) it amounted to 2 to 3s, with occasional lower values, while in Waterford (1440s) it was 3s 8d. The reference to repairing the forge at Waterford "stiff and strong" around the middle of the fifteenth century, could suggest an upgrade in the construction of that building.

In Dungarvan and Rossmire, the rent from the forges, in the form of a certain amount of money, was included in the yearly income, but, unusually for a monopoly, at Dungarvan this related to two smithies. Perhaps at least one of these was dedicated to specialized metalworking, such as anchor manufacture or non-ferrous metalworking. At Fothered, the rent could be paid in horseshoes or money (4d), while at Nobber, it amounted to four horseshoes. Interestingly, in both these cases the description of the place is vague, respectively "smith's house" in one of the relevant documents to Fothered and "a smith's place" at Nobber, while at the three monopoly forges the term *fabrica* was used. At two establishments of the order of the Knoghts of St. John, at Kilmainham, Co. Dublin, and Any, Co. Limerick., a smith was employed full-time, suggesting a similar arrangement.

But most striking is the complete lack of references to forges in the vast majority of agricultural holdings, either as generating income or as buildings listed in the various extents. An extent for the manor of Maynooth, Co. Kildare, drawn up in the same year in which a smith is mentioned (1328), lists a bake-house, a grange, an ox-house, a stable and a kiln, but no smithy (Murphy and Potterton 2010: 179). In Lucan, where a smith is mentioned in AD 1316 and 1334, the description of the manor in AD 1358 mentions a messuage, a garden, two dovecotes, a fishpond and a warren, but again no forge (Murphy and Potterton 2010: 173, 500). The extent of the manor of Swords from AD 1326 includes, among other buildings, a carpenter's workshop, a cow-house and a dovecote (McNeill 1950: 175), while a smith is recorded there in AD 1331. Similar extents for other early fourteenth-century manors also do not include smithies (Murphy and Potterton 2010: 173; Dryburgh and Smith 2005: 59). The above suggests that smithing on most manors, at least in the east of the country, was probably not carried out in specifically designated buildings.

Chapter 8

Archaeological evidence for iron smithing in late medieval Ireland

Not surprisingly, a large number of excavations on Irish late medieval sites have produced evidence of iron smithing. For a long time, however, a large proportion of these have appeared, and where quoted, as smelting sites, based on the occurrence of "furnace bottoms" (see Chapter 1.2.2). Furnace bottoms do exist, but the vast majority of the slag cakes, including the larger ones, are now recognized as smithing hearth cakes. On the one hand, this means that a lot of the information had to be re-evaluated but, on the other, it has provided the opportunity to give smithing the place it deserves in our knowledge of late medieval Ireland. The information in the reports, publications and slag assemblages reflect the complexity of late medieval smithing, with sites varying from isolated hearths to long-lived forges, yielding from several hundred grams of slag to hundreds of kilograms. Some provide an intricate picture of the internal organization of the workplace, while for others the information can optimistically be described as vague. All together, though, they form a data assemblage allowing us to classify sites based on the weight classes of the smithing hearth cakes, the proportion of the latter in the total assemblage, the size of the hearths and the types of anvils. For the first time, we can confidently discuss the fuel types used in late medieval smithing and the way the bellows were protected. And finally, a new type of artefact for Ireland, the still poorly understood smithing plug, emerged from two of the assemblages examined as part of this thesis.

The distinction between the different types of nucleated settlements used in this thesis is a variation of the classification by Graham (1988), that is to say cities (large mercantile towns), small towns (small mercantile towns, small peasant towns and Gaelic towns) (ibid.: 24). This last category consists of Graham's boroughs and the *villae mercatoriae*, the information for which was obtained from the written record. An additional category is used here, the manorial centres, which consists of sites included based on archaeological argumentations. These are, for example, sites which were originally military in nature, such as ring-works and mottes, but which show a long period of use and have associated features such as corn-drying kilns. Next to these nucleated sites, we have several examples of buildings specifically used for metalworking, which have no evidence of other habitation nearby. These are termed isolated rural forges. The definition of a forge, or its synonym smithy, used here is a roofed building in which smithing is carried out. This encompasses both purpose-built structures, generally exclusively used for metalworking, and domestic buildings within which smithing work was carried out. The primary unit of the late medieval rural economy was the manorial farm. In some cases the farm buildings themselves were found in proximity to the ironworking, but examples where corn-drying kilns were contemporary with the smithing activities were also included in this group. Some exceptional sites were grouped into smaller categories, such as the two sites, Johnstown, Co. Meath [73] and Ballykilmore, Co. Westmeath [7], where ironworking was carried out in the upper fills of a circular enclosure at the same time as burial activities were taking place in the interior. At two sites which were the property of the Cistercian monastic order, Aghmanister, Co. Cork [1] and Carnmeen, Co. Down [18], iron- and copper-working took place in substantial stone buildings. On both sites, the activity was likely to be later than the buildings and these were not monasteries. They were still classed as monastic smithing due to their potential close connection with the monastic order in question. Another relatively large group consists of activities connected with the construction or repair of large stone buildings, mostly castles and monasteries. The final category comprises sites where not enough, or only ambiguous, information was available on their setting. Deciding which category some of the sites belonged to was not always straightforward. During the four-hundred-year research period, many of the settlements underwent substantial changes. Many sites originated as military sites and later became the centres of extensive manorial estates or even, in some cases, important towns. Others began as optimistic newly created centres of power, but withered away as a result of political and economic changes. Others still, mainly stone buildings, were abandoned, forcefully and sudden or at the end of a long decline, and became the setting for ironworking activities.

Various aspects of late medieval iron smithing will be scrutinized in detail. Special attention will be given to the relationship between the different site types and their associated smithing activities. Based on this, a model will be suggested detailing the movements of iron in its various states and the conversions it underwent in certain types of settlements. A second aspect of late medieval smithing which will be dealt with in detail is the relationship between the use of tuyeres and the type and chronology of the different sites. Based on this, it will be examined to ascertain if this artefact type can be seen as a cultural marker. Further conclusions will be reached based on the comparison of hearth dimensions with those of the early medieval period, the study of tools and implements used in ironworking activities and the available results from scientific analyses on both smithing slag and iron artefacts.

8.1 Site types related to ironworking

8.1.1 Isolated rural forges

The first site type to be discussed is the isolated rural forge. We have two excavated examples of twelfth- to thirteenth-century rural smithies at Coolamurry, Co. Wexford [31] and Curragh Upper, Co. Cork [42] (Fig. 8.1c and d). At Coolamurry [31], three areas defined by a hearth with evidence of intensive smithing were uncovered. At one of the areas, the hearth area was enclosed by a curving gully. As this gully contained very little slag, it was interpreted as either a drainage gully outside a clay wall or a foundation gully containing the same. The activity on the site, based on radiocarbon dates and pottery types, was estimated to have taken place around the late twelfth to early thirteenth centuries. At Curragh Upper [42], a deposit of ironworking residues was situated in an area enclosed by a curving gully. Like the previous site, the gully contained no slag and a similar function can be envisioned. The hearth was probably truncated by a later field drain. A late twelfth- to early thirteenth-century date was returned via radiocarbon analysis on material from the gully.

Similar forges are also known from the early medieval period. At Cahircalla More in Co. Clare, a sixth- to seventh-century building related to ironworking consisted of three gully-sections enclosing an oval area measuring 6.3 by 4.4m (Taylor 2012: 4, 34) (Fig. 8.1a). Two internal pits contained considerable amounts of slag and hammerscale, while one showed evidence of burning (Keys 2012c: 15), indicating that both could have been hearths. Further metalworking residues were recovered from the gully and other features. At Milltown in Co. Kilkenny, an eighth-century post-built structure enclosed a broadly oval area measuring 5.8 by 5.5m (Wren 2010b: 13–15, 92) (Fig. 8.1b). Some uncertainty exists as to the character of the internal features, with indications for both smithing and smelting being present (Young 2010b: 46).

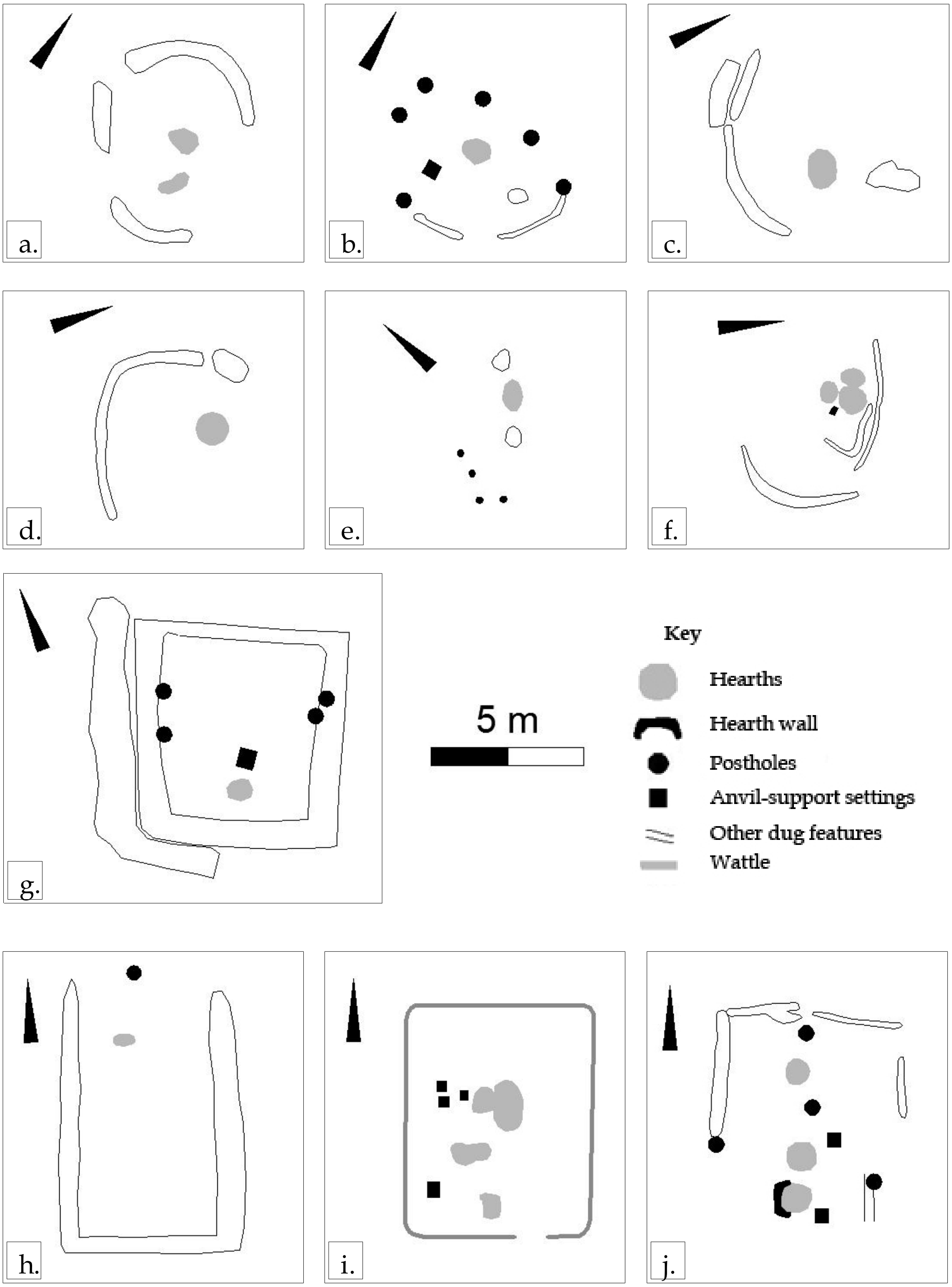


Fig. 8.1 Plans of excavated medieval Irish smithies. a. Cahircalla More, Co. Clare (Taylor 2012: 57), b. Milltown, Co. Kilkenny (Wren 2010b: 139), c. Coolamurry, Co. Wexford [31] (McCullough 2009: 218), d. Curragh Upper, Co. Cork [42] (Molloy 2010: 33), e. Cuffsborough, Co. Laois [40] (Cotter 2009a: 90), f. Ballykeoghan, Co. Kilkenny [6] (Laidlaw 2010: 152), g. Blackcastle, Co. Tipperary [12] (Stevens 2010: 273), h. Mannan Castle, Co. Monaghan [99] (Moore 2001: 62), i. Waterford, Peter Street [127] (Hurley and Scully 1997: 103), j. Aghmanister, Co. Cork [1]. Sources of sites withour Catalogue number, see text.

A likely forge-site, closer in date to the research period was excavated at Ballyellin 1, Co. Wexford, where a rectangular structure containing ironworking residues was found. Only a short notice on the excavations has appeared (McLoughlin 2011, 2013), but the specialist report on the material was available (Young and Kearns 2010a). The structure consisted of a slot-trench or gully, 0.5m wide and 0.4m deep, enclosing a rectangular area on three sides measuring about 7 by 6m (McLoughlin 2011). The slot-trench/gully contained 41kg of metallurgical residues consisting mostly of smithing hearth cake material (24.8kg), next to about 1kg of tuyere material (Young and Kearns 2010a: 1). No internal features were found and it is unclear if the enclosing element was a wall foundation or a drainage slot (ibid.: 2; McLoughlin 2011). The occurrence of many small pieces of ironworking residue, however, would preclude the slag as being packing material. It seems likely that the internal features were truncated. Radiocarbon analysis on a fragment of alder charcoal from the fill of the trench/gully returned a late ninth- to early eleventh-century date (Young and Kearns 2010a: 2).

Structural elements were again recorded at two sites dated to the very end of the period under study, at Cuffsborough 5, Co. Laois [40], which was broadly sixteenth century, and Ballykeoghan, Co. Kilkenny [6], where the activity took place in the fifteenth to early seventeenth centuries. At Cuffsborough [40], the remains consisted of several postholes forming an L-shaped wall de-lineating a deposit rich in ironworking residues (Fig. 8.1e). At Ballykeoghan [6], three areas of intense smithing activity were unearthed. One of these areas consisted of three hearths and associated deposits enclosed by a curving gully (Fig. 8.1f). The small amount of material included in the gully and its proximity to the hearths suggests that it functioned as a foundation trench for holding a clay wall. Other curving gullies, further away, probably represented drainage features.

At both Coolamurry [31] and Ballykeoghan [6], the forges were nearby other areas of smithing activity. The smithy buildings at these sites were defined by shallow curving gullies partially enclosing the areas of activity, while at the latter site it was concluded that the gully represented a foundation for a clay wall. It would seem possible that the other smithing areas on these sites were also contained inside a mud-walled structure, only this time without gullies. Other sites, consisting either of several smithing hearths located close together or intensively used single ones, could similarly represent ironworking activities carried out inside a mud-walled building, with the latter leaving traces. This could have been the case at the late twelfth- to early thirteenth-century site at Loughbown, Co. Galway [96], the thirteenth-century activity at Killaspy, Co. Kilkenny [88], and at fourteenth-century Garryleagh, Co. Cork [66]. A possibly similar situation was observed at Newtown Little, Co. Dublin [110], where the activity was broadly dated to the late medieval period, but here there was uncertainty if the features represented hearths or rubbish pits.

8.1.2 Farms

The focal points of the late medieval Irish rural economy consisted of the manorial farms. Excavations of several of these have provided evidence for ironworking, although the scale of activity is generally low. At Cookstown, Co. Meath [30], just over 6kg of metalworking residues were recovered from an unusual configuration of features. A set of ironworking hearths was located in an area measuring c. 2 by 1m enclosed by an irregular gully. This was set within a larger enclosure, measuring c. 8 by 5m, enclosed by a sub-rectangular gully. This part of the site was originally interpreted as a forge, but the lack of convincing structural elements, the observation that the internal gully was seemingly open during use and the small amount of ironworking residues would suggest otherwise. Part of a rectangular house structure was excavated nearby. At Trevet in Co. Meath [120], the remains of a mud-walled long-house were uncovered. About 5kg of metalworking debris was retrieved from several features and were probably produced in a nearby smithing hearth. Just over 19kg of slag were recovered from the site at Tullykane in Co. Meath [123], where smithing hearths were located near a likely rectangular house structure.

At Curragh, Co. Laois [41] small amounts of slag, either related to smelting or smithing, were obtained from several features in proximity to a post-built structure located within a rectangular enclosure. At Kilferagh, Co. Kilkenny [79], small quantities of slag were found nearby the remains of a possible stone house, a barn and an elaborate corn-drying kiln. Further small amounts of smithing debris were found at Mullamast, Co. Kildare [107] where several late medieval buildings and corn-drying kilns were unearthed. Another potentially similar site was excavated at Danesfort, Co. Kilkenny [43], where slag was found in the demolition fill of a late medieval stone-built house. Another widespread type of late medieval rural settlement, the moated site, has yielded only limited indications of associated ironworking. Only at Shandon, Co. Waterford [115] was substantial evidence for ironworking uncovered. But, while the smithing activity was dated to the late medieval period, both the date of the enclosing rectangular ditch and its association with the metalworking were uncertain. All the above sites, with the possible exception of Danesfort [43], were dated to the thirteenth and/or fourteenth centuries, with some possibly continuing on into later centuries.

On many other sites, ironworking debris was found in, or close, to contemporary corn-drying kilns, providing further evidence for smithing related to arable agriculture, as was observed at Mullamast, Co. Kildare [107], Kilferagh, Co. Kildare [79] and Loughgur, Co. Limerick [97]. Similar kilns were uncovered together with evidence for smithing at Walterstown in Co. Louth [125] and Mullaghmarky AR016, Co. Kerry [105]. The first site is as yet not more closely dated than to the late medieval period, while at the second, the activity was carried out in the mid-thirteenth century. One of the corn-drying kilns at Carnmeen, Co. Down [18] was also in use up until the thirteenth century, when smithing was still carried out nearby. Two other sites where the main activity was iron smelting, Rathglass, Co. Galway [113] and Borris, Co. Tipperary [13], had corn-drying kilns broadly contemporary with the ironworking, respectively late thirteenth to fourteenth centuries and late fifteenth to early seventeenth centuries. Two other rural sites with corn-drying kilns, Cappydonnell Big, Co. Offaly [16] and Tullylish in Co. Down [124], were also late in date, respectively late fifteenth to sixteenth century and late fifteenth to seventeenth centuries.

Evidence for smithing activities was encountered at many other sites, the nature of which was uncertain. At Hallahoise, Co. Kildare [70] and Merrion Road, Co. Dublin [100] the ironworking residues were found in proximity to pits and ditches, possibly part of manorial farms. At Garadice, Co. Meath [64] the material was found in, and around, large waterpits, but the activity was seen as carried out elsewhere, while at Merrywell, Co. Meath [101] the smithing was recovered from a series of ditches. At Caherduggan in Co. Cork [15], limited evidence for ironworking was found in proximity with a late thirteenth-century lime-kiln. The same combination was encountered at Kilkenny, Robing Room [85].

8.1.3 Manorial centres

Of these manorial centres, two, and possibly three, revealed evidence of forges. A smithy excavated at Blackcastle, Co. Tipperary [12], was probably part of the manor of Burgasleith, currently Twomileborris. Here, an almost-square mud-walled structure enclosing an area of 6 by 5.8m was uncovered (Fig. 8.1g). An internal hearth had several fills with inclusions of hammerscale, while an associated external midden contained large amounts of metalworking waste. Radiocarbon analysis of material from a sub-floor level within the building returned a thirteenth-, likely late thirteenth-, century date. A nearby watermill was probably operating at the same time. At Mannan Castle, Co. Monaghan [99], a forge was located at the edge of the bailey. The building enclosed a rectangular area, measuring 8 by 5m and delineated on three sides by substantial wall slots (Fig. 8.1h). On the fourth side, which faced the interior of the bailey, a large posthole was uncovered. Inside, a hearth measuring 0.8 by 0.55m was recorded. Substantial amounts of slag were recovered from the above features and the floor of the building. No direct dating evidence was given, but its association with the motte and bailey would suggest it belonged to the late twelfth to thirteenth centuries. This site is here seen as representing the core of an agricultural manor, although the metalworking could be partially military in nature. Several other motte-and-bailey sites have also revealed remains of ironworking.

The situation at Portmarnock, Co. Dublin [112] is unclear. Here, one plot of a sixteenth-century village had two buildings, each with a hearth and substantial amounts of ironworking slag recovered from the courtyard. A partially preserved hearth in the courtyard and no residues recorded as found inside the house would imply that the activity to have occurred outside, but this is not certain. At Dysart, Co. Kilkenny [60], evidence for both smelting and smithing was found close to a late medieval church on what was an outlying grange of Kells Priory. Due to the presence of a church and its isolated nature from the main demesne, this site is included with manorial centres. At Loughgur In Co. Limerick [97], smithing in at least two locations was found nearby two mud-walled rectangular houses.

Three other sites, at Carlow Castle [17], Ballysimon, Co. Limerick [11] and Woodlands West, Co. Kildare [129], the first dated to before c. AD 1210–1215 and the other two to the thirteenth to fourteenth centuries, consisted of circular enclosures and were interpreted as ringworks. The latter type of site is generally seen as military in nature, and this would seem to be the case at Carlow Castle [17] where it was subsequently replaced by a stone castle. The other two sites, however, had a long period of use, evidenced by a re-cutting of most of the ditch in both cases, and had associated corn-drying kilns, perhaps suggesting that these obtained a more agricultural nature later on in their occupational history. At both Carlow Castle [17] and Ballysimon, Co.

Limerick [11], the evidence for ironworking was limited, while at Woodlands West, Co. Kildare [129] the assemblage was more substantial, over 26kg and including smelting slag. At Ballysimon [11], small amounts of slag, and a possible smithing hearth, were found in and around one of these ring-works dated to the thirteenth to fourteenth centuries. A partially excavated ring-work at Woodlands West [129] revealed both (bloom) smithing and smelting slag of a similar date range, but the activity itself took place outside the excavated area. Further slag was found in ditches seen as part of a ring-work at Ferrycarrig Castle in Co. Wexford [62]. Large lumps of slag were found during field-walking at Mulphedder, Co. Meath [109] and interpreted as related to the ring-work there. Another site included in this category is Tintern Abbey in Co. Wexford [119], where the smithing was carried out after the dissolution of the monastery in question when the site became the centre of the Colclough estates. At Caherduggan in Co. Cork [15] substantial amounts of smithing slag, many of them large cakes, were found in a large ditch contemporary with a nearby tower house.

8.1.4 Boroughs

Regrettably, at only two sites of this important category is there evidence for late medieval ironworking. Limited excavations at Nobber, Bridge Park, Co. Meath [111] revealed *in situ* thirteenth-century smithing activity which was located close to the street, while dumped slag suggested nearby ironworking activity till the end of the research period. At Claregalway, Co. Galway [28], large amounts of slag, including many large smithing hearth cakes, were found dating to the full length of the research period, suggesting large-scale and prolonged smithing nearby.

8.1.5 Smaller towns

There is substantially more information on ironworking from the smaller late medieval towns. At Cashel, Bank Place, Co. Tipperary [23], a large concentration of features related to smithing activity was located between a post-built structure and the street, with only minimal evidence potentially inside the post-built structure. Similarly at Trim, High Street, Co. Meath [122], ironworking was carried out over an extensive period at the street-front, as buildings rose and were abandoned on both sides. It is unlikely that a forge building was present further back from this activity. Two concentrations of ironworking were uncovered during the monitoring of the cutting of a long trench through what would have been medieval Castledermot, Co. Kildare [25]. Large lumps of slag were found at Kells, Church Street, Co. Meath [74] in the late medieval centre of that town and dumped outside the town walls of Thomastown, Chapel Lane, Co. Kilkenny [118]. Abundant hammerscale observed at Abbey Row in Athenry in Co. Galway [4] indicated nearby iron smithing, while more ironworking residues were retrieved elsewhere in the same town. An area of extensive ironworking was excavated at Glendalough, Co. Wicklow [67], consisting of several possible hearths, but the available information was limited, as was the evidence for ironworking uncovered at Duleek, Abbeyland, Co. Meath [57], Dundalk, Rampart Road, Co. Louth [59], the Gaelic town of Armagh in Co. Armagh [2] and at two sites in central Carrickfergus in Co. Antrim [20 and 21].

8.1.6 Large towns and cities

Despite many excavations in the area within the medieval walls of Dublin, no evidence for *in situ* ironworking has been recorded there to date (Fig. 8.2). Metalworking hearths were uncovered at Exchange Street Upper/Upper Gate, just north of Dublin Castle, but no information was available on the metal in question (see Appendix 7). Only at Back Alley/Lamb Lane [46] and Bridge Street Lower [48] were small amounts of slag recovered, presumably the result of smithing. To the south of the medieval walls, several hearths relating to iron (and copper) smithing dated to the thirteenth century were excavated at Bride Street [47], while a “furnace” and a tuyere dated to the fourteenth century were recorded at Longford Street Little [53]. Further to the south, at 48 New Street South [54] small amounts of smithing slag were recovered from a site dominated by tanning pits. Directly outside the western medieval city gate, at Francis Street/Lamb Alley [50], a circular post-and-wattle structure with an adjacent smithing hearth dated to around the mid-thirteenth century was found. This was constructed on the same location where previously non-ferrous metalworking had taken place. About 120m further west along the same road, at 58–60 Thomas Street [51], substantial evidence for late medieval ironworking was found. The exact nature of the features is difficult to interpret, either representing *in situ* smithing or dumps of likely nearby activity. Additional small amounts of smithing residues were found at the nearby site at 119–121 Thomas Street [56]. North of the city, across the river Liffey, likely *in situ* late medieval ironworking activity was recorded at Hammond Lane/Church Street [51], but the available information on the site is limited and ambiguous.

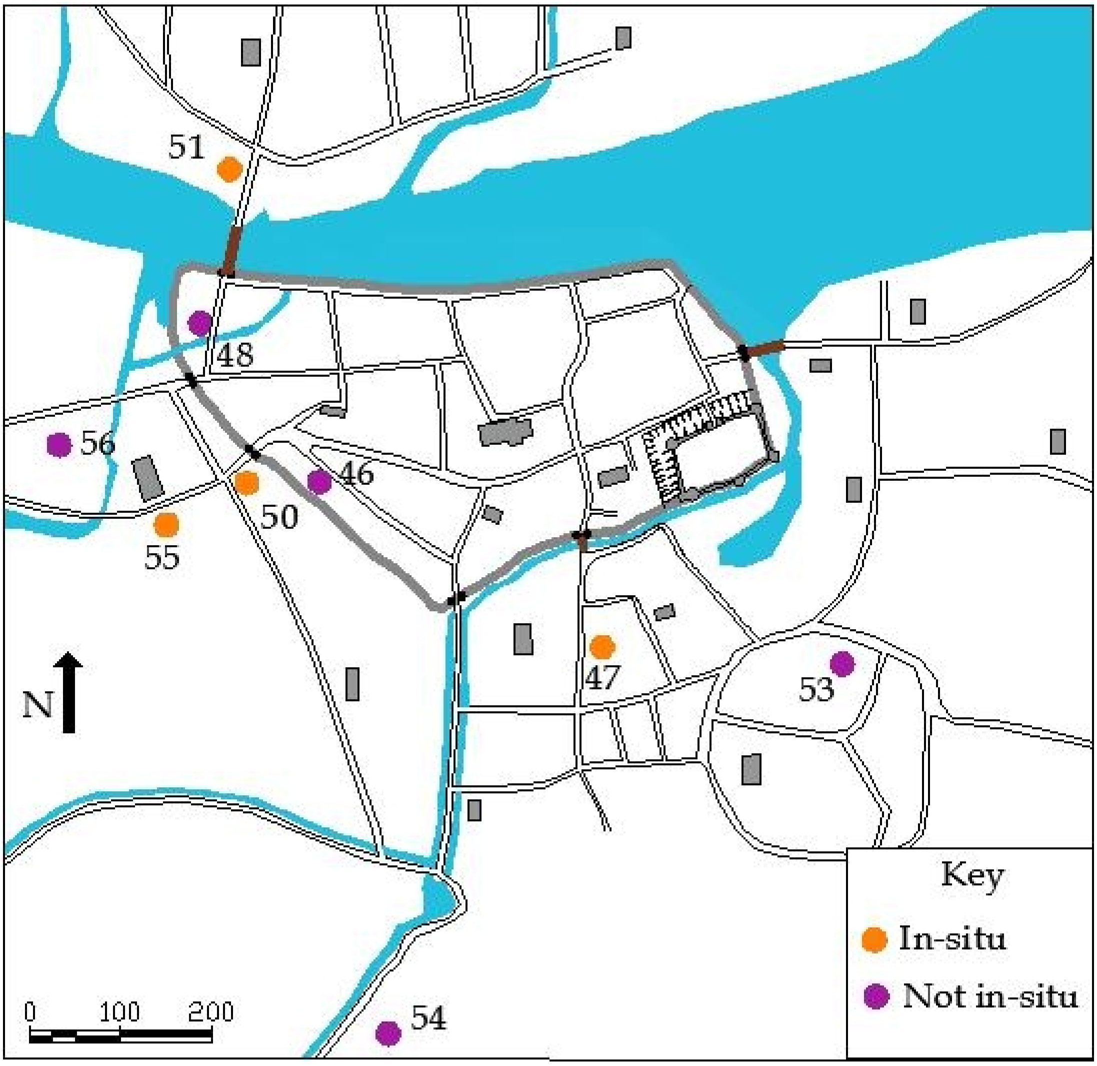


Fig. 8.2 Map of excavated late medieval smithing sites in Dublin. The numbers refer to the Site Catalogue numbers.

In Kilkenny, the area with the highest density of ironworking remains is the north-eastern corner of the large-scale excavation at 27–33 Patrick Street [84] (Fig. 8.3). Only one hearth related to smithing was uncovered, but the large amount of thirteenth- and fourteenth-century features with slag, together with written evidence for the location of the Corporation forge in the fifteenth and sixteenth centuries, located immediately east of this area (see Chapter 7.3.2), points to intensive ironworking throughout the whole of the late medieval period. Smaller amounts of slag were found distributed in a wide area around this locality (Fig. 8.4), both within the same excavation area and during the excavations at 11 Patrick Street [83] and The Parade [82]. Further south-east along The

Parade, towards Kilkenny Castle, more iron slag was found, with indications of potential *in situ* smithing. Excavations inside Kilkenny Castle [80] revealed further evidence for ironworking. Small amounts of iron-smithing slag were recovered from the town ditch outside of Talbot's Tower [86]. In the northern part of Kilkenny, or Irishtown, likely evidence for *in situ* iron smithing was uncovered at Troy's Gate/Vicar Street [87], but the site was not excavated. Not far away, to the west, at the Robing Room [85], iron-smithing slag and tuyere material were recovered from a lime-kiln and other features dated to the late twelfth to thirteenth centuries. A complete tuyere-front of similar date was found at 1 Irishtown [81].

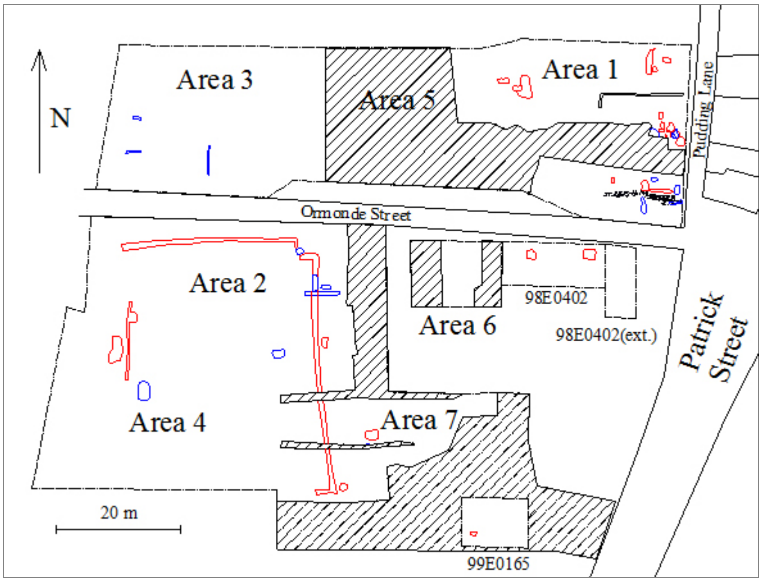


Fig. 8.3 Plan of the excavations at Kilkenny, 27–33 Patrick Street [84]. Red: late medieval features with slag, Blue: later features with slag.

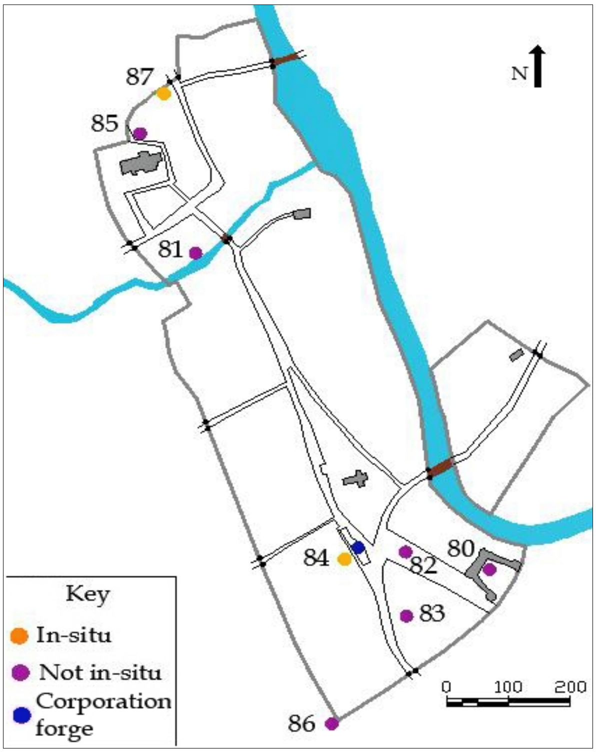


Fig. 8.4 Map of excavated late medieval smithing sites in Kilkenny. Numbers refer to the Site Catalogue numbers.

In Waterford, the only site with late medieval ironworking remains was excavated at Little Patrick Street [126]. Here several hearths, possible anvil block supports and slag-rich deposits testify to quite intensive smithing activity. An earlier, mid-twelfth century, site at Peter Street in the same town [127] also had fairly extensive remains of ironworking activity, situated within a wattle-walled building (Fig. 8.1i). It is unclear if this building was also used for domestic purposes.

Within the medieval walled town, on South Island, the oldest part of medieval Cork, only one site was excavated with clear evidence for *in situ* iron smithing (Fig. 8.5). At Tuckey Street [39], fairly intensive ironworking was carried out in a series of consecutive hearths dated to the late twelfth to early thirteenth centuries. Fragments of tuyere material and "smithing plugs" (see below) were observed among the residues. About 100m east of this site, at the site of Christ Church [33], *in situ* ironworking was suggested as taking place within a mid-thirteenth-century post-and-wattle building, but the evidence was ambivalent. Excavations at two adjacent sites, at 35–39 [36] and 40–48 South Main Street [37], revealed limited amounts of dumped smithing slag, together with evidence for copper-working. Outside the southern town gate, at 3–5 Barrack Street [32], several hearths and many deposits testify to long-term ironworking activities carried out in the thirteenth century and possibly beyond. On North Island, small amounts of ironworking residues were uncovered during excavations at Phillips' Lane [35] and St Peter's Avenue [38]. Excavations at North Main Street [34] revealed infrastrucutre for water-power, a square stone-built structure and a large block of wood interpreted as an anvil. This was seen as the remains of a water-powered forge, but re-examination of the evidence has questioned this interpretation. It is unlikely that the water-power was used for metalworking purposes, while the nature of the "anvil" is similarly unsure.

In Limerick, only limited evidence of late medieval ironworking was found during excavations at The Parade/Broad Lane [94], close to St. John's Castle, at 48–50 Mary Street [93] outside the town walls and at Charlotte's Quay/Broad Street [92] and Charlotte's Quay/Castle Site [91], two adjacent sites in Irishtown. In Galway, extensive ironworking took place within an abandoned medieval colonnaded stone-built hall at Courthouse Lane [63]. Several hearths, belonging to two phases, were found close to a large cruciform anvil (see below). The activity was dated to the sixteenth century. Limited evidence for ironworking was uncovered at Main Street South in Wexford town in Co. Wexford [128].

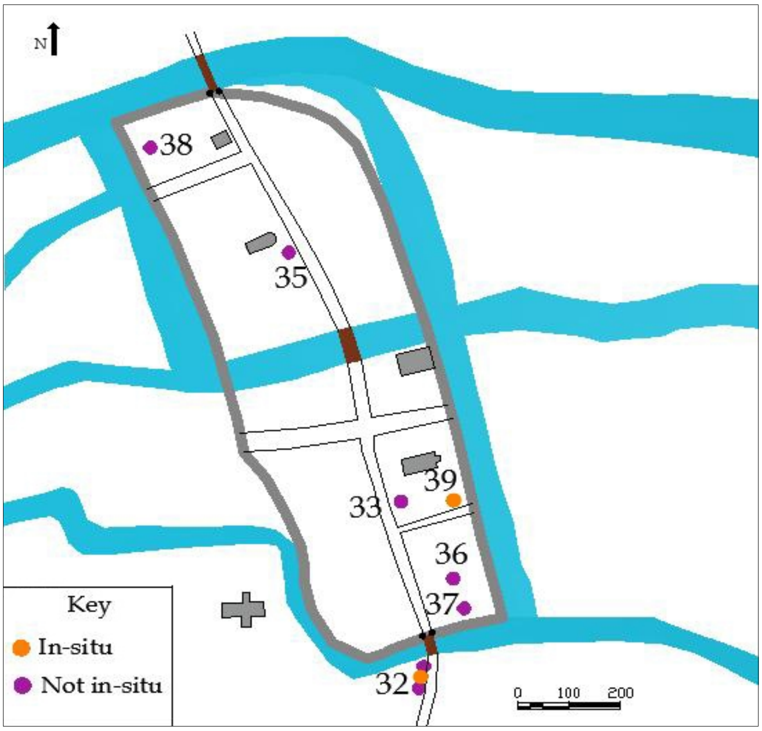


Fig. 8.5 Map of excavated late medieval smithing sites in Cork. Numbers refer to the Site Catalogue numbers.

8.1.7 Military sites

In most cases, the evidence for ironworking at castle sites was interpreted as connected to building activities (see below), but in several cases the location and nature of the activities pointed to a possible military connection. At Dunamase Castle, Co. Laois [58], we have a possible rare Irish example of a forge forming part of an existing stone building. Here, a square hollow was uncovered in the corner of a room, the floor of which consisted of a slag-rich deposit. Further *in situ* ironworking was uncovered during excavations at Ballyloughan Castle in Co. Carlow [8], where the activity was located within the curtain wall. Excavations of the top of Lismahon Motte, Co. Down [95], revealed remains of *in situ* ironworking, but it is unclear if the nearby postholes formed a structure around it. Slag, presumed to be from smithing, was recovered from the base of Ballyroney Motte, Co. Down [10], indicating a possible military nature of the ironworking. At Coney Island, Co. Armagh [29], several hearths related to ironworking were uncovered. These were interpreted as furnaces contemporary with the motte. The activity is more likely to consist of smithing activities, while the dating evidence is ambiguous, casting doubt on its military nature.

8.1.8 Monastic sites

Two sites, Aghmanister, Co. Cork [1] and Carnmeen, Co. Down [18], where smithing was carried out near former ringforts, shared several other common features. In both cases, the ironworking activity, together with non-ferrous metalworking, took place in a derelict stone building and both sites were possessions of the Cistercian order. Preliminary dating evidence suggests a late thirteenth- to possibly fourteenth centuries date for the activity at Aghmanister [1], while at Carnmeen [18] it was carried out since at least the twelfth till the thirteenth centuries. The main difference between the two sites is the actual setting of the smithing. At Aghmanister [1], a rectangular building dedicated to ironworking was located inside an abandoned, or unfinished, stone-walled building with unclear function. The forge consisted of an area of about 6.3 by 4.8m enclosed on three sides by wall-slots (Fig. 8.1j). The fourth side was badly damaged by subsequent burials. Two associated hearths were related to ironworking, while a third was possibly connected to copper-working activities. At Carnmeen [18] no features connected to metalworking were uncovered inside the stone building area.

8.1.9 Construction sites

Evidence of ironworking within, or very near to, stone structures such as castles and monasteries has in many cases been interpreted as related to the construction or repair of those structures. At Greencastle, Co. Down [69], slag was found inside one of the castle towers and in an abandoned quarry, while excavations outside the entrance of the castle revealed a succession of *in situ* iron-smithing activities with associated structures. At least some of this was interpreted as relating to building works on the castle. More evidence for ironworking was found at Trim Castle, Co. Meath [121], Greencastle, Co. Donegal [68] and Kilkenny Castle [80], where the amounts were either small or the stratigraphic information limited. Small amounts of smithing slag were recovered from excavations on tower houses at Kilcoe Castle [76] and Kilcolman Castle [77], both in Co. Cork. Most ironworking evidence related to monasteries was limited in nature and possibly connected to building activities or to smiths using the derelict buildings. This was the case at Bridgetown Priory in Co. Cork [14], Clareabbey, Co. Clare [27], Inch Abbey, Co. Down [71], St Mary's Abbey, Co. Fermanagh [116], the Dominican Priory, Mullingar, Blackhall Place, Co. Westmeath [108] and Jerpoint Abbey [72] and Kells

Priory [75], both in Co. Kilkenny. Several monastic sites, where similar small amounts of ironworking residues were potentially the result of construction activity, were not included here due to the lack of positive dating evidence (see Appendix 7).

8.1.10 Cemetery sites

At two sites, at Ballykilmore, Co. Westmeath [7] and Johnstown, Co. Meath [73], ironworking was carried out in the upper fills of an older circular enclosure ditch, while burials were taking place inside of that same enclosure. This would appear to be very similar to some of the so-called "cemetery settlements" which are known from the early medieval period, the enclosed variety of which consistently showed evidence for ironworking (Williams 2010: 36). Although called settlements, none of these sites, early or late medieval, have evidence of dwelling structures (ibid.: 41). At Ballykilmore, iron smelting was also carried out, while at Johnstown [73] the evidence was ambiguous. At Moneygall in Co. Offaly [104], some of the burials were also contemporary with the ironworking, both smelting and smithing. At this site, however, the metalworking was associated with two penannular ditches, possibly houses, which cut the early medieval enclosure. It is likely that the latter was invisible at that stage.

8.1.11 Other sites

Finally, a handful of sites revealed insufficient evidence to allow the site to be classified in one of the above categories. At Moigh Upper (Hill of the Smith), Co. Roscommon [102] a single smithing hearth cake was directly dated by radiocarbon analysis to the fifteenth- to early sixteenth-, likely mid-fifteenth, centuries. At Killegland, Co. Meath [89], Kilcoole, Co. Wicklow [78] and Kiltotan and Collinstown in Co. Westmeath [90] further limited evidence for late medieval smithing was encountered.

8.1.12 Re-use of older sites

There are several sites where the late medieval smithing activity was carried out, or the debris deposited, in the upper fills of early medieval circular enclosures. This was observed at the sites of Tullylish [124] and Cathedral Hill [26], both in Co. Down, Loughbown, Co. Galway [96] and Mullaghmarky AR016, Co. Kerry [105]. All three of the cemetery sites, at Ballykilmore, Co. Westmeath [7], Johnstown, Co. Meath [73] and Moneygall, Co. Offaly [104] (see above), had both ironworking and burial activity carried out at the same place. At two other sites Cappydonnell Big, Co. Offaly [16] and Cookstown, Co. Meath [30] the earlier ringforts were probably no longer a visible feature in the landscape. At Armoy, Co. Antrim [3] an early medieval souterrain was remodelled as an area dedicated to smithing. Several cases are recorded of ironworking carried out in abandoned late medieval structures. Smiths occupied a tower house at Castle Carra in Co. Antrim [24] after it went out of use. Very elaborate smithing was undertaken in an earlier medieval hall at Galway, Courthouse Lane in the medieval centre of that town [63], and at Tintern, Co. Wexford [119], a dissolved monastery became the setting for both iron- and copper-working.

8.2 Smithing technology

8.2.1 Smithing hearths

In general, late medieval smithing hearths consist of shallow, round to oval pits (Fig. 8.6), but there are also indications for the use of waist-high hearths (see below). The dimensions of the ground-level smithing hearths can vary substantially, while their average length lies between 0.75 and 1m (See Appendix 5). In total, sixty-three hearths were accepted as potential smithing hearths, with varying levels of confidence. Very high confidence was assigned to features with frequent hammerscale or smithing pan in or near them and single hearths inside features recognizably used for ironworking. Sites with less information, either preserved or published, but still probably functioning as smithing hearths were given a high confidence level. Other features for which there were some indications that they could have functioned as ironworking hearths, were assigned a medium confidence level.

A plot of the length and width of the hearths with high to very high confidence level shows the majority of the hearths measuring between 0.6 by 0.6m and 1 by 1m (Fig. 8.7b). There are some interesting differences when we compare these to the graph of early medieval hearth dimensions (Fig. 8.7a). The average dimensions of these earlier hearths cover a larger range, from 0.5 by 0.5m to 1 by 1.5m, but fewer outliers than the late medieval ones. These later hearths are also more often elongated, that is to say located below the line on the graph representing a length double the width. It is unclear

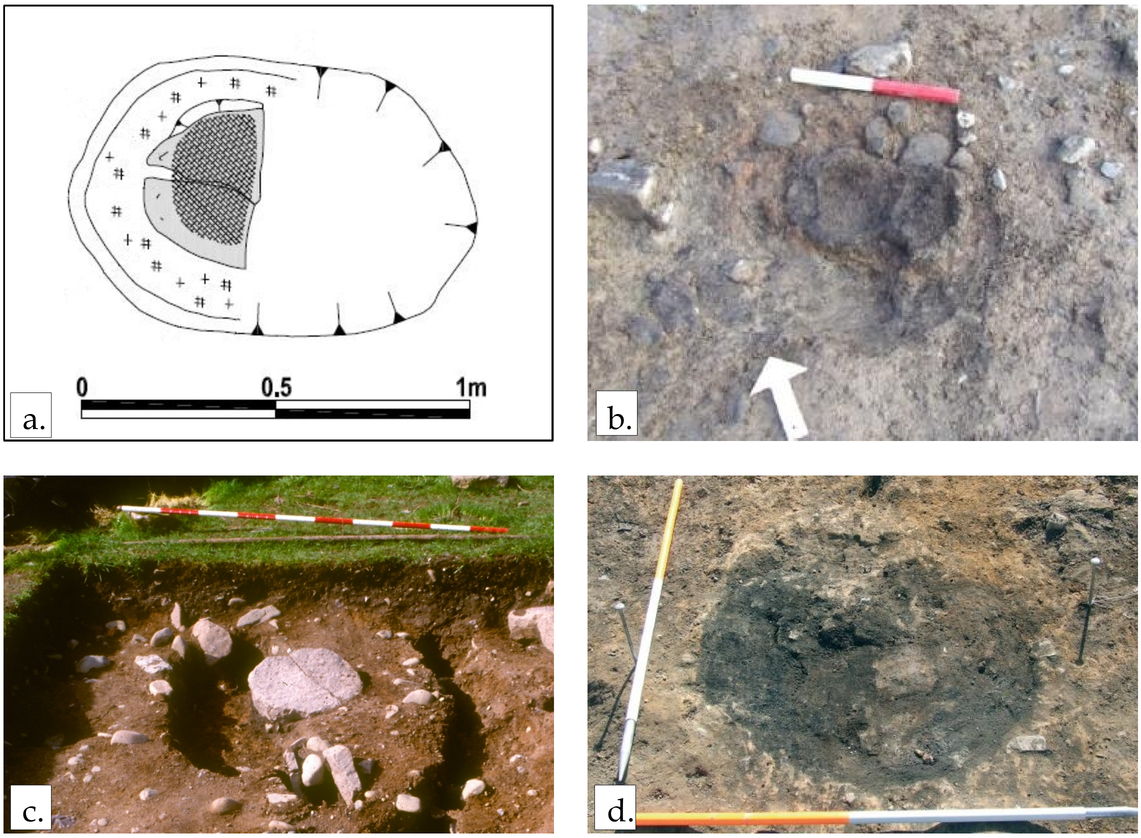


Fig. 8.6 Late medieval Irish (bloom) smithing hearths. a. Plan of probable bloom-smithing hearth C.979, Ballykilmore, Co. Westmeath [7] (Channing 2012: 631), b. Possible bloom-smithing hearth C.2043, Borris, Co. Tipperary [13] (Wallace and Anguilano 2010b: 631), c. Possible bloom-smithing hearth C.557, Dysart, Co. Kilkenny [60] (courtesy of Ben Murtagh), d. Smithing hearth C.13, Garryleagh, Co. Cork [66] (Ó Faolain 2011: 13).

if these dimensions are directly related to the objects manufactured, or if other factors play a role. If this was the case, then the larger objects manufactured in the early medieval period were, on average, smaller and less elongated than those made in the later medieval period. As such, we can imagine larger ploughs, iron used in construction and possibly weapons being responsible for this evolution. The comparison between hearth-dimensions and site type showed no obvious patterns, nor was there any evolution visible through time. This is perhaps unsurprising as hearths with widely varying dimensions are often found on the same site (See Appendix 5).

Evidence for waist-high forges in late medieval Ireland is scarce. Only at Dunamase Castle, Co. Laois [58] could a square cavity in the corner of a building with metalworking waste represent structural indications of a raised hearth. One piece of slag with a distinct straight edge on one side could imply the same at the Dominican priory at Mullingar, Blackhall Place, Co. Westmeath [108]. At Galway, Courthouse Lane [63] a possible waist-high forge was represented by a stone wall (length 0.9m) with likely

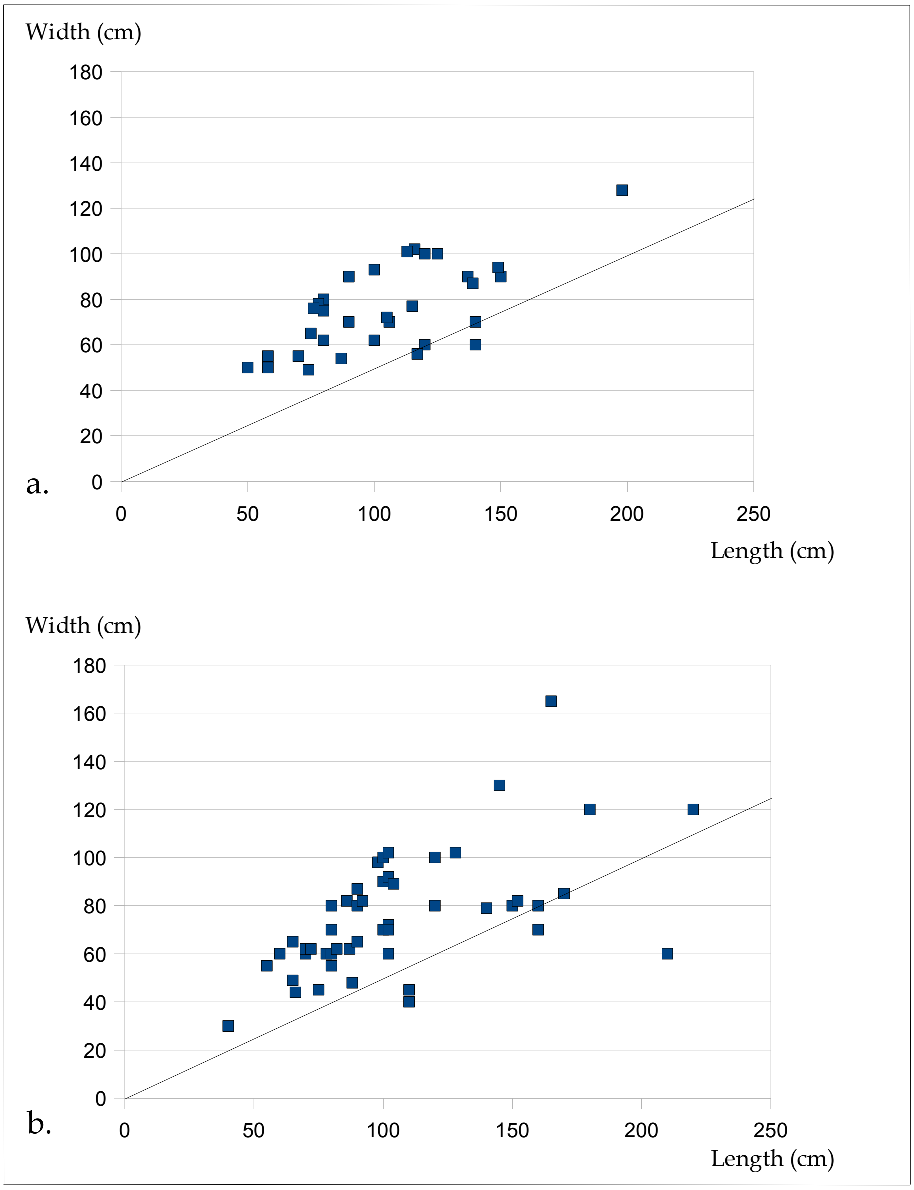


Fig. 8.7 Dimensions of medieval Irish smithing hearths. a. Early medieval (after Young 2011b: 286), b. Late medieval (see Appendix 5 for details). The line represents the values where the length of the hearth is twice the width.

hammerscale between the stones and, together with slag, in a nearby deposit. Perhaps significantly, these three sites were all located within stone buildings. In two cases, around the stone building at Carnmeen, Co. Down [18] and at Armoy in Co. Antrim [3], no hearths were found at sites where both convincing evidence for *in situ* ironworking was present, as well as good preservation conditions.

8.2.2 Anvils

At Ballykilmore, Co. Westmeath [7], Dysart, Co. Kilkenny [60] and Moneygall, Co. Offaly [104] there are reasonably strong indications for the use of stone anvils. All three sites had evidence for smelting, while the latter two had no large smithing hearth cakes indicating bloom refining, which could indicate that these hearths were used solely for bloom compaction. At Cashel, Bank Place, Co. Tipperary [23], one hearth contained a large stone slab, while here the assemblage also pointed towards bloom smithing. A stone, next to a likely smithing hearth at Francis Street/Lamb Alley, Dublin [50], which is visible on the plan but not mentioned in the text, could be another example of a stone anvil. The alternative, an iron anvil, would have been relatively small and set in a block of wood (see Chapter 3.4.2). At Aghmanister in Co. Cork [1], Ballykeoghan [6] and Killaspy [88], both in Co. Kilkenny, we have fairly convincing evidence for pits dug to support such a wooden block. Because of their similarity to postholes, the latter are often difficult to identify with confidence, and this was the case at Tintern Abbey [119] and Coolamurry [31], both in Co. Wexford, Waterford, Little Patrick Street [126], Cookstown, Co. Meath [30], Lismahon Motte, Co. Down [95], Loughgur, Co. Limerick [97] and Borris in Co. Tipperary [13]]. Several sites with *in situ* smithing have no evidence of anvil block supports; Trim, High Street, Co. Meath [122]; Mannan Castle, Co. Monaghan [99]; Garryleagh, Co. Cork [66] and Kiltotan and Collinstown in Co. Westmeath [90].

An exceptionally large cruciform anvil-placement was uncovered at Galway, Courthouse Lane [63]. Its head and arms were of roughly equal dimensions (0.9 by 0.55m), while the shaft was longer (1.75m) (Delaney 2004: 174), giving a total length of 3.2m (Fig. 8.8). In the publication on the excavation, a comparison was made with two other known cruciform anvils at Blackwater Green forge in Crawley, Sussex and Rockley in Yorkshire, both dating to the seventeenth century (Crossley 1990: 153–169). There were differences in the design of the anvils, the one at Blackwater Green having equal lengths for arms and shaft and at Rockley the shaft was at an oblique angle to the arms but, most importantly, these two sites were finery forges, that is to say where sow iron from a blast furnace was de-carburized and made into iron bars. This was definitely not the case at Courthouse Lane. The setting of the Galway anvil could point to the manufacture of anchors, but the known harbour smithy at Stralsund in Germany, presumably making anchors, only had tree trunks as anvil-supports (Kulessa 2004: 130–

131). The chronologies of the sites; thirteenth century for the German site and sixteenth century for Courthouse Lane, might explains the difference in technologies.

Fig. 8.8 Cruciform anvil-base, Galway, Courthouse Lane [63] (Delaney 2004: 173)

8.2.3 Troughs

On only one site, Francis Street/Lamb Alley, Dublin [50], do we have evidence for the potential use of a trough in relation to iron smithing. A wood-lined pit measuring about 1.75m-square was situated next to a feature interpreted as a smithing hearth. It is, however, recorded as containing large quantities of charcoal, possibly indicating a use different to a water trough. At some other well-preserved rural sites, such as Coolamurry, Co. Wexford [31] and Cuffsborough, Co. Laois [40], pits were present which were probably not hearths. But as these were not clay-lined and had concave sides, it is unlikely that these held water or a water container. Probably most containers used to hold water for quenching steel or cooling tools would have been buckets or similar vessels, leaving no traces in the archaeological record.

8.2.4 Tuyeres/Hearth walls

Ireland is the only place in late medieval Europe where ceramic tuyeres are known to be used in iron smithing. Additionally, just as in previous periods, no tuyeres are recorded as used in iron smelting in Ireland. In most cases, only the vitrified front part of the tuyere survives in the archaeological record. Based on this, most recorded examples of late medieval Irish tuyeres appear to have had circular, non- to rather strongly convex fronts. They would mostly seem to have been the shape of a truncated cone. But we do not know if the tuyeres extended back only slightly, as in the case of the disc tuyeres from Carrigmuirish, Co. Waterford (O'Kelly 1964: 100) (Fig. 8.9a) and Lowpark, Co. Mayo (Gillespie 2010: 13) (Fig. 8.9b), tapered back further like those from Carrickmacross, Co. Monaghan (Photos-Jones 2010a: cxxvii) (Fig. 8.9c) or if they were similar to the massive examples from Lisleagh, Co. Cork (Cherubini 2005: 114) (Fig. 8.9d), all of which are early medieval in date.

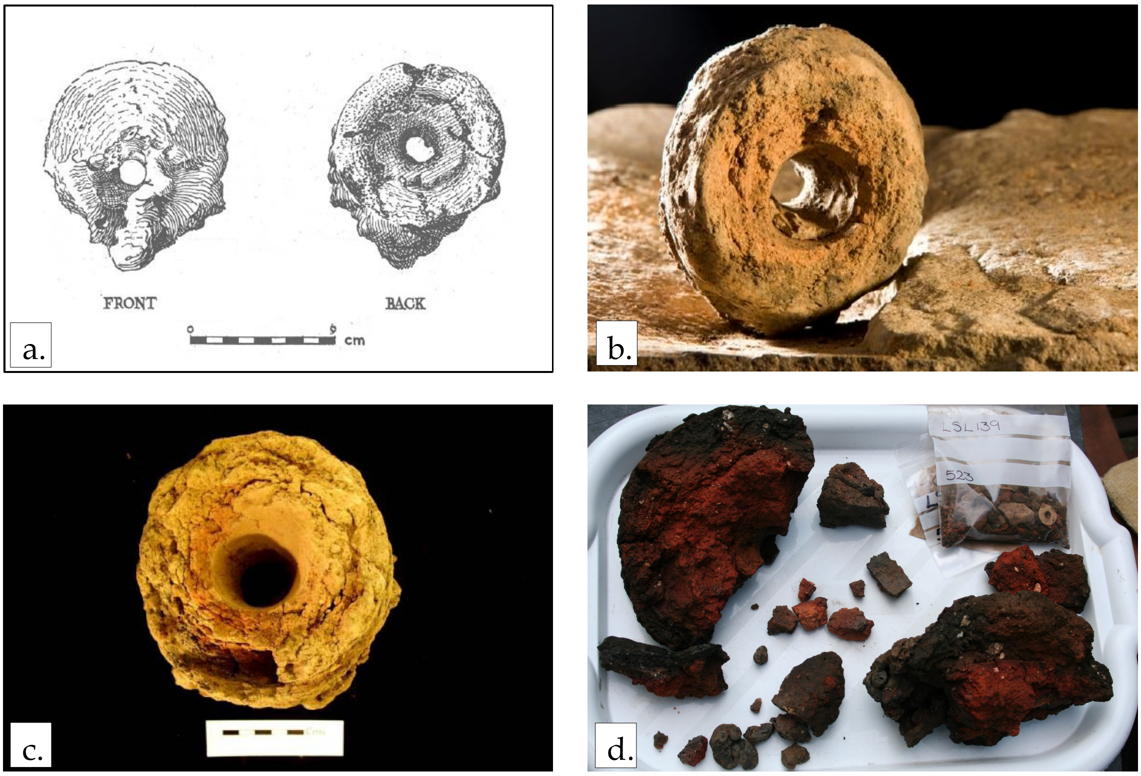


Fig. 8.9 Early medieval Irish tuyeres. a. Carrigmuirish, Co. Waterford (O'Kelly 1964: 100), b. Lowpark, Co. Mayo (Gillespie 2010: 13), c. Carrickmacross, Co. Monaghan (Photos-Jones 2010a: cxxvii), d. Lisleagh, Co. Cork (courtesy of Mick Monck).

Their fragmentary nature and the wide variety of vitrified ceramic material potentially associated with metalworking activities, generally make tuyeres difficult to recognize to the untrained eye. Hearth-lining is only positively recognizable as such when larger pieces showing the concave curvature survive, which makes them even rarer in the archaeological record. Tuyeres have been convincingly recorded on a fair amount of Irish late medieval rural sites, all of which are rather late in date; Garryleagh, Co. Cork [66] [8%][66] (fourteenth century); Kiltotan and Collinstown, Co. Westmeath [90]

66 Numbers in brackets denote the percentage of tuyere material in the full assemblage. The values are

(fifteenth century); Cuffsborough, Co. Laois [40] (late fifteenth to early sixteenth centuries); Caherduggan, Co. Cork [15] [17%] (sixteenth century); Ballykeoghan, Co. Kilkenny [6] [8%] (fifteenth to early seventeenth centuries); Moneygall, Co. Offaly [104] (sixteenth to early seventeenth centuries) and Loughgur, Co. Limerick [97] (late medieval).

Tuyeres were also found at the site of Shandon, Co. Waterford [115], but here they were found associated with smelting slag, probably implying that they were employed in bloom smithing. At Ballykilmore in Co. Westmeath [7] (fourteenth century), substantial amounts of large tuyeres were found in two areas [30 and 21%] in contexts probably connected to bloom smithing but also secondary smithing. Tuyeres were absent from three isolated rural forge sites at Loughbown, Co. Galway [96], Coolamurry, Co. Wexford [31] and Curragh Upper, Co. Cork [42] (all late twelfth to early thirteenth centuries), and the smithing sites adjacent to farm buildings at Cookstown, Co. Meath [30] (thirteenth century) and Trevet, Co. Meath [120] (late medieval). Similarly, at the thirteenth to fourteenth centuries ring-work at Woodlands West, Co. Kildare [129] no tuyeres were recorded.

At Coolamurry, Co. Wexford [31], the material found was identified as hearth-lining [9%] and a row of stakeholes, curving around part of the smithing hearth, was interpreted as indicating a clay rim which would have had a blow hole. There were indications for the use of a hearth wall with blow-hole at Greencastle, Co. Down [69]. At Killaspy, Co. Kilkenny [88] the material was described as vitrified lining [5%], but could have been tuyere fragments, while at Carnmeen, Co. Down [18] one category, Burnt and Vitrified Ceramics [16%], could indicate tuyere material. The material at Nobber, Bridge Park, Co. Meath [111] possibly included tuyere fragments, but positive identification was not possible. At the exceptionally well-preserved site at Aghmanister, Co. Cork [1], substantial amounts of tuyere fragments were recovered [3%], while one of the three hearths had a c. 0.1m-high clay rim around half of its edge. This rim was heat-affected on one side, but there were no indications that it was equipped with a blow-hole.

In urban settings, tuyeres have been recognized at Kilkenny, Irishtown [81] (late twelfth century?) (Fig. 8.10a), Cork, Tuckey Street [39] [18%] (late twelfth to early thirteenth centuries), Kilkenny, Robing Room [85] (late twelfth to thirteenth centuries), Dublin, Bride Street [47] (thirteenth century), Dublin, Longford Street Little [53] as well as at Thomastown, Chapel Lane, Co. Kilkenny [118] (Fig. 8.10b), Athenry, Abbey

calculated from the relevant specialist reports.

Row/Bridge Street, Co. Galway [4], Armagh, Upper English Street [2] and Cork, Phillips' Lane [35] (all late medieval). At the latter site, a clear piece of vitrified lining was also identified (Fig. 8.10c). They were not found at Cashel, Bank Place, Co. Tipperary [23] (thirteenth to fourteenth centuries), in Castledermot, Abbey Street/Market Square/Main Street, Co. Kildare [25], Claregalway, Co. Galway [28] and only in minimal amounts at Kilkenny, The Parade [82] (both late medieval). Tuyeres were also encountered as probably connected to building activities at Mullingar, Blackhall Place, Co. Westmeath [108], Jerpoint Abbey, Co. Kilkenny [72] (both late medieval) and Kilcoe Castle tower house in Co. Cork [76] (late sixteenth to early seventeenth centuries). Large amounts of tuyere pieces, but frequently heavily fragmented, were found at the monastic ironworking site of Aghmanister, Co. Cork [1] (Fig. 8.10d).

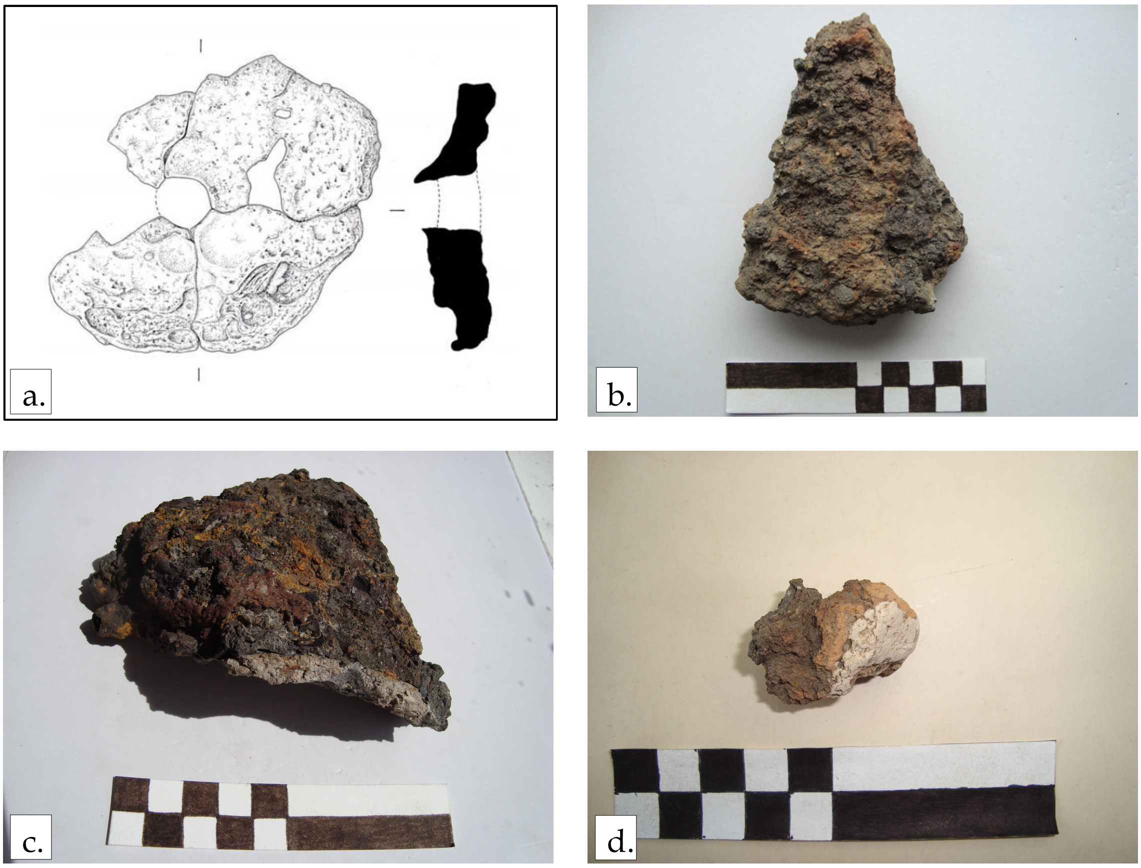


Fig. 8.10 Late medieval tuyeres and hearth-lining from Ireland. a. Tuyere-front, Kilkenny, 1 Irishtown [81] (Doyle 2004: 201), b. Pie-shaped tuyere fragment, Thomastown, Chapel Lane, Co. Kilkenny [118], c. Smithing hearth cake with adhering hearth-lining (basal view), Cork, Phillips' Lane [35], d. Tuyere fragment with adhering white clay, Aghmanister, Co. Cork [1].

Due to the fragmentary nature of the tuyeres, the diameters of their frontal parts can only in some cases be calculated or estimated. We have values for frontal diameters from seven late medieval Irish sites. At the possibly late twelfth-century site at Kilkenny, 1 Irishtown [118] (Fig. 8.10a), the tuyere found had a diameter of 150 mm, and similar values (150 to 180 mm) were estimated for the likely thirteenth- to early fourteenth-century site at Aghmanister, Co. Cork [1] (Fig. 8.10d). Several tuyere fragments from the latter site were made up of two different types of clay: the usual pinkish-red clay, found throughout the assemblage, and fine white clay. The white clay could either represent repair of the tuyere or material used especially for its chemical properties. Large-diameter tuyeres were excavated at two fourteenth century sites at Garryleagh, Co. Cork [66] and Ballykilmore, Co. Westmeath [7]. At the first site, the values were larger than 120 mm, around 180 mm and possibly 300 mm. At the second site, several examples of convex tuyere-fronts measuring around 300 mm were found, with possible smaller examples occurring. At Ballykeoghan in Co. Kilkenny [6], dating to the end of the research period, tuyeres with diameters of around 120 mm, larger than 140 mm, around 160 mm, 200 mm and around 210 mm were found. A fragment of a large tuyere (c. 250 mm) was found at Thomastown, Chapel Lane, Co. Kilkenny [118] and a smaller one (c. 160 mm) (Fig. 8.10b) at Mullingar, Blackhall Place, Co. Westmeath [108]. Both sites were not more closely datable than to the late medieval period.

8.2.5 “Smithing plugs”

A new artefact type for Ireland, and here provisionally called smithing plugs, was found at Cork, Tuckey Street [39] (Fig. 8.11a) and Dysart in Co. Kilkenny [60] (Fig. 8.11b), respectively dated to the late twelfth to early thirteenth centuries and the Anglo-Norman period. The plugs from both sites are near-identical. They are elongated pieces of heavily heat-affected and vitrified ceramic material with an oval- to teardrop-shaped section. At one terminus they have a slightly overhanging, mushroom-cap. The Tuckey Street [39] examples are slightly smaller, 40mm longest section axis compared to 50mm at Dysart [60]. This material is identical to the “*Stopfen*“ (plugs) recovered during field-walking and excavation campaigns at Haithabu, an eight- to eleventh-century Viking settlement on the German-Danish border (Westphalen 1989: 20, 100; 2004: 26–27) (Fig. 8.11c). These artefacts had the same size, shape and material as the Tuckey Street [39] plugs and were also connected to iron smithing. The function was seemingly first thought to be plugs for tapping channels or tuyeres, but this was later considered unproven. Another ceramic plug is also recorded from the site at Dublin, Thomas Street [55], but no further details were available. The function of these artefacts is as yet unclear.[67] A connection with brazing was suggested, but while evidence for copper-working was found at both Haithabu and Dysart [60], this was lacking at Tuckey Street [39]. It would also be unclear what type of object with a teardrop-shaped hollow would need brazing. The same problem persists when trying to explain these plugs as preserving an object's shape during forging.

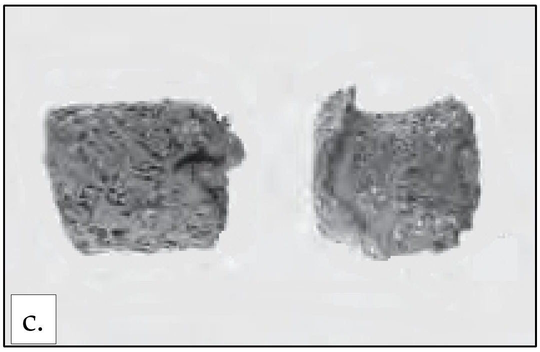


Fig. 8.11 “Smithing plugs”. a. Cork, Tuckey Street [39], b. Dysart, Co. Kilkenny [60], c. Haithabu, Germany (Westphalen 2004: 27)

8.2.6 Tools

Most iron tools, because they were prized possessions of the smith as long as they were functional, are relatively rare finds on archaeological sites. No late medieval hammers, tongs or iron anvils are known from Ireland. The other tools fall into two categories: iron tools such as awls, punches, files and chisels on the one hand, and stone tools such as hones and whetstones on the other. The problem with the first category is that each of

67 Many thanks to Tim Young for his assistance in trying to solve this mystery.

these types of tools were also used by other artisans, such as carpenters, masons, leatherworkers, and so forth. Sharpening stones could also have been used by bronze-workers or by the user of the iron as opposed to the manufacturer. Chisels were found in contexts with late medieval smithing evidence at Johnstown, Co. Meath [73] (two pieces, which could be awls), Nobber, Bridge Park, Co. Meath [111] (also possibly an awl), a possible chisel at Loughgur, Co. Limerick [97] and one each at Ballyloughan, Co. Carlow [8] and Mannan Castle, Co. Monaghan [99]. At Blackcastle, Co. Tipperary [12], a large chisel seen as a stonemason's tool was recovered, together with a smaller one and a punch or awl. None of these iron tools, potentially related to ironworking, were illustrated in the relevant publications. Only at Moneygall, Co. Offaly [104] do we have hollow pieces of slag formed around an iron bar or poker. Hone and whetstone are synonyms although sometimes the former is seen as used for finer work. Hones and whetstones were recovered in association with remains of late medieval smithing acivity at Portmarnock, Co. Dublin [112], Blackcastle, Co. Tipperary [12], Loughgur, Co. Limerick [97] (Fig. 8.12a), Cashel, Bank Place, Co. Tipperary [23] (Fig. 8.12b), Armagh, Upper English Street [2], Cork, Barrack Street [32] and Carnmeen, Co. Down [18]. Three possible whetstones were found at Cork, 35–39 South Main Street [36].

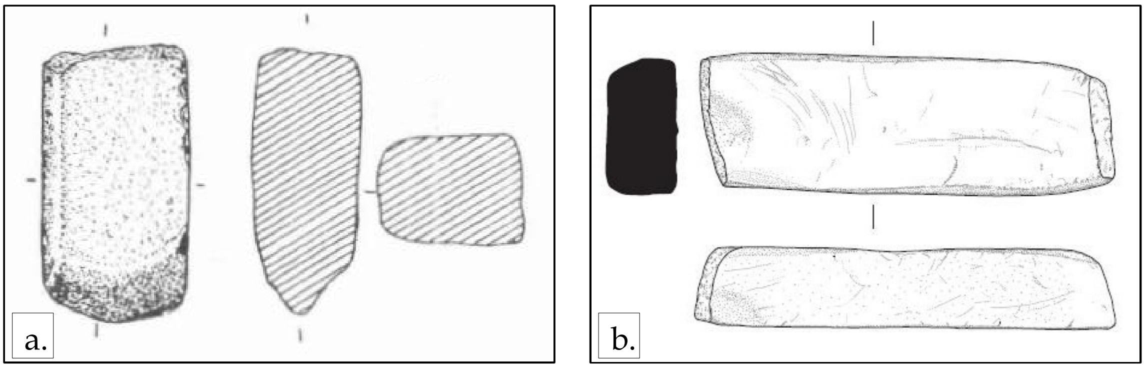


Fig. 8.12 Late medieval Irish hone and whetstones, possibly related to smithing. a. Hone stone, Loughgur (Car Park), Co. Limerick [97] (Cleary 1982: 91), b. Whetstone, Cashel, Bank Place, Co. Tipperary [23] (Hughes 2009: 141)

8.2.7 Fuel

By most frequently observed fuel type is charcoal. In archaeology, the term charcoal is used for three different substances: charred wood, charcoal proper (reduced wood) and burnt charcoal. Although it is often assumed that charcoal (proper) was used in metallurgical processes, this has, at least in Ireland, never been proven. Table 8.1 shows that oak was predominantly used in late medieval Irish smithing. Three of the sites, Coolamurry, Co. Wexford [31], Curragh Upper, Co. Cork [42] and Ballykeoghan, Co. Kilkenny [6], were isolated rural forges, while two others, at Loughbown, Co. Galway [96] and Killaspy, Co. Kilkenny [88] probably were (see above). The type of site at Kiltotan and Colilinstown, Co. Westmeath [90] was unclear. The only notable exception is the charcoal from the hearth at Borris in Co. Tipperary [13], where hazel was the dominant species. Interestingly, this feature was interpreted as a possible bloom-smithing hearth. The remaining taxa could have been used as tinder.

Site	Date	Wood species
Coolamurry, Co. Wexford [31]	L12th–E13th C	Oak (100%)
Curragh Upper, Co. Cork [42]	L12th–E13th C	Oak (100%)
Loughbown, Co. Galway [96]	L12th–E13th C	Oak (99.1%), Pomoideae (0.8%), hazel/alder (0.1%)
Killaspy, Co. Kilkenny [88]	13th C	Oak (100%)
Kiltotan and Collinstown, Co. Westmeath [90]	15th C	Oak (10g), oak/elm (2g), willow, poplar/alder/pomaceous fruit (4g), other (3g)
Borris, Co. Tipperary [13]	L15th–16th C?	Hazel (22.7g), oak (3.7g), spindle (1.3g), willow (1.2g)
Ballykeoghan, Co. Kilkenny [6]	15th–E17th C	Oak (freq.), blackthorn/cherry, alder

Table 8.1 Identification of charcoal from late medieval Irish smithing hearths

Another type of material potentially used as fuel is peat. While turbary rights are often recorded in the contemporary documents and turf is sometimes included in murage grants, as, for example, in Kilkenny in AD 1306 (CDRI 1302–1307: 158), no evidence for the use of peat as fuel in metal-working in late medieval was found. Also, no likely late medieval smithing assemblages have returned exceptionally early radiocarbon dates, potentially pointing to older wood fragments included in peat, or possibly, the use of bog oak.

Coal, on the other hand, was encountered on several sites. A large percentage of the material from Kilkenny, The Parade [82] contained coal fragments (Fig. 8.13), the majority of which was dated to the thirteenth and fourteenth centuries based on preliminary pottery identification. In one case, the coal dust was included in the matrix of vitrified ceramic material associated with smithing. The same material was also observed in a smithing hearth cake and in other slag from two pits which only included locally produced pottery at nearby 26–33 Patrick Street in the same town [84]. Further single pieces including coal were also retrieved from Phillips' Lane [35] and 35–39

South Main Street [36], both in Cork. At the first site, the feature number did not appear in the register, but was likely late medieval. At the second, shell and coal fragments were observed as embedded in a piece of likely oxidized iron from a deposit dated to the mid-thirteenth century. Coal was also present among material from Chapel Lane, Thomastown, Chapel Lane, Co. Kilkenny [118], but here the feature could only be dated to the medieval period. A section of a late medieval slot-trench at Carrickfergus Market Place/St. Nicholas' Church [21] contained both iron slag and coal. Finally, the late fifteenth- to early seventeenth-century isolated rural forge at Cuffsborough, Co. Laois [40], was exclusively run on coal.

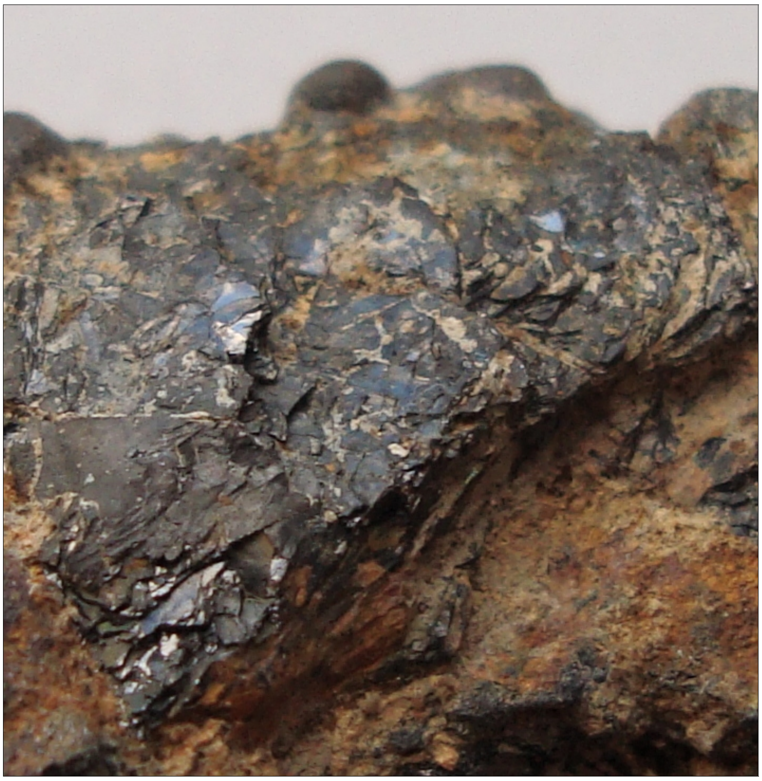


Fig. 8.13 Coal embedded in late medieval Irish smithing slag, Kilkenny, The Parade [82]

After the Roman period, coal disappears from the historical and archaeological record in northern and western Europe, only to reappear again around AD 1200. Some early dates referring to the use and mining of coal are mentioned by Nef (1932: 7): around AD 1195 in Liège, AD 1200 in Scotland, AD 1236 in Northumberland and AD 1249 in Wales. Coal is also recorded in large amounts from a thirteenth-century harbour smithy at Stralsund on the German Baltic coast (Kulessa 2004: 132). In Ulster, Hamilton (1790: 30–31) remarks on the occurrence of coal cinders in the lime mortar used in the construction of Bruce's Castle (early fourteenth century) on Rathlin Island, Co. Antrim and the same work (ibid.: 49–60) records the discovery, around 1770, of extensive old coal-mining galleries in Ballycastle. Davies (1935: 38) refers to the find of a rilled hammer in "medieval coal-workings" at Ballycastle, without further clarification. Sea-coal is mentioned in two pavage charters dating to the first half of the fourteenth century, for Drogheda in AD 1323 (CARD, Vol. 1: 13) and for Dublin in AD 1346 (ibid: 18), while in the murage grant for Callan, issued in AD 1339, includes levies for both charcoal and coal (Dryburgh and Smith 2005: 53). The charters for Kilkenny (Munby and Tyler 2005: 199) are also of interest; whereas only charcoal is mentioned in the 1375 murage grant, which was repeated in 1382 and 1394, the mention of "coals of any kind" in the 1420 charter, repeated in 1441, likely indicates the introduction, in the early fifteenth century, of mineral coal in Kilkenny in that period. The same reference to any kinds of coal is mentioned in a murage grant to Drogheda (Meath) as early as AD 1296 (CDRI 1293–1301: 145).[68] No references in the archaeological literature were found for the identification of coal associated with late medieval Irish non-metallurgical activities, such as lime burning or brewing.

8.2.8 Bloom smithing on smelting sites

The evidence for bloom smithing on smelting sites is rather scant. Small-sized smithing hearth cakes were recorded from Derrinsallagh, Co. Laois [44], Shandon, Co. Waterford [115] and Ballydowny, Co. Kerry [5], while smithing activity was also present on the site of Dysart, Co. Kilkenny [60]. Large smithing hearth cakes of a late medieval date were found at Ballykilmore, Co. Westmeath [7] and possibly at Borris, Co. Tipperary [13]. Tuyere fragments were only mentioned for Shandon [115] and at Ballykilmore [7] (Fig. 8.14), where exceptionally large specimens were found (see above). The latter site also yielded smaller smithing hearth cakes which were demonstrated through chemical analysis to have probably resulted from bloom smithing (Young 2012b: 20). Young suggested that this could imply the forging of either small or split blooms (ibid.: 31). The lack of evidence for bloom smithing on many smelting sites, together with the occurrence of large bloom-smithing cakes on others, led the same author to propose that the two activities were carried out in different places, possibly out of considerations for fuel supply (ibid.: 38–39). In some cases, however, relatively or completely slag-free blooms could have been produced (see Chapter 3.2.3), which would respectively result in the formation of small bloom-smithing cakes or no bloom smithing being required

68 Slattery (2009: 71) lists several more murage grants where coal is mentioned, but in many cases this would have been a translation of the Latin *carbonem*, signifying both charcoal and coal.

after smelting. The occurrence of large smithing hearth cakes on non-smelting sites is detailed in the next sub-chapter.

Fig. 8.14 Fragment of a bloom-smithing slag cake. Ballykilmore, Co. Westmeath (Young 2012c: 424). Scale: 100mm

8.2.9 Smithing slag

The two types of waste products of smithing are the smithing hearth cake and hammerscale. These cakes often have a convex base, but are sometimes irregularly shaped, especially the smaller ones (Fig. 8.15a and 8.15b). In some instances, these smithing hearth cakes show evidence of conditions in the forging hearth. Occasionally, so-called double (or triple) smithing hearth cakes are encountered, which are usually interpreted as representing hearths remaining uncleared after a smithing event. Sometimes the upper surface of the cake shows a dip caused by the last blowing of the slag before solidification (Fig. 8.15c). Hammerscale, both spheroidal or globular (Fig. 8.15d) and flake form, is invariably found on smithing sites, but is very often not detected in the sample residues.

The mean weights and weight distributions of the late medieval Irish smithing hearth cakes have been calculated from several relevant specialist reports and complemented with information from the assemblages studied for this thesis (Table 8.2). For the proportions of smithing hearth cakes compared to the full assemblages, only complete smithing hearth cakes were used, as smaller fragments are often hard to identify as such with confidence. Similarly, it can be difficult to determine if smaller lumps (50 to 100g) are indeed smithing hearth cakes and these have been omitted from the following calculations. Tim Young, in several reports (Coolamurry, Co. Wexford

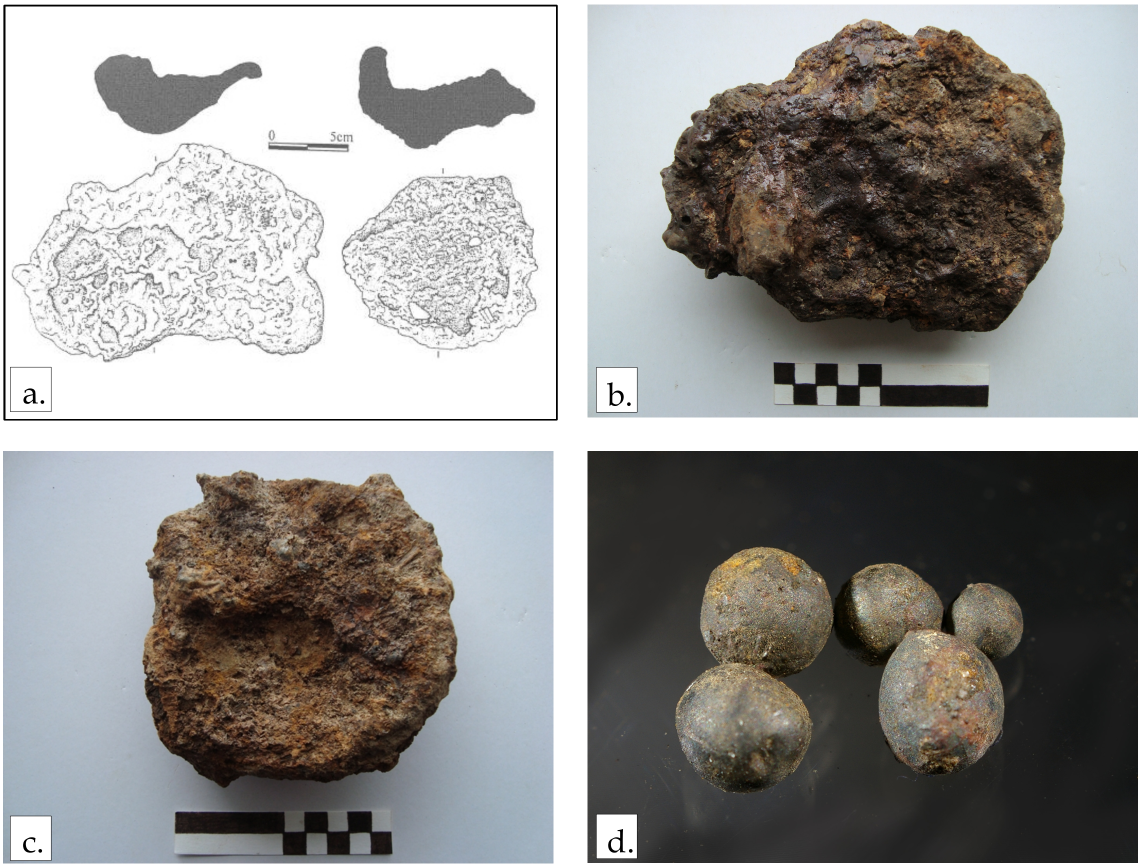


Fig. 8.15 Late medieval Irish smithing slag. a. Smithing hearth cakes, Armagh, Upper English Street [2] (Crothers and Gahan 1999: 68), b. Smithing hearth cake, Cork, 35–39 South Main Street [36], c. Smithing hearth cake showing a blowing-hollow, Thomastown, Chapel Lane, Co. Kilkenny [118], d. Globular hammerscale, Aghmanister, Co. Cork [1] (image length c. 3 mm).

[31], Garryleagh, Co. Cork [66], Ballykilmore, Co. Westmeath [7], Ballykeoghan, Co. Kilkenny [6] and Caherduggan, Co. Cork [15]), adds reconstructed weights of smithing hearth cakes, which will have slightly skewed the data for these sites. In general, this was only done for fairly to near-complete specimens.

For several sites, further information was available. At Moigh Upper (Kiltullagh Hill), Co. Roscommon [103], eight fragments of large smithing hearth cakes with an average weight of 2016g and a maximum weight of 3595g were found during field-walking. At Carnmeen, Co. Down [18], smithing hearth cakes made up 38% of the total amount of metalworking waste recovered from late medieval contexts. Six to seven smithing hearth cakes with a mean weight between 250 and 270g were recovered from Cuffsborough in Co. Laois [40] from c. 22kg of residues. At Cookstown, Co. Meath [30] only one possible smithing hearth cake, of unrecorded weight, was present among 6028g of residues, while at Trevet, Co. Meath [120] three smithing hearth cakes made up 40% of a similarly small mount of material (4.8kg).

Site	Date	N	Max. weight (g)	Mean weight (g)	% <500 g[1]	% 501–1000 g	% >1000 g	% >2000 g	% of assemblage
Coolamurry, Co. Wexford [31]	L12th–E13th C	41	2588	386	83	12	5	5	18
Cork, Tuckey Street [39]	L12th–E13th C	21	494/602[2]	282	80	20	0	0	54
Nobber, Bridge Park, Co. Meath [111]	L12th–13th C	9	1360	621	31	45	2%	0	41
Shandon, Co. Waterford [115]	L12th–13th C	8	634	404	48	52	0	0	58
Killaspy, Co. Kilkenny [88]	13th C	35	1248	471	59	20	21	0	18
Cashel, Bank Place, Co. Tipperary [23]	13th–14th C	8	2270	1083	4	24	72	26	60
Kilkenny, The Parade (Phase 1) [82]	13th–14th C	10	1115	521	38	41	21	0	70
Woodlands West, Co. Kildare [129]	13th–14th C	23	3744	1134	4	23	72	14	71
Garryleagh, Co. Cork [66]	14th C	25	802	331	76	24	0	0	45
Ballykilmore Area 1[3], Co. Westmeath [7]	14th C	9	3453	1040	6	24	70	37	27
Ballykilmore Area 2, Co. Westmeath [7.]	14th C	16	4033	1022	15	19	66	66	44
Caherduggan, Co. Cork [15]	16th C	10	3806	1549	2	20	78	63	65
Ballykeoghan, Co. Kilkenny[4] [6]	15th–E17th C	58	478	170	100	0	0	0	18
Claregalway, Co. Galway [28]	13th–17th C	56	3686	907	6	22	72	50	32
Thomastown, Chapel Lane, Co. Kilkenny [118]	Late medieval	13	1150	438	48	32	20	0	53

Table 8.2 Weight information of late medieval Irish smithing hearth cake assemblages. [1]Weight percentages. [2] The largest piece from this assemblage (1204g) was a composite of more than one cake. It was assumed this represented two cakes. [3]Area 1 is the eastern area with the furnace material, Area 2 the possible "limekiln" further west. N is the amount of smithing hearth cakes.

At Curragh Upper in Co. Cork [42], no smithing hearth cakes were recorded from 2.7kg of residues, which probably represents only part of the original assemblage. At Aghmanister, Co. Cork [1], most of the material was highly fluid and smithing hearth cakes were difficult to recognize. Several pie-shaped dense pieces from this site were fragments of larger, heavy smithing hearth cakes, but no complete examples of these were found, even though over 200kg of smithing waste was collected. The same frequent occurrence of flow-structure on the slag in fairly obvious smithing assemblages was observed at Garryleagh, Co. Cork [66], Cookstown, Co. Meath [30] and Coolamurry, Co. Wexford [31]. At Kells, Church Street, Co. Meath [74] large lumps of slag were recorded as found in deposits of an unspecified late medieval date.

Based on the above sample, admittedly small, the following can be deduced. The majority of sites have around 20 to 25% of their smithing hearth cakes weighing between 500 and 1000g. These sites can then, based on the weight of the remaining cakes, be divided into two groups: sites with predominantly light cakes and sites with mostly heavy ones. Four of the five (possibly six) sites with lighter smithing hearth cakes are rural sites (Coolamurry [31], Killaspy [88], Garryleagh [66] and Ballykeoghan [6]). Two of these, and possibly all four (see above), are forge sites. These sites also have low percentages of tuyere material or vitrified lining in their assemblages (between 5 and 9%) (see above). At Coolamurry [31], Killaspy [88] and Ballykeoghan [6] the smithing hearth cakes made up 18% of the total assemblage, while at Garryleagh [66] the value was 45%. Coolamurry [31], Killaspy [88] and Ballykeoghan [6] also yielded large quantities of hammerscale (c. 15kg, more than 3.5kg and 25.4kg respectively). Garryleagh, Co. Cork [66] was not sampled for hammerscale. The other site with smaller smithing hearth cakes, the urban site at Cork, Tuckey Street [39], conversely had both high tuyere (18%) and smithing hearth cake (54%) proportions. Another site group, at Shandon, Co. Waterford [115], has an almost equal proportion of light- and medium-weight smithing hearth cakes (and none over 1kg). The dumped nature of this assemblage, which would have selected for heavier pieces, might mean that it belongs to the light-weight group. Its (possible) tuyere proportion was also very low (less than 1%). The small average size of the smithing hearth cakes (250 to 270g) at the forge site of Cuffsborough, Co. Laois [40] was seen as the result of the use of coal, but would not be exceptional for this group.

Of the five sites with smithing hearth cakes predominantly weighing over 1kg, bloom-smithing activities were suggested for two of those, Ballykilmore, Co. Westmeath [7] (both areas) and Caherduggan, Co. Cork [15]. Both these sites had medium-to-high smithing hearth cake (respectively 27%, 44% and 65%) and high tuyere (respectively 30%, 21% and 17%) proportions. The other three sites, Bank Place in Cashel, Bank Place, Co. Tipperary [23], Woodlands West, Co. Kildare [129] and Claregalway, Co. Galway [28], also had a high percentage of smithing hearth cakes in its assemblage (respectively 60%, 71% and 32%), but no tuyere material was recorded from these sites.

The sites at Moigh Upper (Kiltullagh Hill), Co. Roscommon [103] and Kells, Church Street, Co. Meath [74] can also be included in this category. As all the material from these sites is either dumped material, the result of prospecting or hand-selected for examination, the weight proportions of all the material produced would have been somewhat lower. Next to these two groups, a third one with a more evenly spread weight distribution of the smithing hearth cakes can be identified. All three sites belonging to this group were situated in an urban setting. At Nobber, Bridge Park, Co. Meath [111] and Kilkenny, The Parade [82], a more evenly spread smithing hearth cake distribution was observed (respectively 45% and 41% between 500 and 1000g) together with a large proportion of the slag consisting of smithing hearth cakes (respectively 41% and 70%). At Thomastown, Chapel Lane, Co. Kilkenny [118] the assemblage was somewhat lighter (48% less than 500g), while still having a high proportion value (53%). The high proportion values for Kilkenny, The Parade [82] and Thomastown [118] are probably at least partially influenced by the dumped nature of the assemblage. The tuyere proportion at The Parade [82] was 3%, at Thomastown [118] 2% and is unknown for Nobber [111].

8.2.10 Analysis of smithing slag and iron objects

Brian Scott, who pioneered many analytical techniques for Irish archaeological artefacts, included the results of analyses of late medieval slag, objects and even a piece of bloom, in his doctoral thesis in 1976. This is still the largest body of analytical data on this type of material to date. Since then, more data was added by specialists Tim Young, Angela Wallace and Effie Photos-Jones, who were engaged in writing reports for the National Roads Authority on archaeometallurgical material recovered during road construction. The results of these analyses, although varying both in quality and quantity, provide invaluable insights into several aspects of ironworking.

Smithing slag

The chemistry of smithing slag is notoriously difficult to interpret, but can be used to rule out certain technologies. The metallographical examinations of iron objects, then, give direct information on available types of iron and provide clues for forging techniques. The results of investigations on late medieval blooms was discussed in Chapter 6.2.5. In only six cases was smithing slag from late medieval sites subjected to chemical analysis, and in one of those, the material from Tintern Abbey in Co. Wexford [119], the data was too minimal to include in the Table 8.4 below. The two sites where relatively large numbers of analyses were carried out, Ballykilmore, Co. Westmeath [7] and Carrickfergus, Market Square, Co. Antrim [20], show a large variation in the content of the various oxides. This clearly illustrates the limited interpretational value of the results for sites where only small amounts of analyses were carried out. This is further compounded by the many factors which can influence the composition of smithing slag, many of which are still debated or poorly understood (see Chapter 3.3.3). One interesting observation is that of the slag from Ballykilmore [7], interpreted as representing both bloom and secondary smithing; it is a small smithing hearth cake which had the highest calcium-oxide levels (9.92%). As this element was seen as signifying that at least part of the assemblage was related to bloom smithing, the latter was interpreted as the result of the refining of smaller blooms or fragments of larger ones (Young 2012b: 20, 31). Further slag was analysed from the sites at Cookstown, Co. Meath [30] and Cappydonnell Big, Co. Offaly [16]. Finally, mineralogical examination of the smithing slag from Coolamurry, Co. Wexford [31] demonstrated the likely use of welding-sand.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	Fe_2O_3
1	0.39	1.20	5.28	25.18	0.22	1.29	1.87	0.33	0.19	50.45
2	0.62	0.22	4.03	24.18	0.21	0.97	2.19	0.22	0.28	66.82
3	0.20	0.45	10.04	20.00	0.49	0.72	5.00	0.27	1.07	68.93
4	1.31	0.58	3.77	31.45	1.14	1.59	5.25	0.35	0.28	54.64
5	n.d.	2.29	16.33	n.d.	0.19	n.d.	1.96	0.24	0.28	n.d.

Table 8.3 Chemical analysis results of late medieval Irish smithing slag 1. Coolamurry, Co. Wexford [31] 2. Cookstown, Co. Meath [30] 3. Ballykilmore, Co. Westmeath [7] 4. Cappydonnell Big, Co. Offaly [16] 5. Carrickfergus, Market Square, Co. Antrim [20]

Iron objects

Iron artefacts from six different late medieval sites have been subjected to chemical analysis and metallographic examination. Nearly all were analysed as part of Brian Scott's doctoral dissertation (Scott 1976). This includes 28 objects from Greencastle, Co. Down [69] (ibid.: 261–266), 24 from Carrickfergus, Market Square, Co. Antrim [20], six nails from Joymount in the same place [19] (ibid.: 268–273) and four knives from two sites in Dublin, High Street [52] and Dublin, Christ Church Place [49] (ibid.: 275–284). Only one other late medieval object, a piece of corroded iron from Cookstown, Co. Meath [30] was chemically analysed. Scott (1988a) also analysed a thirteenth-century sword found in Ulster, but as its place of production was interpreted as central Europe (ibid.: 215), the results were not included below. The same types of iron make up the bulk of the iron objects analysed (see the Tables for the individual sites in the Site Catalogue).

Most objects contain minimal amounts of phosphorus and the highest value (0.213% P) was recorded from the scramasax knife from late twelfth-century levels at High Street in Dublin [52]. Some of the more elaborate pieces, such as the scramasax knife just mentioned and the ornate key and knife from Greencastle, Co. Down [69], but also a nail from the latter site, showed evidence of bands of phosphorus-rich iron. The manganese content of the artefacts was similarly low across the board with only two values above 0.1% Mn (a Carrickfergus [20] nail and the corroded Cookstown, Co. Meath piece [30]). Of the eleven knives from Greencastle [69], six had high-carbon steel components, while of the five Carrickfergus [20] knives, one included high-carbon steel, one low-carbon steel and another steel with uneven carbon distribution. Three of the four Dublin [52 and 49] knives had steel (both low and high C) as a component, and unusually this was at the centre of the piece in one of the Christ Church [49] examples. The more mundane nails showed both even and uneven carbon distribution within their structure.

The metallographic examination of the objects revealed a variety of smithing techniques carried out in late medieval Ireland. Scott uses the term carburization to describe the carbon distribution in the objects. Real carburization, that is to say adding of that element through sustained heating in a carbon-rich environment, however, is only recorded as probably applied to one of the Dublin, Christ Church Place [49] knives. This knife had been manufactured as a piled structure, meaning it was forged by welding small pieces of iron or steel. Only one other knife, from Greencastle [69], showed evidence for piling. A second knife from the Christ Church Place [49] showed that it had been quenched, as did seven of the eleven Greencastle [69], and two of the five Carrickfergus [20] knives. Two of the Carrickfergus [20] knives and one (possibly two) of the Greencastle [69] knives had evidence for edge-welding. One of the edge-welded knives from each of these sites was also possibly pattern-welded, while the scramasax knife from High Street, Dublin [52] was convincingly so. The quenched knife from Christ Church Place [49] was fork-welded. Of the nails, one specimen from Carrickfergus [20] showed signs of die-forging.

8.3 Associated non-ferrous metalworking

At both Aghmanister, Co. Cork [1] and Tintern Abbey, Co. Wexford [119], both copper and iron were worked side by side. At the first site, one hearth was identified as probably being related solely to copper-working, although its exact nature is still unclear. At Tintern [119], the copper appears to have been worked primarily in one hearth together with iron, while it is absent from a second hearth area. At Ballykeoghan, Co. Kilkenny [6], a lot of copper scrap was found in association with the ironworking residues, but no moulds or crucibles. This implied that the copper was probably forged from waste and not re-melted on site. A similar situation, pieces of sheet copper but no crucibles, was found in the ironworking area at Cookstown, Co. Meath [30]. The only currently known site with potential evidence for brazing, in the shape of possible fragments of ceramic brazing-shroud, is Greencastle, Co. Down [69]. At Carnmeen in Co. Down [18], several crucible fragments were recovered from features with ironworking waste but hearths, for either metal, were absent. At Mullingar, Blackhall Place, Co. Westmeath [108], both lead and copper were melted during the late medieval period, but no direct link could be established with the broadly contemporary ironworking activities. At many other sites either crucible fragments, copper droplets or green-stained slag were recovered from features which also included ironworking waste, probably indicating that these two metals were worked together.

8.4 Conclusions

Large smithing hearth cakes, that is to say weighing more than 2kg, do indeed seem to indicate bloom smithing, as was confirmed through chemical analysis at Ballykilmore, Co. Westmeath [7] (Young 2012b: 42, 46). On this site, as elsewhere, smaller smithing hearth cakes also occur, some of which were shown to be equally related to bloom refining. As these large cakes, with one exception at Coolamurry, Co. Wexford [31] (see below), are associated with assemblages with a large percentage of the cakes weighing over 1kg, this criterion will be used to distinguish this activity. Also typical for bloom smithing appears to be large tuyeres, that is to say with frontal diameters over 0.2m, as were found in Ballykilmore, Co. Westmeath [7]. The occurrence, however, of equally large tuyere-fronts at Ballykeoghan, Co. Kilkenny [6] where the heaviest smithing hearth cake, out of 58 specimens, weighed 478g, shows this not always to be the case.

Strikingly, these large smithing hearth cakes are rarely found on smelting sites, the only exceptions being Ballykilmore [7] and Woodlands West, Co. Kildare [129]. At Shandon, Co. Waterford [115], tuyeres were found together with smelting slag, but no large smithing hearth cakes. What is often encountered on these smelting sites, however, are stone anvils, possibly used for bloom compaction as opposed to refining. Examples are Ballykilmore, Co. Westmeath [7], Moneygall, Co. Offaly [104] and Dysart, Co. Kilkenny [60]. In the latter case, both the enigmatic plugs and copper droplets were found in the hearth with the stone anvil, suggesting more activities than just bloom compaction. Possible stone anvils were also recorded at Cashel, Bank Place, Co. Tipperary [23], where large smithing hearth cakes were recovered, and at Dublin, Francis Street/Lamb Alley [50].

Regarding the types of sites and the activities carried out, there are some interesting patterns and correlations (Fig. 8.16). The ironworking carried out at the isolated rural forges, farms and large towns consisted near exclusively of secondary smithing, with some of these isolated rural forges providing evidence of occasional bloom smithing for example at Coolamurry, Co. Wexford [31] where one large smithing hearth cake weighing 2588g, was recovered. The smaller towns and boroughs, on the other hand, regularly had evidence for bloom refining in the form of large smithing hearth cakes. This was the case at Cashel, Bank Place, Co. Tipperary [23], Kells, Church Street, Co. Meath [74], and Claregalway, Co. Galway [28]. At Thomastown, Chapel Lane, Co. Kilkenny [118], a large tuyere-front could also indicate bloom smithing. At the four other smaller towns and boroughs of which the material was examined, Wexford, 56–60 South Main Street [128], Castledermot, Abbey Street/Market Square/Main Street, Co. Kildare [25], Nobber, Bridge Park, Co. Meath [111] and Athenry, Abbey Row/Bridge Street, Co. Galway [4], the excavations consisted of narrow trenches and only limited information was available. At the manor centres of Caherduggan, Co. Cork [15] and Woodlands West, Co. Kildare [129], further evidence for bloom smithing was recorded, at the latter site together with smelting activities. Two other manor centres, Borris, Co. Tipperary [13] and Dysart, Co. Kilkenny [60], also saw evidence of smelting, but with less convincing indications for bloom refining. At Carrickmines Castle, Co. Dublin [22], when the site was the nucleus of a small manor, only definite indications for secondary smithing were encountered, although an undated furnace was excavated on the same site. Smithies were also excavated at two further sites classed as manor centres, Blackcastle, Co. Tipperary [12] and Mannan Castle, Co.

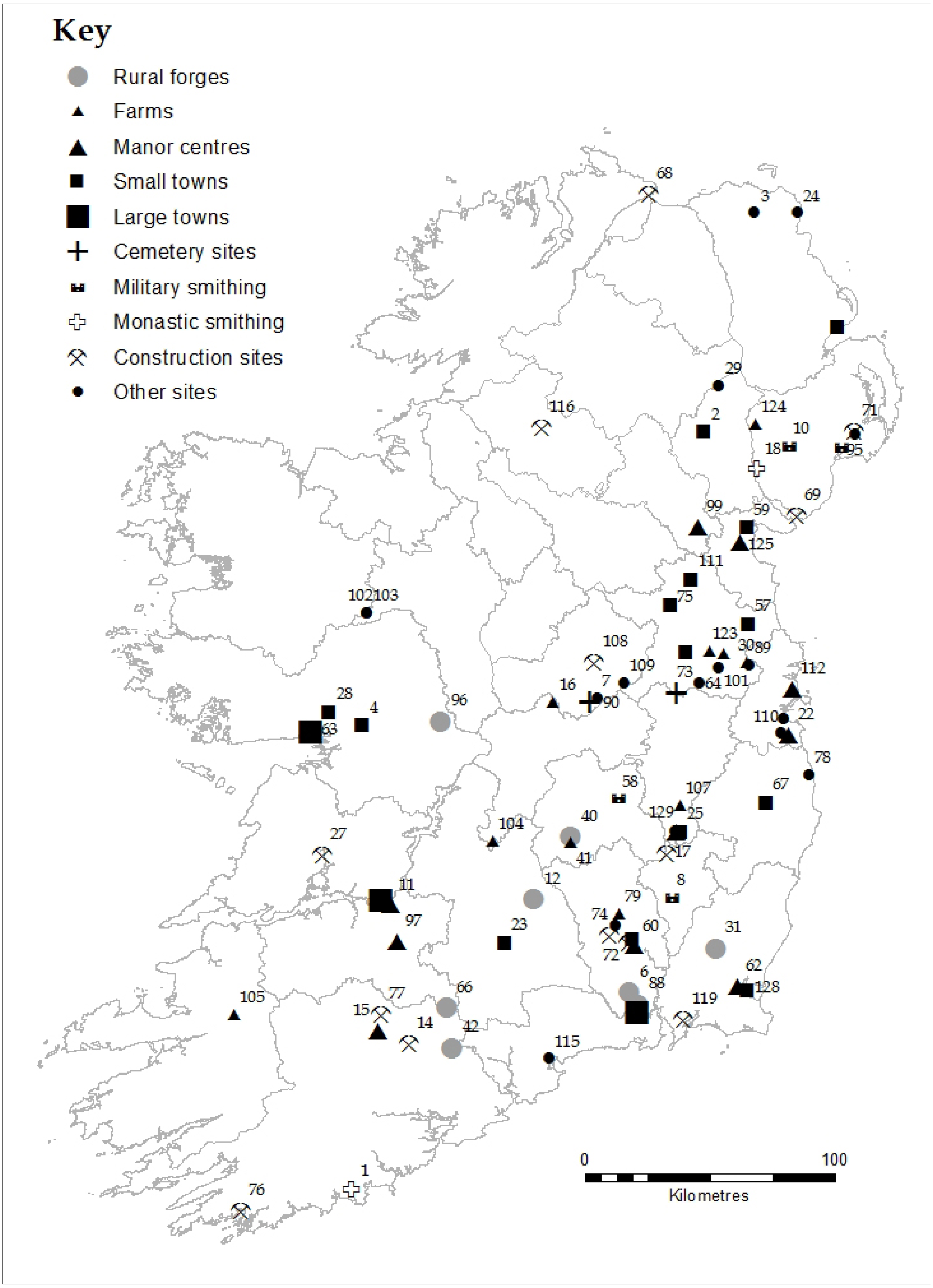


Fig. 8.16 Map of non-urban Irish late medieval smithing sites. Numbers refer to those in the Site Catalogue.

Monaghan [99], but the material itself remains unstudied. Some smaller towns and boroughs, and to a lesser extent manor centres, would have functioned as the centralized points for bloom smithing. This trend towards centralization of bloom smithing in the late medieval period in Ireland was previously noted by Young (2011a: 38; 2012b: 40; 2013: 281), although the main example given of this phenomenon was the site at Caherduggan, Co. Cork [15] (ibid.), which can now be regarded as a possible anomaly. As a manorial centre, Caherduggan [15] is the only example with evidence for bloom smithing, but none for smelting. As such, these manorial centres can be seen as the pivots of agrarian production in late medieval Ireland, and this would seem to have included the production of iron.

The marketplaces, then, received the primary material, the blooms, which were then made into iron objects and bars. A substantial portion of this finished and unfinished iron ended up being sent back to the countryside again for use in agriculture. Another important part of this iron was used in the market towns themselves and in the larger towns, where we have no evidence for bloom smithing. In Kilkenny, at least in the Anglo-Norman part, a single forge, run by the town corporation, was seemingly only dedicated to secondary smithing. In Cork, smithing was carried out inside the town walls in the late twelfth to early thirteenth centuries, and possibly later, while rather intensive ironworking was carried out outside the entrance to the town in the thirteenth century and possibly beyond. Similarly, in Dublin the evidence for smithing is located along three routes into the city, but outside the walls. This has been functionally compared to modern petrol stations (Clarke 1998: 56), which seems to be based on the assumption that smithing consisted mainly of the shoeing of horses. As late medieval smiths were primarily engaged in the manufacture of objects, the location of the work-places could be the result of minimizing the distance that bulk-imported iron had to travel inside the suburbs of the city.

Eight examples of late medieval forges have been excavated to date, with several other examples possibly representing smithing activities carried out, inside a roofed building. The two earliest examples, at Coolamurry, Co. Wexford [31] and Curragh Upper, Co. Cork [42], both late twelfth to early thirteenth centuries, were circular-shaped isolated structures. The two forges interpreted as situated on a manor centre, Blackcastle, Co. Tipperary [12] and Mannan Castle, Co. Monaghan [99], were respectively square and rectangular. The first dated to the thirteenth century and the second was part of a motte-and-bailey site, suggesting a broadly similar date. The smithy at Aghmanister, Co. Cork [1], possibly late thirteenth century, was also a rectangular building. The two later examples at Ballykeoghan, Co. Kilkenny [6], and Cuffsborough, Co. Laois [40], both fifteenth to early seventeenth centuries, had L-shaped corners suggesting a rectangular building, although an additional curving ditch at the first site implies a more irregular shape.

An exceptional forge was uncovered at Galway, Courthouse Lane [63], with evidence of prolonged ironworking activity, a large cruciform anvil and the potential remains of a waist-high forge. At most of the above sites the preserved remains of the structures were very limited, mostly shallow gully sections or a couple of postholes, implying mud-walled buildings. Because of this, it was suggested that several sites with evidence of rather intensive ironworking also represent forges, although no evidence for a building was preserved. This includes the sites at Loughbown, Co. Galway [96] (late twelfth to early thirteenth centuries), Killaspy, Co. Kilkenny [88] (thirteenth, likely late thirteenth, century) and Garryleagh, Co. Cork [66] (fourteenth century). Although several sites with *in situ* smithing evidence, sometimes substantial, were excavated in both the smaller and the larger towns and cities, in none of these cases was there evidence that this activity was located within a structure. The relevant sites were excavated at Cashel, Bank Place, Co. Tipperary [23], Trim, High Street, Co. Meath [122], Cork, Tuckey Street [39] and Cork, Barrack Street [32], Waterford, Little Patrick Street [126] and possibly Dublin, 58–60 Thomas Street [55]. It might seem far-fetched to suggest that these sites also represent mud-walled forge buildings of which no traces remain, but the hearths set in successive clay floors at Trim [122], could indicate this was indeed the case.

Tuyeres appear to be a distinguishing characteristic for Irish smithing assemblages, but they are not found on every site associated with this activity. The four earliest examples of (possible) isolated rural forges, Coolamurry, Co. Wexford [31], Curragh Upper, Co. Cork [42], Loughbown, Co. Galway [96] and Killaspy, Co. Kilkenny [88], have no recorded occurrence of tuyeres. These dated between the late twelfth and late thirteenth centuries. Moreover, at the first site strong indications were found for the use of a hearth wall with blow-hole, a technique which would have been the norm in both Britain and the rest of Europe at that time. Intriguingly, the two sites within this group with structural evidence show circular buildings being used, generally seen as a typical Irish way of building. Interestingly, circular domestic huts were also encountered at Ballysimon, Co. Limerick [11], inside a ring-work, one of the site types introduced by the Anglo-Normans (Collins and Cummings 2001: 41; O'Connor 2002: 203). A comparable situation, New English colonists in circular houses of the Gaelic Irish tradition, was observed in an early seventeenth-century Plantation village at

Movanagher in Co. Derry (Horning 2001). At Aghmanister, Co. Cork [1], provisionally dated to the late thirteenth or early fourteenth centuries, the opposite was encountered. Here, plentiful evidence for the use of tuyeres was found inside a rectangular building. It could be that, in this case, the shape of the forge was determined by the rectangular building in which it was constructed.

The material from the two smithies located in manor centres, Blackcastle, Co. Tipperary [12] and Mannan Castle, Co. Monaghan [99], and the urban forges at Kilkenny, 27–33 Patrick Street [84] and Galway, Courthouse Lane [63], remains unstudied. The three (possible) isolated rural forges dated to the fourteenth century and later; Garryleagh, Co. Cork [66], Cuffsborough, Co. Laois [40] and Ballykeoghan, Co. Kilkenny [6], on the one hand, all had evidence of the use of tuyeres. At the two examples of rural farms, at Cookstown [30] and Trevet [120], both in Co. Meath, no tuyeres were present.

In urban settings, on the other hand, tuyeres were encountered from the very beginning of the research period, for example at Cork, Tuckey Street [39] (late twelfth to early thirteenth centuries), Dublin, Bride Street [47] (thirteenth century), Dublin, Longford Street Little [53] (fourteenth century), and Kilkenny, Irishtown [81] and Robing Room [85] (both late twelfth to early thirteenth centuries). At some urban sites tuyeres were notably absent, such as at Cashel, Bank Place, Co. Tipperary [23], Castledermot, Abbey Street/Market Square/Main Street, Co. Kildare [25], Claregalway, Co. Galway [28] and present only in minute quantities at Kilkenny, The Parade [82]. Significantly the sites where no, or very few, tuyeres were encountered were all new Anglo-Norman settlements, as opposed to the others which were located respectively inside the Hiberno-Norse town of Cork, the ecclesiastical southern suburb of Dublin (Clarke 1998: 51–54) and the Irishtown part of Kilkenny. It would therefore seem that the use of tuyeres in late medieval Ireland would represent a fairly convincing cultural marker for the associated activities. They were not encountered in the early isolated rural forges, but do appear in the later ones, nor recorded in the newly founded Anglo-Norman boroughs, towns and cities. Interestingly, the tuyeres might better indicate the ethnicity of the smith than the buildings wherein the activity took place.

Other aspects of late medieval smithing offer additional insights. There are differences between the dimensions of smithing hearths dated to this period and those from the early Middle Ages, but it is unclear if this is related to differences in the objects produced. The use of coal is convincingly established by the end of the later medieval period, at the isolated rural forge at Cuffsborough, Co. Laois [40], and several sites strongly suggests this was happening at least since the thirteenth century. Especially striking is the predominance of coal directly associated with smithing slag at Kilkenny, The Parade [82], from layers preliminarily dated to the thirteenth and fourteenth centuries. When charcoal was employed as fuel, and examined, oak appears as the species near exclusively used. Remains of troughs are rare, only one convincing example is known at Dublin, Francis Street/Lamb Alley [50], implying either the use of vessels not secured in the ground or that troughs were not always needed in late medieval smithing.

Of particular interest are the newly identified “smithing plugs”, near-identical examples of which were described from two sites, Cork, Tuckey Street [39] and Dysart, Co. Kilkenny [60], and parallels for which are known from Viking-Age Haithabu on the Danish-German border. Although these artefacts are very distinct, an exact function could not yet be ascribed to them. At Greencastle, Co. Down [69], tentative indications for the brazing of iron artefacts was identified. The interpretation of analyses of smithing slag is fraught with difficulties and this is no different for the late medieval Irish material. Moreover, much of the slag analysed from Ireland came from either poorly dated or very limited assemblages. An important exception is Ballykilmore, Co. Westmeath [7], where chemical analysis convincingly established a link not only between large smithing hearth cakes and bloom smithing, but also showed that smaller cakes could be the result of this activity. At Coolamurry, Co. Wexford [31], rare confirmation was found for the use of sand as welding-flux through mineralogical examination. The potentially very information-rich study of the metallographical nature of iron objects has likewise mostly been carried on material with limited stratigraphical data. This research, however, has demonstrated the use of phosphorus-rich iron and various types of steel as well as providing examples of different fabrication techniques, including carburization, quenching, edge- and fork-welding, die-forging and piling. Pattern-welding was convincingly identified in a late twelfth-century scramasax knife at Dublin, High Street [52] and indications of this technique were seen in one knife each from Greencastle, Co. Down [69] and Carrickfergus, Market Place, Co. Antrim [20].

Chapter 9

Ireland and the late medieval trade in iron

In this chapter, the evidence for trade in iron to, within and outside of Ireland during the late medieval period will be examined. Some other mechanisms of iron movement, such as supplies for the army or state and theft, are also considered here. First an overview is given of the broader iron trade along the North Atlantic and North Sea coasts in late medieval times, summarizing the types of iron which could have potentially reached these shores. Next, the information relating to Ireland is presented, beginning with the import, and some evidence for export, of this commodity. Also, a summary of the data relating to domestic trade is presented, including the murage grants and regulations relating to the iron trade. There is a separate consideration of the place of steel in late medieval Ireland. This information will be used to provide insights into the different types of iron available at various times within the late medieval period and the mechanisms behind their distribution.

9.1 The Atlantic and North Sea iron trade in late medieval times

The earliest recorded type of iron traded overseas in north-western Europe is steel produced in Normandy. Steel known as *gladifer de Normannia/Normandie* is already mentioned in taxation lists for Saint-Omer, Pas-de-Calais, France from AD 1159 to 1167 and again in AD 1328 (Giry 1877: 477, 483). In AD 1235/36 steel from the same city was sent over to England to make components of carts (Schubert 1957: 116) and in AD 1278/79, iron from Pont-Audemer, Haute-Normandie, France was used for masons' tools at the Tower of London. Shortly after, in AD 1281, Norman iron was bought for Newgate goal in London (Thorold Rogers 1866b: 457) and in AD 1285 iron, again from Pont-Audemer, is recorded at Norwich (Salzman 1952: 288). The iron in the last three references was sold at very high prices, suggesting a steely kind of iron. Iron from Normandy is also mentioned in the late thirteenth-century Domesday Book of Ipswich (Twiss 1873: 191). In AD 1375, both Spanish iron and *fer d'auge* (iron from the Pays d'Auge, Calvados/Orne, F) was employed in making a big canon for the defence of the city of Caen, Calvados, France (Bonaparte 1863: xx). The former was used for the chamber, while the use of the latter was unspecified. In AD 1428 and 1430, steel was imported into Southampton from Flamanville, Manche in Normandy (Studer 1913: 63, 126). Finally, in AD 1462 and 1466, arrow-heads made from iron of Rouen (*fer de Rouen*) (Haute-Normandie, F) are recorded as being purchased by the city of Lille, Nord, France (Finot 1895: 244, 256).

In AD 1252, when German merchants received trading privileges in Flanders, Spanish iron is mentioned as a commodity in the taxation list for the harbour of Damme in West-Vlaanderen, Belgium on the Zwin river (Höhlbaum 1876: 144) and together with steel and *osmont* in a similar list for the same year for Sluis, Zeeuws-Vlaanderen in the Netherlands located along the same river (van Dale 1860: 32–33). Two years later, in AD 1254, the year of the Anglo-Castillian Treaty, King Henry III pays Spanish and French Basque merchants for iron and steel destined for the construction of siege engines (CPR 1247–1258: 348–349). As this iron and steel was to be paid for in Bordeaux, it is uncertain if it was destined for England, but it does at least indicate that the English Crown was familiar with these materials by that time. Shortly after, in AD 1267/68, a ship from San Sebastián in the Spanish Basque country unloaded iron and other commodities at Winchelsea in Sussex (Childs 2003: 57–58). In AD 1275 and 1280, Spanish iron appears in building accounts at Canterbury (Salzman 1952: 286) and in AD 1278 large quantities of Spanish iron were bought for building siege engines at the Tower of London (Schubert 1957: 110; Storey 2003: 69, 101). It also appears in the accounts of Ospringe in Kent in AD 1282 (Thorold Rogers 1866a: 469–470), as used for window bars at Corfe Castle in Dorset. In AD 1292 (Salzman 1952: 286) and in AD 1294, 250 tons worth of Spanish iron worth over £900 was confiscated at Sandwich, Kent (Childs 1978: 116). Partially preserved accounts from several Spanish ports have allowed an estimate to be made of about four to five thousand tons of iron exported from Biscayan harbours in the late thirteenth century (Bautier 1960: 17). In AD 1294, iron from Bayonne in the French Basque country and Morlaix in Brittany were used in the construction of St. Stephen's Chapel at Westminster (Geddes 2001: 168). It is unclear if the latter iron was produced locally or was imported/re-exported from there.

From the fourteenth century onwards, large quantities of Spanish iron continued to be imported into England. Childs (1981: 26–27) suggested that up to 1000 tons of iron were shipped over annually from Spain in the fourteenth century, rising to 3500 tons by the end of the fifteenth century. Spanish iron is recorded as utilized for repairing the siege engines at Berwick Castle in Northumberland in AD 1333 (Fryde 1988: 45) and in AD 1342, for strengthening the windows of the East Gate at Exeter in Devon (Rowe and Draisey 1989: 103). At King's Lynn, Norfolk, Spanish and Prussian iron were worked for making bars and a portcullis in AD 1371 (Owen 1984: 327) and at Berwick Castle (Northumberland) *Spanishe iron* was used to make the gates in AD 1586 (CBP 1560–1594: 225). In AD 1447, half a hundredweight (c. 25kg) of *ferri Hispanici* was bought for making a hammer for the quarriers working on York Minster (Raine 1859: 62–63).

When, in AD 1546, an agent of King Henry VIII is instructed to source anchors on the Continent, he writes back saying that he could only find a limited amount of old anchors and new ones would be expensive and made not from Spanish iron, but from the inferior Ames[69] iron (LPFD Jan.–Aug. 1546: 119). At the end of the seventeenth century, Spanish iron was described as good, tough iron which was unsuitable for many uses, but good for “great works that require welding” such as the production of anvils, sledges, large bell-clappers, large pestles for mortars, thick, strong bars and particularly for anchors (Moxon 1703: 13–14), or the same type of objects it was used for in the preceding centuries. Tellingly, accounts from San Sebastian in the Spanish Basque region for AD 1293, show that while the city is exporting large quantities of un-worked iron, it is also importing needles, fish-hooks, awls and other iron objects (Bautier 1960: 18). Next to Spanish iron, several entries were found to Spanish steel being used in England. In AD 1336, the sheriff of York was ordered to buy Spanish steel, among other items, to be delivered at Berwick Castle in Northumberland (Storey 2003: 73) and in AD 1397, 94lb of Spanish steel were bought to harden the axes and other masons' tools at Portchester Castle in Hampshire (Salzman 1952: 288).

Many other types of iron were traded over long distances in the later medieval period. We have seen the Osmund iron imported into Damme in AD 1252 and by AD 1280 this material is recorded as purchased at Earsham in Norfolk (Thorold Rogers 1866b: 457). Osmund iron was very ductile iron made in Sweden, and in the German Siegerland, which was typically sold in garbs packed in barrels. It was a high-quality, and hence expensive, product. Other types of iron, apart from the Prussian and Ames iron quoted above, include Danske iron (from Gdansk in Poland), Luke iron (from Liège in Belgium) and Isebroke steel (from Innsbruck in Austria) (Raine 1835: 338, 364; 1837: cccxx, cccxxvii; Ffoulkes 1912: 31, 39).

69 *Ames/amys* iron is generally regarded as imported from Amiens (F) (Schubert 1957: 313; Childs 1981: 34), but a more northerly origin has been suggested by Peter King (pers. Comm.).

9.2 Iron import and export in late medieval Ireland

Although not strictly trade, iron was brought into Ireland in substantial quantities as part of the conquest of AD 1172. Apart from ready-made axes, shovels and nails, iron for 2000 spades worth 100s was sent over by the Burgh of Gloucester, implying that this was iron made in the Forest of Dean (CDRI 1171–1251: 6). In AD 1211 more iron, this time 176 *esperduci*, was accounted for which was sent to Ireland together with food-stuffs, horseshoes and mill stones from Durham via Knaresborough in North Yorkshire (ibid.: 69), presumably for King John's visit to this country the previous year. When iron was needed for the Welsh campaigns of King Henry III in AD 1244, the seneschal of Meath was given a mandate to confiscate all wines, hides, wool, cloth and iron at the fair at Trim (CDRI 1171–1251). Although this iron could have been imported, it would pre-date any known imports of iron into Britain (see above).

Between AD 1270 and 1272, wheat, oats, meat, fish, wine, salt, iron, and other victuals were bought for the castles at Roscommon, Athlone and Raundon (Rindoon) (CDRI 1252–1284: 147), all in Co. Roscommon or on the county borders. Later payments show that it was Richard de la More who supplied this iron (ibid.: 236, 258). The same Richard de la More was previously described as a merchant (ibid.: 338) and paid for delivering wine (ibid.: 358, 409). This fact, together with the iron used in castle building, could be an indication that the iron was imported from Spain, but this is far from certain. Similarly, in AD 1278/79, iron, nails and other articles were supplied to the justiciar of Ireland by Robert de Decer and Robert Turbut (ibid.: 303), the former elsewhere described as merchant of Dublin buying wool (ibid.: 244), the latter as a merchant selling cloth (ibid.: 235, 337).

Perhaps significantly, the income for murage in Galway in AD 1277/78 includes levies on wine, salt, wool, cloth, hides, skins, fish, herring and other diverse and small merchandise, but no iron, while money for that metal is included in the expenditures for the building works themselves (BTR: 53). In AD 1256, Mac Sorley Mac Donnell captured a merchant ship off the Connemara coast carrying wine, cloth, copper and iron (O'Donovan 1856a: 369–371). While the wine could indicate a Spanish origin, copper is not a typical import from Spain. The cargo could be a mixed one from various points of origin. A similar case was recorded in AD 1306, when several people were accused of carrying off goods from the *Nicholas* of Down in Ulster which was wrecked on the coast at Portmarnock, Co. Dublin. (CJR 1304–1307: 507–509). John le Long of

Malahide was said to have taken furs, cloth and barrels of spices and to have drunk or destroyed the wine; several monks of St. Mary's Abbey residing in Portmarnock were accused of carrying off wax, tin and other goods and other people were charged with taking unspecified goods. The ship was also reported to have carried coffers of jewels, copper pots, pitch and steel. Again the nature of the cargo suggests a mixed origin, with no indications where the steel might have come from.

Just over a decade later, in AD 1318, a vessel with wine, iron and other goods was captured off the coast of Brittany and brought to Kinsale, where it was taken for the Crown by Milo de Courcy, then subsequently seized by Philip de Barry of Carrydoogan (Caherduggan, Co. Cork), who removed its cargo (Westropp 1912: 400–401). Although again not strictly trade, this is the earliest reference of likely Spanish iron being brought to Ireland. In AD 1333, a ship carrying wine, Spanish iron, steel and anchors was taken and brought to Drogheda (Gerrard 1931: 217, 251). Three years later, in AD 1336, Spanish iron appears for the first time in a murage grant (for Dublin) (CARD I: 15), while in AD 1337, 1343 and 1358 it appears together with Bristol iron in, respectively, the petty customs, the customs for the tholsel and another murage grant for Dublin (DCA Royal Charter 24, ibid. Royal Charter 25, CARD I: 21).

From this period onwards Spanish iron is found regularly in murage grants until the end of the period under study (see Fig. 9.1 and Appendix 6). In AD 1344, the same material is recorded in the accounts of the Priory of the Holy Trinity in Dublin as bought for making cart tires, nails for the tires and fittings for the wheels (Mills 1891: 99). Several ordnances in the second half of the fourteenth century would be potentially counter-productive for the iron trade to Ireland. The Ordnances of the Staple of AD 1353 set out that all imported goods had to be offloaded in so-called Staple Towns, including Dublin, which led to complaints from merchants who used to land at Dalkey further south, and elsewhere, as Dublin harbour was too shallow for large vessels. An exception was made in AD 1358 for Dublin and the previous practice could continue (CARD I: 19–20, 135–137).

A year later in AD 1354, it was proclaimed that iron, both home-produced and previously imported, could not be exported from England (Thorold Rogers 1866a: 474), but shortly after an exception was made for Ireland on behalf of the Abbot of Furness Abbey in Cumbria and two Liverpool merchants (CPR 1354–1358: 267, 299). Nearly a decade later in AD 1363, Calais was designated as the Staple Town for wool exported from the Realm. The problem for Irish merchants was that other desired imports, such as wine and iron, were unavailable at Calais, and an exception was made for Dublin merchants in the same year (CARD I: 21–24). Around the same period, licences are recorded to merchants for importing and exporting goods. An early example involving iron was issued to John Karlell in AD 1387 to export Irish goods and import wine, salt and iron for the household of Robert de Vere, Marquis of Dublin (RCH: 137). Various licences were granted to merchants from Bristol, London, Dartmouth, Dublin and Drogheda to import cargoes including iron from either Spain or Brittany (RCH: 257). The latter iron very likely also originated in Spain.

We have more information on the import of Spanish iron into Ireland as a result of the records of ships which were captured or confiscated. A ship carrying iron belonging to a Dublin merchant and coming from Bordeaux was seized in AD 1405 (RCH: 179); another owned by Italian and Aragonese merchants, coming from Venice and loaded in Guérande in Brittany was brought into Portsmouth as a prize in AD 1431 (CPR 1429–1436: 199); a second ship laden in Brittany and belonging to merchants from Nantes was taken into Penzance in Cornwall in AD 1433 (ibid.: 300) and the *seynt Antonye of Byskey* with wine, iron and other merchandise on board was seized in Dublin harbour and brought to Bruges in AD 1443 (CPR 1441–1446: 201).

The city records of Dublin include multiple references to buyers of salt and iron between AD 1455 and 1471, illustrating the attempts by this city to regulate the incoming trade and the prices of these commodities (CARD I: 286, 300, 329, 334, 341, 346). We have seen that the merchant's manual *The noumbre of weightes* of AD 1471 suggests exporting iron from Ireland (Chapter 5.2) and it also advises bringing Spanish iron and steel into the country (Jenks 1992: 308). From the same period onwards we are informed of the substantial sizes of the cargoes of iron coming into Ireland. In AD 1468/69, Breton ships destined for Limerick or Drogheda were carrying 12 tons 16 cwt of iron (Touchard 1967: 182); 70 milliers (c. 35 tons) of iron from the Bay of Biscay to Galway in AD 1490 (Bautier 1960: 22; Tranchant 2003: 268); several tons from Bordeaux to various Irish ports between AD 1508 and 1517 (O'Brien 1995: 64) and more iron from Normandy into Limerick (AD 1515 and 1517) and Drogheda (AD 1529) (ibid.: 40–41).

The vast majority of this iron, although shipped from French harbours, was undoubtedly Spanish in origin and some of it was further traded out of harbours like limerick, Cork and Waterford and into Dublin, Drogheda and Dundalk so as to avoid paying taxes on imported iron (Quinn 1941: 112). The iron exported from Bristol into

Ireland as recorded in its Port Books is also very likely to have been Spanish (see Table. 9.1). Interestingly, for the year AD 1525/26 no iron was exported from Bristol, and although no ports of origin are given in this account, it is clear that eight entries of imported iron totalling just under ten tons, judging by the other commodities in the same cargo (sheep skins, wool, fish, timber), originated in Ireland (Flavin and Jones 2009: 197–284). Again this very likely consistsed of Spanish iron re-exported this way because of political or commercial considerations and we are informed that French goods were re-exported to England from Ireland during the sixteenth century (Lyons 2000: 14). According to the same accounts, two knives were exported from Ireland to Bristol in AD 1526, one at a time, and they were very expensive, valued at 3s 4d and 6s 8d apiece (Flavin and Jones 2009).

Smaller amounts of iron reached Ireland from the nearby port of Bridgewater, for example a hundredweight in AD 1560/61 (Longfield 1929: 221) and two hundredweights in AD 1591 (Longfield 1921: 331). In AD 1541, the Lord Deputy and Council of Ireland reported to King Henry VIII that iron, weapons and other commodities were being brought into the country through its northern harbours by the Scots and its southern harbours by the Spanish, and that it would bring "great humility" to the Irish if this trade could be brought under control (SPHen. VIII Vol. III: 443). Between AD 1549 and 1558, the accounts of the Holy Trinity guild in Dublin show that this institution was receiving money from its members for licences for importing wine and iron (Gillespie 2009: passim) and in AD 1563 the Mayor of Dublin was receiving five percent from the sale of salt, wine and iron from the same guild, who were described as the buyers of the same (CARD II: 28). In AD 1556, it was enacted that foreign merchants could only sell iron and other goods in bulk, and in Dublin, in the case of iron, this was per ton (CARD I: 456), all of which seems to have given the Trinity guild a monopoly on iron sales in the city.

A licence issued in AD 1559 to import wine, salt and 400 tons of iron into Wexford, Dublin, Drogheda and Dundalk, includes Thady Duffe as one of the merchants involved (CPCRI I: 374), undoubtedly the same Thade/Thadie Duffe who was treasurer of the Holy Trinity guild in AD 1552 and a member in AD 1553 (Gillespie 2009: 414, 417). Other licences for AD 1556/7 include one for 400 tons of iron per year by Walter Peppard of Dublin into the same ports as above together with Carlingford (CPCRI I: 374); another for a hundred tons imported to Ireland by a merchant from Glasgow; a similar amount, carried by Scottish vessels and destined for the same ports

Date range	Iron (tons)	Steel (kg)[70]	Source
11/1378–5/1379	1[71]	0	(Carus-Wilson 1968: 180–189)
7–9/1437	0	0	(ibid.: 203–209)
3–9/1461	0	0	(ibid.: 209–218)
9/1479–7/1480	0	0	(ibid.: 218–289; Childs 1982: 17)
?/1485–?/1486	1.5[72]	0	(Childs 1982: 17)
?/1486–?/1487	3.6	0	(ibid.)
?/1492–?/1493	6.25	0	(ibid.)
10/1503–9/1504	3.13	0	(Flavin and Jones 2009: 1–102)
9/1516–9/1517	2.95	0	(ibid.: 103–196)
9/1525–9/1526	-9.88[73]	0	(ibid.: 197–284)
10/1541–9/1542	12.11	0	(ibid.: 285–383)
9/1542–9/1543	15.8	40.75	(ibid.: 384–456)
9/1545–9/1546	41.84	407.5	(ibid.: 457–545)
10/1550–9/1551	1 [5.75]	529.75	(ibid.: 546–613)
9/1563–9/1564	10.55	285.25	(ibid.: 614–669)
9/1575–8/1576	17.28	1467[74]	(ibid.: 671–732)
9/1594–9/1595	12.15	326	(ibid: 733–850)
10/1600–9/1601	13.75	3147[75]	(ibid.: 851–942)

Table 9.1 Iron and steel imported into Ireland recorded in the published Bristol customs accounts

as above as well as Waterford and (New) Ross; by merchants from Arselott (= Arbirlot, Scotland?) and Skerries and a final one for a hundred tons to the same harbours, this time specifically stated as brought from Scotland (ibid.: 374–375). Shortly after, we have licences granted to Limerick merchants in AD 1557 to trade with French, British, Scottish or other foreigners for iron and other merchandise (ibid.: 389) and records of Irish ships registered in Bilbao for transporting iron in AD 1568, 1594 and 1597 (Schüller 1999: 85, 88). In AD 1580, an Irish vessel was registered in Bilbao, and transporting iron to Lisbon (ibid.: 87), while the iron trade between Bilbao and Ireland

70 In the records, the values given are generally in burdens of steel, one of which weighs c. 81.5kg (180lb) (Zupko 1985: 54)

71 A further 7 tons of iron is exported from Bristol and while this was likely destined for Ireland the sources are not clear.

72 The values in (Childs 1982) are given in monetary units only in the publication and were recalculated based on a rate of 4 £ per ton of iron, the value from AD 1503/04 until 1550/51. As no iron is exported to Ireland in this period, no direct evidence for this is available, but the rate of 2.5 £ per ton on imported iron stays constant from AD 1437 until 1550/51.

73 In this period no iron is recorded as exported from Bristol into Ireland, the 9.88 tons are imported into Bristol from Ireland.

74 The iron from Flanders, see above, is not included

75 18 bars of steel of unspecified weight were also imported in this period

was being used for spying operations by the Spanish side in AD 1580 (CSPF Jan–June 1583: 562) and several people involved in the iron trade with Ireland were being questioned for information by the English in the final decades of the sixteenth century (CSPI 1586–1588: 25, 26; Appleby 1992: 355–356; CSPD 1595–1597: 431–432). The latter source is a good illustration of the complex world of iron trade and politics. The informant, based in Lisbon, relates how two ships coming from Cork and pretending to be Irish, were unmasked. One of the ships was a Biscayan laden with iron, while the other belonged to Thomas Norris, President of Munster and at that time owner of the blast furnace at Mallow (see Chapter 5.3). And that not all the iron imported into Ireland was of Spanish origin is shown by the import into Dublin of just over 200 tons of iron from the recently set up ironworks at Glamorgan in Wales in AD 1569/70 by Sir Henry Sidney (Kingsford 1925: 413–414), who was both Lord Deputy of Ireland and owner of the Welsh ironworks (Crossley 1975b: 1).

9.3 The Irish domestic trade in iron

It is known that some form of iron trade existed shortly after the Anglo-Norman conquest of Ireland as a certain Robert the *iremongere* (ironmonger) is listed in the AD 1213 Dublin Roll of Names (Connolly and Martin 1992: 20; HMDI: 41). Interestingly, while the early charters for the coastal cities of Dublin (1192), Waterford (1232) and Cork (1242) do not mention iron, it does appear in the charter for Kells in Co. Kilkenny (1211–1216) (CPI: 6, 22, 24–25; Mac Niocaill 1964a vol. 1: 128). Except for a few early examples, most murage grants include entries on iron (see Appendix 6). We have seen above that iron was confiscated, hence available, at the market at Trim in AD 1244.

Remarkable are the grants for Youghal in AD 1275 and Drogheda for AD 1278 which explicitly state that no money was to be levied on iron (CDRI 1252–1284: 199–200, 297). This could indicate the scarcity of iron, the will to encourage the iron trade, the power and influence of the iron merchants of those places or might be the result of a number of other causes. Further information regarding the domestic trade in iron in Ireland in the later medieval period is scarce. We know that in Meath, Louth and Dublin a maximum price of 10d per stone of iron was established in AD 1364 (Betham 1834: 301), likely to counteract the price rises as a result of the Black Death. At Dublin, in AD 1436, salt, iron and coal were to be sold at a set price as part of the *Charter to the Dublin Gild of Merchants* (Berry 1900: 52), while the fixed prices for a whole range of commodities in Dublin and the Pale enacted in AD 1470, including iron at 10d per stone, were already repealed in AD 1472 because of the "intolerable damage of the subjects" (Hardiman 1843: 21–22).

As relations between the Gaelic Irish and the English in Ireland deteriorated badly from the mid-fourteenth century onwards, the sale of iron, as a strategic commodity, would become severely curtailed. Before AD 1375, a proclamation was made to prevent horses, arms, iron, gold, silver, grain or other victuals being sold to the King's enemies out of the Counties of Meath, Louth and Dublin, and officials were appointed in that year (RCH: 97), in AD 1386 (ibid.135) and again in AD 1424 (ibid.: 232) to enforce it. In AD 1394, the same restriction was expanded to include all Irish not among English lieges, and seems to have applied to the whole of Ireland (Berry 1907: 499). Similarly, no trade was permitted, including of iron, between the citizens of Waterford and the surrounding county in AD 1465 (Byrne 2007: 83, 84), while in AD 1536 the same limitation was ordained for the town of Galway (SPHen. VIII: 310–311).

Not surprisingly, the hostilities of this period resulted in iron becoming a coveted war booty, such as an iron grate, or yett, taken at Ballylahan Castle in Co. Mayo and brought to Ballymote in Co. Sligo in AD 1381 (Murphy 1896: 307). Iron is among the articles taken by the Irish from the land of Clogher in Co. Tyrone and the parish church of Ballyloughloe in Co. Westmeath in AD 1427 (Chart 1935: 64, 70). Rich plunder, including iron, was carried off by the Irish after the sacking of Ardee in Co. Louth and Navan in Co. Meath in AD 1539 (O'Donovan 1856a: 1453), while similar booty was seized during the raids on Loughan Island Castle in Co. Derry and Ballylough Castle in Co. Antrim in AD 1544 (ibid.: 1488). From the end of the sixteenth century we have records of iron stolen in AD 1581, when Cashel, Co. Tipperary and Kilfeacle, Co. Kilkenny were plundered by the Earl of Desmond (ibid.: 1761) and again in AD 1597, when both Athenry in Co. Galway and Mullingar in Co. Westmeath were raided (ibid.: 2009, 2039).

Another source of iron for late medieval Irish smiths consists of disused or discarded objects which were recycled. In some cases, with nails, structural iron and so forth, the object could be reused without modification, while in others, the object was remodeled for its new use (Dillmann and L'Héritiér 2008: 160–161). In other cases again, a new object could be made from fragments of scrap iron (ibid.). The Irish historical sources are mute on this subject, but the general lack of larger iron objects, and high quality tools and weapons, in the archaeological record suggests that substantial amounts of iron were indeed recycled. Apart from stealing and recycling, iron was throughout the late medieval period readily available in un-worked form at most marketplaces. This either means that the smiths bought this iron and forged it into objects or that others bought it and took it to the smith to be converted. A rare and interesting reference is the obligation by the burgesses of the manor of Moyaliff, Co. Tipperary to bring salt and iron, against payment, from Cashel in the same county, and about 15km south (White 1932: 66). This document is not directly dated, but is likely early fourteenth century.

9.4 Steel in late medieval Ireland

That the Scandinavians in Dublin were acquainted with the use of steel is shown by the composition of a post-800 AD Viking sword found at Donnybrook (Hall 1978: 76) and by the reference to a magical coat of mail "which no steel could bite" owned by Brodir, one of the Danes involved in the Battle of Clontarf in 1014 (Dasent 1900: 322). Axes of exceedingly well wrought and tempered iron, that is to say steel, were said by Giraldus Cambrensis to be used by the Irish, who had borrowed the practice from the Norwegians and Ostmen (Forester 2000: 69). The use of steel in knives, both from Hiberno-Scandinavian and native Irish sites of the same period and earlier, appears to have been widespread, although differences in technology were noted, as demonstrated by metallographic research by Hall (1992, 1995). The former community used steel more frequently and of better quality.

The invading Anglo-Normans were also familiar with steel weaponry, as is evidenced by the recording of the beheading of seventy captured Irishmen with an axe of tempered steel (Redmond 1900: 42). For the first century or so after the invasion, we have no written evidence for either the use of, or trade in, steel in Ireland. Metallographic examination, however, by Scott (1976: 275–282) of two knives from thirteenth-century contexts at Dublin, Christ Church Place [49] showed both to contain steel, one with a high-carbon steel cutting edge welded on to a ferritic back and showing signs of quenching, the other with a high-carbon layer of steel in between two of low-carbon steel. The cutting edge of this last knife was further carburized.

The earliest reference found in Anglo-Norman sources to steel is the payment for the year AD 1280/81 to the burgh of Drogheda for iron, nails, steel, salt, pitch and other small articles previously delivered (CDRI 1252–1284: 358). Shortly after, steel also appears for the first time in murage grants (see Fig. 9.1), that is to say the one granted to Kilkenny in AD 1282 (ibid.: 280), the grant for Bennet's Bridge in AD 1285 (ibid.: 35) and the one for Waterford in AD 1291 (ibid.: 411). The earliest records relating to trade are of the steel taken off the wreck of the ship on its way to Co. Down in AD 1306 and the Spanish iron and steel as stolen cargo in AD 1336, both mentioned above.

Several sources inform us of some of the uses of steel in late thirteenth- and fourteenth-century Ireland. Steel for ploughs is recorded in the AD 1285/86 Bigod accounts for the manor of Ballysax in Co. Carlow (Lyons 1981: 46); in AD 1304, when

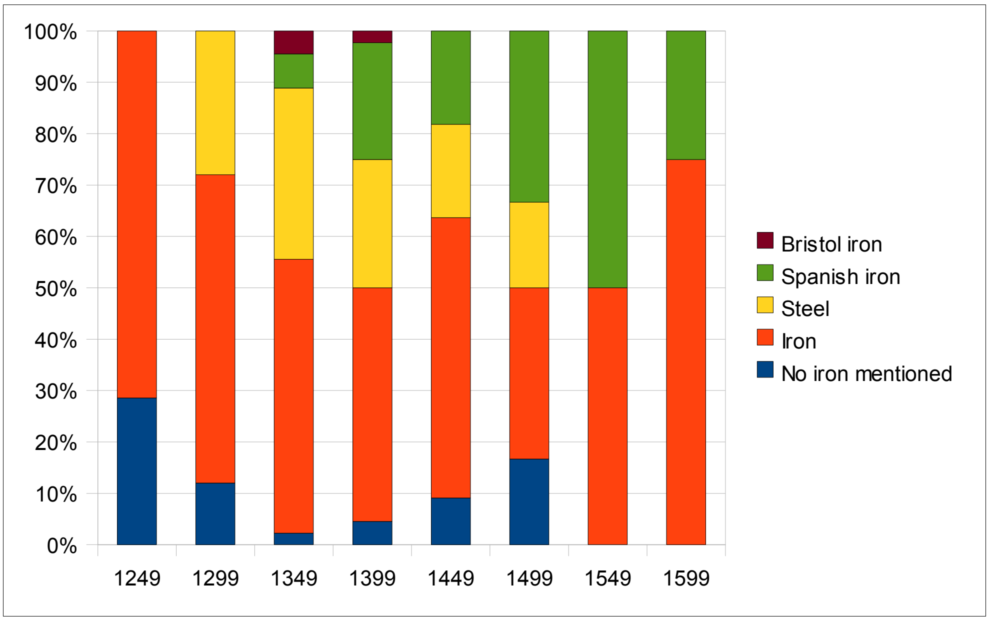


Fig. 9.1 Different types of iron in the Irish murage grants (the dates on the X-axis are end dates of 50 year periods)

iron and steel are needed for ploughs at the manor of Cloncurry (White 1932: 28) and in AD 1344 it is bought for a plough for the manors of the Priory of the Holy Trinity in Dublin (Mills 1891: 29–30). In AD 1314, iron and steel are used for repairing the King's mills next to Dublin Castle (HMDI: 471); in AD 1356/58 money is paid for steel for forty axes used in building works at Dublin Castle (Crooks 2012: 32-edward-iii), while the AD 1375 murage grant for Thomastown includes steel tools (CPI: 68).

Apart from murage grants and the earlier-mentioned merchant's advice on importing Spanish steel into Ireland, sources relating to this metal in Ireland for the fifteenth and early sixteenth centuries are virtually non-existent. It is imported together with iron, wine and salt from La Rochelle to Drogheda in AD 1468, so possibly of Spanish origin (Bautier 1960: 22). Steel does not occur in the published Bristol Port documents up until AD 1542/43, when small amounts are imported initially, and increasing towards the end of the century (see Table 9.1). The latter could have been re-exported steel from Germany or possibly home-made at the steel forge in Ashdown Forest in Sussex, which was erected in AD 1509 (Schubert 1957: 314). In AD 1539, we have the peculiar entry in the will of Piers Butler, Earl of Ormond, namely that every townland in Kilkenny was to receive one stone of steel (COD 1509–1547: 187).

The proctor accounts for the building works at Christ Church Cathedral in Dublin for the year 1564/65 give us some detailed insights into the use and origin of steel in sixteenth-century Ireland (Gillespie 1996). The expenses, mostly related to quarry work, include payments to a certain Thomas, a smith and Frenchman, to steel pickaxes and crowbars (ibid.: 31), for pointing crowbars and pounces with steel (ibid.: 33), steeling and mending chisels and pounces (ibid.: 44, 57) and steeling the masons' great hammer (ibid.: 91). Some of the steel was given by Sir William Dermot, chancellor of Christ Church, who obtained it from merchant James Weldon (ibid.: 31, 33), and it was also supplied directly by Mr. Pyppart (ibid.: 72) and Robert Stevens (ibid.: 89). Mr. Pyppart is likely the same Walter Pepparde who received a licence to import 400 tons of iron, most likely Spanish, into Ireland in AD 1556/57 (see above).

After AD 1565, when steelworks were built by Sir Henry Sidney, newly appointed Lord Deputy of Ireland, small amounts of it were imported into this country (Crossley 1975b: 34). The iron from Flanders, of which 24lb was valued as high as a ton of “normal” iron or 11520lb of steel[76], exported into Wexford in AD 1576 (Flavin and Jones 2009: 677–678), was possibly also a type of steel. From around the end of our period of research we have two sources mentioning locally produced steel. We have seen the references from AD 1580 to the bloom made by the “rude cuntry people” around Burrishoole in Co. Mayo, described as “more steele then yrun” and one from AD 1610 describing how a smith in Ulster makes high-quality steel from iron in under an hour (see Chapter 5.2).

9.5 Conclusions

In the thirteenth century, the only types of iron traded by sea in north-western Europe, which we have evidence for, are steel from Normandy and, in the latter half of the century, Spanish and Osmond iron. Some iron seems to have been imported into Ireland during this century, but it also appears to have been exported out of Waterford.

76 Steel was indeed valued substantially lower than iron.

Quantities of iron reached Irish shores as part of military campaigns and we know it was available on several of the newly established market centres. By the end of the century, steel appears frequently in the murage grants and other documents.

Spanish iron became an important trading product internationally in the fourteenth century and we have evidence of it being brought into Ireland in increasing amounts. Several references indicate that this was supplemented with iron from England in the latter half of that century. A contemporary publication advising merchants, suggests selling Spanish steel in Ireland and exporting iron from there. Around the same time, laws were introduced in Ireland to prevent the sale of iron to the enemies of the Crown. Steel still appears frequently in the fourteenth-century Irish documents. While previously Spanish iron seems to have been brought directly into the country, from the later fifteenth, and especially the early sixteenth, centuries it was often imported indirectly. It reached Ireland through Bristol, French, and seemingly even Scottish, ports. The expansion of the English blast furnace iron industry in the sixteenth century led to more iron from there being imported into Ireland in the second half of that century. In the same period, this was supplemented by steel made in England, and possibly some originating in Germany. Whereas the murage grants show a decline in references to steel in favour of Spanish iron from the fifteenth century onwards, the Bristol port books show that this latter type of was imported in increasing amounts from the middle of the sixteenth century onwards. It is unclear if this hiatus in the fifteenth and early sixteenth centuries indeed implies a dearth or less use of steel in Ireland at that time, but the regular mentions of armourers in Dublin in exactly that period (see Chapter 7.3.1) could suggest otherwise.

Very little is known about the mechanisms behind the domestic trade in Ireland, except for the frequent state regulations for both political and economic reasons. Iron was available on the markets in the Irish town and boroughs throughout the later Middle Ages, indicating that merchants were distributing this metal. In the latter half of this period most, if not all, of the iron sold in the harbours was probably imported, but we are told hardly anything about the origin of the iron and steel, sold further inland. Only once, in the Thomastown murage grant of AD 1375, is local production implied by the mentioning of the sale of blooms.

Chapter 10

Iron smelting in western Europe in the late medieval period

Research into late medieval iron smelting in Europe has almost exclusively concentrated on the advent of the application of water-power to the various production stages. This concentration on the “most advanced” forms of iron production not only led to the neglect of the study of the non-water-powered bloomeries of the late medieval period, but also, in some areas, to that of the other technology arising in the late medieval period: the water-powered bloomery.

The first major study incorporating European medieval manuscript sources in to the history of iron production was Beck's seminal four-volume *Die Geschichte des Eisens in Technischer und Kulturgeschichtlicher Beziehung* (1891, 1895, 1897, 1899). Schubert (1937, 1938), building further on Beck's work, had published, with extensive historical research, the history of iron in the Siegerland and the Lahn-Dill-Gebiet. After Schubert moved to England around the beginning of the Second World War, he took up researching the early iron industry in that country. This led to a series of articles (Schubert 1943, 1948, 1949, 1951, 1953) relating to early English water-powered ironworking, and eventually to his very influential *History of the British Iron and Steel Industry from c. 450 B.C. to A.D. 1775* (Schubert 1957). Earlier, two important English iron-master's accounts had already been published, for Byrkeknott/Kyrkeknott, Durham (early fifteenth century) (Lapsley 1899) and Tudeley, Kent (fourteenth century) (Guiseppi 1913), while Salzman (1913, 1952) had published important works on medieval industrial Britain.

The first publication to look beyond the technological side of European ironworking was Sprandel's (1968) *Das Eisengewerbe im Mittelalter*. Around the same time, several accounts relating to blast furnaces were published by Crossley (1966, 1974, 1975b). In France, Gille (1947, 1960) had researched the documentary evidence for the early iron industry and, in Belgium, the available material for the Namur area was collated by Gillard (1971). Later, in France, Braunstein (1972, 1987), Belhoste (1986, 1995) and Arnoux (1991; 1994, 2001; Arnoux et al. 1991) carried on the historical research, concentrating on the use of water-power in iron metallurgy and specifically the early liquid-iron production. In the same period, Brian Awty (1981, 1990a, 1990b, 1994, 2007) published extensively on various aspects of the early blast furnace in Belgium, France, England and beyond, while in Germany, Lohrmann (1995) collated the latest knowledge on water-powered ironworking in Europe for a domestic audience.

It was, however, Tylecote (1986: chapters 8 and 9) who would first offer an overview of late medieval ironworking, in this case in Britain, fully incorporating the archaeological and historical data available. Regrettably, but perhaps understandably, the same scope was not applied to the same author's works dealing with Europe (Tylecote 1987: 162–175) and later the world (Tylecote 1992: 75–77). Pleiner (2000: 282–286), although offering an analysis of bloomery-iron production in Europe, was limited on late medieval ironworking, and especially brief on water-powered bloomeries, while concentrating mostly on the post-medieval examples. Also, the recent overview works by Buchwald (2005, 2008), although containing much interesting information, do not give a comprehensive synopsis of the knowledge of iron production in late medieval Scandinavia. Several, more local, studies have combined both the documentary and the archaeological evidence relating to late medieval iron smelting. Most notably is the research done as a background to the targeted excavation investigations on both bloomeries and blast furnaces in the märkische Sauerland (Willms and Jockenhövel 1996; Willms 2003), the Dietzhölzetal in the Lahn-Dill region (Lammers 2003; Jockenhövel and Willms 2005) and the Schwäbische Alb in southern Germany (Kempa and Yalçin 1996; Yalçin and Hauptmann 2003). Many other early blast furnaces have been excavated to date, but this has not led to the publication of a concise analysis of the archaeology of the early European liquid-iron production.

Initially, a critical review will be given of the available sources, both documentary and archaeological, for iron smelting in the Middle Ages covering the area north of the Alps over western Europe to Britain and Scandinavia. Throughout the literature on the documentary sources, many vague references are quoted as evidence concerning the early use of water-power. Here, only the more convincing examples are listed, while some erroneous references are pointed out. More detailed analysis and scrutiny will be applied to evidence from areas closer to Ireland or if the sites are of particular importance.

It is generally accepted that the introduction of water-powered installations in iron production should be seen in the light of the expansion of production capacity (for example Arnoux 2001: 448; Jockenhövel 2005: 565). To illustrate and put into context this assertion, various technological aspects of the medieval ironworking will be dealt with in more detail. The available information on the sizes of the products from bloomeries with water-powered bellows, and those without, will be collated and compared to the production yields of the early blast furnaces. Next, both the efficiency in ore and fuel consumption of the various installations will be compared.

10.1 Hand- and wind-powered bloomeries

10.1.1 Documentary evidence

Certain Cistercian monasteries were heavily involved with iron mining and production in the twelfth and thirteenth centuries, as can be seen by the many deeds and grants listed by Sprandel (1968: 359–362), the vast majority in France (see various authors in Benoît and Cailleaux 1991) and England. Many of these grants relate to existing ironworks or mines, indicating that the monks, in many cases, were taking over rather than establishing an industry. Some important iron mining and smelting areas in the twelfth and thirteenth centuries, however, such as the Comté de Foix in southern France, saw no recorded involvement by monastic orders, including Cistercian and Benedictines, which were present in the area (Verna 2001: 25–42). This was seen as the result of either the lack of a market for iron or because of strong local, but unrecorded, competition. Limited involvement of monasteries in a vibrant iron industry was noted in some parts of Normandy, where local nobles kept possession of their iron mines and forges (Arnoux 1991: 14–15). The same lack of Cistercian involvement in iron production is observed in Germany, although there was a similar concentration of monasteries belonging to that order as in France or England (Sprandel 1968: 47).

We have little documentary evidence pertaining to individual non-water-powered bloomeries. The accounts of a bloomery furnace at Tudeley in Kent, covering the years AD 1329–1334 and AD 1350–1354 are preserved and were published by Guiseppi (1913) and subsequently translated by Hodgkinson and Whittick (1998). As there is no mention in these documents of the use of water, it is widely accepted that Tudeley was a non-water-powered bloomery producing one bloom per day (ibid.: 12, 17; Arribet-Deroin 2010a: 150–151, 159). Apart from the reference to the tools and implements used, including an iron tuyere, the documents give little insight into the nature of the installations. At the end of the fourteenth century, two *grosses forges* (large forges/furnaces) were built in the Pays d'Othe, Aube/Yonne, France for the Countess of Flanders (Braunstein 1987). Apart from clearly being non-water-powered (ibid.: 754), the accounts for the works give very little technological details. One interesting aspect is that the forges could be dismantled and re-built elsewhere, which happened twice with the same forge. As late as AD 1531, the bellows at the then recently established bloomsmithy at Llantrisant in Glamorganshire were still operated manually (Schubert 1957: 141, 146), but we have no indications of the type of furnaces used.

10.1.2 Archaeological evidence

The majority of excavated late medieval non-water-powered furnaces are shaft furnaces. Examples of these have been found at the site of Genoeserbusch in Luxembourg, where five of these furnaces were accompanied by two refining hearths, ore deposits and roasting hearths (Overbeck 2011). One of the furnaces, with an internal diameter of 0.64 by 0.91m, was much larger than the others and was considered the youngest on site (Fig. 10.1a), with all activity being carried out between the second half of the thirteenth and the beginning of the fourteenth centuries (ibid.: 51–56, 312–314). In central western Germany, to the south-east of Siegen, in and around the Dietzhölzetal, Hesse, several medieval iron-smelting furnaces were excavated (Willms 2005; Jockenhövel 2005b). Most dated broadly to the thirteenth century, but both earlier and later examples were present (Willms 2005: 377). A reconstruction, based on the excavation results and furnace-wall fragments, shows a bottle-shaped exterior with a stone-lined slag channel incorporated into that wall (fig. 10.1b). The internal diameter varied around 0.5m. In the same area, at Ewersbach, an additional furnace, also interpreted as bottle-shaped but with a lower-lying hearth and a slightly smaller internal diameter, was more recently excavated (Lammers 2003). This site was dated, based on pottery found, to the thirteenth to early fourteenth centuries.

The area around Lüdenscheid, Nordrhein-Westphalen to the north-west of Siegen has been the subject of extensive excavations which unearthed thirteen iron smelting sites dated by pottery finds to between the eighth to the thirteenth centuries, with a concentration in the last two centuries (Sönnecken 1958, 1971, 1994). Two types of furnaces were encountered. One was built into a slope and was seen as originally about 1.5m high (Sönnecken 1958: 133). The front of this furnace type had to be demolished after each smelt to remove the bloom. The other type was built in flat areas,

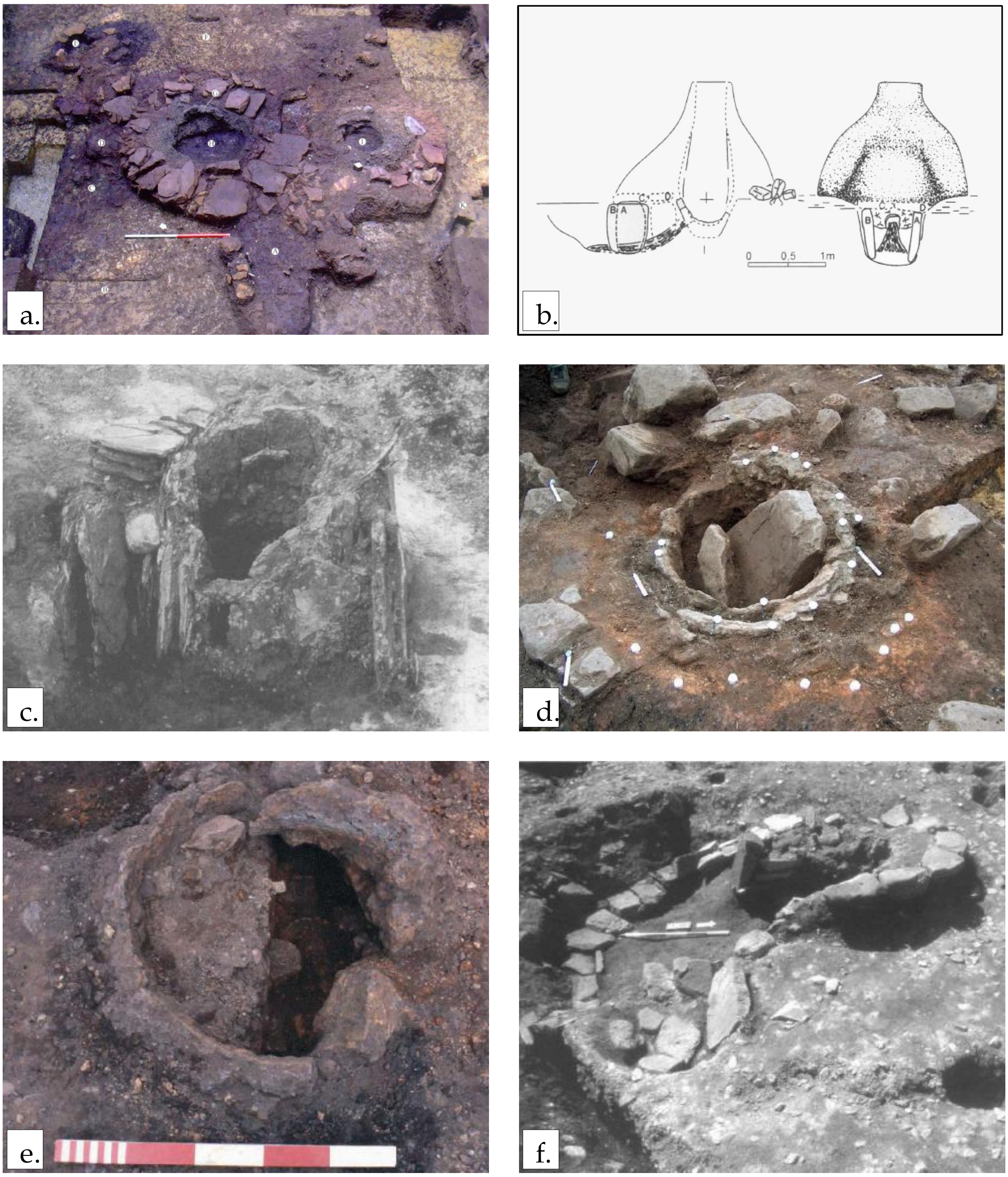


Fig. 10.1 Western European late medieval shaft furnaces. a. Genoeserbusch, Luxembourg (Overbeck 2011: 494), b. Dietzhölzetal, Hesse, Germany, reconstruction (Willms 2005: 383), c. Dokkfløy area, Oppland, Norway (Espelund 2011: 92), d. Stingamires, North Yorkshire (Powell 2008 vol. 2: 6), e. Oakamoor, Staffordshire (Harding 2004: 27), f. Llwyn Du, Merionethshire (Crew and Charlton 2007: 220)

was deemed originally about 0.7m high and the bloom would have been removed through the top. The internal hearth of the latter furnace type was lower than the tapping channel, leading to slag accumulating inside. The internal diameter of both types was about 0.4 to 0.45m. Recently, however, it has been suggested that the latter installations were not furnaces at all, but early examples of Osemund refining hearths (Knau et al. 2003: 180).

Further to the north-east, the remnants of a small slag-tapping furnace were excavated north of Flensburg, Schleswig-Holstein, just south of the Danish border, which had an internal diameter of 0.45m, a 0.2 to 0.25m thick wall and a shallow slag-tapping hollow in front of the furnace (Hingst 1969: 424–428). The activity was dated by a tile fragment and pottery sherds to later than the twelfth century (ibid.: 429–430). More recent excavations, ahead of construction works just west of Flensburg, revealed similar furnaces, which were accompanied by pottery broadly dated to the medieval period (Hingst 1991: 269). The excavation of a slag heap at Hiddingen in Niedersachsen revealed the base of a slag-tapping furnace with walls up to 0.3m thick and an internal diameter of around 0.4m (Dehnke 1967). The walls of the furnace were made of clay fortified with pieces of bog ore and iron slag. Pottery recovered from the heap was dated to around AD 1300. Excavations of an iron-smelting site near Isernhagen, also in Niedersachsen, just north of Hannover and some 50km south of the previous site, revealed several pits, but very little traces of the furnace itself (Schulz 1973). Based on wall fragments, an internal diameter of about 0.4m was suggested. The slag indicated lateral slag-removal and the ore used was bog ore. The dates of the pottery found on the site spanned the twelfth to the fifteenth centuries and two radiocarbon dates from material in the pits gave dates in the thirteenth and fourteenth centuries.

In Scandinavia, the late medieval furnaces are likewise of the shaft furnace type. The excavation of an iron-smelting site at Arnås, Västra Götaland, Sweden revealed twin clay-shafted furnaces embedded in a single large square stone structure (Englund 1995). The hearths were oval and measured 0.4 by 0.3m (ibid.: 37). This type of furnace was, based on this and two other excavations, seen as representative for the type used in the area from the ninth to the middle of the fourteenth centuries. Excavations in the Dokkfløy area in Oppland, Norway have shown the same type of smelting site in use between AD 900 and 1400, with a marked increase in production in the first half of the thirteenth century (Larsen 1992). The sites consisted of houses with adjoining furnaces and charcoal-production pits. The ore used was bog ore. The furnaces had lateral slag-removal and consisted of clay shafts with an internal diameter of 0.35 to 0.45m and which were supported by upright slabs on three sides (Fig. 10.1c).

Similarly in Britain, nearly all known late medieval furnaces are of the shaft furnace variety. Several of these were excavated as part of geophysical survey programmes in Bilsdale valley in North Yorkshire. A relatively well-preserved furnace was excavated at Hagg End, the base of which was found to have been dug into the soil at the top of a drop in the terrain, with the slag being tapped at the lower level (Powell 2008 vol. 2: 7). The internal diameter measured about 0.5m (Vernon 2004: 81) and archaeomagnetic dating indicated a time of use between AD 1160 and 1320 (Powell 2008 vol. 1: 212). Another, rather similar, installation was excavated at Stingamires (ibid. vol. 2: 8) (Fig. 10.1d), but no dimensional information was found. Archaeomagnetic dating placed this furnace between AD 1140 and 1300 (ibid.: 256). Further excavation, at Kyloe Cow Beck, revealed a furnace with an internal hearth diameter of about 0.4m and walls about 0.15m thick, set in a slope of the terrain (Powell et al. 2002: 655). Archaeomagnetic dating on clay from this furnace retrieved a date of between AD 1280 and 1400 (ibid.: 658). A final furnace, at Ewecote, was significantly disturbed, but did not seem to have a sunken hearth (Powell 2008 vol. 2: 6). No information on dimensions was found, but archaeomagnetic dating placed the installation between AD 1250 and 1430 (ibid. vol. 1: 212).

Further north, at High Bishopley in Durham three furnaces were excavated, two of which were consecutively-used shaft furnaces with slag-tapping at the front of the furnace (Tylecote 1959). The two earlier furnaces had hearth-sizes of about 1 by 0.8m. The third, and chronologically later, was markedly smaller (internal diameter c. 0.5m) and had an internal ledge for resting the tuyeres and slag-tapping at a right angle to this ledge. Of the walls of the latter furnace, only the inner vitrified part was well preserved, but the original thickness was estimated at some 0.7m. The site was dated by pottery to the thirteenth century. The bases of two consecutive slag-tapping furnaces were uncovered at Castleshaw, Greater Manchester (Redhead 1994). The internal diameter of the later, and better-preserved, furnace was calculated at 0.38 to 0.4m (ibid.: 24). A later excavation campaign, of an area already excavated in the early twentieth century, revealed a badly damaged furnace base with associated pits and working floor (Redhead 1996). Two archaeomagnetic and four radiocarbon dates placed the activity at both sites around the thirteenth century (ibid.: 102). Excavations at Myers Wood in West Yorkshire uncovered the remains of a relatively long-lived iron-smelting site, including five furnaces, three of which were covered by a later ore-roasting hearth (Clay et al. 2006). The best-preserved furnace, which had its tapping arch preserved, allowed a reconstruction of an internal diameter of 0.3 to 0.4m with clay walls about 0.2m thick (ibid.: 21). The three other furnaces, of similar construction, were clearly used consecutively, with one of them tapping in the opposite direction to the others (ibid.: 17). The ore-roasting hearth overlying these furnaces consisted of a U-shaped arch of large stones of about one metre internal diameter (ibid.: 16–17). The pottery recovered from the site indicated a thirteenth- to fourteenth-century date for the use of the site (ibid.: 27), archaeomagnetic dating suggested a date range from the twelfth to the fourteenth centuries while radiocarbon analysis dated both the solitary furnace and the ore-roasting hearth to the thirteenth century (ibid.: 29).

A further shaft furnace was excavated at Oakamoor in Staffordshire (Harding 2004: 12–14). The furnace measured 0.5 by 0.4m internally and had walls of about 0.15m thick (Fig. 10.1e). A tapping-channel led into a large, shallow tapping-pit. Although no artefacts were recovered and no other dating methods applied, it was stated that there was "a strong possibiliy"that the furnace dated to the thirteenth to fourteenth centuries. A different type of furnace was excavated at the site of Stanley Grange in Derbyshire (Challis 2002). Eight furnaces were exposed, seven of which had pits below the furnace which functioned as receptacles (Fig. 10.2a). These furnaces had internal diameters varying between 0.5 and 0.75m and extensive channels were cut, leading up to and joining with the slag pits (ibid.: 37). As the interior of these pits was heavily burnt and the channels were all pointing to the main wind direction it was concluded that these furnaces functioned with natural draught. The site was dated to the thirteenth to early fourteenth centuries, based on pottery and archaeomagnetic analysis.

Thus far, only in Britain is there evidence for iron smelting in urban centers. Excavations in the early 1990s at Trelech in Monmouthshire, one of the largest towns in medieval Wales, revealed consecutive phases of iron smelting (Howell 1995). The phase dated to between AD 1240 and 1270 consisted of a furnace base (0.8 by 0.7m) with an adjoining tapping-pit (ibid.: 74) and a similar feature (0.75 by 0.7m) was found in the layers above, dating to around AD 1270 (ibid.: 75–77). The next phase, dated to between AD 1270 and 1290 revealed the most intensive ironworking. A furnace base of comparable dimensions (0.8 by 0.78m) was located in the southern half of a building which was half stone-, half post-built and measured 7.3 by 5.2m (ibid.: 76–78). Next to a tapping-pit for the slag it also had an adjoining stone platform, interpreted as a support for bellows, and a surrounding working surface made of slag. A similar situation, iron smelting (and smithing) in a built-up environment, seems to have taken place at Crawley (Sussex), but here no convincing furnace remains have been unearthed. Excavations along High Street revealed two areas producing both tap slag and smithing residues, dated by pottery to between the twelfth and the fourteenth centuries (Saunders 1998); high concentrations of slag, the majority from smelting, were excavated together

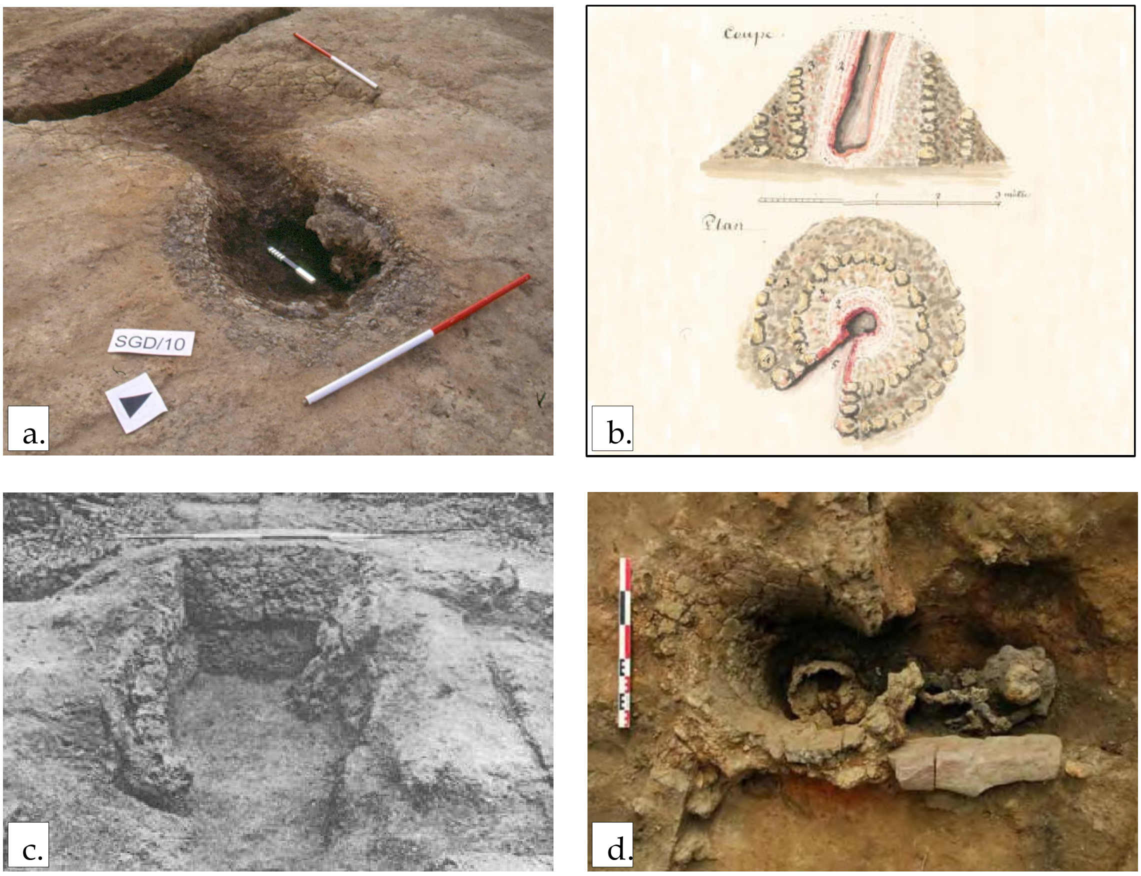


Fig. 10.2 Other types of western European non-water-powered bloomery furnaces10.2a Possible induced draught slag-pit furnace, Stanley Grange, Derbyshire (Online image)[77], b. Quiquerez-type furnace, Swiss Jura (Online image)[78], c. Roly, Liège, Belgium (de Boe 1977: 114), d. Péronnette, Ille-et-Vilaine, France (Online image)[79].

with thirteenth- and fourteenth-century pottery at the High Street/Kilmead site (Stevens 2006) and at London Road (the continuation of High Street) large quantities of tap slag were found associated with thirteenth- to fifteenth-century pottery (Cooke 2001). Archaeomagnetic dating on a smithing hearth of the same period returned a date of AD 1325 to 1425. Small amounts of smelting slag (83g) and smithing slag were found at a site at the southern end of High Street (Priestley-Bell 2009). The smithing activity was dated to the fifteenth to sixteenth centuries, while a pit (0.4 by 0.4m, depth not given), interpreted as a possible furnace, was dated by pottery to the fourteenth to fifteenth centuries. Many other sites in and around the centre of Crawley have revealed remains of ironworking activity (Barton 2006). Further smelting slag, but no furnace bases, was also recorded in an urban environment at Deansway, Worcester (see Chapter 11.3.2).

77 Visible at http://www.nottingham.ac.uk/archaeology/research/projects/current/ stanleygrange.aspx. Accessed 24.11.2013

78 Visible at http://www.patrimoineculturel.ch/sentiers-didactiques/jura/sentier-auguste-quiquerez/images-quiquerez/bas-fourneau.jpg/view. Accessed 01.08.2013

79 Visible at At safemm.free.fr/bulletins/Safemm_bulletin_2010-2011.pdf. Accessed 17.04.2013

This material was dated to the late eleventh to mid-thirteenth centuries. Two sites with fifteenth-century dates are remarkably similar. In the 1960s excavations were undertaken at Minepit Wood, Withyham in Sussex (Money 1971). The medieval part of the site had two phases of activity, the earliest almost exclusively represented by an ore-roasting place. The later phase consisted of a large building, measuring 11 by 7–8m, which held a furnace and dumps of both ore and charcoal. Outside the building was a three-sided stone-built ore-roasting hearth. The furnace walls were about 0.7m wide and made of clay and blocks of stone. On one side, a pierced fragment of tap slag was found which was interpreted as a tuyere. The internal diameter of the furnace measured about 0.45 to 0.55m at the level of the air inlet.

Several carbon dates from the site, as well as a nearby ore extraction pit, all fell within the fourteenth to fifteenth centuries. More recently, a well-preserved furnace was excavated at Llwyn Du in Merionethshire (Crew and Crew 2001). The site, dated to the late fourteenth and early fifteenth centuries by radiocarbon dating (Crew 2009: 20), consisted of a furnace and a smithing hearth, both set inside a large elongated building (Fig. 10.1f). The furnace had an internal diameter of about 0.4m and walls varying between 0.3 and 0.5m thick. The slag was tapped through a large arch into a slag pit and the use of a circular tuyere was implied by a 0.1m splayed blow-hole in one side of the furnace wall. Extensive chemical analysis of slag from different levels within the spoilheap have shown changes occurring over time, implying not only different recipes being used, but two branches of iron production appearing (Charlton 2009; Charlton et al. 2010). This was interpreted as the result of both intentional experimenting with the smelting charges (demonstrated by the non-random evolution of slag chemistry) and adopting the best-suited working practices (shown by decreased variability in reducing conditions) (ibid.: 362–364).

Two furnaces were excavated as part of the Scottish Bloomeries Project. One of these, located in Tamheich Burn, Argyll, consisted of a small squarish shaft of 0.3 by 0.32m (internal?) diameter (Atkinson and Photos-Jones 1999: 274). It was surrounded by a structure made of stone slabs and was equipped with a "tuyere-hole". It was slag-tapping (ibid.: 275) and a fifteenth- to seventeenth-century radiocarbon date was obtained (Johnson et al. 2006: 147). The other furnace, at Allt na Ceardaich, also in Argyll, had a slightly inclining slab-lined base and vertical walls delineating a rectangular area of 0.42 by 0.38m (Atkinson and Photos-Jones 1999: 275). The associated slag was of the tap-slag variety and radiocarbon analysis returned a date between the mid-fifteenth and the mid-seventeenth centuries. The installation was interpreted as a type of "Catalan Hearth" (ibid.: 276).

In other parts of Europe, other unusual furnace types are found. In the third quarter of the nineteenth century, engineer Auguste Quiquerez (1866, 1870) excavated, and esthetically published, several iron-smelting furnaces discovered in the Swiss Jura, which the author believed to date to the Iron Age (Quiquerez 1866: 46). The furnaces consisted of clay-lined tubes, preserved up to nearly two metres high, centrally placed in mounds of stone and earth and clearly functioning without the aid of bellows (Fig. 10.2b). In 1972/73 a similar furnace was excavated at Le Grand Pré in Lajoux, this time with a rather irregularly shaped tube (diameter varying between 0.25 and 0.4m), which had associated pottery dating to the period between AD 1380 and 1440 (Joos 1994: 55, 60). More recently, Eschenlohr (2001) attempted to locate Quiquerez' furnaces, excavate several more and date the sites using radiocarbon analysis.

Two of the Quiquerez furnaces, at La Seigne, Lajoux (ibid.: 49, 265) and Blanche Maison, Undervelier (ibid.: 49, 245), gave respectively thirteenth- and fourteenth-century dates. Other, newly excavated sites at Sous-ce-Mont 2, Monible (ibid.: 50–51, 292) and Envers-des-Combes in Lajoux (ibid.: 260; 2011) produced thirteenth- to fourteenth-century dates, while a furnace at Village 8, Grandval gave fourteenth- to fifteenth-century dates (ibid. 2001: 310). An earlier furnace dated to the eleventh to twelfth centuries, at Combe Chopin in Roches was built exclusively from large blocks of stone, while still operating with induced draught (ibid.: 310). At the badly truncated furnace of unknown shape at Montéporigat I, Undervelier, which was dated to the thirteenth to fourteenth centuries, a 0.6m long tuyere was found, implying for installations owned by the use of forced draught (ibid.: 247).

The use of water-powered furnaces is suggested at the Cistercian abbey of Lucelle (ibid.: 146), but the relevant sources only mention a *furno veteri* (old furnace) in the acts of the abbey in AD 1136 and 1152 (ibid.: 52) and a grant to Lucelle of the right to exploit minerals in AD 1225 (ibid.: 33–34). Another site at La Creuse in Corcelle, with vitreous slag and an eleventh-century date, was also tentatively interpreted as water-powered, but structural evidence was lacking (ibid.: 53, 104). Furnaces dated by radiocarbon analysis to the twelfth to thirteenth centuries were excavated at Lécussy, Côte-d'Or in France (Mangin et al. 1992: 55–66). These installations were built with large blocks of granite forming an inverted cone. Most of the slag consisted of light porous masses along with some denser slag which ran along the inside of the furnace (ibid.: 64). The hearth-sizes varied widely, one measured 0.55 by 0.45m, while another was 0.9m long by 0.6m wide (ibid.: 56, 64). In an overview publication by Buchwald (2008: 40), a similar type of furnace is illustrated which was excavated in the village of Remmet, Jämtland, Sweden. It consisted of large blocks of stone set in a pit with a diameter of 1.5m and is dated to the seventeenth century. In Roly, Liège, Belgium, six furnaces were excavated, which consisted of large heaps (6.5 to 9m diameter) surrounded by a shallow ditch (de Boe 1977). The furnace hearths consisted of large rectangular areas (1.9 to 2.2m by 1.03 to 1.4m) flanked by near-vertical walls preserved up to a metre high (Fig. 10.2c). The bases of the hearths were almost horizontal and the front walls were consistently destroyed, presumably to remove the blooms. Several radiocarbon dates put the activity in the sixteenth to seventeenth centuries.

Finally, at the site of Trécélien, Ille-et-Vilaine, France a relatively small furnace (0.3m internal diameter) was unearthed which had a striking box-like feature, made up of three large stones, constructed in front it (Vivet and Girault 2009: 47–52). Altough some tap slag was found, most of the waste material, consisting of large heaps, was spongy in nature. Pottery recovered from the site is dated between the end of the thirteenth and the middle of the fourteenth centuries (ibid.: 65). The stone-lined box was tentatively interpreted as an area for the further processing of the bloom (Girault and Fluzin 2009: 190). About 6km to the north of this site, five furnaces in varying states of preservation were excavated at Vert Pignon also in Ille-et-Vilaine (Vivet 2009a). Two of the better-preserved furnaces consisted of elevated clay bowls with similar box-like structures attached, while a third showed a clear connecting channel between both, interpreted as functioning for the removal of slag. This site was dated by pottery, radiocarbon and stratigraphic considerations to the late thirteenth to fourteenth centuries (ibid.: 101). Further identical furnaces were excavated at Péronnette, located between the two former sites. Only preliminary results were published (Girault 2009), but more detailed information and photographs (Fig. 10.2d) were available online.[80] These furnaces were dated to the late thirteenth to fourteenth centuries.

10.2 Foot-powered bloomeries and hammers

Traditionally, late bloomeries are classified by the energy source which was used to drive their bellows: water-powered versus non-water-powered. The latter are generally assumed to have been powered by hand, but seventeenth-century references to "foot-

80 At safemm.free.fr/bulletins/Safemm_bulletin_2010-2011.pdf

blasts (Dudley 1885 [1665]: 50; Schubert 1957: 187) seem to indicate that the bellows of some bloomeries were treadle-operated. This was certainly happening in seventeenth- and eighteenth-century Sweden as witnessed by contemporary illustrations (1864: 321; Buchwald 2008: 41) (Fig. 10.3). Fifteenth-century "foot-blasts", this time furnaces for smelting lead, are recorded as being used during the dry season (Salzman 1913: 52), as a substitute for water-power. There are *fabrica pedales* ("foot forges") mentioned as operating in the forests around Carcassonne in Aude, France in AD 1313 (Arnoux 2003: 320) and in the fourteenth century in the Oberpfalz, Bayern in Germany next to water-powered hammers (Sprandel 1968: 222). *Tretthutten* are recorded in Nassau, Rheinland-Pfalz, Germany between AD 1400 and 1600 (Jockenhövel 2005a: 563). It is as yet unclear if the foot-power used in these installations was to power the bellows or a hammer (Pichol 1998: 133).

Forges à pied were used in the middle of the sixteenth century in the Champigneules area in north-eastern France, a century and a half after the earliest record there of water-power used for both bellows and hammers (Girardot 1976: 278). Foot-powered hammers are known to have been used in the West Riding of Yorkshire up until the nineteenth century, where they were known as olivers (Schubert 1957: 138). Schubert (ibid.) stated that the olivers mentioned in late medieval records, in Creskeld, West Yorkshire in AD 1352 when Sir Richard Goldborough leases an oliver (Crump 1954), for example, were similarly foot-powered and the author quotes an example of a foot-powered hammer operating at a water-powered bloomery in Bilsdale, North Yorkshire in AD 1541 (Schubert 1957: 147, 395–396). Several other accounts, for West Yorkshire ironworks, mention water-power and olivers together, for example at Thurstonhagh in AD 1497 (Moorehouse 1981: 775) and Farnley in AD 1582 (Crump

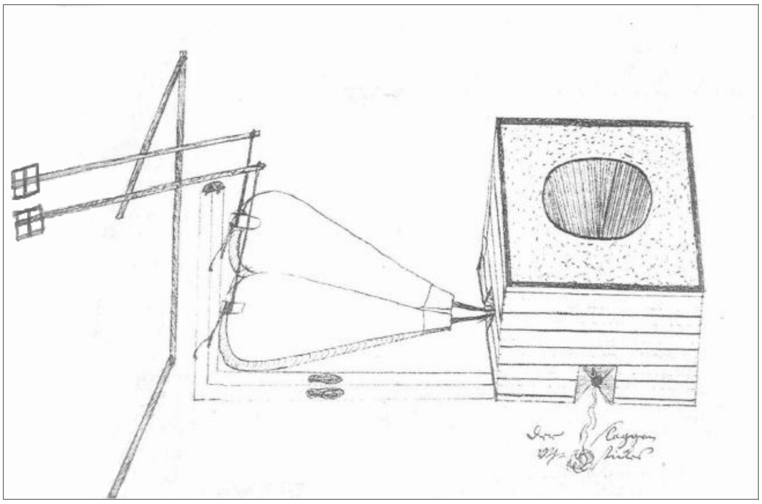


Fig. 10.3 Foot-powered bloomery, Lirna, Dalarna, Sweden, by D. Milander, 1682 (Buchwald 2008: 41).

1954: 304). An earlier reference to "the watercourse leading to the said smithy for burning iron there" and an oliver in AD 1418 at Clayton West could imply that the hammer was water-powered (Moorehouse 1981: 775–776) or that only the furnace bellows used this energy source.

10.3 Water-powered bloomeries and hammers

10.3.1 Documentary evidence

The exact nature of the early use of water-power in European ironworking is obscured by the vagueness of the terms used in the written sources, together with the many applications water-power can have both in smelting and a smithing environment. At the furnace, water can be used to operate ore hammers, the furnace bellows or a hammer to consolidate the bloom. In the forge, it can be used to work the bellows, move a hammer or turn grinding stones. Archaeological investigations are only very recently starting to add to the discussion. An early reference is the sentence *Baccorlaco super fluvium Carusium ubi faber noster Majorianus mansit, et filius ejus Ramnulfus de Blaciaco* from AD 738 (Giraud 1904: 212), which is sometimes quoted as indicating the early use of water-power in ironworking (e.g. Knau and Sönnecken 2003: 223). The sentence, however, only refers to the smith being settled near the river, without implying the use of water-power (Schubert 1957: 90). In AD 1086, the Domesday Book records two mills in Somerset which were paying their rent in blooms, which has been interpreted as evidence of water-powered ironworking (White 1962: 84; Reynolds 1983: 86), but this has been criticized by others (Schubert 1957: 89).

Often quoted as the earliest reliable source relating to the use of water for iron-working, is the passage in the biography of St. Bernard of Clairvaux, founder of the Cistercian order, written in AD 1156 (Verna 2001: 81). An early translation of this source (Le Maistre 1649: 154) can be rendered as follows:

> The monks themselves contributed everywhere to the works, some chopping wood, others cutting stone, some building walls, others diverting the river into several channels and bringing the water to the mills, where fullers, bakers, curriers, smiths and other workmen make ready their machines for their works, so that the stream, flowing and exiting all parts, serves for the commodity of the entire House.

It is, however, unclear what this water-power was applied to, bellows, hammers or sharpening stones. When, in AD 1197 or 1224 (both dates are mentioned throughout the literature), the grange of Tvååker in Halland, Sweden was donated to the Cistercian abbey of Sorø in Denmark, mention is made of *silva monasterii protenditur de molendino, ubi fabricatur ferrum, & per viam, quae ducit ad Syndre jernwirke* ("the woods of the monastery extending from the mill, where iron is made, & by the road, which leads to the Syndre ironworks") (Langebek 1776: 471), which is often quoted as indicating water-powered iron making (Reynolds 1986: 62; Lucas 2005: 349). Excavations in Tvååker in 1993–1995, revealed two sites within a kilometre of each other, both radiocarbon dated to the twelfth century (Buchwald 2005: 134–138). One site, at Jernvirke, had small (0.2m internal diameter), twinned furnaces, while the other, at Ugglehult, was clearly water-powered. The furnaces at the latter site were damaged by later activity, but the water-power was assumed to have been used to drive bellows, and not a hammer (Buchwald 2008: 76).

The potential confusion of terminology related to early water-powered ironworking is clearly illustrated by the documents relating to the Cistercian monastery at Évreux in Normandy, France. While a first text from AD 1202 refers to a *molendina fabrorum* (smith's mill) at this monastery, a second text from AD 1204 refers to a *molendina ad cultellos* (cutlery mill, for sharpening tools) (Delisle 1852: 288). The earlier text is sometimes quoted as referring to a water-powered forge, and both are sometimes seen as separate installations (Lucas 2005: 255–256, 349, 387–388), while both references could clearly apply to the same mill. Some sources (Schubert 1957: 342) mention the Cistercian abbey of Kirkstall as an early example of water-powered ironworking based on the grant of a *fossatum* (fosse or goit) granted to the forge. Subsequent research (Mott 1972: 154–155; Moorehouse 1981: 787), however, has shown the original reference to be unconnected with ironworking.

From AD 1261, we have the reference to a *molendino, quod ibiden materiam ferri massam in quam (?) sive metallum molit* ("the mill where iron blooms are (?) or metal ground/milled") belonging to the village of Rudniki, which could be several places, coming into the possession of the Cistercian abbey at Andrejov/Jędrzejów in Świętokrzyskie, Poland (Rzyszczewski and Muczkowski 1858: 81; Sprandel 1968: 362; Reynolds 1986: 65). Another reference frequently quoted as an early testimony to hydraulic ironworking is about a *mo(u)line a battre fer* ("a mill for hammering iron") at

Escoussens, Tarn in France in AD 1283 (Gille 1947: 14; Verna 2001: 99–100). This sentence, however, does not appear in the original text (Belhoste 1995: 386). In AD 1299 we have a further early reference to water-powered ironworking: a mention of *de censu molendini ad ferrum* (“on the account of the iron-mill”) at Villeneuve-sur-Yonne in Yonne, France (ibid.: 389), but it is unclear if the power was used for bellows or a hammer. In AD 1311, at Gincla in Aude, France we know of a reference to a *molina ferrara*, a denomination which appears regularly after that, sometimes specifying they had between one and three *foci* (hearths) (Belhoste 1995: 386).

In northern France, shortly after in AD 1323, we have the contract, between the Duke of Bar and a local merchant and his son for constructing a *forge faisant feir per yawe* (“forge making iron by water”) in Briey (Lorraine) (Collin 1975; Belhoste 1995: 386–387). The forge was to be built on condition that it could produce at least twice the amount of iron as installations *sans yawe* (“without water”). The reference to the forge with water expending more wood than the one without confirms this to relate to the use of water-powered bellows. Interestingly, an account relating to the Briey ironworks from AD 1326 mentions the sale of “six pairs of *gousses*” which are interpreted as blooms (Weyhmann 1905: 41–42; Sprandel 1968: 251). The reference to pairs of blooms could relate to the new way of making double-sized blooms which were then cut in half to resemble the older blooms. In AD 1375, in Oranienstad, Brandenburg in Germany, there was a *molendinum et malleum fabricans per motum aqua* (“a mill and forging hammer moved by water”) (Lisch 1842: 54).

In France, a forge donated in AD 1269 to the Benedictine monks of Saint-Evroult, Orne, is described in AD 1337 as *une forge o la getee appartenant d'icelle* (“the forge to which the *getee* belongs”), which was regarded by Arnoux (1993: 106) as referring to the spoilheap (*jetée* = “what is thrown”). Lohrman (1995: 34), however, pointed out that *jetée* also means a dam and hence refers to water-powered ironworking. Similarly in England, several indications exist for older water-powered ironworks, but the *molendinum ferri* mentioned in AD 1346 as located in Lancashire is often seen as one of the oldest conclusive ones (Schubert 1957: 342; Lucas 2005: 266). A published translation of this text (Farrer 1915: 67–152), however, does not mention an iron mill, and the reference to both mills (wind- and horse-powered) and a ferry may have led to confusion. In AD 1391, an old mill at Champigneules in Meurthe-et-Moselle, France is granted by the Abbot of Saint-Arnoul, a Benedictine monastery, to the former provost of the Duke of Lorraine and his son, who are to convert it into a *forge pour faire fer*

(Girardot 1976). The ironworks are to have two water-wheels, one to drive the hammers and the other the bellows for two hearths (ibid.: 279). The earliest convincing evidence for water-powered ironworking in England seems to be the agreement made in AD 1395 by Sir Richard Goldsborough and John Ardsley from Ardsley (south of Leeds) for ironworks at Creskeld, West Yorkshire, which included the construction of a watercourse for a water-wheel (Moorehouse 1981: 775). Shortly after, we have the important accounts from Byrkeknott in Durham for November 1408 to November 1409, concerning a newly built water-powered bloomery for Thomas Langley, Bishop of Durham. These were published by Lapsley (1899) and partially translated into English by Mott (1961) and by Myers (1969: 1005–1008).

Lapsley (1899: 509) saw the accounts as the probable testimony of an unsuccessful experiment rather than part of a larger body of documents. A water-wheel is clearly referred to in the text (ibid.: 518), and the author ruled out its application to a hammer as too early in date. At the same time, however, the author did not believe that the mentioning of the wife of the *blomer* getting paid for working the furnace bellows for two weeks in April meant she was actually blowing the bellows, as these would have been too large for “a woman alone”, nor that in April the watercourse was likely to be affected by drought or freezing and the author tentatively suggested that she might have been adjusting the bellows while they were in operation (ibid.: 513–514). Little information is available about the nature of the installations, but it is clear that it produced, on average, a bloom per day (Arribet-Deroin 2010a: 159).

Schubert (1957: 137–138) agreed with Lapsley on the water-power being used to drive the bellows, but on the basis that hydraulic hammers, which required a larger investment than water-powered bellows, were not needed, even in the case of Byrkeknott where blooms weighing close to 90kg are recorded. Moreover, mechanized, if foot-driven, hammers in the form of olivers did exist at that time (see above). Mott (1961: 156–157), on the other hand, based on the comparison of the values of tools mentioned in various medieval accounts, comes to the conclusion that the water-wheels at Byrkeknott were operating a hammer. And, although only one wheel is mentioned, the same author (ibid.: 157) further states that both a hammer and the bellows of the smelting hearth were water-power-driven. Arribet-Deroin (2010a: 157–158), in a recent article closely re-examining the evidence, came convincingly to the conclusion that it was indeed the bellows, and more specifically those working the furnace, which were water-powered. The argument is based on the observation that during the two periods when the wife of the bloomer is recorded as working the bellows, once clearly and once possibly, the water-wheels were out of action. Interestingly, when the Byrkeknott furnace was built, a Thomas Child was sent to another furnace at Blakamore, “so that the craftsmen who were making this forge [at Byrkeknott] could the better inform themselves about the building of it” (Myers 1969: 1006). If Blakamore can be identified with Blackamore in North Yorkshire (see for example Dimbleby 1961)[81], this would suggest water-powered iron smelting was already practised further south than County Durham. Mention is also made of bloomers and colliers being brought over from Wakefield, West Yorkshire and Rotherham, South Yorkshire (Lapsley 1899: 511), which could, but does not have to, imply that similar installations were operating between Leeds and Sheffield.

By AD 1421, the same Bishop of Durham owned a derelict, but unspecified ironworks at Smithyhurst (unlocated) (Drury 1992: 23) and in AD 1430 he grants Robert Kirkhouse, *ironbrenner*, land and woods to start ironworks at Crawcrook, Tyne and Wear, to work “when water will serve him” (Schubert 1957: 343; ibid.: 24). Shortly after the Byrkeknott accounts, in AD 1418, we have a reference to “the watercourse leading to the said smithy for burning iron there” and to an oliver in that area, at Clayton West in West Yorkshire (Schubert 1957: 342; Moorehouse 1981: 775–776).[82] Around the same time, in AD 1416, Basque ironmakers got in touch with their local representative to enquire about available *molinas* and rented the one at Léca, Pyrénées-Orientales, France, which unmistakably had water-powered bellows (Verna 2011: 639; Hilaire-Pérez and Verna in press: 40). This would imply that the working with water-powered bellows was known in the Basque region in this period.

The earliest definite use of water-power for bellows for iron in south-western France is at the very end of the fifteenth century in Quercy, Tarn-et-Garonne, France, but this is known to have been applied for smelting silver ores in the middle of the fourteenth century on the Spanish side of the Pyrenees (Verna 2001: 82). Mariano di Jacobi, better known as il Taccola, included a drawing of water-powered bellows in the first book of his *De Ingeneis* (Fig. 10.4) (Taccola and Scaglia 1984 [1449]: 70). Although this book was finalized in AD 1449, many of the drawings date to an earlier period (McGee 2004: 73) and little is known of Taccola's life, so it is also unclear where he saw the installation which he illustrated. The installation is sometimes considered as

81 Drury (1992: 23) suggests Black Hill about 4 miles west of Byrkeknott as a possible location.
82 Schubert refers to permission being given to erect smithies, while according to Moorhouse the watercourse is included in the rent of a smithy.

a water-powered bloomery (Schubert 1957: 135–136; Pellequer 2008: 70) but, due to the similarity of the installations, we have no way of being certain that the drawing does

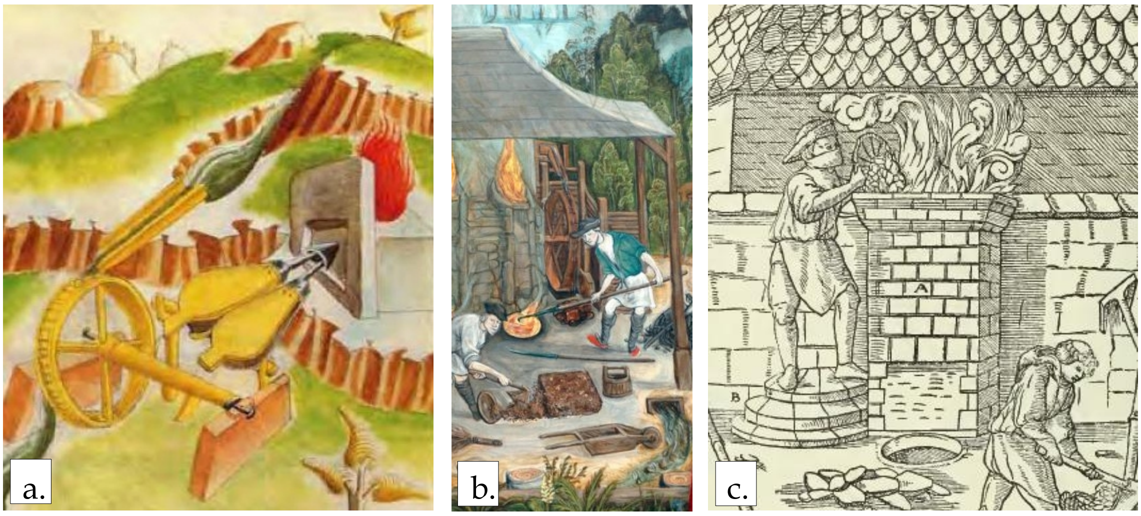


Fig. 10.4 European late medieval water-powered bloomeries. a. Water-powered bloomery or finery in Italy, by M. Di Jacobi, before AD 1449 (BnF Ms. Lat. 7239, fol. 47v), b. Water-powered shaft furnace near Rožnava, Slovakia, *Metercia of Rožnava* by Anonymous in AD 1513 (Online image)[83], c. Square water-powered bloomery, Bohemia, Czech Republic, by G. Agricola (Agricola et al. 1912 [1556]: 424)

not depict a finery hearth (see below and compare with Figs. 3.2 and 3.3). In the same year of AD 1449, a smithy at Tong in West Yorkshire was granted permission to divert streams and build pools (Schubert 1957: 343). A document, dated to between AD 1474 and AD 1495 mentions an “Iron mill” in Bourne Pool, Staffordshire (Gould 1971: 60). A limited excavation was undertaken at the site, but no conclusive results could be obtained, although a water-powered hammer was suggested (ibid.: 62–63).

In AD 1496 Roger Eyre of Holme Hall leases a “bloom harth” with the “Smethy Dam” from and at the Premonstratensian Beauchief Abbey in Derbyshire (Pegge 1801: 189; Raine 1884: 66).[84] In AD 1507, we know of the unpublished accounts of an ironworks at Treeton in South Yorkshire where the bellows for both the furnace and the string-hearth were driven by water-power (Schubert 1957: 141) and in the same year John Selyok of Hasilbarowe leases land in Smethefeld near Norton, Derbyshire to build an “Irnesmethe both blome herth and strynge herth” together with a stream “to turne the said Smethes” (Hall and Thomas 1914: 124–125). From AD 1513, we have what is probably the earliest depiction of a bloomery in Europe in the anonymous painting known as the *Metercia of Rožnava* (Fig. 10.4b), which is a former mining town in

83 Visible at http://www.rovart.com/en/the-metercia-of-roznava_159. Accessed 05.10.2012
84 When the same abbey leased out all the lands within its precincts in AD 1463, the “smythees” were exempted as they were already leased out to others (Hey et al. 2011: 19). It is probably, but not confirmed, that these smithies were also water-powered.

eastern Slovakia. It clearly shows a pair of water-powered shaft furnaces and a large bloom being cut in the foreground. Several decades later, in AD 1556, Agricola published his *De Re Metallica.*[85] Although mostly focused on non-ferrous metallurgy, the author included illustrations, and descriptions, of two iron-smelting furnaces (Agricola et al. 1912 [1556]: 420–423). The first is described as a hearth measuring about 1.5m square and a metre high. The actual hearth is 0.45m diameter and 0.3m deep and the woodcut clearly depicts a slag-tapping channel at its base (see Fig. 3.2). The water-powered bellows are regulated by a lever operated by the smelter. The bloom produced is subsequently hammered, seemingly first manually and then with a hydraulic hammer. The other type of furnace, used for ores containing copper and which are more difficult to smelt, is much higher and wider so it can hold more ore and charcoal (Fig. 10.4c). In the latter furnace, the ore is referred to as smelted once or twice (ibid.: 423).

Earlier, in AD 1540, the waterworks at the bloom-smithies of Rievaulx Abbey in North Yorkshire had been expanded to serve two bloom-hearths (furnaces) instead of one and a string-hearth (Schubert 1957: 148). Importantly, a water-powered hammer was added for processing the blooms. The bloom-smithies at Middleton in Warwickshire in the early 1570s were very likely water-powered, judging by the size of the blooms produced (100 to 150kg) (Smith 1967: 96), but this is nowhere specifically stated. The water-powered hammer, however, built at the same place in the late 1570s seems to have processed blooms from these bloom-smithies (ibid.: 96–97). In AD 1612, Walenty Roździeń described the furnaces using water-powered bellows near the Polish-Silezian border as low and round, while those in Bohemia were “high like chimneys, and built square” (Różański and Smith 1976: 61). The latter furnaces are reminiscent of the second type described by Agricola about a half a century earlier, while the former are either a shorter version of the Rožnava shaft furnaces or the open-hearth bloomery described by Agricola (for all, see above).

In other areas in Europe, water-powered bloomeries similarly continued to operate past the early seventeenth century, although by that stage the blast furnace had become widespread in Europe (see Chapter 10.5.1). We have seen the description of the open-hearth bloomeries described by Gerard Boate in Ulster in the 1630s (see Chapter 3.2.2). We have another, similar description of one of these installations at Milnthorpe in Lancashire in the 1670s (Lister 1694). The publication is a series of letters from a correspondent who describes the furnace, after initial erroneous information, in

85 Water-power was known in Bohemia since the fourteenth century (Piaskowski 1976: 22)

Milnthorpe as follows (ibid.: 698):

> It is very much like a common black-smiths, viz. A plain open hearth or bottom without any enclosing Walls, only where the nose of the Bellows come in through a Wall there is a hollow place (which they call the Furnace) made of Iron Plates, as is also that part of the Hearth adjoining. This hollow place they fill and up-heap with Charcoal, and lay the Oar (broken small) all round about the Charcoal upon the flat hearth, to bake it as it were, or neal and thrust it in by little and little into the Hollow, where it is melted by the Blast. The glassie *Scoriae* run very thin, but the Metal is never in a perfect Fusion, but settles as it were in a Clod, that they take out with Tongs, and turn it under great Hammers, which at the same time beat off (especially at first taking out of the Furnace) a deal of courser *Scoriae*, and form it after several Heats into Bars.

A more detailed description of the furnaces at Milnthorpe can be found in Harrison's *Lexicon Technicum* (Harrison 1708: 391) and very similar installations are described from the Oberpfalz in Bayern, Germany at the end of that century (Flurl 1792: 353). Large open bloomery hearths, but this time operated at ground level, are known from Tworóg in Śląsk, Poland, where they were still operating at the end of the eighteenth century (Eversmann 1804:frontispiece). At the same time, different types of water-powered bloomeries were in operation in both the French and Spanish Pyrenees (Catalan forge/furnace) (Tronson du Coudray 1775: 45–50). Smaller ones, where the ore is reduced in a two-step process, were active on Corsica (ibid.2–3) and funnel-shaped furnaces, which we have seen previously (see Fig. 10.3), occurred in Scandinavia, but this time equipped with water-powered bellows (for example Buchwald 2008: 49).

10.3.2 Archaeological evidence

Perhaps surprisingly, no excavations have been carried out on convincing examples of late medieval water-powered ironworking sites which were not related to blast furnaces. Excavations at Fabregada in Lleida, Spain uncovered a building next to a stream containing a bloomery furnace. The site was interpreted as having an eleventh-century water-powered hammer, but the evidence, both for the function and the dates, was unconvincing according to Verna (2001: 78–79). The remnants of six furnaces, four of which were well preserved, at Hochwaldhausen-Ilbeshausen in Hesse, Germany were described by Harrassowitz (1923). The furnaces, U-shaped in plan, were built out of clay without stones and measured about 5 by 3m. The author mentions a funnel-shaped interior preserved up to 2m and heaps of maximum 4m high with slag containing up to 37 percent iron. An artificial watercourse ran from the nearby stream to the furnace and back again. Later, thirteenth- and fourteenth-century pottery was found at the same site (Jockenhövel 2005a: 560–561).

Two sites have been excavated in England and interpreted as indicating the use of water-power in the thirteenth and/or fourteenth centuries. The first site, the monastic mill at Bordesley in Worcestershire, operated from the late twelfth/early thirteenth centuries to the late fourteenth/early fifteenth, and consisted of a sequence of post-built wooden buildings next to, mostly, wood-lined races and wheel-pits (Astill 1993). The structures interpreted as connected to metallurgical activity, not only of iron but also various non-ferrous metals, were several hearths and anvil-bases, either in the shape of large stones or postholes. Striking was the relatively small amount of slag recovered from the site (7.2kg), of which 3.4kg belonged to period 7 (abandonment and post-medieval), and 2.6kg of the earlier slag was incorporated into structures (calculated from Tables 43 and 44, ibid: 203). This was explained by the possible secondary use of the slag material elsewhere (ibid.: 272). Some slag was found adhering to tiles making up one of the pitched-tile hearths next to the wheel-pit. The only concentration of slag (from period 6, both phases, fourteenth/early fifteenth centuries) was found next to the base of a raised-hearth smithing hearth located within a stone structure interpreted as a possible forge; this structure, however, lay about 15m north-west of the wheel-pit (ibid.: 42, 49). More slag was found in a structure further west again (ibid.: 49).

More difficult to explain is the lack of hammerscale recovered from the site. The sampling method is not explained, nor is the amount quantified, but the hammerscale is classified into three categories (present, small quantities and moderate quantities). Only the floor next to one of the tile-hearths is recorded as having moderate amounts of hammerscale, with another eight having small quantities and hammerscale present. The hammerscale was recovered from two consecutive pitched-tile hearths and later floor levels. The structural evidence was limited to a large stone situated next to the two hearths mentioned above and a pit interpreted as the foundation for an anvil (ibid.: 282). The author proposed that water-power was abandoned after phase 2 of period 6 after which the ironworking was carried out manually (ibid.: 51, 282). Some smithing activity clearly took place at the Bordesley Abbey site, around the anvil-stone and at the structure located away from the wheel-pit, but the available evidence seems to point to small-scale non-water-powered smithing, which only in the later phases would appear to have been permanent.

The second site, at Chingley in Sussex, was the location of a sixteenth-century blast furnace with an associated water-powered hammer, finery and chafery (Crossley 1975a). The excavations also revealed some evidence of earlier thirteenth to fourteenth-century milling and metalworking activity. The slag from this early period is not quantified and the only reference is to small amounts of tap slag (ibid.: 14). The site, however, was considered a hammering site and the tap slag explained as potentially arriving there attached to blooms or for construction purposes. No anvil (base) was found, but the possibility was put forward that it could have been destroyed by a later anvil-pit (ibid.: 15). A fragment of a gear-wheel was also recovered, but the teeth were closely set, making their use for directly working the hammer helve unlikely. It was interpreted as part of a right-angle drive (ibid.: 15–16). The available evidence for this site is insufficient to conclude that it was a smelting or a hammer mill, or even that hydraulic power was used in ironworking at all (Cleere and Crossley 1995: 107). In fact, the only evidence for water-powered bloomeries of any kind in the Sussex and Kent Weald comes from the finds of "bloomery tap-slag" at known finery sites (ibid.: 107–109), but, as we have seen (Chapter 3.3.1), the distinction between finery slag and bloomery slag can be very slight.

Tylecote (1960) carried out an excavation at Harthope Mill in Durham, for which there was "a strong possibility" that it was the site of Byrkeknott. The slag found in the mill building, was "of a porosity much finer [than earlier tap slag] and widespread, giving it a honeycomb texture" (ibid.: 455), which we know is characteristic for slag from water-powered bloomery smelting (see Chapter 3.2.4). Pottery found in the same layer as the slag was dated to the fourteenth and fifteenth centuries (ibid.: 457). Hearths were not found, but a depression containing stones located centrally in the building was regarded as a possible remnant of a hearth (ibid.: 454, 457). A reconstruction drawing of the possible arrangement of the bellows and hearth, however, puts the hearth next to the wall and, according to Arribet-Derroin (2010a: 156), has the tuyere too high and the hearth too shallow. Tylecote seems to have relied heavily on nineteenth-century drawings of Catalan furnaces (cfr. for example Johannsen 1953: 126). In a later work, Tylecote (1986: 205) suggested that Byrkeknott, partially based on the results of his excavations at Harthope Mill, would have had two water-powered bellows and a hydraulic hammer, but later concluded that the water-power was solely used for the bellows as no hammers are mentioned in the accounts (Tylecote 1992: 76).

We have the earliest indications for the use of water-powered bellows in Norway on the excavated site at Tolga in Hedmark and dated to around AD 1400 (Espelund 2003a: 182). Apart from this, the only site with clear evidence for water-powered bloomery ironworking is the early seventeenth-century one excavated at Rockley Smithies in South Yorkshire (Crossley and Ashurs 1968). Here a furnace and two string-hearths (bloom-refining hearths), all water-powered, and a non-water-powered hammer were unearthed. All the water-powered installations were lined up at the base of the dam containing the pond, with each unit having its own wheel-pit and bellow-house. The furnace was a circular mud- and stone-built structure built against a bank and had an internal diameter of about 0.6 to 0.7m (ibid.: 24). At the front it was preserved up to a height of 0.3 to 0.35m and at the back up to 0.6m. Only one of the string-hearths was preserved well enough to allow some conclusion to be drawn regarding its shape. The hearth consisted of a simple flat and rimmed hearth (ca. 0.75m diameter) constructed on top of horizontal stone slabs. A (non-water-powered) hammer was also implied by the occurrence of the base of an anvil surrounded by hammerscale.

10.4 Non-water-powered liquid-iron production

Experiments have shown that it is possible to produce liquid iron in a shaft bloomery-furnace. An early publication by Tylecote and co-workers (1971: 362) demonstrated that a carbon content of up to 1.8% could be obtained by using a high fuel-to-ore ratio in a furnace without slag-tapping. Cast iron contains between 1.4 and 4.6% carbon. The experiments by O'Kelly, using bowl furnaces, apparently led to the production of cast iron (Scott 1990: 39). More recently, an experiment using bog ore in a shaft furnace produced 9.4kg of cast iron with local carbon content higher than 4.3% (Crew et al. 2011). Pieces of cast iron are regularly encountered on excavations of ironworking sites. Metallographic examination of what were thought to be seventy blooms from across Europe revealed 10% of these to be lumps of cast iron, while a quarter contained inclusions with carbon contents of 2% and higher (Pleiner 2003: 183). These lumps of high-carbon iron are often seen as discarded waste products, with one explanation being the accidental smelting of ore with a higher manganese content than usual (Navasaitis and Sielskiené 2007: 172). Several cast-iron objects have been claimed to be of Roman date, but some of the more famous ones were shown to be either forgeries or intrusive (Craddock and Lang 2005). One piece, however, from the Roman site at Wilderspool in Cheshire was interpreted as the result of an early experiment in producing cast iron using coal as fuel (ibid.: 43). Metallographic examination of artefacts from eighth- to ninth-century Southampton, Hampshire revealed homogeneous steel with little slag inclusions, which was interpreted as being the result of direct liquid-steel production (Mack et al. 2000). This was criticized by David Killick on the online Arch-Metals discussion forum in 2001 by pointing out that the same result could be obtained by the crucible steel method, not requiring a liquid phase.[86]

Some early ironworking sites have been interpreted as yielding evidence for the early production of liquid iron. On the fourth-century Roman site at Oulches in Indre, France, east of Poitiers, not only was the usual dense iron-rich tap slag found, but frequently pieces of light glassy slag were encountered, some of which contained grains of metal up to 10mm in diameter containing up to 4.3% carbon (Mahé-Le Carlier et al. 1998: 93; Dieudonné-Glad 2000: 72–73). These grains of iron were seen as one of the intended products made on the site. At the fifth- to sixth-century ironworking site of Ponti di val Gabbia III in Brescia, Italy several pieces of iron were found which showed clear signs of controlled de-carburization of intentionally-made cast iron (Fluzin 2003: 144). About half of the slag found on this site was also of the glassy *laitier* variety, frequently containing iron droplets (Cucini Tizzoni and Tizzoni 2003: 52). The "groynes/greyn" of iron, mentioned as sold in the mid fourteenth-century accounts of the ironworks at Tudeley in Kent, were similarly interpreted by Craddock (1999) as grains of cast iron produced as a by-product of the bloomery process. This author quotes a nineteenth-century account from India of similar droplets being decarburized to produce steel.

Perhaps significant in this light is the reference to blue slag "with the texture of sealing wax" being collected by local potters for colouring their glazes from a heap of ironworking slag at Blards, Yonne in central France (de Tryon-Montalambert 1955: 198–199). The site was excavated and shown to be Roman in date (ibid.: 192–196). An excavation at Kippenheim in Baden-Württemberg, Germany uncovered a series of pits containing both iron ore and slag (Gassman et al. 1995). The vast majority of the slag was relatively poor in iron (10 to 26% FeO) and had inclusions of iron droplets with a

86 https://www.jiscmail.ac.uk/cgi-bin/webadmin?A2=arch-metals;405a65b7.01

very high carbon content (2.2 to 4%) (ibid.: 47–48). It was suggested that high-carbon iron was intentionally produced on the site, with an eye on de-carburization it into either wrought iron or steel (ibid.: 50). The pottery recovered in association with the slag was dated to between the eighth and ninth centuries, while radiocarbon analysis on associated charcoal returned a calibrated date of AD 640 to 870 (ibid.: 44).

In 1993 and 1994, excavations were carried out on an ironworking site at Metzingen-Neuhausen "Äuβerer Wald", also in Baden-Württemberg, south of Stuttgart (Yalçin et al. 1995; Kempa and Yalçin 1996). A horseshoe-shaped furnace with an internal diameter of about 1m and clay walls about 0.25 to 0.3m thick was found associated with mainly low-iron/high-calcium slag (Fig. 10.5). Iron-rich slag, representing about 6 to 7% of the assemblage, was interpreted as slag solidified in the furnace and was also found covering the one excavated. Several fragments of thin-walled tuyeres with an internal diameter of c. 60mm and lumps of iron with up to 4% carbon and between 0.4 and 2.6% phosphorus were also found. Analyses of the slag led to the conclusion that the product was, "without a doubt", liquid iron (Yalçin and Hauptmann 2003: 143). There was no evidence for the use of water-power at the site. Nine radiocarbon dates carried out on material from this site gave dates ranging between the eleventh and the thirteenth centuries and centering between the late twelfth to late thirteenth centuries (Kempa 2003: 63).[87]

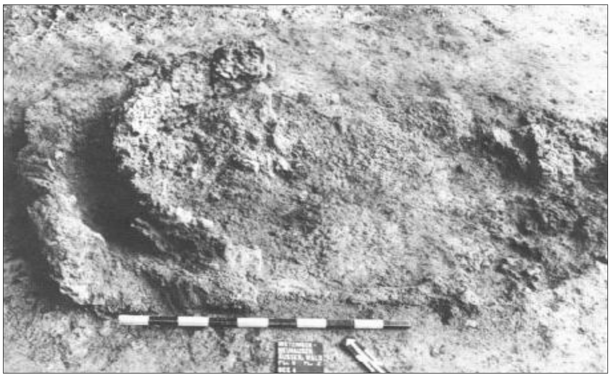


Fig. 10.5 Shaft furnace producing liquid iron, Metzingen-Neuhausen, Baden-Württemberg, Germany (Kempa 2003: 52).

10.5 The blast furnace

10.5.1 Documentary evidence

In AD 1345, the ironworkers of Marche, Namur, Belgium received far-reaching

87 As most 2σ dates are smaller than the 1σ dates, it is clear the dating information contains errors.

privileges from the local Count, the installations were described as *forges à eawe* (water[-powered] forges), while it was specified they could not make steel as the workers at Jausse, or Pont au Weys, had a monopoly on its manufacture (Gillard 1971: 231–233). In the previous year mention is made of a *forge à deux fers* (forge of two irons) at Jausse, half of which was rented out to Colart Loste, the other to the *acherons* (*aciérons*, steel-makers) (ibid.: 60). In AD 1345, the year of the charter, the workers at Jausse threatened to return to their country in Germany because of the high rents of the forge (ibid.: 41). Founders (*fondeur*) and a finer (*affineur*) are mentioned in AD 1356 at Jausse and in AD 1371 at Ermeton. The iron at Jausse was called *fer de plokestoire/ploxtore* in AD 1345 and 1356 respectively (ibid.61) and in AD 1371 a furnace *pour fondre plouk* was built at Marche-les-Dames (ibid.: 63). The evidence up to now points to the use of furnaces making both iron and steel, as in the Swedish and German furnaces of the same era, worked by German immigrant steel-makers and possibly others. The Jausse steel monopoly could have caused iron-smelters to adopt the same technology, but solely producing cast iron as was clearly done by the 1350s. For the year 1395 we have the entry mentioning the construction of a furnace at Gougnies "for smelting iron (*fondre le fer*) like the one at Marche" (ibid.: 54) and in the same year a forge à *forger, affiner et estraire a un grand marteau* (for forging, fining and drawing out at a great hammer) is recorded between the mills of Gougnies and Biesmes (ibid.: 68; Awty 2007: 791). Recent research, combining dendrochronology to date church timbers and microscopic examination of slag inclusions in the associated iron fittings, have indicated that the use of iron produced in blast furnaces might date back as far as the 1330s in the Liège district, about 50km north-east of the Marche area (Mertens et al. 2009: 28).

Awty (2007: 789–790) suggested that the blast furnace proper, that is to say one with a fore-hearth, originated at this time because of the connections between lead- and iron-smelting technology. This was based on the assumption that lead smelting produces a lot of slag, necessitating a fore-hearth. Lead ore, however, is nearly always galena, a very pure combination of lead and sulphur generally producing limited amounts of slag. The confusion stemmed from the interpretation of the *Sumpofen* quoted from Beck (1895: 188) and Gilles (1952: 409, 413)[88], who indeed saw this furnace as the forerunner of the "real" blast furnace, and illustrations of the same in Agricola.[89] The *Sumpofen*, however, was a furnace for smelting silver and gold containing copper ores

88 A further source (Johannsen 1953: 222) is given, but this work only contains 214 pages.
89 Chapter IX, and not VIII as Awty states.

to which lead was added. The lead, due to its weight, would leave the furnace first and was captured in the fore-hearth. Several lead-smelting furnaces are depicted in Agricola's *De Re Metallica*, all of which are either simple heaps or open-hearth furnaces (Agricola et al. 1912 [1556]: 393). Awty (2007: 789) further quotes several references of iron-smelting furnaces being used to smelt lead, all at Marche-les-Dames. It would seem that Awty assumed that the numbering of the different ironworking installations in different time periods, as classified by Gillard (1971: 62–64, 73–74), referred to the same locations, which was not intended. One example, however, also at Marche-les-Dames, is described as a forge for smelting iron and lead, and was destroyed by water (floods?), suggesting it was water-powered (ibid.: 74). So, either blast furnaces were used in Wallonia for smelting lead ore or other types of furnaces, in this case possibly an open-hearth water-powered furnace, existed side by side with the blast furnaces as was later the case in the Oberpfalz (see below).

From the late fourteenth century onwards, we have records of iron cannons being cast: in AD 1390 in Frankfurt am Main in Hesse, Germany (Wertime 1962: 67), in AD 1400 in Wesel, Nord-Rhein Westphalen, Germany (ibid., Johannsen 1912: 368), in AD 1430 in Dijon, Côte-d'Or, France (ibid.: 371) and in AD 1497 in Nürnberg in Bayern, Germany (Johannsen 1912: 380). In AD 1415 an *Eisengießer* is casting cannonballs in Freiburg-im-Breisgau in (Baden-Württemberg, Germany (Johannsen 1919: 1460). Striking is that all these references relate to the casting of iron in an urban environment, suggesting this was not the result of smelting ore but rather of old iron, as is described in the *Feuerwerk Buch* from AD 1454 (Johannsen 1910). This work also mentions making liquid iron from ore, either “steel ore” or iron ore containing copper, but it is to be made in a hearth at a *Hammer*, where the water-power should be supplemented with treddle-powered bellows (ibid.: 1374). Interestingly, the installation for making cast iron from scrap iron is stated as one similar to making bells (that is to say for bronze casting). The same author has brought together further arguments connecting early iron casting with existing bronze casting technology (Johannsen 1913).

Nearly a century later, in AD 1556, Biringuccio described how to make cast iron cannonballs from scrap iron or “some of that crude, corrupted kind [of iron] that has been sent through the furnace in order to purify it of earthiness” (Buchwald 2008: 109–110). Starting in the early fifteenth century, we get more explicit references to furnaces for making cast iron from iron ore, either for further fining or for obtaining cast-iron objects. In AD 1402, two Germans, an *affineur* (finer) and a *fondeur* (smelter) are recorded as working at the ironworks at Précy, Cher, France, which consisted of "*la forge, la fondoère, le martinet, le gros marteau* (the large hammer)" and other things (Arnoux et al. 1991: 38; Arribet-Deroin 2012: 9) and in AD 1414 cannon shot is cast at Jausse-le-Ferons in Namur, Belgium (Awty 2007: 783–784). The ironworks of the monastery of Bèze, Cote d'Or, France are recorded in AD 1427 as an installation *à fondre, affiner et forgier* (smelting, fining and forging) (Arnoux et al. 1991: 38) and in AD 1478/79 iron-masters at Bèze, and at Diénay in the same département, were paid for cast iron cannonballs (Johannsen 1918: 73–74). In AD 1445, thirty cannons were cast at a *Hütte* near Siegen in Nordrhein-Westphalen, Germany for which ore was recorded in the accounts (Beck 1910: 84–85). In AD 1449, three ironworkers from Wallonia, Henry Malherbe, hammer-man from Liège, Pierre the smelter from Franchimont in Liège and Henri the ironworker (*féron*) from Jausse-le-Féron (Namur), settled at Saint-Paul (Le Becquet, Oise, F) after they heard about the iron there (Quignon 1903: 270). The ironworks were built two years later (Awty 1990b: 20).

From the 1480s onwards, blast furnaces were constructed in nearby Normandy (Arnoux et al. 1991), one of which, at Glinet, Seine-Maritime, France has recently been excavated (see below). Other places where we have early references to liquid-iron production in France include Vendeuvre-sur-Barse, Champagne, where in AD 1461 cast iron cannons were made (Johannsen 1912: 372), at Breuillet in Ile-de-France in AD 1468 and Randonnai, Orne in AD 1475 (Arnoux et al. 1991), in AD 1476 at Diedolshausen/Le Bonhomme, Haut-Rhin in the Elsaz region (Johannsen 1918: 71), in the 1490s at Sexey-aux-Forges, Meurthe-et-Moselle in Lorraine (Overbeck 2011: 360) and in Britanny at Missillac, Loire-Atlantique (Vivet 2009b: 205).

Around that same time, blast furnaces appear in Britain, first in the south-east where they were built and run by immigrants from Normandy (Awty 1981). The earliest record of one of these installations dates to AD 1491, when "ye irenefounders" are mentioned at Buxted in Sussex (Awty 2003: 52). These iron-founders were employed on the lands of the Archbishop of Canterbury (Awty and Whittick 2002), but neither the exact nature nor which side took the iniative are recorded. More furnaces were built in the Weald area of Sussex and Kent in the following decades, several of which have been excavated, such as those at Panningridge, Sussex (Crossley 1972), Batsford, Sussex (Bedwin 1980) and Chingley in Kent (Crossley 1975a), but it would take until the second half of the sixteenth century for the first blast furnaces to appear further afield. Between AD 1561 and 1563 one was built at Cannock Chase in Staffordshire, the earliest in the Midlands (Schubert 1957: 179). We have a report on these ironworks, written in AD 1590, detailing the raw products and the processes carried out at both the furnace and the finery forge with its hammer (Jones and Harrison 1978). The earliest recorded blast furnace in northern England was built at Rievaulx Abbey, North Yorkshire around AD 1576/77, while northern Wales saw its first at Nannau/Llanfachreth, Merioneth in AD 1597 (Schubert 1957: 181). By that time, and possibly decades earlier, blast furnaces had been built in Ireland (see Chapter 5.3).

In the meantime, blast furnaces had also spread into eastern, southern and south-western Europe. In the Black Forest in Germany, cannonballs and cast-iron ovens were made at the *Hütte* at Kandern in Baden-Württemberg in AD 1512 (Johannsen 1912: 385), about a year later an ironwork was making both cast and wrought iron near Helsingborg, Skåne, Sweden (Johannsen 1918: 76–77; 1919: 1462) and in AD 1514, at Wiebelskirchen, Saarland, Germany, a contract was made with some smiths to make cast-iron cannons, cannon shot and ovens (Schubert 1938: 55; Johannsen 1912: 385–386). In AD 1517, *Kugelgießern* (cannonball founders) were employed at an *Eisenmühle* (iron-mill) in Marienwerder/Kwidzyn in Pomorskie, Poland (Johannsen 1919: 1462) and in AD 1525 an ironworks was erected for making cannonshot in Schmalkalden in Thuringen, Germany (Johannsen 1912: 392). In AD 1544 a blast furnace with a hammer-works making sheet-metal was active in Neustadt in Mecklenburg-Vorpommern, Germany (Lisch 1842: 56–57). In France, an early blast furnace at Vendeuvre-sur-Barse, Aube is the subject of a poem by Nicholas Bourbon in AD 1517 (Bourbon and Anonymous 1517 [1965]).

10.5.2 Archaeological evidence

In the late 1970s and early 1980s excavations took place at the site of Lapphyttan, Västmanland, Sweden (Magnusson 1986b). The site consisted of a complete iron-production landscape with ore storage and roasting facilities, a blast furnace with its associated water-supply system, finery hearths and an iron depot. The furnace excavated at Lapphyttan consisted of a square stone-built structure of about 4.5m side length with a tap-hole for both the metal and the slag, and a tuyere opening at right angles (ibid.: 25–26) (Fig. 10.6a). The walls were preserved up to 3 metres high where they were 1m thick. The actual smelting hearth was a square area situated under a tapering furnace shaft. The ore-roasting hearth consisted of a stone-lined pit (2.6 by 1.8 by 1m deep) and

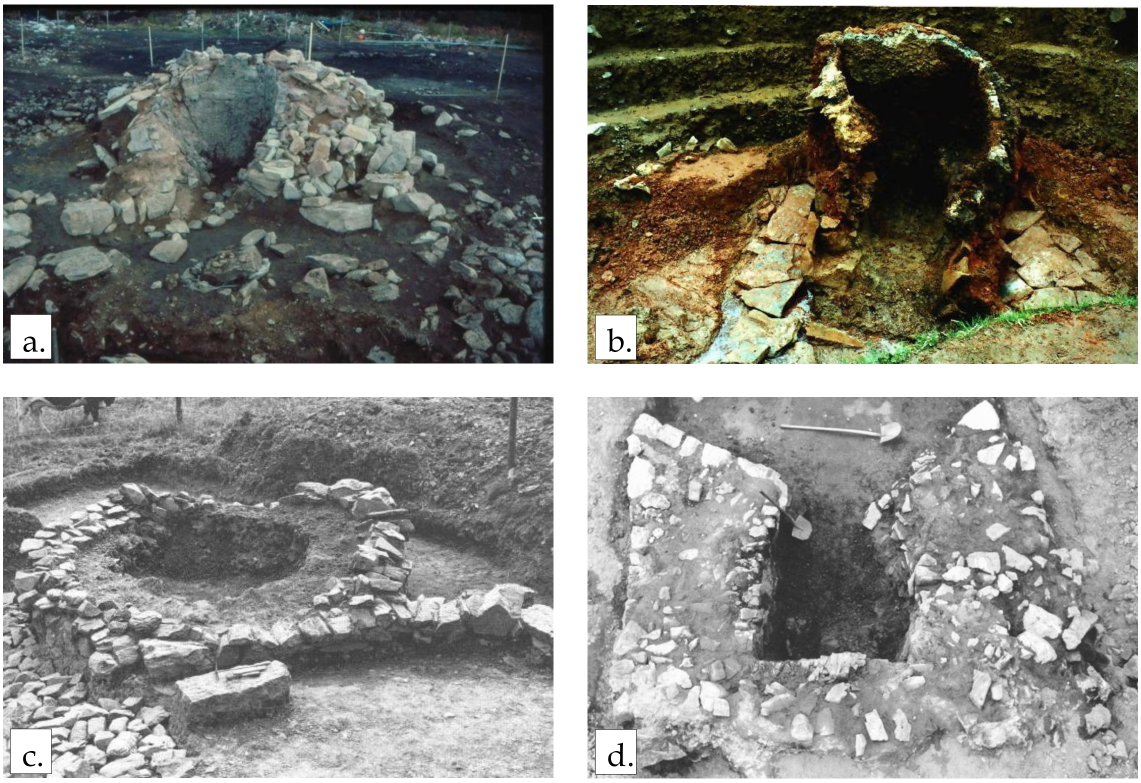


Fig. 10.6 Early European blast furnaces. a. Lapphyttan, Västmanland, Sweden (Online image)[90]. b. Kerspetalsperre, Nordrhein-Westphalen, Germany (Online image)[91], c. Haus Rhade, Kierspe, Nordrhein-Westphalen, Germany (Sönnecken and Knau 1994: 409), d. Jubach, Kierspe, Nordrhein-Westphalen, Germany (ibid.: 406)

still containing a layer of roasted ore (ibid.: 27). Twenty ore storage places were found concentrated in the south of the site. Eight non-water-powered finery hearths, were also found, seven of which were excavated. Five were broadly square structures (0.5–0.6 by 0.4–0.48m), while the remaining two were rectangular (0.85 and 0.9 by 0.4m) (ibid.: 28). All were between 0.2 and 0.25m deep. Around the fineries, numerous finds of “iron shot” were recovered, some of them decarburized (ibid.: 28–29). In a later publication this iron shot is described as droplets measuring between 5 and 40mm across (Björkenstam and Fornander 1986: 199). Analysis of the un-carburized droplets, and a larger piece of cast iron, showed carbon contents between 2.8 and 4.6%, while the carburized droplets had 0.4, 0.83, 1.06 and 1.6% carbon, (ibid.: 211, 213), all of which can be considered as steel.

Some pottery was found on the site, which dated to between AD 1250 and 1300 (Magnusson 1986b: 30). Thermoluminescence dating was carried out on one specimen of clay from immediately below the tuyere-hole, giving a date between AD 1270 to

90 Visible at http://www.nyalapphyttan.se/wp-content/uploads/2011/01/masugnen-630x410.jpg. Accessed 05.10.2012

91 Visible at http://www.uni-muenster.de/UrFruehGeschichte/forschen/maerkischessauerland.html. Accessed 11.04.2013

1390, while the other samples returned later date spreads up to the early sixteenth century (ibid.: 49). Additionally, twenty-six radiocarbon dates were obtained from various features across the site (ibid.30). These gave date ranges from the ninth till the sixteenth centuries (ibid.: 48) and although it was realized that the introduction of the furnace would have been followed by the cutting of a mature forest, meaning that older wood would have been used on the site, the dates between AD 1150/1200 to 1375/1425 were regarded as representative for the production periods (ibid.: 30).

Separate articles by the excavator elaborated on the dating of the site. When the radiocarbon dates were considered in function of their position in the different layers, the samples from the lower strata were concentrated around AD 1150 to 1225, while the ones from the upper layers centred around AD 1325 to 1400 (Magnusson 1986a; 1988: 190). Unfortunately, the fact that the pottery from the site, which was dated to the second half of the thirteenth and the first half of the fourteenth centuries, would fall exactly between these peaks, was not commented upon. The early ranges were subsequently widely adopted in the literature (see for example Tylecote 1992: 76; Buchwald 2008: 240). Also, there is very little phasing visible in the activity at Lapphyttan, which is somewhat inconsistent with a site where ironworking was supposedly carried out during two phases, or continuously, from around AD 1150 till 1400. A similar date, AD 1110–1298, was obtained through radiocarbon analysis of the carbon from a piece of iron at Lapphyttan (Possnert and Wetterholm 1995: 29). Radiocarbon dating on both charcoal and iron from a blast furnace at Moshyttan, Västmanland gave two dates in the tenth century, several in the fourteenth and fifteenth centuries and more in recent periods (ibid., Wetterholm 1996: 165).

Earlier, radiocarbon dates were obtained from Vinarhyttan, also in Västmanland, spanning the period from the eleventh to the sixteenth centuries (Serning 1986). More recently, a different method was carried out to date early Swedish blast furnaces (Bindler et al. 2011). A core sample was taken from a lake near Lapphyttan and four radiocarbon dates were obtained from the sample: two at 0.49m depth (sphagnum and wood), one at 0.59m depth (charcoal) and one at 0.69m depth (bulk peat) (ibid.: 294). The median values where plotted on a graph and the average of the two 0.49m values were connected to the others by a “second-order polynomial function” (a parabola), while a linear model was assumed for the top 0.49m. This was then used as a linear calendar to interpret the pollen analysis, which showed a marked increase in both larger charcoal fragments and, to a lesser extent, of lead at AD 1180. This method clearly has many methodological issues, such as the small dating sample, the use of wood for two of the four dates, the conversion of average radiocarbon dates to absolute calendar dates and the presumption of the undisturbed nature of the organic material sampled. Moreover, the increase in large charcoal particles together with a continued increase in lead, which was already under-way for centuries, does not necessarily indicate the starting up of an iron industry. Although multiple early dates have been retrieved, which might indicate the use of mature timber, a cautious approach will here be adopted in accepting only the late thirteenth- to early fourteenth-century dates as potential starting dates of the Swedish liquid-iron industry. Perhaps significantly, a tract on the Swedish economy, published in AD 1240, while treating the metals industry, especially the silver production, in detail, does not specifically mention iron smelting (Bautier 1963: 37).

A further site, as yet not fully published, was excavated between 1995 and 1998 at Dürstel, Langenbruck, Basel-Land, Switzerland (Tauber and Serneels 1997; Tauber 2011). The blast furnace itself was heavily truncated by later construction work and consisted of a section of rounded stone wall (ibid.: 69–70). This allowed the calculation of the diameter of the original furnace to around 4.5m (ibid.: 70). Although the water-supply infrastructure had been removed, the location of the furnace, wedged between the bank of the stream and a steep slope, indicated the use of water-power (ibid.: 69). Nearby, a finery hearth built of limestone was uncovered. Small (0.1m diameter), bowl-shaped slag pieces were earlier analysed and interpreted as finery slag, but the difficulty in distinguishing them from smithing slag was noted (Guénette-Beck and Serneels 2007: 9). Nearly all the iron found on the site was cast iron (2 to 3% C), with rare finds of wrought iron (Guénette-Beck and Serneels 2007: 8; Tauber 2011: 70). Another furnace excavated on the same site was originally interpreted as a bloomery furnace, but analysis of the slag showed it to have produced cast iron as well. It was tentatively interpreted as an experimental non-water-powered furnace to test the local ore. The 31 radiocarbon dates returned for the site spanned the period between AD 1000 and 1400, which, in consideration of old-wood effect and the artefacts recovered, led to a secure production date in the thirteenth to early fourteenth centuries, with a possible beginning in the late twelfth century.

Four early blast furnaces were excavated in the area between Siegen and Bochum in the south of the German state of Nordrhein-Westphalen. At the Kerspetalsperre, two furnaces were excavated, of which only the inner vitrified hearth-lining was preserved (Fig. 10.6b) (Willms 1997; Abdinghoff and Overbeck 1999). This was the result of the furnaces being built out of clay which had weathered away. The furnaces were originally circular with an outer diameter of about three metres, while their interior measured 1 by 0.5m (Willms 1997: 14). Remnants of water channels and post-holes were interpreted as connected to the water-supply system for powering the bellows. Secure radiocarbon analysis results have dated the oldest of the two furnaces to the last half of the thirteenth century (Willms 1998: 353). At Haus Rhade, Kierspe, was a circular stone building (3.5m external diameter, 2.5m internal) with an earthen platform at the back and a stone platform on one side (Sönnecken and Knau 1994: 407–417) (Fig. 10.6c). The floor sloped down towards a semi-circular opening (0.5m wide, 0.3m high), presumably for the evacuation of both iron and slag (ibid: 408–409). The pottery found on the site was dated to the thirteenth to fifteenth centuries, while radiocarbon analysis returned a calibrated date of AD 1270 to 1400.

In 1992, at the bottom of a drained water reservoir on the Jubach, Kierspe, a further blast furnace was unearthed (Sönnecken and Knau 1994) (Fig. 10.6d). The structure was more or less square (4.5 to 5 wide) with 1.5 to 1.6 m-thick walls leaving an internal area some 1.7m across (ibid.: 442). The front of the furnace consisted of an opening about 0.8m across between the inwardly curving butt ends of the side walls, which tapered inwards. In a nearby smithing area, six heavily disturbed fining hearths were observed (ibid.: 444). In this area a squarish lump of iron was recovered, which contained more than 3% carbon in the form of graphite and showed signs of oxidization (Rehren and Ganzelewski 1996: 176). The latter could have happened accidentally during the smelting, or could point to a two-step fining process: oxidization to convert the graphite/ferrite to cementite/austenite and then further oxidization to wrought iron (ibid.: 176). The associated ceramics found on the site were dated to the fourteenth and fifteenth centuries (Sönnecken and Knau 1994: 445).

Excavations at Site No. 90, Marienheide revealed a rather similar, but smaller squarish stone-built structure (c. 3.5m across) with a straight back wall, convex side walls and a strongly concave front which included the tapping bay (Willms and Jockenhövel 1996; Willms 2003). On three sides, water channels were uncovered which were either stone- or wood-lined. Pottery recovered during the excavation was dated to the fourteenth to fifteenth centuries, with possible earlier, even twelfth-century, examples (ibid.: 217).

Another early blast furnace was recently excavated at Glinet in Normandy, France. The furnace itself consisted originally of a squarish structure with a shorter rear end (c. 5m) and longer front (c. 7m) where both the slag and iron was tapped (Arribet-Deroin 2010b, 2011). Adjacent to the furnace, both the bellows placement and part of the water-supply infrastructure were uncovered. Nearby a finery and a chafery with associated hammer-works were excavated. The ironworks were built in the 1480s, and repairs were carried out until the beginning of the second half of the sixteenth century.

10.6 Comparison between the technologies

10.6.1 Production capacity

We have seen that both types of bloomeries produced one bloom on average per day. The first author to estimate the weight of late medieval blooms seems to have been Thorold Rogers (1866a: 472), who based this on price and weight information of iron (sometimes in the form of blooms) in numerous English contemporary manuscripts. The author considered them to weigh around a hundredweight, that is to say about 45kg, in the fourteenth century. The prices for blooms from one place, Tendale identified as Tindale in Cumberland by Thorold Rogers (ibid.: 469), were considerably less than the other entries (ibid., 1866b: 463–467). The publication of the fourteenth-century accounts of the Tudeley (*Teudele*) ironworks by Guiseppi (1913), which have identical values as the "Tendale" blooms for the same years, indicates that Thorold Rogers had mis-identified the site. These accounts give moneys received for the blooms, but no direct weight information. Salzmann (1913: 31) suggested weights between three-quarters (Tudeley) to two hundredweight (Byrkeknott) for late medieval blooms. In a later work, the same author (1952: 287) offered weight values for a unit of iron known as the piece, at both seven and two pounds. It was this lower value which would be quoted by subsequent authors such as Schubert (1957: 139–140) who then arrived at a weight for the Tudeley blooms of 14.7kg. Tylecote (1965a: 158) suggested 13.6kg for the same blooms.

The Tudeley bloom at 20kg, is the only value from a late medieval non-water-powered works quoted by Tylecote (1986: 211) in a list of bloom weights and in the graphical representation of the same, this is rounded down to 10kg. The same two-pound value for the piece, and its six-fold equivalent the dozen, was used also by Smith (1995: 247, 278) to calculate bloom weights of 9 to 10kg for non-water-powered bloomeries in late fourteenth-century Wales. Williams (2003: 878, 890) using the same information as Tylecote in 1986, supplemented with weights of blooms from archaeological excavations, arrives at an average bloom weight of around 10kg for the Roman period, which then decreases to around 3 to 4kg by c. AD 1000 to 1100 and gradually rises to 10kg by AD 1400 and 80kg by AD 1600. Recently, Arribet-Deroin (2010a: 159), using Salzman's two-pound piece to calculate the Tudeley blooms, arrived at a weight of about 15kg, which was comparable to blooms obtained by experiments and known from ethnographical examples which vary between 5 and 10kg. These low values were criticized by Sprandel (1968: 251), who pointed out that the two-pound piece was half the weight implied by Thorold Rogers' data and hence proposed a weight of 35kg for the Tudeley blooms.

There are more direct references to the weight of blooms from non-water-powered ironworks: a hundredweight (c. 45kg) at Llantrisant in AD 1531 (LPFD 1531–1532: 118–119); the same weight quoted by Dud Dudley (1885 [1665]: 50) as produced in former times with “foot blasts” and the German equivalent of the same weight (*Zentner*) for a bloomery in Saxony in the eighteenth century (Wille and Tronson du Coudray 1786: ix). That blooms of nearly double this weight can be produced in non-water-powered bloomeries is shown by an example from Burkina Fasso, where a bloom of nearly 90kg, made in a furnace with natural draught, is recorded (Verna 2001: 84). It has recently been proposed that the Roman-age domed furnaces from Laxton, Northamptonshire, and by extension other similar furnaces known in Europe from the Iron Age onwards, produced up to 100kg of bloom per operation (Crew et al. 2008), although not necessarily in one piece.

The early fifteenth-century Byrkeknott, Durham accounts describe the blooms produced at these water-powered works as weighing 195 pounds (c. 88kg) (Lapsley 1899: 515). Other blooms produced with water-power weighing around 130kg were made at Rievaulx in North Yorkshire in AD 1541 (Schubert 1957: 396); between 100 and 150kg in Bohemia around the middle of the sixteenth century (Agricola et al. 1912 [1556]: 421) and about 100kg in Middleton, Warwickshire in the 1570s (Smith 1967: 95–96). Water-powered bloomeries in Austria (*Stückofen*) were, by the fifteenth century, capable of producing blooms up to 400kg (Johannsen 1953: 132).

More recent Scandinavian blooms made with water-power were substantially smaller: around 15kg in Norway (Evenstad et al. 1790 [1991]: 39) and 6.7 to 13.5kg in Finland (Buchwald 2008: 69), both at the end of the eighteenth century, and 7 to 8kg in Nornäs, Dalarna, Sweden in 1851 (Busch 1972: 31). It would appear that the values given by Thorold-Rogers for blooms from non-water-powered furnaces in the Weald in the fourteenth century, that is to say about 45kg, can be considered normal bloom weights. Similar, and much higher, weight values are recorded for later blooms from non-water-powered installations. The furnace excavated at Minepit Wood in the Weald, dated to the fourteenth to fifteenth centuries, would then possibly be an example of such a furnace. This shows that the difference between the weights of the products of both technologies was much less than previously accepted. Blooms from water-powered furnaces were between two to three times the weight of those from non-water-powered works. As both represent average daily production values, this conforms well with the condition in the lease for the water-powered bloomery in the French Lorraine district, dated AD 1323, that it should produce at least twice the amount of iron as installations without water. Most of the above figures are for iron that was destined for the commercial market, and it is likely that smaller blooms would have been produced for own or local consumption, as shown by the eighteenth- and nineteenth-century Scandinavian blooms.

Daily production values for sixteenth-century English blast furnaces were summarized by Schubert (1957: 347) and varied between 600 and 1000kg. The blast furnaces operating in the Lahn-Dill area, Hesse, Germany around AD 1600 produced about 1200kg of sow iron a day, which, after fining, amounted to 900kg of wrought iron, or a ratio of 3/4 (Herwig 1951: 351). Conversion ratios recorded for sixteenth-century British works were somewhat higher, that is to say 1/2 to 2/3 (Hammersley 1973: 604), leading to average bar-iron production of around 400 to 600kg per day.

10.6.2 Fuel-to-ore ratios

Fuel-to-ore ratios for bloomery-iron smelting have been calculated as between 1:1 and 1:1.5 (Pleiner 2000: 133; Kronz and Keesmann 2003: 267). Similar ratios specifically for slag-pit furnaces have been estimated at 0.8:1 to 1.2:1 and between 1.1 to 1.3:1 for “slag tapping” (shaft) furnaces (Joosten et al. 1997: 67). This corresponds well with the amounts documented for the (water-powered) bloomery at Middleton, Warwickshire in AD 1571, when 8 loads of fuel were used to smelt 8 loads of ore (1:1) and in AD 1577, when 1220 dozen of charcoal were used for 1408 dozen of iron ore (1.15:1) (Smith 1967: 92, 132). Around AD 1600, in the Lahn-Dill area in Hesse, Germany a similar value of 1.07:1 has been calculated for a water-powered bloomery based on detailed contemporary accounts (Herwig 1951: 351). Experienced experimental iron-smelter Sauder (2011: 3) equally suggests a 1:1 ratio for successful smelts. The fuel/ore ratios for early blast furnaces seem generally lower, but higher variations are recorded. In AD 1546, the blast furnace at Panningridge in Sussex consumed 4.9 loads of charcoal to smelt 5.9 loads of ore (0.83:1), while the furnace at Newbridge, also in Sussex, used 5.5 loads of fuel for 7 loads of ore in the same year (0.78:1) (Crossley 1966: 280). Around AD 1590, the blast furnaces at Hints and Oakamoor, both in Staffordshire, used charges with equal amounts of charcoal and ore (Smith 1967: 134–135).

The calculations for the Lahn-Dill ironworks operating around AD 1600, mentioned above, give a ratio of 0.71:1 (0.84:1 when including fuel for roasting) (Herwig 1951: 351). At the Codnor, Derbyshire blast furnaces in AD 1591, on the other hand, 43.5 dozen of fuel was used to smelt 14.5 dozen of iron ore, that is to say a ratio of 3:1 (Smith 1967: 137). The exceptionally high amount of charcoal recorded as needed for the smelting (and also fining) of the iron led Smith (ibid.: 121) to suggest that the values for the Codnor ironworks may not have been real weekly averages, but based on remaining stock of iron. A high fuel ratio was used at the Glamorgan furnace in AD 1568, where 301 loads of charcoal were used to smelt 200 loads of ore (1.51:1) (Crossley 1975b: 245), but here the products were cast-iron plates which were to be converted into steel, perhaps justifying a higher charcoal input. If the iron was further fined to wrought iron, the fuel consumption was substantially higher than in the direct process.

For the Lahn-Dill area, around AD 1600, just over 48kg of fuel was needed to convert 23.75kg of ore into wrought iron, a ratio of 2.02:1 (Herwig 1951: 351). The total cost per weight-unit of iron in the latter area was only marginally less for the blast furnaces compared to the water-powered bloomeries. In fact, some ironworking plants in the area, for example at Asslar in Hesse, Germany consisted of forges for processing both the products of the bloomery and the blast furnace (ibid.: 353). Highly variable ratios, about 2:1 to 5:1, are implied by the values provided by Hammersley (1973: 604) for charcoal used in both smelting and fining operation.

10.6.3 Iron yields

Iron yields, that is to say the amount of iron produced out of the ore, is obviously heavily dependent on the iron content of that ore, information which can often only be approximately calculated. The Llantrisant, Monmouthshire non-water-powered bloomery, in AD 1531, had an expected iron yield of 35%, but an actual one of around 12.5% (Schubert 1957: 147). This is comparable to the yield of 12% in AD 1540 at the water-powered bloomery at Rievaulx in North Yorkshire (ibid.: 148). In AD 1610, iron ore made into iron, and then steel, by an Irish smith near Toome, Co. Antrim in what was presumably a non-water-powered bloomery, was considered rich as “near the sixth part would be iron” (16.7%) (CSPI 1608–1610: 290). Seventeenth-century bloomeries in Lancashire are reported to have had a yield of 33% (Schubert 1957: 152). Eighteenth-century water-powered bloomeries in Finland had an iron yield of 21% from ore to bloom and 17% from ore to bar iron, which was considered a fine result (Buchwald 2008: 43, 68). Successful experimental bloomery smelts are recorded as having a yield of 60% of an ore containing 58% iron (Sauder and Williams 2002: 123, 127), that is to say a yield of 34.8% of iron vs ore.

Early blast furnaces seem to have had similar yields, with 12% recorded for the ironworks at Newbridge in Sussex in AD 1548/49 (Schubert 1957: 244). Richard Boyle, in AD AD 1616, in an estimate presumably for his ironworks at Cappoquin, Co. Waterford, expected to produce 1 ton of bar iron out of every 4.85 tons of ore and cinders (bloomery slag), or a yield of c. 20.7% (Grosart 1887 vol. 2: 35–38), while his son achieved a yield of not more than 25% at Araglin (Co. Waterford) in AD 1655 (Schubert 1957: 244). Twenty years later, in AD 1675, at William Petty's ironworks near Kenmare in Co. Kerry the yield was 28.6% from ore to bar iron (Barnard 1982: 13). Other late seventeenth- and eighteenth-century blast furnaces are recorded as having, on average, higher yields (27 to 41%) (Tylecote 1965a: 167).

	Non-water-powered bloomeries	Water-powered bloomeries	blast furnace (with fining)
Daily wrought iron production	c. 40–50kg	c. 80–100kg	c. 400–600kg
Fuel-to-ore ratio	c. 1:1	c. 1:1	c. 2:1 to 4:1
Iron yield from ore	c. 12–34%	c. 12–33%	c. 12–25%
Daily ore consumption	c. 200–300kg	c. 400–600kg	c. 2000–3500kg
Daily fuel consumption	c. 200–300kg	c. 400–600kg	c. 5000–10000kg

Table 10.1 Comparison between the different late medieval smelting technologies

10.7 Conclusions

It is important to remember that the above is a critical appraisal of sources based on a very small amount of original material which is often difficult to interpret. Many of the processes mentioned in the historical sources could have been around long before being first convincingly recorded, indeed, the majority of references are based on a single document. The archaeological record on the subject, perhaps except for the early blast furnaces, is very limited, and for many important areas for late medieval iron production, such as Wallonia and the Forest of Dean, is virtually non-existent. In some cases, as with the early Swedish blast furnaces, whole industries went unrecorded until archaeological excavations unearthed the remains.

The internal diameters of most of the shaft furnaces rather consistently measure between 0.3 and 0.5m. The exceptions to this are the site at Genoeserbusch and, possibly, High Bishopley. It would seem likely that furnace hearth-size would imply bloom-size. The only area where we have some information on the weight of the products, the Weald, has blooms of around 45kg (c. 35kg for Tudeley), while the only furnace excavated in that area, at Minepit Wood, has a diameter of c. 0.5m, which is at the higher end of the hearth-sizes. It is unclear, however, if this is representative for furnaces in the Weald. The only excavated water-powered bloomery furnace, at Rockley Smithies, measured 0.6 by 0.7m.

Remarkable is the variety of furnace types used in late medieval Europe. This applies to those furnaces broadly classified as belonging to the shaft variety, including the encased examples from Arnås, the bottle-shaped furnaces from the Dietzhölzetal and the enigmatic furnaces of small dimensions, but producing substantial amounts of frothy slag from Brittany. Next to these we have furnaces consisting of large blocks of stone at Lécussy and Remmet, the likely natural-draught operated slag-pit furnaces at Stanley Grange, the “mound furnaces” from the Swiss Jura, and the later funnel-shaped furnaces of western Sweden. Two furnace types with flat bases, at Allt na Ceardaich and Roly, are possibly not furnaces at all, but might be examples of non-raised finery hearths. Both installations are dated to periods when blast furnaces would have operated nearby.

The large range of furnaces, with different types being used within a limited time period, is not easy to explain. If a wide range of designs resulted in many different products, this is not obvious in the written documents, which generally only distinguish between steel and, with some geographical designations accorded to the latter, that is to say Spanish, Gloucester, Danske. Neither does it seem seem to be the result of adapting to the use of new ore types as the medieval iron industry, in many places, had been preceded by earlier smelting activity. In contrast, the few areas where we have evidence over longer periods show a more consistent technology over time. At Bilsdale, three similar furnaces, all built into the top of a slope, were unearthed, two of which (Hagg End and Stingamires) were dated to the late twelfth/early thirteenth centuries, while another (Kyloe Cow Beck) was dated to the late thirteenth to the fourteenth centuries. A furnace built on level ground (Ewecote) belonged to the late thirteenth/early fifteenth centuries. Other areas where multiple furnaces were excavated, around Lüdenscheid and the Dietzhölzetal, show broadly the same consistency of types, with the former area having two types present.

With regard to the early water-powered bloomery sites, we can say little due to our limited knowledge of the installations in question. At least two distinct smelting installations were being used, the water-powered shaft furnace, both circular and square (respectively at Rožnava/Rockley/Silezia and Bohemia) and the open-hearth furnace (Bohemia/Pyrenees/Ulster and other areas). Striking is also the resemblance of these open-hearth bloomeries to the contemporary fining hearths processing the products of the blast furnace and we have evidence of cases where the same installation was used for both purposes.

The contribution of the monastic orders, especially the Cistercians, to both the development and spread of the use of water-power in medieval European ironworking has been prevalent in the literature for several decades. This seems to go back to Lynn White Jnr's (1940: 156) early proposition that the adoption of water-power in the later Middle Ages was not the result of economic motives, but an altruistic project by the Church to release humanity from the toil of hard labour. The same author's influential *Medieval Technology and Social Change* (1962) does not repeat this hypothesis, but the idea that the Cistercian order was instrumental in the development and spread of water-powered ironworking was taken up by Forbes (1954: 606, 1965: 109–110). Gille (1960: 27) and later Gimpel (1976: 67–68), stated that, in the case of the Cistercians, it was the order's ideal of self-sufficiency which led to a reliance on advanced technology such as water-power, with the former also suggesting it was this order that was responsible for its appliance to medieval ironworking. Other authors have retained the idea of the connection between monasteries and early use of water-powered iron production, but now because these orders were one of the few medieval entities with the necessary capital and organization to finance and utilize this new technology (Karlsson 1986: 346; Tylecote 1992: 76). More recently, the transfer of water-powered iron-smelting technology was seen as facilitated from mother to daughter monastery (Lohrmann 1995:

37; Eschenlohr 2001: 144–147; Hilaire-Pérez and Verna 2006: 561). Early on, Sprandel (1968: 221) had called Gille's idea that the Cistercians had introduced water-power into medieval iron production “highly surprising”. Lucas (2005: 23) has recently pointed to the paucity of evidence for the use of water-powered mills by the monastic orders in England, but still proposes that the Benedictines and Cistercians were more reliant on this technology in connection with iron, based on the secondary sources mentioned above.

The earliest recorded iron mill at Tvååker was already functioning when it was mentioned in the grant to the Cistercians at Sorø, as were the iron mill at Rudniki given to the Cistercians at Andrejov/Jędrzejów and the water-powered hedefitii ferri granted to the Cistercians at San Galgano. The areas of many of the Cistercian monasteries involved in ironworking, such as Rievaulx, Furness and the Clairveaux, do not have evidence for the use of water-powered ironworking until centuries later, except smiths using water-power within the latter abbey's precinct. This reference, often quoted, could refer to a polishing mill, such as is recorded at the Cistercian monastery at Évreux in the early years of the thirteenth century. On the other hand, if it was the smiths' bellows which were operated by water, this could be seen as an uneconomic and probably short-lived aspect of the idealistic first years of the new order. This would also explain the rather odd inclusion in the same text of bakers also using water-power.

Until AD 1202, the *conversi* or lay brothers employed on the Cistercian estates were expected to carry out shoemaking, milling, baking, weaving, leather-working, animal husbandry and stable keeping, and some are recorded as smiths (Noell 2006: 258, 268–269). This, however, is hardly an indication of the use of advanced technology, let alone developing it. Likewise, the metallurgical literature originating from the monastic orders, such as the Benedictine monk Theophilus' *De Diversis Artis* (c. AD 1125) (Dodwell 1986) or the Dominican friar Albertus Magnus' *De Minerabulis et Rebus Metallicus*, and *Semita Recta* attributed to him (both late thirteenth century) (Williams 2012a: 91–93, 106–107), are decidedly alchemical works barely mentioning iron smelting and do not touch upon technical issues such as water-power. Similarly, except for some pre-existing mills donated to Cistercians, as happened at Sorø and Jędrzejów, none of the sites with early liquid-iron production are convincingly connected to monasteries. Only at Langenbruck has a connection been suggested, based on the proximity of the Cistercian monastery of Schöntal, situated two kilometres away (Guénette-Beck and Serneels 2007: 1). Of the four foundations involved, one was

Cistercian in origin (Lucelle), another was a dependency of the prince-bishop of Basel (Moutier-Grandval), Bellelay was a foundation by the provost of the latter, while the fourth (Saint-Ursanne) was a secular foundation (Eschenlohr 2001: 145–146). The technology seems to be fairly homogeneous throughout the possessions of the four monasteries, changes little until water-power is applied to the furnaces and the type of furnaces used is unknown outside of the Swiss Jura. The technology transfer would appear to be limited to a small geographical area and not necessarily related to the monasteries, although these foundations probably did control the industry. As we have seen, the documentary evidence even for this is scarce, however.

Apart from this example, only the Bishop of Durham sends somebody away to investigate far off ironworks. The area mentioned, Blakamore, probably the southern side of the North Yorkshire moors, would be the area around the abbey of Rievaulx. Interestingly, the grant of AD 1260 of the manor of Greater Raisdale, higher up the Bilsdale valley where Rievaulx Abbey is situated, stated that the mineral rights were to be reserved to the donor (Atkinson 1889: 226), suggesting potential rival and secular ironworking in the immediate vicinity of the abbey. In a later period, at Rievaulx, the introduction of the water-powered hammer, the use of water-power for the string-hearth, the adding of a second smelting-hearth and, later on, the introduction of the blast furnace, all take place shortly after the dissolution of this abbey (Schubert 1957: 148, 385). Tylecote (1992: 76), using the argument of financial capability for introducing water-powered ironworks gives the example of Byrkeknott established by the Bishop of Durham in the early fifteenth century, but from the accounts it is clear that inspiration for this ironworks was sought at similar bloomeries further south.

In the late twelfth and early thirteenth centuries, we have seen many areas across western Europe involved in iron smelting (Fig. 10.7). The monastic orders, especially the Cistercians, seem to have been strongly involved in the industry in large parts of France and England, but much less so in Germany. It appears that here, and other areas, secular lords retained their mines and furnaces. This industry was based, according to present evidence, on non-water-powered bloomeries. At the same time, we know of a water-powered bloomery at Tvååker and a shaft furnace producing liquid iron at Metzingen. By the latter half of the thirteenth century, liquid iron was being produced in large clay furnaces with water-powered bellows at the Kerspetalsperre, and in stone-built ones at Lapphyttan and in Dürstel.

In France, except for the polishing mills mentioned above at its eastern and southern borders, we only have the uncertain *getee* at Saint-Evroult in AD 1337 which could point to water-powered iron-working before the advent of the blast furnace. In England, the available sources show water-power being used for bellows only from the very end of the fourteenth century, first around Leeds (Creskeld), very shortly after further north (Byrkeknot, Blakamore) and, by the end of the next century, south around Sheffield (Beauchief Abbey) and possibly in the Birmingham area (Bourne Pool).

Concerning the agents of the spread of technology, we see many examples of ironworkers moving over considerable distances to introduce the technology they know into new territories, such as the Germans making steel at Jausse, the Belgians and Germans setting up blast furnaces in Normandy and then French iron-masters doing the same in southern England. The names Osemund and Osmond in respectively Germany and Sweden for broadly the same product made in similar installations, presumably indicates some transfer of technology, although its direction is as yet unclear. When we do have documentation about how new technologies were introduced, it is secular lords who give far-reaching liberties to ironworkers, such as at Bormio/Semogo at the end of the thirteenth century (Arnoux 2001: 453) and by the *Charte des ferons* at Marche in AD 1345. And it is from the same Bormio region that, two hundred years later, workers will be enticed by the Duke of Ferrara to set up new industries in Tuscany (Baraldi 2001: 81; Hilaire-Pérez and Verna 2006: 561). This would suggest that the ironworkers had formidable bargaining power and some competition between feudal lords is likely to have taken place to either keep or attract the artisans. In some cases, as when the Walloons set up ironworks at Le Becquet in Normandy "after they heard about the iron there" and when the Basque ironworkers rent the works at Léca in the French Pyrenees, it is clearly the ironworkers themselves who take the initiative, knowing that their skills would be both welcomed and lucrative. In other cases, as in the Lorraine area in the fourteenth century, at Briey and Champigneules, it is respectively a merchant and a higher civil servant who are contracted to construct and run water-powered ironworks. They are both local and either had the necessary contacts or their own artisan teams who were able to complete the works. In other cases again, such as Byrkeknott, workmen were brought over from some 80 to 100km away.

The range of skills of the people directly involved in the ironworking is demonstrated by the case of Lambert Symar/Seimar, who was hammer-man at the blast furnace at Newbridge in AD 1511/1512 and later put in charge of the water-powered bloomeries at Rievaulx and Bilsdale, where he was responsible for upgrading the works

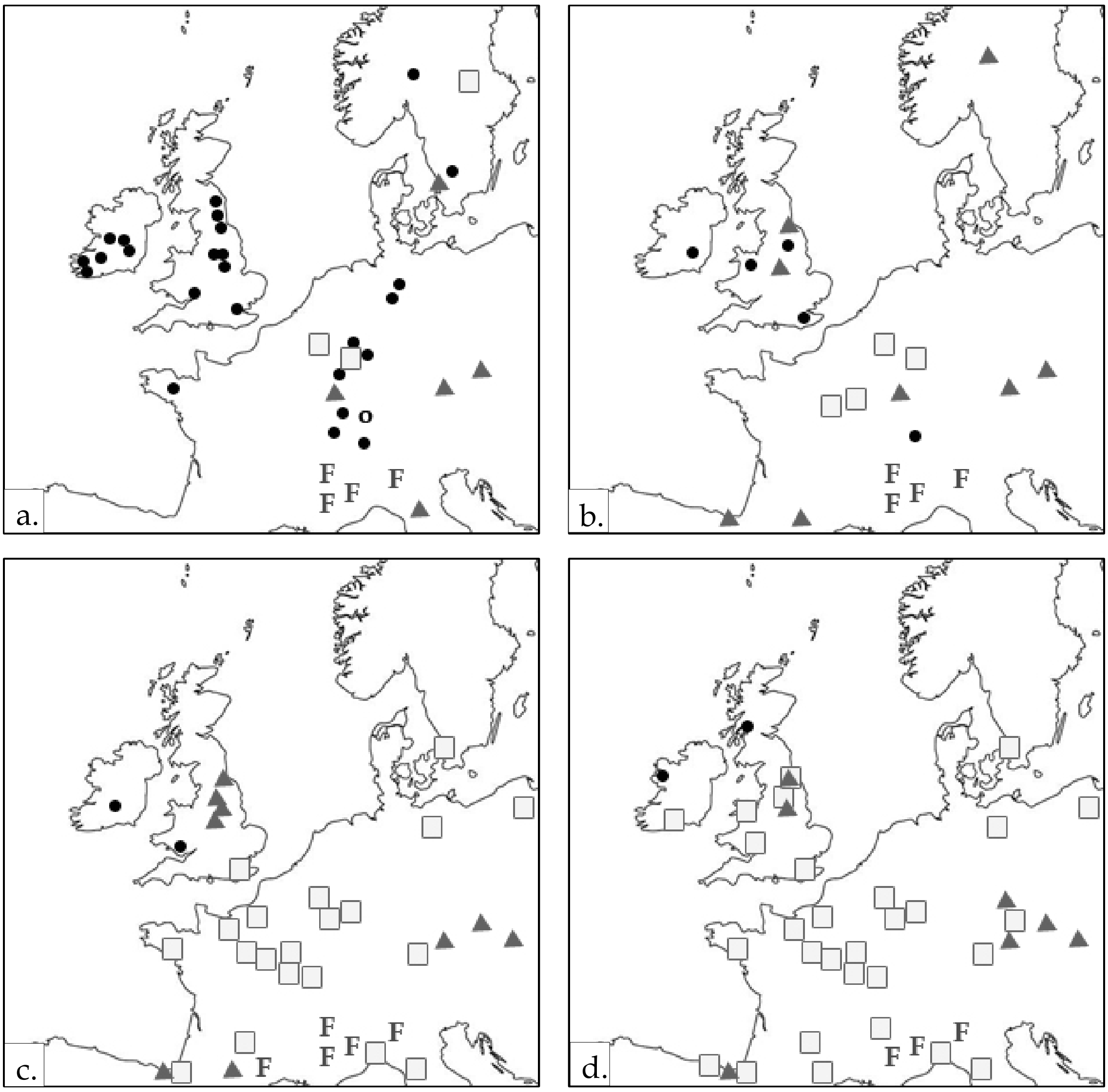


Fig. 10.7 Chronological overview of late medieval western European iron smelting. a. 13th to 14th centuries, b. 14th to 15th centuries, c. 15th to 16th centuries, d. Late 16th century. Key: ● Non-water-powered bloomeries, **o** Non-water-powered furnace producing cast iron, **F** Fusinae[92], ▲ Water-powered bloomeries, □ blast furnaces (sites described above and additional research)

(Schubert 1957: 148, 156, 395–397). Several sites, Genoeserbusch, High Bishopley and Stanley Grange, show evidence of different furnace designs used on thesame site, seemingly adopted within a short period of time, with modified furnaces appearing at the end of the production history of the site. And at Llwyn Du, chemical analysis has convincingly demonstrated that different ore mixtures and blowing regimes were tried out over time. So it would seem that it was first and foremost these smelters and iron-masters who experimented with and perfected new ways of making iron and who developed the new iron technologies of medieval Europe. The powers that were, abbots as well as dukes, were on the receiving end of this practice and, in the case of the more elaborate technologies, undoubtedly footed the bill. But to say that they were

92 A type of water-powered ironworks making liquid iron (Baraldi 2001: 79–81)

responsible for technological changes would do injustice to both the sources and the medieval iron-smelters. In some cases it was the feudal lords who seem to have been instrumental in moving these workmen around, but only by offering high wages, more freedoms or both. In other cases, it was apparently the iron-masters themselves who made the decision to move into new areas, confident in the worth of their knowledge and skills.

The construction of a water-powered installation required a substantial investment and would only have been carried out if a profit was expected. In the case of a water-powered bloomery, a larger production, about two to three times that of a non-water-powered site, seems to have been the outcome. The presence of a market large enough to take in the additional iron, and hence realize a profit, was obviously a prerequisite. Liquid iron appears to have been made into specialized types of iron long before the late medieval period. When water-power was applied to this technology, it became clear that the liquid iron could also be cast into objects and, through fining, converted into wrought iron. These blast furnaces, with their fineries, could produce five times as much as the water-powered bloomery in the same time period, but at a substantially higher charcoal consumption per unit of iron produced and investment cost.

This leaves us with the question of why certain parts of western Europe, notably Britain and most of France, were seemingly so late in adopting water-power to ironworking. There, in the thirteenth and fourteenth centuries, the technology was known and applied extensively to other industries, such as food and cloth processing, but not, as far as we know, to ironworking. A lack of demand could be one explanation, particularly as, early on, mostly specialized types of iron were produced in water-powered installations. Remarkable is also that these are exactly the areas where the monastic orders had such a large stake in the iron industry. Although the orders never fully controlled the industry, and their influence was waning in the fourteenth century, a certain technological conservatism could have played a role. The same mechanism could have been in play in the fifteenth and sixteenth centuries, when these same areas saw the largest expanse of the blast furnace technology. Perhaps significantly, this did not occur until late in the more northerly English counties, as well as the Pyrenees and the Alps, where water-powered bloomeries were flourishing. If this is correct, instead of being an agent for technological innovation and distribution, the Cistercians and other monastic orders could have been one of main obstacles to change in late medieval ironworking practices.

In Ireland, then, there is no evidence for either the monastic orders nor secular lords being involved in large-scale iron production before the sixteenth century. The current information, both archaeological and historical, points to small-scale operations supplying local needs, although larger production units could still await discovery. The dispersed nature of the Irish iron industry at that time might be a result of ubiquity of the ore sources, that is to say bog ores, which would have made centralized control of these ores impractical if not impossible. Regarding smelting technology, late medieval iron smelting furnaces in Ireland broadly compare with the rest of Europe: mostly based on shaft furnaces, with examples of unusual furnace types, but again this is based on a small number of excavated examples. In the sixteenth century, we have indications for the use of water-powered bloomeries and, towards the end of that century, the introduction of the blast furnace in Ireland. The late use of water-power for iron production in Ireland would appear to set it apart from the rest of Europe, but both the nature of the economy, largely based on non-arable agriculture, and the reliance of the coastal towns on imports could provide an explanation for this. The introduction of the blast furnace, on the other hand, is part of a well-documented broader expansion of this industry out of the English Wealden counties.

Chapter 11

Iron smithing in late medieval western Europe

Somewhat surprisingly, although a vast amount of late medieval sites have been excavated in Britain, our knowledge of the nature of smithing in the same period remains limited. In most cases, only varying amounts of smithing slag are recorded, without any traces of the actual working places. This was explained by Astill (1996: 186) as the result of both the limited amount of smithies being present and the re-use of smithing slag leading to mis-interpretation by archaeologists. The author could only report on eleven non-urban sites excavated up till then, the majority being connected to monastic sites (ibid.: 186, 188). Sixteen years later, Williams (2012b: 20) could still only list twenty non-urban sites with *in situ* evidence for blacksmithing for the whole of England. This was regarded as “evidence of absence, rather than absence of evidence”.

A similar situation was noted by Starley (2005: 77) regarding smithing in English medieval castles. In this case, as we possess many written references to smithing on such sites, the lack of archaeological evidence was interpreted as a result of the re-use of slag, ignoring of the evidence or the ironworking possibly taking place at the generally unexcavated peripheries of the castle sites (ibid.: 77, 83). Regarding urban iron smithing, the situation is somewhat similar. A decade and a half ago, ironworking in English medieval cities and towns was still poorly understood and, when there was evidence, it was often surprisingly small scale (Astill 1997: 209–210), or as in the case of London, even after 25 years of extensive excavation, it consisted almost solely of occurrences of slag (Egan 1996: 91). A similar situation was noted for medieval Nottingham (MacCormick 1996: 106–107).

This has led to our knowledge of British late medieval smithing, with the exception of insights gained through analysis of the objects themselves, being based on archaeological assessments of only a handful of sites (Tylecote 1981b; Astill 1996). As we will see, however, our knowledge has increased, especially for the urban centres, since the late 1990s, but has not been summarized. The information on late medieval smithing outside of Britain is even more limited again. Only very recently have publications come to light which provide short overviews of the current knowledge on the archaeology of iron smithing for Germany (Röber 2008) and France (Vivet and Girault 2009), both, however, only treating a handful of sites each. Apart from these, additional detailed information on individual sites was scarce, possibly as a result of different research questions and strategies in the other western European countries.

This chapter will commence with a discussion of the available documentary sources where information on the unit systems used revealed relevant information on the nature of the iron available in Britain. Next, the surviving iconographic sources will be examined and critically appraised. These provide not only information on the types of hearths employed, but also on the working conditions of the smiths. After this, we have an overview of the most important sites where smithing was carried out between c. AD 1200 and 1600. Because of both the amount of information available and its geographic proximity, most of these sites are located in Britain. The discussion of the sites will be presented per site type, that is to say rural, urban, military and monasic. Although the distinction can be unclear, rural here will be seen as incorporating manors and villages, while urban will apply to towns and cities. Monastic sites are those where the ironworking is in direct relation to the abbeys, monasteries, churches, and so forth Included in this are sub-chapters on the relative sizes of smithing hearth cakes on various site types and the results of chemical analysis and metallographical examination of finished objects. The above information will then be compiled to elucidate various organizational and technological aspects of late medieval iron smithing. For the former, this will mean suggesting a model describing the location of the activities and especially the relation of the site types to the activities performed there. The discussion on the technological aspects includes an examination of the buildings in which the smithing takes place, the techniques employed by the late medieval smiths and the reasons behind the appearance of waist-level hearths in western Europe .

11.1 Historical sources

In his seminal work on the prices of commodities and services, Thorold-Rogers (1866a: 470) remarked that in the late thirteenth century, iron objects were imported ready-made into the towns. In the fourteenth century, on the other hand, the iron was mainly bought unwrought and the smith was employed to manufacture the needed goods. From the later fourteenth century onwards, still according to Thorold-Rogers, the iron was bought in finished form off the local smith. Regrettably, this is not elaborated upon or explained. Somewhat confusingly, while there is a marked drop in the accounts of the amount of entries for iron (and steel) purchases in the later stages of the fourteenth century, there are many references to these materials in the later thirteenth century, except perhaps in the first decade under study, that is to say AD 1259 to 1269 (ibid.: 455–470). Equally regrettable is that this information cannot be compared with other analyses, as virtually no historical research into medieval smithing has been carried out to date. References to smiths, including many specialized ones such as blade-smiths and arrow-smiths, were collated by Lloyd (1913: passim). The same publication includes some information on the organizations of the smiths' guilds, both in Britain and other European countries (ibid.: 79–81). Keene (1996) recorded the occurrences of various kinds of metalworkers in medieval London and looked at their location within that city. The blacksmiths, however, were not mapped (ibid.: 97). Similar, but more limited, studies were carried out for Nottingham (MacCormick 1996) and York (Finlayson 2004: 883–887). A detailed study, based on the historical documentation, was also available on the forge of Caen Castle in Normandy (Léon 2007).

Other valuable information the written sources contain for understanding the material aspects of iron in late medieval times are the units used to express its weight. In the documentary sources, two sets of units were regularly used for the weight of iron traded in late medieval Britain, although many other units were used. The first, based on the pound, with its multiples of the hundredweight and the ton and its sub-division of the ounce, is ultimately derived from the weight of a grain of wheat (Prior 1924: 79). Although this was the unit system favoured by the Crown with a view to standardizing the weights in England, several varieties of the pound were in use in medieval Britain (ibid.: 80–81). The other unit system was based on the seem, the piece and the dozen. There were consistently 6 pieces to the dozen (Zupko 1985: 291) and 12 dozen, or 72 pieces, to the seem (Gough and Essex 1783: 106; Smith 1877: lvii; Salzman 1952: 287).

Of particular interest, in this respect, are the accounts of two sixteenth-century water-powered bloomeries. The first, at Rievaulx Abbey in Yorkshire and dated to AD 1541, states that every bloom is equal to 12 pieces, and that one seem contains 72 pieces (Schubert 1957: 396). The other account, for the Farnley ironworks near Leeds in AD 1567 and 1568, records production numbers expressed in bloom, pieces and dozens, at a ratio of 6 pieces per dozen, and two dozen per bloom (Crump 1954: 308). The implication of this is that the piece-dozen-seem system is based on sub-divisions of the blooms themselves. This would also explain the discrepancy Thorold-Rogers (1866a:

471) noted between the prices expressed in pounds and those in pieces as time went by: this was a direct result of the blooms becoming bigger. While the trade of iron in the form of blooms was known (Thorold Rogers 1866b: 463, 465, 467; Hodgkinson 1996: 7), the above would suggest that the majority of the iron traded in thirteenth- and fourteenth-century Britain was in the shape of parts of blooms (Thorold Rogers 1866b: 455–470). The Rievaulx accounts might then also provide a clue as to why the piece disappears from the accounts from the fourteenth century onwards (ibid.; Thorold Rogers 1882: 346–356). Here, the weight unit system, including the piece and based on the bloom, is specifically stated as that operated by the string-hearth smith who then delivers the pieces, and so forth, to the hammersmith (Schubert 1957: 396).

The water-powered ironworks near the Polish-Silezian border, run by Walenty Roździeń in the early seventeenth century, also had final processing of the bloom carried out on site, evidenced by the reference to the small smithy-hearth, which was connected to the water-powered hammer (Różański and Smith 1976: 89). At Byrkeknott, on the other hand, the early fifteenth-century accounts only mention a bloom-hearth and a string-hearth (Lapsley 1899). It is unclear where the iron produced was destined for, but it is unlikely that there was a forge nearby as several of its tools, some from iron made at Byrkeknott, were made at Westauckland, some 10km south-east of the proposed site of its location at Harthope Mill (Lapsley 1899: 518, 529; Tylecote 1960). The ironworks at Byrkeknott, however, are possibly not representative, as they were newly built and the building of a forge for processing the iron might have been delayed pending the outcome of its first year's operation.

In contrast, at the non-water-powered ironworks at Tudeley the iron was sold as blooms and no mention is made of either refining or further forging on site (Hodgkinson and Whittick 1998). Interestingly, an axe for splitting the blooms is regularly mentioned in these accounts, but it is unclear if this was used for cutting the bloom into smaller units or for partially splitting it for quality control (ibid.: 11). If the Rievaulx and Roździeń ironworks are representative for other water-powered bloomeries, then the iron at these installations only left in processed form, after the hammersmith's work. The disappearance of the piece in the British accounts from late fourteenth century can then be seen as a direct result of the introduction of water-powered bloomeries, where the blooms were processed at an adjacent refining hearth. As we have seen (see Chapter 10.3.1), these installations are first recorded in exactly that period.

11.2 Iconographic sources

The late medieval European illuminated manuscripts often contain depictions of smiths and forges. The illustration of Tubalcain in the eleventh- to twelfth-century *Old English Hexateuch* (Fig. 11.1a) is difficult to interpret as no bellows are shown. The stones or bricks could represent either a wall or a floor and it is thus unclear if the smith is standing up or kneeling on the ground. In the latter case this would be a representation of some kind of stone-lined or pitched-tile hearth. In an illustration in *Moralia in Job*, dated to the same period, the smith is clearly sitting on the ground (Fig. 11.1b).

It is interesting that this is a monk working iron (in exchange for goods?) and that the work was produced in a Benedictine monastery at the time when monks of that order, Bernard of Clairveaux being the most famous, would found the Cistercian order on the original principles of Benedict, such as *ora et labora* (pray and work). As such the illumination could represent an ideal to strive for, the monk surviving on the labour of his hands, rather than a depiction of reality. The thirteenth-century Norwegian woodcut showing a smith and a bellows-man (Fig. 11.1c) probably depicts ground-level smithing, as an *Essestein* is visible at the end of the bellows. These soapstone versions of the ceramic tuyere are considered to have been situated on the ground next to the hearth (see Chapter 3.4.3). The next three illuminations (Figs. 11.1d, e and f), all dated to the early fourteenth century, are of raised smithing hearths, with the Holkham Bible example clearly showing the bellows mechanism. Although the latter has two smiths, this is just part of the story which is depicted, and all three installations are worked by only one person.

The first of the next two illustrations (Figs. 11.1g), both from the same fourteenth century *Romance of Alexander*, is often quoted as an example of ground-level smithing (Tylecote 1981b: 14; Geddes 2001: 171). And while it is possible that early smithing hearths with chimneys could have been operated while sitting down, the picture may also attempt to depict how smithing was done in an earlier period or a far-away place, the chimney then being an anachronism in a remembered setting of seated smiths and a bellows-man. Significantly, it is the only example showing a person other than the smith working the bellow-levers, while these would not have been necessary with a hearth at ground level. Another argument for this would be the occurrence of an illustration of a raised hearth being operated by a single smith in the same manuscript (Fig. 11.1h). As the illuminations in this manuscript are seemingly related to the text, a careful study of this text might validate or refute this interpretation. The mid-fourteenth-

Fig. 11.1 Medieval images of smiths. a. Lamech and Tubalcain, England (BL, Cotton MS Claudius B IV f.10), b. Monk blacksmith, France (BmR, ms. 498), c. Smith and bellows man, Hylestad Church, Aust-Agder, Norway (Oslo University Collections), d. Smith, Gorleston, Norfolk (BL, Add. MS 49622 f.193r), e. Smith, London, (BL, Harley MS 6563 f.68v), f. Wife of smith forging nails for the Crucifiction, London (BL, Add. MS 47682 f.31r), g. Smiths, Doornik, West-Vlaanderen, Belgium (Bodl. MS 264 f.84r), h. Smith, same place (ibid. f.165r), i. Forging swords into ploughs, France (Bodl. Douce MS 313 f.5r), j. Blacksmiths, Netherlands (BL, Sloane MS 3983 f.5), k. Smiths, Gondar, Ethiopia, (WAM, Walters MSS W.835 f.72v).

century Franciscan Missal (Fig. 11.1i) is just one example of the near-exclusive occurrence of raised forging hearths being manned by a single smith as depicted in Europe from this time onwards. In the contemporary *Liber Astrologiae* (Fig. 11.1j), a second person is present involved in hammering, but the bellow-levers imply that the hearth is worked by only one smith. A later example from Ethiopia (fig. 11.1k), by contrast, shows again the connection between ground-level smithing and the two people necessary for this work, while giving a rare depiction of the use of a ceramic tuyere.

11.3 Archaeological sources

11.3.1 Rural smithing

All late medieval rural sites with evidence of *in situ* smithing activities were parts of small manorial settlements. The deserted medieval village at Goltho, Lincolnshire was excavated by Beresford (1975). Occupied since Late Saxon times, a building connected with ironworking only appears in the late fourteenth to early fifteenth centuries, towards the end of the occupation of the site (ibid.: 46). The structure consisted of stone-padded postholes and was built in the centre of the settlement. Smithing slag was found in features around the building and paths leading up to it. In its interior, three pits were excavated and pad-stones were uncovered next to each of these pits and were interpreted as supports for chimney hoods. A clay-lined pit in the centre was seen as representing a bosh for cooling instruments. Coal was recovered from the features. The information is difficult to evaluate due to the lack of detail, but it is possible that the site is similar to the one at Towton (see below) and that the pad-stones represent anvil-supports. The pits would then be rubbish pits or boshes.

A metalworking area was unearthed on what was probably the sub-manor of Alsted in Netherne Woods, Surrey (Ketteringham 1976). A thirteenth-century phase revealed two bowl-shaped hearths, the first of which had a thin layer of slag lining the sides, while the other was a saucer-shaped depression with small pieces of iron cinder at its base (ibid.: 17). Both were clay-lined. Shortly after, two more hearths were constructed., one which was lined with a thin layer of slag (ibid.: 18), while the other contained a large lump of slag together with nodules of “blister bronze” and bronze slag. Both coal and charcoal were recovered from this phase. While two of the hearths were potentially connected to smithing, another was clearly used for copper processing. The fourth installation is more difficult to interpret and could either also have been connected to copper-working or represent a small version of a slag-pit furnace. If the interpretation of some of the material from this period as bloomery slag (ibid.: 30) is correct, the latter interpretation is more likely. Before AD 1270, thick layers of charcoal were deposited in the area of the hearths, followed by the construction of a stone-built house which was in use until c. AD 1340 (ibid.: 20–21). A pit, belonging to the phase when the house was in use, was lined with clay and stones and contained broken iron objects, slag and hammerscale (ibid.: 22). A narrow gully containing slag led upwards to an area with much “iron refuse”. A sketch of the installation (ibid.: 30) shows a second hearth at the top of this gully. The function of the pit is unclear, but the occurrence of hammerscale indicates smithing activities. About two tons of ironworking refuse was found, both on a tip in the yard of the house and used for making paths (ibid.: 22). Around the year 1400, after a period without ironworking, an elaborate new building, roughly square in shape, was constructed. The smithing installation was built over, and re-using parts of, both a clay tank and a possible tile kiln (ibid.: 25). It consisted of a rectangular hearth and two stone surfaces. A stone platform behind the hearth showed the remains of a brick chimney and another platform to the right show signs of heavy burning. A stone anvil-base was found on the floor level in front of the hearth.

Excavations at Newington, Oxfordshire, which in medieval times was a manor in the possession of the Archbishop of Canterbury, revealed the remains of two buildings connected with smithing (Williams 2011b). The central area of the earliest, dating to the late twelfth century, could not be excavated (ibid.: 34). The opposing sides of the building, consisting of wall-slots, enclosed an area which consisted of a beaten earthen floor. Smithing hearth cakes, hearth-lining and hammerscale were recovered from features in the immediate vicinity of the structure, but no internal features were encountered. In the thirteenth century, a smaller structure was built immediately to the east of the latter, which went out of use around the same time (ibid.35).

This structure had stone footings on three sides, while one of the long sides consisted of postholes. In the interior, an anvil-setting surrounded by cobbles and yielding hammerscale was revealed. Additionally, two perpendicular hearths and a water bosh are recorded, but no specifics are provided. From the site plan, the bosh seems to measure about a metre in length and slightly less in width, while a presentation on the same excavation (Williams 2011a) shows a pitched-tile hearth. Pieces of hearth-lining are also illustrated in the same presentation, next to a tubular tuyere recovered during earlier excavations on the site from a nearby partially uncovered early thirteenth-to fourteenth-century building.

Rescue excavation at the medieval village of Towton (North Yorkshire) revealed a large building with evidence of ironworking (Fern 2006). The stone walls enclosed an area of just over 10m by 5.8m (ibid.: 9). The pottery associated with it ranged from the twelfth to the late fifteenth centuries. Inside, a large stone footing was uncovered (ibid.: 8). Next to this, a figure-of-eight-shaped hollow was found containing smithing slag and hammerscale. Although the latter contained late fifteenth-century pottery, and did not cut the building floor, it was assumed to post-date the building as the fumes would have made living there unlikely (ibid.: 11, 14). The pit was subsequently dated to the late fifteenth to sixteenth centuries (ibid.: 14). It seems more likely, however, that the stone socket is the base of a raised forge and the pit an associated rubbish pit.

11.3.2 Urban smithing

The British city with the most complete record relating to late medieval smithing is undoubtedly York. Excavations at 41–49 Walmgate, in what was the industrial centre in the south of the medieval city, revealed several phases of late medieval ironworking (Macnab 2003).[93] Earlier metalworking activities were carried out on the same plot and between the late twelfth to early thirteenth centuries a stone-walled building was newly constructed which was devoted to iron-smithing. A poorly preserved pitched-tile hearth was regarded as an ironworking hearth and was located directly next to a pit seen as an anvil-base. A second pitched-tile hearth, inside the same building, was interpreted as a potential second smithing hearth. Metalworking debris recovered from this phase included predominantly smithing slag, two pieces of burnt clay and some indications for copper working. In the next phase, early thirteenth to early fourteenth centuries, a D-shaped stake-and-wattle building was constructed which had a badly damaged large hearth on one side. This was seen as possibly connected to metalworking, but the evidence was tentative. Between the early and mid-fourteenth centuries, several pits were constructed in which iron-smithing waste was dumped, but no structural remains were found within the excavated area.

In the mid- to late fourteenth century, a new building was constructed containing two pitched-tile hearths. Although interpreted as relating to ironworking, the hearths were barely used and ironworking debris was virtually absent. Between the late fourteenth and early fifteenth centuries, a new rectangular stone-walled building was built which had several floor levels containing substantial amounts of smithing debris. No associated features were recovered, but parts of the building were truncated by later activity. During the next phase, in the early fifteenth century, the same building

93 This is a web-based excavation report, so page numbers are not available.

continued in use as an ironworking location, but now a limestone footing was constructed in one of the corners. The backfill of the feature contained slag and vitrified hearth-lining and the structure was seen as the footing for a raised hearth. The robbing cut contained smithing slag and vitrified hearth-lining. Another building had floor-level tile and brick hearths which were seemingly used for copper-working. In the next phase, between the early and late fifteenth century, a pit hearth was uncovered in the latter building also containing copper-working debris. In a different building on the same plot, a brick-built structure was constructed which was interpreted as the base for a raised hearth. Slag around this hearth indicated both copper- and ironworking. Metalworking continued until the mid-sixteenth century, but now concentrated more on non-ferrous metals (copper and lead). Ironworking was still carried out, but no related features could be identified with certainty.

Archaeological investigations at the site at 62–68 Low Petergate, York, which is an extension of Walmgate but closer to the city centre, revealed further evidence for both iron- and copper-working (Reeves 2006). The activity was carried out in workshops located at the back of several tenements and some 66kg of smithing slag was recovered in total (ibid.: 146, 177). The earliest indication of smithing activity consisted of layers dated to the late thirteenth to fourteenth centuries with a high content of metalworking debris excavated in different areas (ibid.: 65, 72). This represented the lowest level of excavation and it was assumed that a building connected to this activity lay below. In at least one case, the material was located inside a building and compressed into the floor at a fourteenth-century date, suggesting *in situ* metalworking inside that structure (ibid.: 78). Further *in situ* remains dated to the fifteenth century were excavated in the south of the site, where two hearths[94] were set in a pitched-tile floor (ibid.: 44). It is unclear if these hearths were located inside a building or not.

In a side-street of Lower Petergate, at St Andrewsgate, more evidence for ironworking was uncovered (Finlayson 2004). Here, several phases of metalworking were identified as taking place between the fourteenth and mid-fifteenth centuries (ibid.: 890). A lot of the ironworking material was residual, presumably from nearby activity, but likely structural evidence was recorded from the phase dating to the late fourteenth to early fifteenth centuries (ibid.: 899–903). Floor surfaces with frequent iron slag and hammerscale were uncovered next to an L-shaped gully. It was unclear if the area was covered due to the limited area excavated. A raised hearth was suggested, based on the lack of hearth-lining fragments, but direct evidence for this was also not present (ibid.:

94 Referred to as furnaces in the report.

901–902; Keys 2004: 912–913).

A smithing hearth was unearthed at Tipping Street, Stafford in Staffordshire in what would have been the centre of the medieval town (Carver 2010). It was located between a cobbled area and a potential post-built building. The hearth was lined with sandstone and contained large quantities of smithing slag and had *in situ* burning, but no hammerscale. An archaeomagnetic date of c. AD 1170 was returned for this feature and a possible construction date of around the mid-twelfth century was proposed.

An excavation was carried out at 80–86 High Street, Perth in Perthshire, in what would have been the interior of the medieval burgh (Moloney and Coleman 1997). In a construction phase dated to the late twelfth to early thirteenth centuries, one of a series of wattle-built booths or stalls with street frontage was equipped with a squarish hearth containing both slag and hammerscale (ibid.: 716–718). This very likely represents small-scale ironworking.

In Godmanchester, Cambridgeshire, two thirteenth-century cob-walled buildings were excavated in what would have been the medieval town (Webster and Cherry 1975: 259–260). One half of one of the buildings had a cobbled floor and what were interpreted as several smelting furnaces. Astill (1996: 186) re-interpreted the building as a forge and the furnaces as likely dug smithing hearths.

Excavations in what would have been the centre of the medieval city at Much Park Street, Coventry in Warwickshire revealed evidence for long-lived metalworking activity in the same area (Wright 1982). The interpretations in the text are often difficult because of the paucity of information of the individual features and the discrepancy between the dating information in the overview table (ibid.: 15) and that in the rest of the article. The dating used below is taken from the data in the text itself. Although the three areas excavated in Much Park Street revealed iron-smithing (and copper-working) residues, *in situ* evidence in the form of hearths was only found at the 122–123 plot. In the earliest phase (early thirteenth century), remains of iron-, copper- and glass-production were found, but a dug feature could only be tentatively interpreted as a hearth (ibid.: 24, 52).

The late thirteenth-century features include what looks like several intercutting metalworking hearths used for both iron- and copper-working (ibid.: 24, 53). Postholes and slot-trenches were unearthed close to these features, but it is unclear if the metalworking activity was carried out inside or outside a structure. In the next phase, dated to the early fourteenth century, further hearths of similar dimensions and associated with both copper- and iron-working were uncovered, while now it seems that these were not located within a wooden building (ibid.: 24, 54). Around the middle of the fourteenth century, the plot was cleared and stone buildings were erected (ibid.: 36–38, 55). There is no indication that these were initially used for metalworking, but by the late fifteenth and into the early sixteenth centuries, stone-built, presumably raised hearths are centrally located within a large stone building (ibid.: 39, 56). Of interest are two tubular tuyere pieces recovered from respectively early and late thirteenth-century context (ibid.: 85). At least one had adhering droplets of copper containing zinc, tin and lead.

While ironworking residues, both from smelting and smithing, have been found on many excavations in and around the centre of Crawley in Sussex (see Chapter 10.1.2), few remains of smithing hearths were found. Only at London Road was a series of *in situ* features encountered, all of which were broadly contemporary and likely dated to the late fourteenth to early fifteenth centuries (Cooke 2001). In total, eight round to oval hearths associated with ironworking were uncovered (ibid.: 154–156). One of the latter was dated by archaeomagnetic dating to AD 1375–1425 AD (2 σ).

Excavations were carried out in an area which would have been situated just inside on of the town gates of the medieval town of New Radnor, Radnorshire (Jones 1998). At the end of the occupation history of this section of the town, in the late fourteenth to fifteenth centuries, part of an earlier building was converted into an ironworking area (ibid.: 144–146). Many pits with iron-smithing residues were uncovered, but no associated installations. Several pieces of large fragments of hearth-lining, however, indicated the use of a raised smithing hearth, presumably located outside of the excavated area (ibid.: 146). The ironworking debris was subjected to specialist analysis (Salter 1998).

Another excavation in a medieval town, at Deansway, Worcester, revealed evidence for rather intensive, long-term metalworking (Dalwood and Edwards 2004). During the first part of the late medieval period, from the late eleventh to mid-thirteenth centuries, two sets of smithing hearths were located in what were presumably two adjoining plots (ibid.: 63, 65). These pit-hearths were not situated within a structure and were surrounded by spreads of slag, mostly from smithing, but included smelting slag. The activity continued during the following period, between the mid-thirteenth to mid-fifteenth centuries, but the evidence was slighter (ibid.: 71). No smithing hearths were found.

In the centre of medieval Bocholt, in Nordrhein-Westphalen, Germany, excavations uncovered evidence of seemingly continuous ironworking from the eleventh to the sixteenth centuries (Röber 2008: 104–105). The best-preserved remains dated to the thirteenth to fourteenth centuries and consisted of a post-built structure with a large internal hearth set in one of the five rooms. Interestingly, on three sides of the hearth the remains of a clay wall were observed, which was heavily heat-affected on one side. Close-by, the setting of an anvil-block was found.

In Trondheim, Sweden, an outlying part of the medieval city was used for metalworking from around AD 1150 to the mid-fourteenth century, yielding about 600kg of slag (McLees 1996: 127). The structures consisted of a series of timber-built cabins with earthen floors. Internally, hearths and anvil-bases were present, some of the former showing evidence for clay hearth-walls. Analysis of part of the material confirmed the activity to consist of smithing, together with the processing of non-ferrous metals (Espelund 1992).

11.3.3 Military smithing

A trench excavated in the Mill Mount area inside the walls of Edinburgh Castle revealed subsequent layers of ironworking remains (Driscoll and Yeoman 1997). The earliest phase, dated between c. AD 1000 and 1325, revealed three hearths interpreted as relating to ironworking (ibid.: 45).[95] No formal remains of building were discernable. In the next phase, dated to between AD 1325 and 1400, a square stone-built raised smithing hearth was constructed (ibid.: 49–50). The hearth had a pit which was interpreted as an anvil-setting at its right-hand front corner and a large rock-cut trough on the left of it. This trough contained many fragments of vitrified lining together with coal-fired smithing waste (ibid.: 166). Next to the trough, but further away from the hearth, was a rectangular wooden box lined with sheet iron set into the ground (ibid.: 53–54). It was interpreted as a possible second trough or a box for the safe-keeping of tools or other valuable materials. Little evidence for a forge building was found, but this could have been the result of the limited extent of the excavations (ibid.: 54–55).

Excavations at Portchester Castle in Hampshire revealed ironworking activity in the western part of the building (Cunliffe and Munby 1985). At the end of the fourteenth century, a hearth, built of limestone blocks set in marl, was constructed against an

95 A fourth one is mentioned (C.1372), but this appears elsewhere in the publication as a posthole (ibid.: 49).

earlier wall (ibid.: 32–33). The hearth was surrounded by a charcoal-rich layer containing lumps of iron and some postholes nearby suggested that is was covered by a timber structure. The ironworking activity was short-lived, the hearth was removed before the floors were put in place, and was seen as connected to intensive building works carried out at that period. Although the information on the installation is scant, this is likely the base of a raised hearth based on the mentioning of its subsequent removal.

The remains of a smithy were uncovered within the walls of the castle of Guildo in Brittany (Vivet and Girault 2009: 56–57). The late fourteenth- to late fifteenth-century stone-walled structure, located immediately inside the gates of the castle, contained the remains of the foundations of a waist-level hearth, an anvil-base and a rubbish pit (ibid.: 57).

11.3.4 Monastic smithing

The large-area excavation of a preceptory belonging to the Knights Templar at South Witham revealed a cluster of stone-walled buildings, one of which was interpreted as a smithy (Mayes 2002). The structure in question contained the base of a waist-level smithing hearth, a likely anvil-block setting and “several hundredweight” of slag were recovered from the floor, together with evidence for coal (ibid.: 37). The activity in this building was considered to have taken place between the early thirteenth and early fourteenth centuries (ibid.: 6).

In the early 1970s, excavations were carried out at the forge building connected to Waltham Abbey in Essex (Huggins and Huggins 1973). This consisted of a stone-built building measuring 15.7 by 10.1m (ibid.: 131). One quarter of the building was relatively devoid of features, while the three others each had a raised hearth surrounded by clay-lined pits, other hollows and layers of hammerscale. One of the hearths was brick-built, while the others were constructed of flint and chalk. The dating of the hearths, however, is unclear (ibid.: 138). The brick in the former hearth were similar to fourteenth century bricks. One of the flint and chalk built hearths could have been contemporary with the construction of the building, estimated at c. AD 1200, based on a similar building method, while the deposits of hammerscale around the hearths contained sixteenth-century pottery. The features around the hearths contained pottery dating between the late twelfth to the sixteenth centuries.

At Bordesley Abbey in Worcestershire, a timber-posted building with several pitched-tile hearths was interpreted as related to water-powered smithing activity (Astill 1993). As argued earlier (see Chapter 10.3.2), the evidence for smithing inside the wooden building is slight, a possible anvil-stone and small amounts of hammerscale, and a more convincing waist-level forge was found 15m removed from the hearths, situated between two parallel stone walls (ibid.: 46). The floor of an elongated building excavated at Tintern Abbey, Monmouthshire was covered by a layer of smithing slag (Courtney 1989: 112–113). The lack of any sign of a hearth and a wooden beam running lengthways across the floor of the structure make it unlikely that this was a building dedicated to ironworking. The chronology was also unclear and could date anywhere between the thirteenth and sixteenth centuries (ibid.: 131). During monitoring of works at Whitby Abbey in North Yorkshire around six kilograms of slag were found and two pieces of tuyere, provisionally dated to the fifteenth to sixteenth centuries (Vince and Steane 2006). The largest of the tuyere pieces (84g) is described as having a straight rim and light, cindery slag attached (ibid.: 8). No copper-working residues were recorded.

11.3.5 Smithing hearth cakes

Only for a limited amount of sites is information available on the maximum and mean weights of late medieval smithing hearth cake assemblages, and they are mostly concentrated on British urban sites (Table 11.1). There does, however, appear to be a difference between these urban sites and the one rural site at Cricklade in the maximum cake weights, the former being mostly well above 1kg, the latter below. The later material from Lavinadière is also substantially lighter than the earlier cakes. Cakes from Iron Age or Roman assemblages with a weight above 1kg are seen as deriving from bloom-smithing activities (Young 2008b), but the same author seemed to suggest a different, but unspecified, reason for the larger late medieval cakes.

11.3.6 Bellows-protectors

The material relating to late medieval British bellows-protectors is near-exclusively described as vitrified hearth-lining. In the case of pit hearths, an upstanding clay hearth wall would have been present, which would have had a blow-hole for inserting the bellows (Young 2012b: 44) (Fig. 11.2), as the ground-level hearths are generally not

Site	Type	Date	Max. weight	Mean weight	Reference
Cricklade, Wiltshire	Rural	11th–15th C	729 g	329 g	(Young 2007a)
Worcester, Deansway	Town	11th–13th C	1490 g	492 g	(McDonnell and Swiss 2004)
Worcester, Deansway	Town	13th–15th C	1800 g	499 g	(ibid.)
York, St Andrewsgate	City	14th–M15th C	1510 g	335 g	(Keys 2004)
Burton Dassett, Warwickshire	Town	14th–15th C	1670 g	550 g	(McDonnell 1992)
New Radnor, Radnorshire	Town	L14th–15th C	c. 1050 g	230 g	(Jones 1998: 185)
Lavinadière, Corrèze, France	Monastery	13th–14th C	c. 1500 g	800 g	(Dieudonné-Glad and Conte 2011)
Lavinadière, Corrèze, France	Monastery	16th C	c. 900 g	400 g	(ibid.)

Table 11.1 Weight information of late medieval European smithing hearth cake assemblages

clay-lined, nor are air-inlets known which are located below ground level. Concerning the raised hearths, it is clear from the contemporary illustrations that the bellows were inserted into the back wall of the hearth with the blow-hole being positioned at the top of the hearth surface. While more recent raised smithing installations do not have concave hearths, the smithing is carried out on a level area, and at least some medieval examples seem to have had hollow hearths, judging by the vitrified hearth-lining recorded in association with them (Edinburgh Castle, 41–49 Walmgate and probably New Radnor). It is unclear how bellows were protected when pitched-tile hearths were used. While the tubular tuyere from Newington is potentially connected to non-ferrous metalworking, and at least one of those from Much Park Street in Coventry certainly is, the finds at Whitby Abbey, and another at St. John Triangle in Cambridge (Newman 2008: 167), might indicate some use of these implements in iron smithing in the fifteenth to sixteenth centuries. Regrettably, no details on the nature of these latter tuyeres was available.

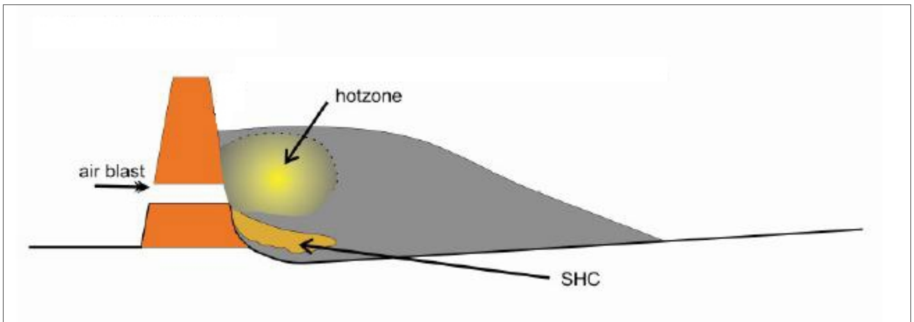


Fig. 11.2 Smithing with a hearth wall (Young 2012b: 44)

11.3.7 Object analysis

One of the largest assemblages of iron knives which was subjected to metallographic examination and chemical analysis was that recovered from several excavations at York, both from late medieval as well as earlier contexts (Starley 2002). This revealed a wide variety of materials and techniques employed. The types of iron used included ferritic and phosphoritic iron, as well as steel, the latter often used for the cutting edges. Interestingly, chemical analysis pointed to a likely different geographical origin for the irons and the steels respectively (ibid.: 2790). In several instances, evidence for tempering in the form of martensite were recorded (Wiemer 2002).

A wide variety of welding techniques was observed among the late medieval material, including pattern- and scarf-welding. Although the sample-size, twenty-one knives, was rather limited, the techniques used, and their relative proportions, did not differ significantly from material studied from earlier Anglo-Scandinavian contexts (Starley 2002: 2790). Ten knives from late medieval contexts in London were also subjected to metallographic examination (Wilthew 1987). Here again, the same types of iron alloys were encountered, which were forged using various welding techniques (ibid.: 62–63).

In London, evidence was also found for the more elaborate welding techniques such as pattern-welding (Cowgill 1987: 16). Fourteen knives from the excavations at Bordesley Abbey (discussed in Chapter 10.3.2) were metallographically examined (Ridge 1993). These showed a relatively high level of sophistication, including piled structures, scarf-welding and frequent use of tempered steel (ibid.: 183). Other tools from the same site, such as an axe, a chisel, a punch and a hammer, were forged using even more elaborate techniques (ibid.: 185).

Heat-treatment (tempering and carburization), the use of steel and different welding techniques were also observed on isolated examples of knives from other rural sites subjected to metallographical examination (Tylecote and Gilmour 1986: 49–50). Similar examination of objects found during the excavation of a fourteenth-century village of Dracy in central France, showed a high proportion of the objects, including knives, to be made of high-phosphorus steel (Piaskowski 1995: 351), perhaps reflecting the use of different types of ores.

11.4 Conclusions

The impression from the above is that while some sites have indeed been ignored, unrecognized or mis-interpreted, the suggested paucity of late medieval ironworking is foremost the result of this activity being concentrated in certain areas for long periods of time. The wide area over which smithing slag is transported, either to discard it or for construction purposes, then leads to many references of this type of material being found on excavations, but relatively little *in situ* evidence. This is aggrevated by smithing activities connected to construction and building repair, which would not have required an easily recognizable smithing hearth, but would have still produced the waste.

Even though the evidence is rather scant, we can suggest a model for how the iron-smithing industry was organized during medieval times. As we have seen previously, there is very little evidence of bloom smithing on the many late medieval smelting sites excavated throughout Europe (see Chapter 10.1.2). Also at the non-water-powered ironworks at Tudeley the blooms were sold unrefined. This implies that if refining of the blooms took place, this happened away from the smelting sites. On the other hand, many urban centres, from small market towns to cities such as York, have yielded large smithing hearth cakes (over 1kg) which, for older assemblages, would be seen as indicating bloom smithing. However, the apparent ubiquity of these large smithing hearth cakes could be the result of the places where the blooms were processed, that is to say the medieval town centres, being most frequently subjected to slag examination. If this was the case, the bloom material, probably consolidated but unpurified, was then transported to the market centres where they were either converted to objects or pieces of merchantable iron. The former, or perhaps both, of these operations would then have resulted in the larger smithing hearth cakes.

There is also convincing evidence that the piece, and its multiples the dozen and the seem, are sub-divisions of blooms as opposed to standardized weight units. This would also indicate that bloom fragments, purified or otherwise, were widely available in thirteenth- and fourteenth-century Britain, when they regularly appear in the accounts. By extension, this model is perhaps also applicable to those areas in western Europe where non-water-powered bloomeries were still in use, but currently the necessary data needed to confirm this is lacking. From the end of the fourteenth century, examples of the piece unit system become scarce in the British accounts, while at the same time we have the first recorded instances of water-powered bloomeries. At the latter, the blooms underwent a first processing at the string-hearth, after which the hammersmith converted it into wrought iron, or possibly objects. From this time onwards, and well into the blast furnace era, these were the types of iron available to the smiths. This also means that the bloom-smithing waste will disappear from the settlement sites, something possibly illustrated by the diminishing sizes of the smithing hearth cakes at the monastery of Lavinadière in Britanny.

One of the most striking evolutions in late medieval ironworking is the introduction of the raised smithing hearth. Judging by the iconographic sources, this not only meant a different working position for the smith, but also that from then on he was essentially working alone. The cost saved by not having to employ a bellows-man could be one reason for the spread of this type of installation. Another explanation could be that this was connected to regulations concerning fire-prevention. After the Great Fire of London of AD 1212 it became illegal to construct buildings with thatched roofs in London (Riley 1860: 86–88). Consequently many buildings were constructed with either ceramic tiles or shingles as a roof. Whereas the smoke produced by domestic fires could escape the house through the walls, rafters and so on (Brown 1841: 146), in settings such as forges, which would have produced much smoke, a chimney, or a hole in the wall at a certain height would have been necessary. Previously, this smoke would have escaped through the thatch. The use of a chimney, or hole in the wall, would then have required some type of hood over the hearth. It is difficult to imagine this could be carried out at ground-level, while a raised hearth would be more practical.

The apparent exception to this in the *Romance of Alexander*, floor-level smithing with a hooded chimney, could in reality represent an anachronistic representation of a poorly remembered past. The hooded-chimney/raised-hearth connection would then explain why at 41–49 Walmgate in York we see floor-level copper-working pit hearths, which would produce less smoke, contemporary with raised iron-smithing hearths. From the early fourteenth century, both the iconographic and archaeological sources show the near-ubiquitous use of waist-level smithing hearths, with the excavated examples either located inside a stone-walled building or the setting being unclear (Fig. 11.3). The only exception is the late twelfth- to early thirteenth-century pitch-tiled hearth located within a stone-walled building at 41–49 Walmgate in York. Significantly, the late remains of a floor-level pit hearth at Crawley were not situated inside a building.

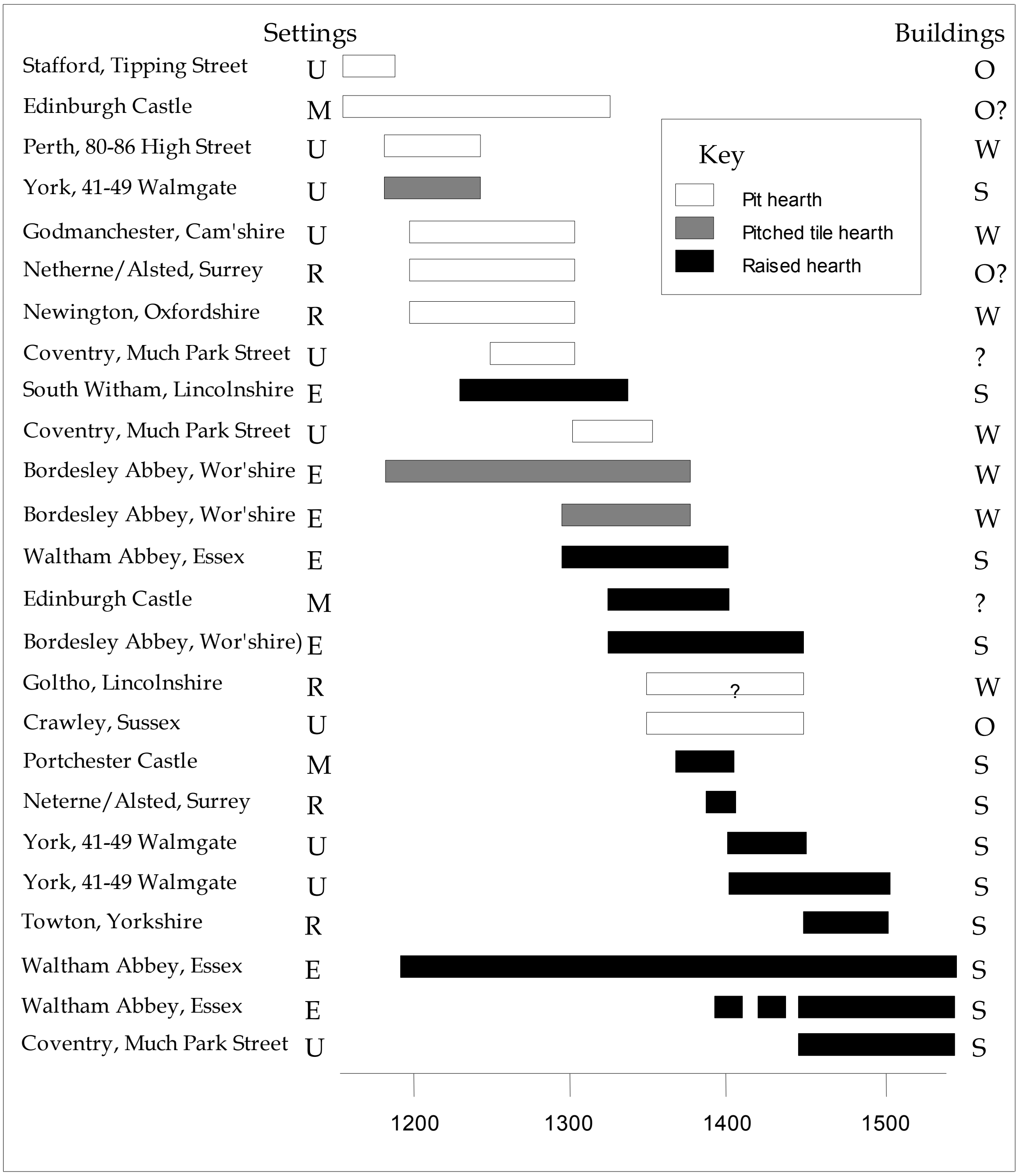


Fig. 11.3 British smithing hearth types, chronology and settings. Settings: U. Urban, M. Military, R. Rural, E. Ecclesiastical/Monastic. Buildings: O. Open air, W: Wood, wattle or cob, S. Stone

There does not appear to be a strong correlation between the types of buildings inside which the ironworking took place and their settings. We have very elaborate smithies at both monastic sites (Waltham Abbey) and on manor sites (Alsted). There are also examples of the same types of sites which have much more modest structures, respectively the re-interpreted remains at Bordesley Abbey and at Goltho. In urban settings, although at several sites the activity spanned several centuries, the structures are rarely elaborate and in some cases dated to the beginning of the late medieval period, the smithing is carried out in the backyards of other structures. In many cases the ironworking is accompanied by evidence for the processing of copper and other non-ferrous metals.Another potential change in late medieval technology, at least in England and as yet poorly documented, is the renewed use of ceramic tuyeres at the end of the research period. Before this time, everywhere in western Europe outside of Ireland, the smith's bellow-ends would have been inserted into a hole in a clay wall which surrounded at least part of the hearth. We have direct evidence for clay walls at Bocholt and Trondheim, while on many British sites, this is evidenced by the frequent finds of vitrified hearth-lining. On two sites in Britain, however, at Whitby Abbey and St. John Triangle in Cambridge, tuyeres were reported, seemingly connected to ironworking and, at least at Whitby, non-tubular. In both cases the tuyeres were retrieved from contexts dated to the fifteenth to sixteenth centuries.

Chemical analysis and metallographical examination of finished iron objects has shown that most of the smithing techniques, introduced by the Scandinavians during the centuries preceding the late medieval period, were still being carried out during that time. This includes several forms of heat-treatment, such as carburization and tempering of steel, but also more complicated techniques such as piling and pattern-welding. Chemical analysis of the objects has also shown the potential for distinguishing the geographically diverse origins of different types of iron, but the current volume of knowledge remains small.

Compared to this evidence, several aspects of smithing in late medieval Ireland differ substantially. Ceramic tuyeres continue to be used in Ireland up until the end of the period, and probably beyond, although their use appears confined to the Irish portion of the population. The are no recorded contemporary comparisons to the Irish smithing plugs. The smithing hearths, as opposed to elsewhere in Europe, are near-exclusively operated at ground-level. There also seems to be more variation in the location of urban smithing in Irish towns compared to their European counterparts, which consistently saw this carried out inside the town walls. Also, in general, non-ferrous metalworking is carried out in different locations, or at least in different hearths, outside of Ireland, whereas Irish smiths appear to have mostly used the same installations to work different metals. There are, potentially, also similarities. As far as we can tell, but this is based on limited information, neither the available types of iron, nor the fabrication techniques in Ireland during the late medieval period differed substantially from elsewhere in Europe.

Chapter 12

Conclusions

12.1 Sources of iron in late medieval Ireland

Iron ores are varied and widespread in Ireland, while some areas have concentrations of certain types of ores. Clusters of iron carbonate occurrences are located around the Counties Kilkenny/Laois border, in the vicinity of Lough Allen in Counties Leitrim and Roscommon, and possibly the hills on the Kerry and Limerick county border. The latter area had extensive mining in the late sixteenth century, while Sliabh an Iarainn (Iron Mountain) next to Lough Allen was known as a placename since early medieval times. Rich oxides, haematite and magnetite, have been mined in more recent times in the Wicklow Mountains, in Antrim (pisolites) and elsewhere, while limonites were the main source for the Earl of Cork's ironworks in Co. Waterford in the early seventeenth century. Bog ores, which we know were smelted in Ireland in late medieval times, both through analyses and written sources, are especially widespread. Although the least-studied of the ore types by geologists, we know of over a hundred occurrences with concentrations in Counties Donegal, Mayo and Westmeath. We have as yet no archaeological evidence for the mining of iron in late medieval Ireland, but the written sources show that this was carried out in many areas in the country in the late sixteenth century. Numerous mines of iron are recorded in the surveys of the newly acquired Desmond lands in west Limerick, iron was produced locally at that time in Co. Cork according to Payne and in Co. Mayo on the lands of Richard an Iarann ("of the Iron") where the evidence points to the mining of rock ore.

Chemical analyses of Irish iron ores show widely varying compositions, even within the same type of ore. The variations in the proportions of elements such as manganese and phosphorus, for example, are such that they can not be used to distinguish one type of ore from another. Only high levels of calcium would seem to be typical of bog ores. This type of ore was demonstrated to have been used at Ballykilmore, Co. Westmeath [7] through chemical analysis. This site, and others nearby, are the only ones which are near known ore sources of a single type (Fig. 12.1).

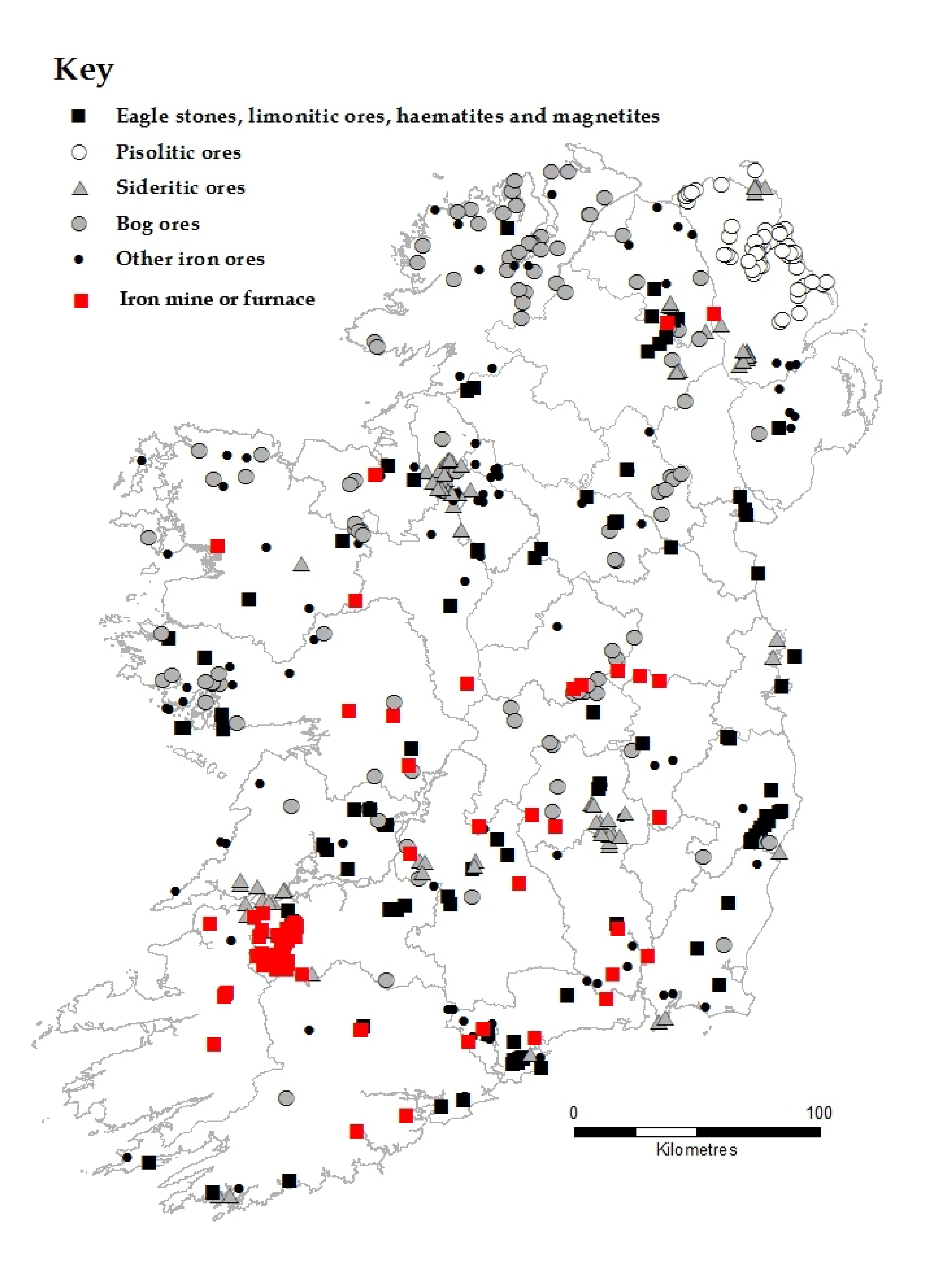


Fig. 12.1 Map of late medieval Irish iron mining or smelting sites and iron ores

At present, we know very little for certain about the relationship between the composition of an ore used in smelting and its product. A high level of manganese in the charge, however, is now recognized as resulting in a high-carbon iron, that is to say steel. This will also lead to a high manganese content of the smelting slag, as was recognized at late medieval sites at Borris, Co. Tipperary [13] and possibly at Johnstown, Co. Meath [73] and Ballyonan. Co. Kildare [9]. While most bog ores for which we have chemical analysis results have rather moderate manganese contents, manganese-rich concretions are also known to exist in boggy environments, like the specimen analysed from Ballyvourney, Co. Cork. At Kinnegad, Co. Westmeath, likely early medieval smelting slag had inclusions of material with exceptionally high manganese, and rather low iron content. It would appear possible that, at least in some cases, it was not high-manganese iron ores which were smelted to obtain steel, but low-manganese iron ores together with this manganese-rich material.

Steel is often mentioned in the murage and other grants awarded to Irish towns and was regularly observed in the Irish late medieval knives metallographically examined. We are also informed on the production of steel through the written record, referring to it being made in Co. Mayo in the 1580s and in Ulster in the early seventeenth century. But not all steel used in Ireland in late medieval times was made there. At least from the fourteenth century onwards it is mentioned as imported from Spain and by the sixteenth century from England, and possibly from further afield. Another type of iron, called Spanish iron in the sources but archaeologically still poorly understood, was imported into Ireland from northern Spain from the early fourteenth century onwards. It appears that Spanish iron was especially suitable for welding, and large quantities of it were used in construction work and for the fabrication of larger, composite iron objects. A final type of iron in use in late medieval Ireland was phosphoritic iron, known through metallographic examination of iron objects. The details about its mode of production are as yet not fully understood, nor does it appear to have been mentioned in the written sources.

Iron appears to have been readily available in most parts of the country throughout the late medieval period, evidenced by its frequent occurrence in the town grants and on the many excavations. Some of these, for example at Woodlands West, Co. Kildare [129], where both smelting and smithing activities were carried out, demonstrate that some communities were potentially self-sufficient in iron supply. This would also appear to have been the situation in Co. Derry, as is historically documented in the early seventeenth century, and at Burrishoole, Co. Mayo a half a century earlier. At the very beginning of the sixteenth century, the author of the *Red Book of Kildare* went so far as to claim that the Irish needed no iron as they made all they needed themselves. There is even some evidence that iron was exported from Ireland early on during the late medieval period. In other cases, such as the on the Bigod manor of Old Ross in the south-east of Ireland, locally produced iron appears to have supplemented the iron purchased from other sources. In some places, however, as in the 1270s at the coastal towns of Drogheda and Youghal, the explicit reference that no taxes were to be levied on iron could indicate a scarcity of this metal, but other explanations are plausible. From the late fourteenth century onwards, several ordnances were enacted aimed at curtailing the trade between the Pale and some of the coastal towns, on the one hand, and the Irish enemy, on the other. Iron was obviously regarded as a strategic material and often specifically included in these acts. It is unclear, however, if this was strictly followed, and if this would have restricted access to iron for the Irish. Apart from iron made themselves, it was regularly acquired through raids and theft, and, for more enterprising individuals, through piracy.

12.2 Late medieval iron-production technology in Ireland

12.2.1 Iron smelting

With the exception of the unusual furnace at Ballydowny, Co. Kerry [5], all the securely identified and dated late medieval iron-smelting furnaces in Ireland are of the shaft furnace variety. The slag-pit furnace, so abundant in the Iron Age and in early medieval times appears to have gone out of use from the Hiberno-Scandinavian period onwards and we have no securely dated examples of this type after that time. Because of their nature, having a pit under the furnace as a receptacle, these slag-pit furnaces would be expected to appear more prominently in the archaeological record, so the lack of them dated to after the Anglo-Norman invasion is a strong indication of their overall scarcity. The situation in areas which have seen little research, for example the northern half of the island, could be different. The Ballydowny [5] furnace is exceptional; a large oval hearth inside which a lump of slag weighing 20kg was found. It is tentatively interpreted as a domed furnace, which would make it unique in late medieval Europe, while the large slag lump would be a-typical for the earlier furnaces of this type.

As the shaft furnace for smelting iron was in use in Ireland before the Anglo-Norman invasion and would have been the norm in Britain and beyond in the thirteenth and fourteenth centuries, it is not possible to conclude if individual furnaces represented imported technology, or not. The dates of known examples, at Dooneen, Co. Kerry [45], Rathglass, Co. Galway [113] and Borris, Co. Tipperary [13] show that this type was in use throughout the late medieval period. The furnaces at Borris [13], seemingly used to produce steely blooms, had unusually deep tapping-pits in front of the furnaces.

The variety identified as potentially having a raised hearth, that is to say shaft furnaces from which the slag showed signs of having flowed over large pieces of wood, is only convincingly recorded at Woodstown, Co. Waterford and Derrinsallagh, Co. Laois [44] and there are about four to five centuries between the dates of these two sites. Although this latter type of furnace is unknown in the rest of western Europe at this time, many unusual furnace types are in use outside of Ireland in late medieval times. This includes the Quiquerez furnaces of the Swiss Jura, the large slag-pit furnaces at Stanley Grange in Derbyshire and the narrow furnaces producing frothy slag found in Britanny. In common with Britain, the internal hearth diameter of the furnaces tended to increase with time, but the later Irish examples were not located within buildings as were the two main British examples at Minepit Wood, Sussex and Llwyn Du, Merionethshire.

Based on a study of air supply in many non-European bloomeries, it appears that the lack of ceramic tuyeres at furnace sites implies either that the smelting took place using natural draught, or that iron tuyeres were employed. While we have evidence for the use of iron tuyeres from the accounts at the non-water-powered bloomery at Tudeley in Kent, it is unclear if this was generally the case, although the use of single tuyeres, and hence bellows, is often implied. The size of the blooms produced in non-water-powered bloomeries can be calculated to around 30 to 50kg based on a variety of fairly consistent historical sources, which is at least double the figure usually proposed. These lower values were often influenced by the results of experimental smelting operations. If the hearth-sizes of furnaces are an indication of the size of products made, then the Irish furnaces would have produced blooms of similar weights and would have required charges of about 200 to 300kg of both ore and fuel.

The only weight information we have for Ireland is the *pec* of locally made iron, sent from Burrishoole (Co. Mayo) in 1580 and weighing around 20kg. It is unclear, however, if this relates to a full bloom or part of one. The only indication we have of ore-to-iron ratios is the statement made at Toome in Ulster in AD 1609, when a local bloomer produced iron amounting to a sixth part of the ore. The end result at Toome, however, after an hour's work, was steel, so it is uncertain if the bloom would have necessarily been so large. It is unclear if the two results we have from charcoal analysis from smelting contexts, both consisting predominantly of oak, are representative of other sites.

From the second half of the sixteenth century, we have two intriguing, but vague, references to the use of water-powered bloomeries by the Old English in Munster. The first, a reference to Spanish ironworkers operating in that province in the mid-1560s, if correctly interpreted, probably does not refer to either blast furnaces or non-water-powered installations. The other reference, the name Forgepool recorded during the survey in the late 1580s after the Desmond rebellion, could also indicate water-powered, but solid, iron production. We know from documentary sources outside of Ireland that water-driven bloomeries had a daily production capacity of a bloom roughly twice the size of those from the non-water powered version. This amounted to about 80 to 100kg of iron per day.

The same period saw the first sources mentioning blast furnaces in Ireland, all of which, with the possible exception of Athenry in Co. Galway, refer to a relatively small area in Co. Cork and Co. Waterford. Compared to the bloomeries, these installations not only produced around five times the amount of iron per day, they also consumed between two and four times the amount of fuel per unit of wrought iron. This means that whereas the bloomeries needed between about 250 and 500kg of charcoal a day, depending on if they were water-powered or not, blast furnaces would have required some 5000 to 10000kg of fuel per day, which included that needed by the finery to decarburize the cast-iron sows into wrought iron.

Our knowledge of late medieval iron smelting in Ireland is still too limited to draw far-reaching conclusions about overall production. We do see the furnace hearths getting larger towards the end of the period, but it unclear if this had an effect on the wider production capacity; there might just have been less furnaces. If we look at the economic reality of the thirteenth and fourteenth centuries, compared to the fifteenth and sixteenth, it is difficult to judge when more iron would have been needed. In the first two centuries, agricultural activities such as land clearance and especially ploughing would have required substantial amounts of iron and steel. The two latter centuries, while less concentrated on arable agriculture, saw potentially more iron-consuming building activity such as tower houses and in the stone houses of the growing towns. For these construction activities, however, imported Spanish iron would have been more suitable. Weaponry, previously mainly brought over from England when the occasion arose, could in this later period constitute a substantial pool of locally made iron and steel. If proven correct, the use of water-powered bloomeries could have been either a symptom of the enhanced centralization of the industry or indicate a growing demand for iron in Munster in the late sixteenth century. The blast furnaces introduced into large parts of Ireland in the same period can be seen as an extension of the movement of these installations, out of the Weald in the south-east of England. But the large amount of cheap wood available on newly confiscated lands was undoubtedly an important factor in the construction of these high-investment blast furnaces, even when the political situation was far from secure. It is only after the turn of the seventeenth century, however, when the Irish and Old English political elite are incapacitated or incorporated within the new order, that liquid-iron production becomes a feature of the landscape in many parts of Ireland.

12.2.2 Iron smithing

We now know that the two main products of smithing are bun-shaped lumps of slag, termed smithing hearth cakes, and hammerscale. Globular hammerscale particles are currently recognized as resulting from forge-welding and as such appear regularly in examined assemblages, while the cakes come in a wide variety of shapes, densities, and so forth. Metallographical examinations and chemical analyses of finished iron objects have provided evidence for a large number of techniques, often with different ones applied to the same object. An important handicap in discussing smithing technology is that we still poorly understand the connection between the different types, forms and other properties of the smithing hearth cakes and these forging techniques. Some early steps to fill this gap in our knowledge, however, have been taken. Exemplary is the research undertaken at the Swiss early medieval site at Develier-Courtételle, but similar research is necessary before we can extrapolate the results confidently to Ireland.

One area where great advances have recently been made, however, is in distinguishing smithing hearth cakes resulting from primary, or bloom, smithing and secondary smithing. On several sites, including the late medieval Irish one at Ballykilmore, Co. Westmeath [7], chemical analysis has demonstrated that large smithing hearth cakes are related to bloom refining. This is based on the fact that the slag incorporated inside the bloom, which will make up the bulk of the refining slags is, in essence, smelting slag. This results in bloom-refining slag having a different chemical composition than that of slag produced during forging. However, at Ballykilmore [7], as at Develier-Courtételle, smaller cakes were also shown to occasionally result from bloom smithing. The Irish bloom-smithing cakes are, on average, very large, that is to say weighing more than 2kg. In Britain, the only place in Europe where comparable information is available, Iron Age and Roman assemblages with smithing hearth cakes larger than 1kg are generally seen as indicating bloom smithing. The origin of similar British assemblages from the late medieval period, however, were questioned because of their seeming ubiquity. The majority of these British studies were carried out on material from late medieval market towns, which is also the type of site where a large part of the Irish bloom-smithing assemblages are found. Because of this, and the fact that no other sites have been recognized as the location for British late medieval bloom smithing, it is here suggested that the market centres filled this role, both in Britain, Ireland and possibly beyond.

One possible reason for the difference in size between the cakes resulting from bloom smithing from Britain and Ireland can be seen as the result of the use of ceramic tuyeres in the latter country. At Ballykilmore [7], for example, tuyeres with frontal diameters of over 0.2m were found in direct association with slag cakes weighing up to 4kg. On other sites, however, such as at Claregalway, Co. Galway [28] and Woodlands West, Co. Kildare [129], smithing hearth cakes weighing over 3.5kg were found, but no tuyeres. The explanation might lie in an Irish smelting technology resulting in a higher slag content in the bloom. Furthermore, there also appears to be a strong connection between the use of stone anvils and bloom smithing.

Apart from vague references to the use of ceramic tuyeres on two fifteenth- to sixteenth-century English sites, this type of artefact is only known to have been used in Ireland in late medieval times. Elsewhere, the wooden ends of the bellows were protected by inserting them into a hole made through a clay wall which surrounded, fully or partially, the smithing hearth. This led to the formation of vitrified hearth lining which is, however, notoriously difficult to recognize with confidence. Only when large pieces showing a concave shape are present can vitrified lining be identified with certainty. Interestingly, one of the best-preserved Irish sites excavated to date, the post-and-slot-built smithy located inside a stone structure at Aghmanister, Co. Cork [1], showed evidence of both a hearth wall and copious amounts of tuyere material, but no hearth lining. Due to the fragmentary nature of their preservation, with only parts of the vitrified fronts of the tuyere found, the overall shape of the Irish tuyeres is currently still unknown. These tuyere-fronts are mostly, but not always, circular and at Ballykilmore, Co. Westmeath [7] the large bloom-smithing tuyeres had clay footings as supports. Although the tuyeres with frontal diameters over 0.2m are often associated with bloom-smithing remains, at Ballykeoghan, Co. Kilkenny [6] large tuyeres were recovered from an assemblage solely consisting of remains of secondary smithing. Of particular interest, although their function is not as yet understood, are the so-called smithing plugs. This new artefact type for Ireland was previously recorded from the Viking-Age site of Haithabu on the German-Danish border and consists of heavily heat-affected elongated pieces of ceramic material, teardrop shaped in section. with a mushroom-cap terminus at one side. These smithing plugs were found at Cork, Tuckey Street [39] and on the manor site of Dysart, Co. Kilkenny [60]. It is tentatively suggested that these plugs were used to preserve a teardrop-shaped hollow on iron artefacts, as yet unidentified.

Another major difference between Irish and non-Irish iron smithing in late medieval times is the types of hearths used. Whereas elsewhere, from the early fourteenth century onwards, smithing hearths tended to be of the waist-high variety, smithing in Ireland mainly took place in floor-level hearths, and this until the sixteenth century and beyond. It is suggested that the use of waist-level hearths is a direct consequence of the smithing taking place in buildings with non-thatched roofs. Whereas thatched roofs would allow the fumes generated during forging to escape, tiled and shingled roofs, or an additional floor within a stone building, would necessitate the use of hooded chimneys above the hearths. The hearths, then becoming impractical at ground-level below a chimney, would be raised to waist-level. Significantly, there is a very close correlation between excavated waist-high hearths and their location within a stone building. This also applies to the few possible examples of raised smithing hearths from Ireland.

The best examples of Irish late medieval forges, that is to say buildings wherein smithing activities took place, are isolated, circular, mud-walled structures. These have no internal structural elements such as postholes and are often only recognized through the survival of shallow gullies curving around areas of intensive smithing activity. It is proposed that similar areas with evidence for long-term smithing activity also represent mud-walled forges, but then without gullies. It might even be possible that the several urban sites with intensive smithing activity, but no related structural evidence, could also have been located within mud-walled buildings. The clay floors associated with one of these sites, at Trim, High Street, Co. Meath [122], could suggest this was indeed the case. The use of this type of building can possibly be explained as a reaction to fire hazards. The only flammable material in these building would have been the organic roof, which, if built high enough, was unlikely to catch fire as a result of smithing. Perhaps significantly, the only late medieval forge with internal postholes in Ireland, at Aghmanister, Co. Cork [1], is the only one with evidence of having burnt down.

Although little analytical data is available, we have a good idea of the forging techniques applied in late medieval Ireland. Different alloys of iron were regularly combined through various welding techniques to manufacture objects composed of parts with different properties. Knives, one of best-studied object categories, could be made wholly out of steel but mostly this more expensive material was reserved for the cutting edges. The properties of this steel were then enhanced through heat-treatments such as tempering, while low-carbon iron was sometimes further hardened through carburization. Some sophisticated techniques, such as pattern-welding and piling, introduced earlier by Scandinavian craftsmen, were still employed in late medieval times. In some cases, phosphoritic iron was also incorporated into objects. While this type of iron was more brittle, its corrosion resistance and hardness would have made it a suitable type of iron for certain objects.

Finally, although charcoal appears to have been the main fuel type used in late medieval times, we know that mineral coal was employed from at least the thirteenth century onwards in Britain and further afield. Up to now, no archaeological evidence for the use of coal had been reported for late medieval Ireland, in ironworking or otherwise, although it is recorded as imported from Britain from the fourteenth century onwards. Several sites, some as early as the thirteenth century, have now been identified where coal was used in smithing activities. The high proportion of slag which had embedded coal fragments and was dated to the thirteenth to fourteenth century at the inland town of Kilkenny could indicate a local source for this fuel type.

12.3 Ironworking and late medieval Irish society

12.3.1 Ethnicity and late medieval ironworking

Assigning labels of ethnicity to people, including those involved in ironworking mentioned in historical sources, is fraught with difficulties. During the late medieval period occupational surnames evolve into patronyms and judging if somebody was indeed an ironworker can be difficult. In many cases, only the first name of the person involved is recorded, and frequent examples are known of Irish people adopting or being given English names. The ethnicity of whole populations of fifteenth- and sixteenth-century Ireland, including the nobility whose lives are recorded in detail, is still a contentious issue for modern-day historians of Ireland. Somebody's ethnicity was also liable to change during their lifetime, as is clearly illustrated in the case of Maurice Segyn or Sogyn. This Irish-born smith received English citizenship at a young age when he settled in Dublin, only to become one of the founding members of the Smiths' Guild of that city, the charter of which included the stipulation that no Irish could join. The question of ethnicity in late medieval Ireland is further complicated by the frequent references to smiths of other nationalities being active in Ireland, both during the initial colonization phase in the thirteenth century, as well as in the sixteenth century, when Ireland once again became part of a wider international economy. At the same time, people from Ireland travelled to Bristol to earn their apprenticeships as smiths.

What we do know from the written sources is that at an early stage of the colonization, many Irish were employed on the Anglo-Norman manors, some as smiths. Many others, presumably English judging by their names, were working both on these manors and in the urban centres. Some were specialized smiths, such as armourers, locksmiths and arrowsmiths. Late medieval Irish smiths could sometimes attain a relatively high social standing. We have five recorded instances of female smiths, all active during the fifteenth century. Noteably, three of these were armourers, or an apprentice of the same, working in Dublin.

Many of the large towns had a dual nature, an Irish and an Anglo-Norman part and sometimes, as in the case of Kilkenny, with each part having its own corporation. Additionally, some of the coastal urban centres also had areas occupied by the Scandinavian populations, such as Oxmantown in Dublin, who had been moved from the town centres after the Anglo-Norman take-over. Overall, the cities and especially Dublin, appear to have been highly cosmopolitan with the Irish being ever-present, if not always with full citizenship rights. Other areas, such as the north-west of the island, are unlikely to have been deeply affected by outside influences, but we are very poorly informed about smiths in the Gaelic parts of late medieval Ireland, with limited archaeological excavations and silence from both the Anglo-Norman and the Gaelic Irish written sources.

As discussed above, it is impossible to deduce from the furnace types in use in late medieval Ireland if they represent a continuation of a previous indigenous technology, an imported technology or an evolved type of either. The shaft furnaces are too similar in both cases, the Ballydowny [5] furnace is as yet unique, and the furnaces with raised hearths are too few in number and chronologically removed. The locations where hearths were found also give few clues as to the identity of their users. Nearly all of the thirteenth- to fourteenth-century examples are close to manor centres, which could imply imported technology. All of these manors, however, are located in the west of the country, heightening the likelihood of the presence of Irish tenants, perhaps smelters. An exception to this is the fourteenth century site at Ballykilmore, Co. Westmeath [7], where iron was smelted and the blooms processed using large ceramic tuyeres, and this next to a recently demolished church. There might be a possibility, but no proof, that the end products manufactured here could have been weaponry, rather than for agricultural use. The later, fifteenth to sixteenth centuries, furnaces were operated within the ethnically contentious world of the Old English and include the only examples known for the production of natural steel.

It is perhaps surprising then, in the light of the above, that we do appear to have an artefact, the ceramic tuyere, which can be seen as a cultural marker for late medieval Irish smithing assemblages. Tuyeres were absent from all four late twelfth- to thirteenth-century isolated rural forges, discussed in more detail below, while they were present on the three sites of the same type, dated to the fourteenth century and later. At both Anglo-Norman farms where the material was examined, at Cookstown [30] and Trevet [120], both in Co. Meath, no tuyeres were found. Of the larger urban sites Kilkenny is possibly the best example, with tuyeres being very scarce in the large assemblage from The Parade [82], while tuyeres were recorded from two sites in Irishtown of the same town. Although none of the material from Dublin has been visually examined, the two sites from which tuyeres were recorded are located in the southern, ecclesiastical suburb, and perhaps the most Irish part, of that city. Ceramic tuyeres were also absent from three smaller market towns where the material was examined, at Claregalway, Co. Galway [28], Cashel, Bank Place, Co. Tipperary [23] and Castledermot, Abbey Street/Market Square/Main Street, Co. Kildare [25] while at the fourth, at Nobber, Bridge Park, Co. Meath [111], the identification was inconclusive. There are some apparent exceptions. At Aghmanister, Co. Cork [1], tuyeres were used inside a rectangular building, which is not normally regarded as a native Irish building style. The shape of the smithy building, however, could have been determined more by its location within a rectangular stone structure, than by cultural factors. At Coolamurry, Co. Wexford [31], the evidence points to the use of a hearth wall instead of tuyeres, while the activity is located inside a late twelfth- to early thirteenth-century circular building, generally seen as representing Irish building techniques. This is also the case at three other, broadly contemporary, sites interpreted as isolated rural forges where there is no evidence of tuyeres having been used. However, we do have other examples of the adoption of local building techniques by newcomers to Ireland and if the structures were based on clay walls as fire-prevention, as suggested above, a circular construction could have made more architectural sense.

12.3.2 Organization of the late medieval Irish iron industry

There are very few indications as to who exercized control over the mining and smelting stage of the Irish iron production in late medieval times. The monastic orders, so instrumental in taking over large parts of the iron industry in France and Britain, have left no evidence of doing anything similar in Ireland. The only reference we have to iron mining in monastic charters is in the one relating to the foundation of the only Carthusian monastery ever built in Ireland at Kinaleghin, Co. Galway. A possible explanation as to why the other orders in the late twelfth and early thirteenth centuries, including the Cistercians, were involved in salt production but not in that of iron, could lie in the dispersed nature of both the iron ores and the industry as a whole. By the later thirteenth century then, when the demand for iron would have grown, the involvement of the Irish orders in economic life was waning.

Although the reference to the export of iron from Waterford in AD 1225 implies some sort of organization, if not of the actual smelting then certainly of the collection of its products, the industry on the Anglo-Norman manors, judging by the few excavated remains we have, appears to have been small scale and dispersed. From the written sources, we have records for the Bigod manors of the use of small amounts of iron which are seemingly locally produced, while the smelting itself is not accounted for. For the fifteenth and sixteenth centuries, the situation is equally unclear. Richard an Iarainn is likely to have owned, or profited from, the iron mine near Burrishoole, Co. Mayo, just like the occupant of the tower house at Borris, Co. Tipperary [13] could have profited from the nearby furnaces producing steel, but we have neither proof nor details of this. If water-powered bloomeries were indeed operating in Munster in the last half of the sixteenth century, the costs involved in these would probably imply at least some involvement by the local lord, but even with the early blast furnaces we see that in some cases, such as on Raleigh's lands, these appear to be private enterprises with little or no supervision from the ultimate owner of the land. At Mallow, Quartertown, Co. Cork [98], on the contrary, the blast furnace and finery were an integral part of the manor infrastructure and directly run by its owner, the Lord President of Munster.

Several excavated sites have evidence of both smelting and bloom smithing. Two of these are the ring-work at Woodlands West, Co. Kildare [129] and Borris, Co. Tipperary [13], both interpreted as functioning as the centre of a minor manor. Another, at Ballykilmore, Co. Westmeath [7], could have been connected to the manufacture of arms, as argued above. At two other sites, an outlying manor of Kells Priory at Dysart, Co. Kilkenny [60] and Moneygall, Co. Offaly [104], a late fifteenth- to early seventeenth-century settlement, both smelting and secondary smithing are evidenced, but not the large smithing hearth cakes typically associated with bloom smithing. This would suggest a certain degree of self-sufficiency in the supply of iron of these sites, perhaps fully, or partially as in the Bigod manor of Old Ross mentioned above. Interestingly, Woodlands West, Co. Kildare [129] is located only 1.5km from the relatively important town of Castledermot, showing that iron-bloom producing and processing units could be active very close to market places. The other late medieval Irish smelting sites have no evidence for bloom smithing.

On the contrary, the assemblages from the market centres, the boroughs and smaller towns, frequently showed evidence for large smithing hearth cakes, that is to say weighing over 2kg, implying bloom-smithing activities. This was the case at Claregalway, Co. Galway [28], Cashel, Bank Place, Co. Tipperary [23] and Kells, Church Street, Co. Meath [74], while the large tuyere from Thomastown, Chapel Lane, Co. Kilkenny [118] could also point to the purifying of blooms. It is from this latter town that we have the only reference to dues being levied on blooms (*massae ferri*) in its murage grant of AD 1375. Regrettably, in general, the murage grants do not specify if the iron sold in the markets is metal coming into the towns or merchandise purchased there for use further afield, or both. The mentioning of the blooms in the Thomastown grant, on the one hand, and the reference to iron (and salt) being transported from Cashel to the manor of Moyaliff, both in Co. Tipperary, on the other, would suggest that both occurred. The processing of blooms at the market places would also appear to have happened in thirteenth and fourteenth-century Britain, when we have little or no evidence of bloom smithing on the smelting sites, no further processing of blooms recorded in the one account we have of a non-water-powered bloomery at Tudeley in Kent and smithing hearth cakes assemblages which, if they were of an earlier date, would indicate bloom smithing. Here, though, the weights for the largest cakes are considerably less than for the Irish ones, or mostly between 1 and 2kg. It was suggested above that this might be the result of the Irish blooms being more slag-rich. It might therefore be possible that bloom smithing also took place on the sites in Ireland with comparable assemblages. The assemblages with maximum cake weights between 1 and 2kg were found at Kilkenny, The Parade [82], Thomastown, Chapel Lane, Co. Kilkenny [118] and the borough of Nobber in Co. Meath [111].

Little is known about the structures wherein the ironworking took place in these market places. When *in situ* remains are found in Irish towns, these invariably appear to have been located in open air. In contrast to the British examples where uncovered *in situ* ironworking was mostly found at the back of structures, several Irish examples were located at the street-front. It is tentatively suggested here that the activity in the Irish towns could have taken place in mud-walled structures which left little or no trace, as perhaps was indicated by the succession of clay floors, but no visible structure, associated with intensive ironworking in Trim, High Street, Co. Meath [122]. If this was the case, fire-prevention might have equally played a role and as such would then represent a different solution to the same problem in Britain, where this was solved through non-thatched roofs, leading to the use of chimneys and hence waist-high forges. The Irish written sources mention several examples of forges. In some cases, these represent feudal monopolies, the smithies being leased, and sub-leased, on a yearly basis, while in others the rent was paid in kind. There are indications that only the first were designated as forges or smithies (*fabricae*), which would imply a different distinction from the archaeological one, which is based on the ironworking taking place within a building.

There are striking differences between how ironworking was organized in the different larger urban centres. In Kilkenny, the feudal forge was run by the local lord and subsequently by the corporation responsible for the Anglo-Norman part of that town, and as such was seemingly active throughout the late medieval period. Its location is known to have been on one of the plots fronting on to the market place, which indeed forms the area around which the vast majority of ironworking residues were uncovered in that part of the city. The Irishtown part of Kilkenny, from at least the fifteenth century, had its own corporation, but less is known about the ironworking there. In Dublin, by contrast, while a smiths' guild was established in AD 1473, we have no references to either forges or other locations where ironworking was carried out from the copious amount of records relating to that city. These same records also show an apparent lack of smiths in Dublin in the late thirteenth and first half of the fourteenth centuries.

If this reflects reality, then in this period, when Anglo-Norman power in Ireland was at its apogee, smithing was largely confined to the rural areas around Dublin. Judging by the excavation evidence and properties owned by smiths from the written sources, the bulk of the smithing was located outside the city walls along the main traffic arteries, although smithing was likely also carried out in the area just outside Dublin Castle known as Lormeria, from lorimers or makers of bits, spurs and other small metal objects. This distribution of smithing sites in Dublin potentially reflects the greater dependence early on in the late medieval period of that city on iron brought to it overland, rather than from overseas. In Cork, intensive ironworking was similarly carried out just outside the gate on the south side of the town, but here there is more evidence for ironworking inside the walls, although, except for late twelfth- to early thirteenth-century smithing at Tuckey Street [39], the location(s) of the later activity is as yet unknown. The explanation for these differences could lie in the histories of the places involved.

The newly created centres, such as Kilkenny and some of the smaller towns, offered the opportunity for the creation of feudal forges. The coastal towns, on the other hand, saw a relocation of the Scandinavian population, but no centralization of the ironworking. In Waterford the situation appears to have evolved over time, with *in situ* thirteenth-century ironworking without evidence of a superstructure outside the town walls and a recorded corporation forge to be repaired “stiff and strong” in the mid-fifteenth century. The Irish situation also differs from that in Britain, where the ironworking is generally located within the town walls and carried out on separate plots, sometimes concentrated in certain industrial zones.

From the fourteenth century onwards, imports of iron from Spain to Ireland are increasingly recorded. It is suggested that this Spanish iron was a type of iron especially used for its weldability and as such not a direct replacement for indigenously-produced iron. Its use in construction explains the large quantities in which it is imported into

Ireland and elsewhere. In the late fourteenth century, possibly as a result of the growing isolation of the coastal towns, references are found to English iron imported from Bristol. The same harbour became, especially in the sixteenth century, an important supplier of re-exported Spanish iron to Ireland and, in the second half of the century, of products of the British blast furnace industry. The high volumes of Spanish iron for which licences were obtained around the same period could have been needed for building activity in the towns, and possibly the countryside, but might also have been re-exported to other parts. We have virtually no knowledge of the Irish domestic iron trade in late medieval times, apart from the generic references in murage grants and acts against trading with non-citizens mentioned above.

Apart from the urban centres, the main consumer of iron in the thirteenth and fourteenth centuries would have been arable farming, needing large amounts to make and mend agricultural implements, especially ploughs. At two rural farms, at Cookstown [30] and Trevet [120] (both Co. Meath), the slag assemblages consisted of relatively small amounts of light smithing hearth cakes, consistent with secondary smithing activity. Excavated remains of small-scale smithing are also regularly recorded in proximity to corn-drying kilns, suggesting agricultural end-products. Some of the best-studied sites related to late medieval ironworking are what can be called the isolated rural forges.

Most of the Irish examples appear to be isolated, away from other habitation. We know of two of these smithies, both very similar, from the late twelfth to early thirteenth centuries from Coolamurry, Co. Wexford [31] and Curragh Upper, Co. Cork [42]. These consisted of gullies curving around areas of intensive *in situ* ironworking, interpreted as settings of circular mud-walled huts inside which the smithing took place. At other sites, Loughbown, Co. Galway [96], Killaspy, Co. Kilkenny [88], Garryleagh, Co. Cork [66] and separate areas at Coolamurry, Co. Wexford [31], similar concentrations were uncovered, but without the gullies. As explained above, it is suggested that these also represent mud-walled smithies which had no surrounding gullies. Further isolated rural forges are known from Cuffsborough, Co. Laois [40], a more rectangular structure where coal was the main fuel, and from Ballykeoghan, Co. Kilkenny [6]. The sites dated to the fourteenth century and later, that is to say Garryleagh, Co. Cork [66] and the latter two sites, had evidence for the use of tuyeres, while the earlier ones did not. All of these isolated rural forges were characterized by slag assemblages with the majority of the smithing hearth cakes weighing less than 500g. Occasional bloom smithing also took place at some of these forges, for example at Coolamurry, Co. Wexford [31] which yielded a smithing cake of over 2.5kg, and possibly at Killaspy, Co. Kilkenny [88] where several cakes weighing over 1kg were found. A further two forge buildings are known from smaller manor centres, one square and mud-walled at Blackcastle, Co. Tipperary [12], the other rectangular and probably timber-walled in the bailey at the motte of Mannan Castle, Co. Monaghan [99].

The above sites represent high-volume and medium- to long-term smithing activity and must have been responsible for supplying a large catchment area with iron. In the thirteenth and fourteenth centuries, the lack of tuyeres, and the hearth wall at Coolamurry, Co. Wexford [31] would indicate non-Irish smiths. It is possible that these isolated rural forges are sites related to periods and places without easy access to market. The location and dates of the known rural smithies would conform to this, we have no examples of these in the well-settled Anglo-Norman areas and, significantly, no forges are recorded in the many manor surveys, which mostly deal with the Pale. The later examples would then be part of the Old English agricultural world which had an equal scarcity of market centres.

Based on the above, we can then propose two models reflecting the different economic realities for the production of iron in late medieval Ireland (Fig. 12.2). In the first model, the market centre was the place where the blooms were purified, after which the iron was brought to the agricultural areas, where further small-scale smithing took place. This reflects the fully developed feudal system and would have occurred in many places in Ireland in the thirteenth and fourteenth centuries, and in some beyond, and also throughout most of Britain and, likely, Europe. The second model represents the situation where the agricultural manors had no access to market places. The refining of the bloom probably took place on the smelting sites and the products were brought to the rural smithies from where the iron was distributed in finished form to the users. Any repair or alteration would probably have taken place at the isolated rural forge. This, then, occurred in places and at times where the first model was either not yet implemented or had ceased to function. Outside of Ireland, the evidence suggests further models existed. In Britain, smelting activity is recorded in urban settings. Significantly, the three sites where this is the case, Trellech, Monmouthshire, Deansway, Gloustershire and Crawley in Sussex, were all located next to two of the most important late medieval iron-producing areas in Britain, respectively the Forest of Dean for the first two and the Weald for the latter.

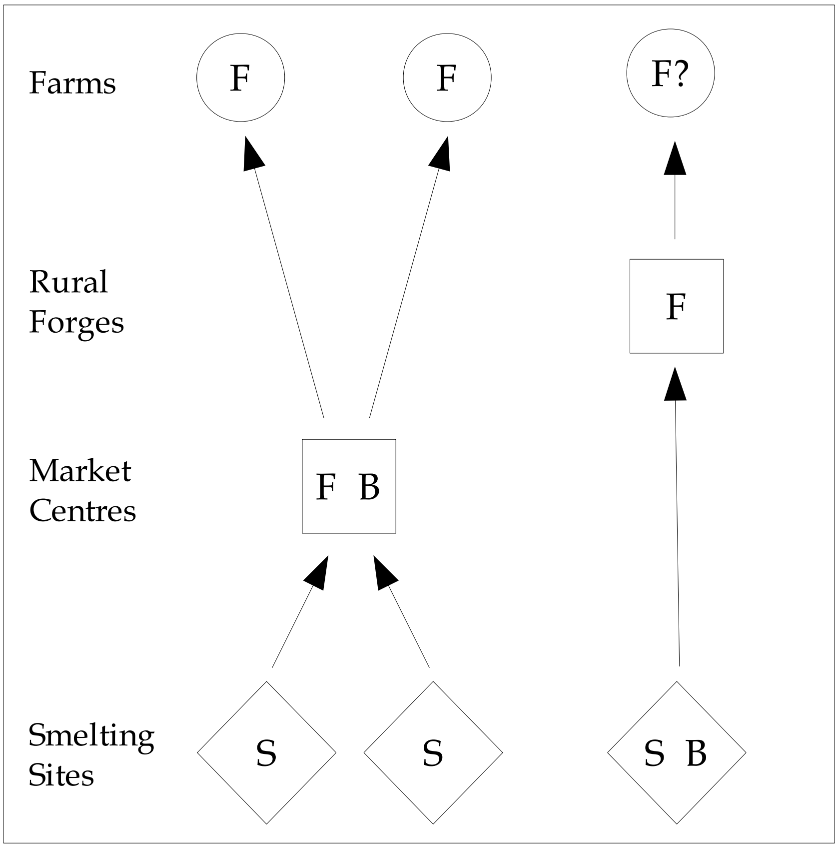


Fig. 12.2 Models of the distribution of locally produced iron in rural late medieval Ireland. S = Smelting, B = Bloom smithing, F = Forging or secondary smithing.

In England, we also have evidence of several manor settlements which had smithy structures, some rather elaborate, such at Alsted in Surrey. As these places are presumably dependent on market centres for their supply of iron, this would imply an additional level in the first model. As such, the monastic forges, potentially including the Irish ones mentioned in the written sources, could also be seen as belonging to this extended version of the first model.

Some sites do not fit into these models. Many of the large non-urban buildings, mainly castles and monasteries, frequently have evidence for ironworking, which is usually small scale. Much of this activity appears to be related to construction and repair works on the structures in question, although some castles did have smithies, as might have been the case at Dunamase, Co. Laois [58]. We have seen Ballykilmore, Co. Westmeath [7], which might represent iron production for military instead of agricultural use. The relatively nearby site of Johnstown in Co. Meath [73], could represent a similar activity. Interestingly, at both of these sites the ironworking is carried out in the upper fills of an earlier enclosure and burials are carried out at the same time within it. The reuse of older sites, which often also saw metalworking, for carrying out ironworking is surprisingly common and it is possible that the choice was not always purely practical, a good location potentially near suitable ores. Finally, two sites, one at Aghmanister, Co. Cork [1], the other at Carnmeen Co. Down [18], showed some interesting similarities. Both were located on Cistercian land and their metalworking activities were located within abandoned stone-walled buildings. The ironworking on both sites was accompanied by seemingly elaborate working of non-ferrous metals, indicating that at least part of the production of these sites was not destined for agricultural purposes. A clue to the nature of these sites might be found in the agreement between a Gaelic Irish lord and the Bishop of Armagh in AD 1297, detailing that the former's tenants were no longer to levy dues on artisans, including smiths, who were living on church lands. If this tax-free nature of church lands also applied to Cistercian lands, then these would have presented tempting locations for metalworkers.

12.4 Late medieval Irish ironworking in its European setting

Because of the current paucity of evidence, it need to be kept in mind that the following is a provisional overview of the available data and that a single discovery, both archaeological or documentary, can necessitate a full review.

Smelting

In general, late medieval bloomery iron-smelting technology in Europe, including Ireland, appears mostly based on the use of traditional shaft furnaces. But in many areas we also known of unusual types of furnaces: the Quiquerez-type furnaces from Switzerland, the large slag-pit furnaces from Stanley Grange, Derbyshire and the Irish raised-hearth furnaces, for example. Based on the current information, these furnace types appear to have developped locally within the late medieval period. It is not known if this situation, one dominant furnace type with local exceptions, is typical for this period or a continuation of an earlier pattern. We also do not know if these unusual furnaces were used to make different products, process varying ore types or if the reasons are non-technological.

Another development in late medieval iron production, arguably the most important in its history next to the introduction of the use of coal as fuel in the eighteenth century, was the application of water-power. This led to two distinct branches of iron smelting technologies would compete with each other until the early twentieth century. The first, the water-powered bloomery, primarily led to a higher production capacity. The second, the production of liquid iron, appears initially to have been used for the production of specialized iron alloys and, later, for the mass production of iron in blast furnaces. In Ireland, where the market for iron would have been rather limited throughout the research period, these technologies were introduced rather late, that is to say unlikely before the sixteenth century. While this is late for the water-powered bloomery, the introduction of the blast furnace in Ireland can be seen as part of the spread of this technology into northwestern and eastern Europe at that time.

Smithing

Whereas the smelting of iron in late medieval Ireland seems to generally conform to what happened across Europe at that time, various aspects of smithing vary substantially. Whereas tuyeres associated with iron smithing are not recorded in late medieval mainland Europe, and only possible occurrences are known from Britain, these are widely used in Ireland up the end, and beyond, of the research period. There are strong indications, however, that their use was limited to the native Irish population, even within the urban centres.

In many cases, the settings for the smithing of iron differ markedly in late medieval Ireland from elsewhere. Whereas the rectangular smithy, first built in wood, later replaced by stone, appears ubiquitous outside of Ireland, here forging is often undertaken in circular structures with mud walls. This is interpreted as the continuation of a local solution to fire hazard, which, interestingly, appears to have been adopted very early on by the Anglo-Norman newcomers. The use of this type of forge building also means that smithing in late medieval Ireland is mainly carried out at ground level, whereas elsewhere waist-high hearths become the norm.

Organisation

In late medieval Europe the bulk of the iron industry became part of the feudal estates of the secular and ecclesiastical lords. Especially the Cistercian order appears to have been instrumental in controlling the production of iron in England and France at the beginning of that period. For Ireland, we are poorly informed about the organisation of iron production in the first two centuries of the late medieval period, but it appears unlikely that this order, or any other feudal power, was involved in iron production on any significant scale. While the newly introduced Anglo-Norman economy, based on arable agriculture, would have certainly required large amounts of iron, a fact confirmed by the plentiful evidence for smithing at that time, we do not how or where the iron was sourced. Both the archaeological and documentary sources offer no comprehensive data, while there are also very little indications to the import of iron. For the fifteenth and sixteenth centuries, we do have many references to iron brought into the Irish coastal towns, but also evidence for continued smelting in the interior of the country.

We are also nearly completely in the dark concerning domestic iron trade in late medieval Ireland. Based on archaeological evidence, the newly founded towns appear to be the setting for the primary processing of the blooms, the resulting iron and objects then finding their way to the users inside and outside these towns. Interestingly, there are indications that this would have been also the case in Britain and possibly the rest of late medieval Europe. Inside the Anglo-Norman influence sphere, the social position of the Irish smiths shows the same variability as elsewhere, including unfree part-time smiths on some manors, highly regarded specialized craftsmen (and women) in the urban areas and others fulfilling important tasks within the administration.

12.5 Suggestions for future research

While it is hoped that the above conclusions relating to late medieval ironworking in Ireland are the result of a correct interpretation of the available information, this still represents a relatively small body of data. More research will be needed to either confirm, qualify or refute some of these interpretations. This could be done through targeted archaeological investigations. Field-walking, traditionally rarely undertaken in Ireland, could lead to the discovery of many new sites. This would, however, be complicated by both the dispersed nature of the smelting and the rural smithing sites. Probably more productive would be the excavation of additional areas at some of the sites discussed in this thesis, where only the dumping areas of the residues were found. The *in situ* remains, in these cases, are likely to be located close-by and easily found using geophysical prospecting techniques. Excavations as a result of infrastructure works, historically the most important body of archaeological research in Ireland, will undoubtedly continue to uncover evidence for ironworking, both late medieval and otherwise. While its random nature is very important for uncovering the more isolated and minor sites, some parts of the landscape, especially higher terrain, are rarely affected by this type of investigation. The research on late medieval iron mining sites would be hampered because of the likely superficial nature of many of them. Extensive field research, however, of some of the more promising areas, such as Burrishoole and the Kerry/Limerick border, could uncover invaluable examples of this site type. Further historical research, especially into the unpublished sources, will undoubtedly lead to more examples of smithing, and possibly smelting, activity in late medieval Ireland. Especially the full transcription of the Bigod manor accounts, the only series of its kind for Ireland, would provide invaluable insights into ironworking in Anglo-Norman times.

The full potential of ironworking sites has not always been fully appreciated in the past, which in many cases severely limited the scope of the interpretations in this thesis. Some of these can still be remedied. Organic material, sometimes embedded within the slag itself, from sites with unclear dating evidence could be submitted for radiocarbon dates. For several important sites, only part of the assemblages of metalworking residues was visually examined, while for others, including all the sites in Dublin, no specialist analysis has taken place at all. It is hoped that the value of this type of visual examination of the residues, on complete assemblages, was clearly demonstrated in this thesis. In some cases, especially for some of the larger sites, a review of the primary site archive would be necessary to fully appreciate the role of its ironworking component. In other instances, the loss of data is irreversible. The metalworking residues from some of the sites, including some very important ones, were either not collected during excavation or later discarded. On most sites where the ironworking took place in the upper fills of older ditches, the cutting of sections through these ditches has led to the loss of valuable evidence. It should be born in mind by archaeologists in the field that enclosure ditches are regularly the settings for metalworking and, if encountered, a different excavation and recording strategy should be adopted.

Perhaps most surprisingly is that on only a hand-full of sites the soil samples were consistently checked for hammerscale, although this cost-effective operation offers some of the best, and often only, evidence of *in situ* smithing activity. It is hoped this will eventually become standard practice on all sites dated to the Iron Age and later, even without apparent metalworking activity, as the possibility exists that non-slag producing smithing was also carried out in the past.

There is also an urgent need to create a comprehensive catalogue of late medieval iron objects present in our various repositories. Metallographic examination combined with chemical analysis of these iron objects then has the potential to provide invaluable insights into the smithing techniques carried by different groups in different settings. A judicious choice of objects to be analysed, that is to say from secure, well dated contexts, would be imperative. Currently, chemical and mineralogical analysis of smithing slag has more limited value and the unravelling of the relations between the forging residues and the objects produced remains the Holy Grail of the archaeometallurgy of iron. The determination of the elemental composition of smelting slag could uncover more examples of potential steel making and point towards certain ore types used. Hypotheses concerning technological choices could be tested through experimentations by the growing body of modern blacksmiths familiar with bloomery iron production. For these reasons it is essential that well stratified ironworking assemblages are preserved in their entirety and it is hoped that this research has demonstrated the information potentials these assemblages hold.