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Water and Wind Power

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Abstract and Keywords

The inhabitants of most urban and rural communities in both Britain and Ireland during the later medieval period would have lived a relatively short distance from either a watermill or windmill. This chapter examines the most recent archaeological evidence for water- and wind-powered mills in later medieval Britain. The use of water power, in particular, was widespread in the later medieval period for a wide range of industrial activities. However, during this same period nearly all of the grain harvest was processed in either wind- or water-powered mills. The archaeological record also demonstrates a large degree of continuity, from the late Roman and early medieval periods, in the design of waterwheels and the mechanisms they actuated.

Keywords: watermill, windmill, dams, weirs, mill ponds, millraces, machinery, millstones

THE inhabitants of most urban and rural communities in both Britain and Ireland during the later medieval period would have lived a relatively short distance from either a watermill or windmill. Some 6082 watermills are recorded in the Domesday survey of 1086 (Darby 1977, 361) which, if anything, is an underestimate of the milling capacity of late eleventh-century England, as many mills in northern counties were not enumerated (Holt 1988; Langdon 2004, 9). In Ireland around 153 mill sites, mostly horizontal-wheeled mills, dated to AD 613–1124 (Rynne 2013), have been recorded to date and, based also on the documentary record, must surely have existed in their thousands before the advent of the Anglo-Normans in 1169. Between ten thousand and fifteen thousand watermills and windmills are estimated to have been operating in Britain by *c.*1300 (Langdon 2004, 171). Of these, upward of some four thousand mills are believed to have been windmills (Langdon 1992, 55) which only come into use from the 1180s onwards.

Even the most basic water-powered installation required expensive and often elaborate preparatory groundworks. The *mill system* was designed to abstract and direct a supply of water from an adjacent, natural water source to the mill-works. The source of water might include natural springs, small streams, and rivers and even, from at least the seventh century AD in Britain and Ireland, water impounded from tidal estuaries. In most cases, this entailed the construction of artificial impounding and diversion elements (dams and weirs), water-courses (head and tail-race channels), and storage reservoirs (millponds). In landscape terms, the creation of a hydraulic system for any variety of watermill could be spread over several acres, alternately draining or irrigating the areas through which the artificial feeder channel for the mill was led. From the early medieval period onwards the law codes of regions as far distant as early medieval Ireland and the Germanic kingdoms of post-Roman Europe were obliged to regulate the working environment of watermills (Rynne 2015b). Windmills, on the other hand, while a useful supplement to watermills where sources of hydraulic energy were either unavailable or unsuitable, suffered from the disadvantage of being unable to store their energy. (p. 492)

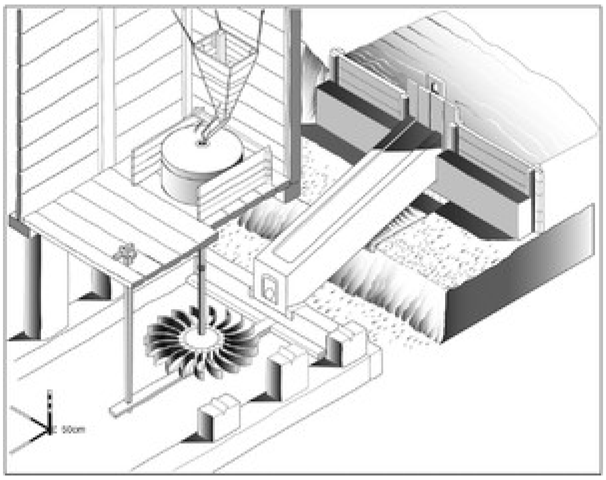

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Figure 31.1 Reconstruction of horizontal-wheeled watermill at Cloontycarthy, Co. Cork, Ireland, dendro-dated to AD 833

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Watermill Types

Horizontal Mills

In *horizontal-wheeled* mills (Figure 31.1) the water wheel is set in the horizontal plane and turned the upper millstone, directly, without intermediate gearing via a vertical driveshaft. In most cases a small storage reservoir, or millpond, would be formed by impounding an adjacent natural watercourse, or springs, through the construction of a rudimentary dam with a core of earth and stone reveted with either timber planks or stone walling. From this latter the water was led in an open channel, or headrace, to the millworks. Before the water was allowed to strike the waterwheel it was directed into a large chute hollowed-out from a tree-trunk. As the drive to the rotating upper millstone was direct, one revolution of the waterwheel produced a corresponding revolution of the millstone. There are basically two different paddle types. In the first, the paddle has a complicated dished or spoon-shaped profile, which has been recorded throughout early medieval Ireland and at a number of pre-tenth century English sites (p. 493) such as at Northfleet, Kent, and Tamworth, Staffordshire (Rahtz and Meeson 1992; Watts and Hardy 2011). However, the earliest recorded paddle form, from Nendrum Mill 1, in County Down, Ireland, is of a second variety, the inclined flat-vaned paddle. Both forms now appear to have existed contemporaneously (Rynne 2015a).

There can be little doubt that horizontal mills continued to be used in Gaelic and gaelicized areas of Ireland throughout the high medieval period, even though vertical-wheeled mills (see the following section) are likely to have been favoured within the Anglo-Norman colony (Rynne 1998; 2011). On mainland Britain, with the exception of Scotland and the northern isles of Orkney and Shetland, continuity of use has hitherto been difficult to prove (Fenton 1978). Indeed, many historians, based solely on the absence of references to them in the written sources, have been perhaps a little too quick to rule out continuity of use (Holt 1988; Langdon 2004). However, while the documentary evidence, as John Langdon has asserted, 'seems to be entirely unambiguous' in this regard (Langdon 2004: 72), this would also appear to be the case for the admittedly sparser manorial records from the Anglo-Norman lordship of Ireland. The discovery of a thirteenth-century horizontal-wheeled example at Corcannon, County Wexford (dendrochronology *c.* AD 1228), within a heavily feudalized area of the Anglo-Norman lordship of Ireland, on the other hand, tells a rather different story (Rynne 1998). There is also, indeed, a growing body of archaeological evidence for the continued use of horizontal-wheeled mills in northern England during the late Saxon and early Norman periods (Moorhouse 2003a; 2003b). The written sources have always been notoriously unreliable with regard to the types of waterwheel employed in early and later medieval Europe, even in regions where horizontal-wheeled forms became the seigneurial mill.

Vertical Watermills

In *vertical watermills* the axle is set horizontally (Figure 31.2), which required the use of intermediate gearing to transmit the motion of the axle, indirectly, to the millstones. The use of intermediate gear transmission provided it with the added advantage of being able to be either geared up or down to suit its water supply. It was, therefore, inherently more flexible than horizontal wheeled forms and could be used with a wider and more challenging range of water sources. The three basic types of vertical waterwheel (*undershot, breast shot*, and *overshot*) used during the later medieval period are all archaeologically attested in the Roman world (Wikander 2000; 2008). In medieval Europe as a whole, however, the overwhelming majority of the excavated early and later medieval vertical watermill sites employed undershot waterwheels.

Undershot wheels were generally found on sites in low-lying areas, where the fall of water was negligible, such as large rivers or tidal estuaries, or in mills built on bridges in urban areas. Based upon both surviving fragments of waterwheel rims and known paddle widths, most early and later medieval undershot waterwheels recorded in Europe consisted of a single rim, into which either single piece or composite paddle blades were morticed. Individual rim segments were usually assembled together using lap (p. 494) joints. The only high medieval example to be recorded in either Britain or Ireland is that recently excavated at Greenwich, England, which has been dendro-dated to AD 1194 and has an estimated original diameter of *c.*5.1 m (Davis 2009). Not only is this the largest known vertical waterwheel, of any type, to have come to light from medieval Europe, it is also the earliest example of its type associated with a tidal mill. Its basic mode of assembly, however, while closely comparable to undershot wheels excavated at Thervay, France (AD 1160–1170; David and Mordefroid 2011) and Ahrensfelde, Germany (*c.*1330–1500; Issleib 1955), is also similar to those from Dasing, Germany (eighth century; Cyzsz 1998), and Audun-le-Tiche, France (AD 840–51; Rohmer 1996).

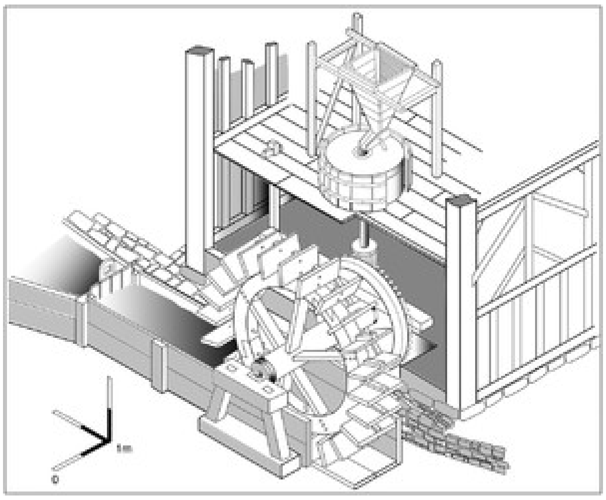

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Figure 31.2 Reconstruction of fourteenth-century undershot watermill at Patrick Street, Dublin, Ireland

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Between the seventh and the sixteenth centuries, two basic forms of undershot waterwheel paddle assembly have been identified (Figure 31.3). In the first, the float and paddle tenon (or ‘start’) is fashioned from one piece (e.g. Dasing, Audun-le-Tiche, Colomby, and Thervay). The second paddle form, of which there are a number of variants, is essentially a two-piece construction, in which the start is affixed by dowels to the float section. On present evidence, some four basic varieties of single- and two-piece paddles have been recorded throughout Europe (Fischer 2004, 43). A number of important recent discoveries, indeed, have demonstrated a degree of often startling similarity between paddle (p. 495) forms recorded in Britain and Ireland and contemporary examples on the Continent. Furthermore, not only do these stylistic similarities, between what are essentially early medieval forms, continue to be employed not only throughout the later medieval period and into recent times, they also extend across a wide geographical area. Two excavated examples from Britain, from Bordesley

Abbey (thirteenth century; Astill 1993) and Greenwich, have mortices parallel to their upper edges which were used to position props. By effectively wedging the rear face of one paddle to the front face of the paddle immediately behind it, these props (or stabilizers) provided further protection for what were, in most cases, relatively thin paddle tenons. The twelfth-century paddle floats from Bordesley Abbey (Astill 1993) and the St Giles Mill, Reading (Ford et al. 2013) were each 0.54 m wide, and are similar to an example from a mill at Colomby, France (Bernard 2011). A fourth example of this type of paddle float has been found at a mill site at Tovstrup, Denmark (AD 1407–1531), which was 0.44 m wide (Fischer 2004, 43–4).

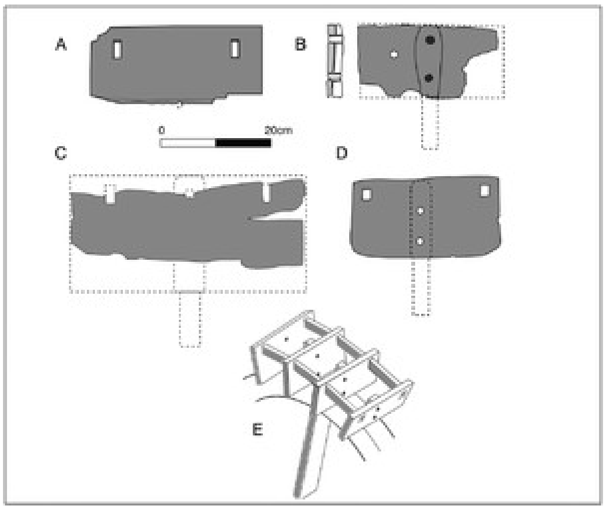

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Figure 31.3 Undershot waterwheel paddle floats from (a) Bordesley Abbey, Worcestershire (twelfth century; after Astill 1993), (b) St Giles, Reading (after Ford et al. 2013), (c) Colomby, France (twelfth century; after Bernard 2011), (d) Tovstrup, Denmark (late-fifteenth/early sixteenth century; after Fischer 2004); (e) reconstruction of paddles struts

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In undershot waterwheels the incoming water strikes the vanes or floats at the lowest part of the wheel's circumference. Since the Roman period, the lowest section of such (p. 496) wheels have been provided with a single-piece or composite wooden trough, which carefully guided the water onto the floats, while at the same preventing it from escaping around their sides. To date, three main types of wheel trough have been identified in Britain, Ireland, and Europe during the high medieval period. These latter, again, demonstrate clear continuity with very similar forms recorded at early medieval undershot watermills. They include:

- Single piece wheel troughs, carved out of a large tree trunk, with the inlet side curved downwards to base of the interior and with its outlet end open; examples of this type include Galten (AD 1143), Tovstrup (AD 1155; Fischer 2004) and Hessel in Denmark (*c.* AD 1140–50; Oleson 2001), and Greenwich, England (AD 1194; Davis 2009);
- Composite forms, where the trough consists of separate sections but where an internal longitudinal curvature is imparted to individual sections, as recorded at Bourges, France (AD 1140–50), Castle Donington, England (early twelfth century; Clay and Salisbury 1990);

- Composite forms, where the trough is constructed with boards and is open at both ends (e.g. Bordesley Abbey, *c.* AD 1174–6; Astill 1993; Patrick Street, Dublin, fourteenth century; Rynne 1997).

Of the twenty-two recorded European examples of these wheel troughs, dating from the second century AD to the sixteenth century, there are close similarities, not only in their basic design but also in their overall dimensions, and over a wide geographical area (e.g. Morett, Co. Laois, Ireland; Rynne 2013; and Bordesley Abbey; Astill 1993). The dimensional similarity is suggestive of technological continuity in their construction.

In the *overshot* waterwheel the water is delivered into buckets, which are fed from directly above the upper section of the wheel's circumference. Of all the traditional varieties of waterwheel this was the most effective, being capable of providing from the same volume and fall of water almost twice as much power as an undershot wheel. However, while the latter and the breastshot variety (where water was directed into the buckets about midway up the circumference of the wheel) are illustrated in (mostly later) medieval manuscripts, only a very small number of examples have come to light. These include the overshot wheels, Chingley, Kent (thirteenth century; Crossley 1975, 14) and Batsford, Sussex (fourteenth century; Bedwin 1980). On present evidence, all varieties of early and later medieval waterwheels had four (or less frequently six) wooden *compass arms* or spokes with which to support the waterwheel's rim. In the most commonly recorded arrangement, the individual spokes were morticed at one extremity to the rim and at the other to the axle, as was evident on the Batsford overshot waterwheel. The waterwheels from Dasing (Cyzsz 1998), Audun-le-Tiche (Rohmer 1996), Colomby (Bernard 2011), and Thervay (David and Mordefroid 2011) each had four compass arms, set at right angles to each other. With the notable exception of the twelfth-century Greenwich undershot waterwheel, nearly all of the recorded early and later medieval examples do not exceed 3 m in overall diameter.

(p. 497) Mill Buildings and Components of the Mill Landscape (Dams, Weirs, Mill Ponds, and Millraces)

Although the medieval watermill is essentially a technology of timber, stone walling and earthfast posts along with combinations of the latter with sill beams have all been recorded in later medieval Britain and Ireland. The most common of all, however, involved the use of morticed sill beams with tenoned uprights which formed part of an interlocking framework of beams, incorporating the wheel pit (in which the pit-wheel rotated) and the structures housing the millstone assembly. These include the twelfth-century Greenwich tide mill (Davis 2009), Batsford, East Sussex (Figure 31.4a, fourteenth century), Chingley forge, Kent (Figure 31.4b, *c.* AD 1300), and the early fourteenth-century phase of the St Giles mill (Figure 31.4c; Ford et al. 2013, 89). Similar timber framing was also combined with stone mill house structures at two later medieval Irish sites, at Twomileborris, Co. Tipperary (AD 1199–1217) and that at Patrick Street, Dublin, built in the early thirteenth century (Figure 31.4d; Rynne 1997). The stone structure housing the grain mill at Fountains Abbey, begun in the 1140s, the earliest surviving mill at any Cistercian site, exhibited four main construction phases over the twelfth to the fourteenth centuries (Coppack 1998). In later periods it operated with two overshot wheels. The Abbey Mill at Abbotsbury, Dorset, was also a two-storey stone building, which accommodated two waterwheels, although in this instance operating side by side (Figure 31.4e; Graham 1986).

The surviving earthworks within the monastic precinct of Bordesley Abbey included a triangular millpond, a mill dam and a complex series of timber-lined mill-races, and mill buildings, operated through six main phases of use from the late twelfth to the early fifteenth centuries (Astill 1993, 3). The millpond was formed by two earthen banks, that at the south being formed with upcast material from an exterior ditch. The northern millpond bank was similarly constructed, although the sequence in which it was constructed was more complicated. At the base of this bank was laid a roughly square in cross section, timber pipe or drain, fashioned from an oak tree, the upper face of which was covered with a well-made, plank-lined lid (Figure 31.5). The southern extremity of the wooden drain was jointed to a transverse wooden baseplate with a series of braces, which held a pivoted post. When the mill was in operation, an upward movement of this post lifted a bung, which allowed water from the bed of the millpond into the pipe. This water could then exit via the wooden drain, pass underneath the millpond bank, and then discharge into an overflow channel in the adjacent field (Astill 1993, 89). This particular drain was dendro-dated to 1227, but seems to have replaced an earlier, similar device (Allen 1993a).

The Wharram Percy mill site (apparently derelict by the twelfth century) produced evidence for a series of clay dams faced with wattle hurdling, which were regularly (p. 498) repaired and rebuilt (Beresford and Hurst 1990, 66–7; Hurst 1984, 101–2), while that at Castle Donington (first half of the twelfth century) consisted of two rows of vertical oak timbers, with a mixture of brushwood, gravel, silt, and stone packed in between (Clay and Salisbury 1990, 283). The documentary evidence for the construction of dams and related features in medieval Yorkshire indicates that mill dams were normally constructed by fixing vertical piles in the river bed, inserting horizontal planks, and filling the area enclosed by them with a mixture of stones, turves, faggots and clay (Faull and Moorhouse 1981, 713–15).

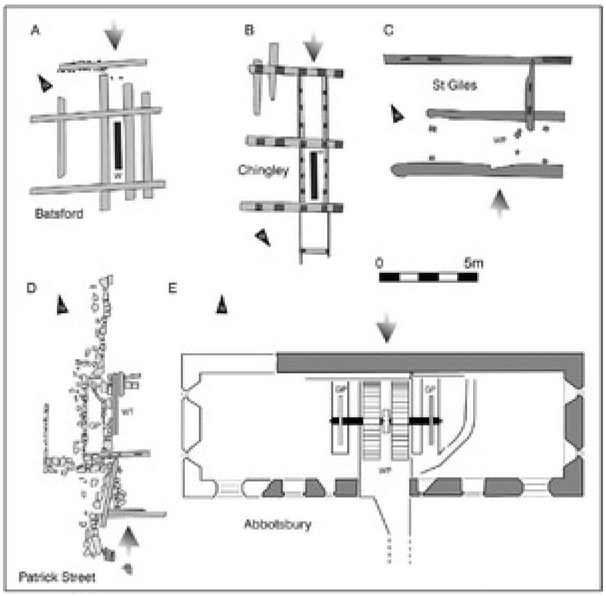

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Figure 31.4 Ground plans of later medieval watermills at Batsford (after Bedwin 1980), Chingley (after Crossley 1975), St Giles (after Ford et al. 2013), Patrick Street (Walsh 1997) and Abbotsbury (after Graham 1986). Key: W = waterwheel *in situ*, WP = wheel pit, WT: wheel trough, GP = gear pit

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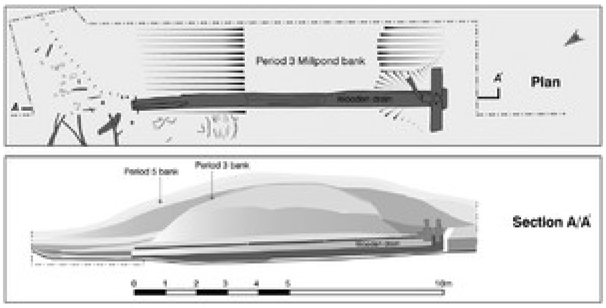

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Figure 31.5 Mill-pond drain at Bordesley Abbey, dendro-dated to AD 1227 (after Astill 1993)

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While for the most part the site on which a mill was to operate was carefully chosen, considerable effort and resources could often be expended on the opening up and (p. 499) maintenance of mill leats/races. One later medieval leat, which led from Kinewards Bridge to Baltonsborough Mill in Somerset, was around 6.4 km long (Hollinrake and Hollinrake 2007, 241).

The means by which mill channels were protected against erosion in the later medieval and post-medieval periods were exactly the same as those found in the early historic period (Rynne 2013). Timber-lined channels have been recorded at the fourteenth-century and later mills excavated at Chingley (Crossley 1975), at Batsford (Bedwin 1980), Bordesley Abbey (Astill 1993), Patrick Street, Dublin (Rynne 1997), Twomileborris, Co. Tipperary, the King’s Mills, Leeds (Goodchild and Wrathmell 2002), and St Giles Mill, Reading (Ford et al. 2013). Indeed, the archaeological evidence from Europe would suggest that this practice was almost universal during the medieval period in Europe.

Mill Machinery

The vast majority of water-powered mills constructed during the later medieval period were used for grinding cereals. And although other industrial processes such as iron-processing (bloomeries and forges), fulling (in which woollen cloth was degreased and pre-shrunk), and the grinding of oak bark for tanning were also mechanized, thus far only the remains of water-powered bloomeries and forges have come to light in both Britain and Ireland. Recent discoveries, and in particular, the excavation of a complete, twelfth-century pit-wheel, at the St Giles mill in Reading, Berkshire, have greatly improved our knowledge of the working of the internal machinery of the medieval water-powered grain mill. The St Giles pitwheel (Figure 31.6, no. 1) was 1.38m in diameter (p. 500) and was formed with four 'felloe' sections cut from naturally curving oak branches. Each section was jointed to another with scarf (i.e. 'end to end') joints, with thirty-six evenly spaced holes to receive cogs (Allen 2013). A small section of a pit-wheel of a similar diameter to that at St Giles was also recovered from Chingley Forge, Kent (Crossley 1975), and at two further English sites at Beckside and Beverly (Allen 2013). Nonetheless, while archaeological evidence for pit-wheel segments is rare, the cogs or pegs inserted into them have become an increasingly more common find in recent years. Pit-wheel gear pegs have been excavated at early medieval mill sites such as Dasing, Germany (Cyzsz 1998), and at later medieval sites such as Verjeslev and Tovstrup in Denmark (Fischer 2004), and Ballyine, County Limerick (Figure 31.6) in Ireland (Rynne 2007, 24–6). Similar gear pegs have also been found at water-powered iron-working sites such as Bordesley Abbey, Chingley Forge, and Batsford, England (Figure 31.6). In all cases the (p. 501) gear pegs, whether from pit-wheels or cams, are generally made of oak (or *pomoideae* woods as at Bordesley Abbey), have a T-shaped profile, and share a distinctive wear pattern, in which one upper corner of the peg is worn down at an angle of about 45 degrees where it had meshed with either a pinion or a cam wheel (Allen 1993b, 215; Bedwin 1980, 199–200; Crossley 1975).

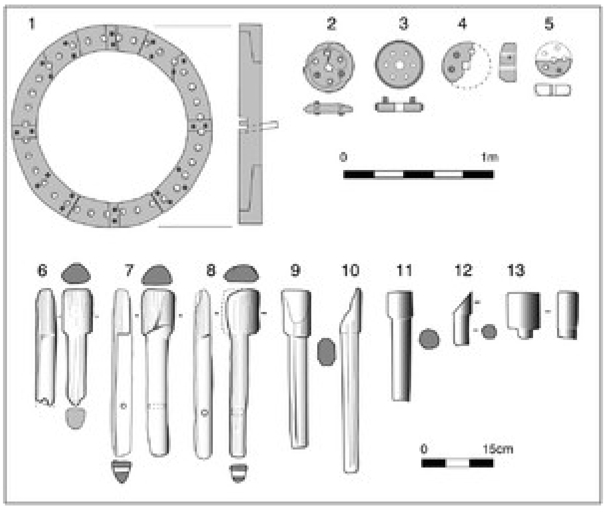

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Figure 31.6 Machinery from later medieval watermills. (1) Pit-wheel from St Giles mill, Reading (twelfth century; after Allen 2013). Lantern pinion disks from (2) Colomby, France (after Bernard 2011), (3) Bardowick, Germany (after Kruger 1934), (4) St Giles, Reading (after Allen 2013), and (5) Thervay, France (after David and Mordefroid 2011). Gear pegs (6–8) from Ballyine, Co. Limerick, Ireland (after Rynne 2007), (9–10) Chingley, Kent (after Crossley 1975), and (11–13) Batsford, Sussex (after Bedwin 1980)

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The pit-wheel meshed with a second gear wheel, the lantern pinion, constructed using two circular wooden disks with six concentric perforations into which were received the opposing ends of six wooden gear staves. The upper disk also had a central rectangular perforation, which held the vertical, iron mill *spindle*, whose upper section was tied to the mill rynd. The spindles-and-rynd combination formed the power take-off for the upper rotating millstone (see the following section), whose lower face usually had dovetail sockets to hold the rynd. Lantern pinions recorded from the Roman and succeeding early and later medieval periods are remarkably similar in size and construction (e.g. at Gimbscheim, on River Rhine; Höckmann 1994; and at Bardowick in northern Germany; Krüger 1934).

To date no medieval examples of rynd-and-spindle assemblies have come to light in either Britain or Ireland, and in nearly all cases it would appear that the high-quality iron and steel used in their manufacture would have ensured that most mill iron would have been recycled. From later medieval English mill accounts the spindle (*fusillum*) and rynd (*ynkum*) clearly required regular maintenance, with anything up to 28 lb of iron being used in the manufacture of a single spindle (Holt 1988, 123; Langdon 2004, 94). Both horizontal and vertical watermills also required bearings to support the ends of vertical and horizontal drive-shafts. The so-called 'pivot-stones', which acted as footstep (i.e. thrust) bearings for vertical shafts, are common to both horizontal and vertical- wheeled mills. Indeed, so close are the types of stone bearing employed, as the Irish and ethnographic evidence demonstrates, that in the case of stray finds it is impossible to determine whether the bearing stone was used in either a horizontal or vertical mill. The footstep bearings recovered from the eighth-century undershot vertical mill at Morett, Co. Laois (Lucas 1953), and from later medieval and Twomileborris, Co. Tipperary, and Ballyine, Co. Limerick, for example, are virtually indistinguishable (Rynne 2007).

Horizontal bearing blocks, used to support the journals of the axles of vertical waterwheels, have been recovered from at least three Roman sites. Several examples have also been excavated at two English monastic sites, Bordesley Abbey and Abbotsbury Abbey, Dorset. At Bordesley Abbey all of those recovered were manufactured from large pebbles, mostly quartz or quartzite, from which it was possible to estimate the diameter of the journals as being 170–236 mm (Astill and Wright 1993, 110). Of the nineteen bearing stones found at Abbotsbury Abbey, thirteen were for horizontal journals (Graham 1986, 123–4). Given that nearly all of the watermills with which these horizontal bearing stones were associated were timber structures, it seems likely that these were emplaced in wooden brackets. One such bracket was recorded at Mølleån, Denmark (C^{14}-dated to AD 1000), and exhibited abrasion marks, presumably caused by the jolting action of the journal (Friis-Hansen 1991, 107). A less-elaborate wooden bearing (p. 502) bracket, dated to *c*. AD 1150, was also recovered from the Castle Donington mill (Clay and Salisbury 1990, 293, fig. 16.4).

To date, water-powered iron-processing mills have been excavated at the Cistercian abbeys of Kirkstall Abbey (Lucas 2014), Bordesley Abbey (Astill 1993), and at Chingley, Kent (Crossley 1975). Yet only Bordesley Abbey, from which a section of a wooden cam wheel was recovered, has produced surviving evidence of the mill's mechanism.

However, at two sites, the late thirteenth-century water-powered forge at North Gate Bridge, Cork, Ireland (Hurley 1997, 45–9), and at Chingley, the original wooden anvils were examined *in situ*. There is also a building at Beaulieu Abbey, Hampshire, which has been interpreted as a possible fourteenth-/fifteenth-century fulling mill (Watts 2002, 115).

Millstones

Querns of basalt lava stone had been imported into England from at least the first century AD, but by the third and fourth centuries these were somewhat less common. Until recently it was believed that the trade in Mayen quernstones from Germany was not revived until the seventh and eighth centuries, but it is now clear that lava querns can be dated to the earliest period of Anglo-Saxon settlement in Britain (Coulter 2011, 181–2; Parkhouse 1997). In Britain, therefore, this trade appears to have been largely uninterrupted. The absence of either imported lava querns, or millstones blanks, in northern England and Scotland has been interpreted as self-sufficiency in these regions in stone suitable for milling (Campbell 1987, 105–17). It seems likely that stone from the Mayen quarry was transported to Andernach on the Rhine (via the River Nette), and thence to Denmark, via Deventer, and to Britain via Utrecht (Pohl 2011, 171). Finds from early medieval wrecks indicate that blanks for quernstones, of 20–25 kg (50 kg for a full set), were being shipped to destinations throughout Europe (Mangartz 2008, 125; Parkhouse 1997, 102; Pohl 2011, 173). However, the tenth-century Mayen and Niedermendig millstones from West Cotton, Northamptonshire, which were, on average, 64 mm thick, weighed around 80–85 kg each, a millstone set weighing *c.*160–170 kg (Chapman 2010, 142; see also Chapter 29 in this *Handbook*). The persistence of this trade in early and later medieval Europe is quite striking: not only were slightly over 50 per cent of the known corpus of millstones sourced from distant locations, but also from quarries that had been exploited since the Roman period (Rynne 2017).

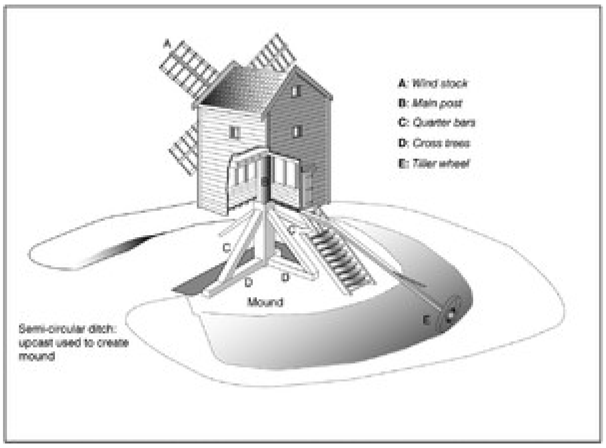
The native millstones employed in animal-, water-, and wind-powered mills included millstone grit from the Peak District of Derbyshire, granite from Dartmoor and Wales along with some sandstones from the West Midlands (Farmer 1992, 98). In Ireland, where both English and French millstones began to be imported into the Anglo-Norman colony from at least the beginning of the fourteenth century (Lydon 1981; O’Neill 1987, 92), locally manufactured stones were generally cut from sandstone, usually conglomerates (Carey 2007; Lynn 1982; Manning 2009). With very few exceptions, recorded examples of European, water-powered millstones from pre-1300 contexts, from both (p. 503) horizontal- and vertical-wheeled mills, rarely exceed 1 m in diameter (Rynne 2017). By way of contrast, the diameters of the millstones, described in ‘hands’ in fourteenth-century English documents, are the equivalent of 52–56 inches (*c.*1.32–1.42 m; Langdon 2004, 172). The wear and tear on the upper rotating millstone in later medieval Britain also required that it be replaced at least every five years (Langdon 2004, 171). As in the early medieval period, special iron mill picks were used for preparing grinding surfaces, and a number have been recovered from medieval vertical mill sites in England and on the Continent as, for example, at South Witham (late twelfth century), West Cotton (thirteenth-/fourteenth-century contexts), and King’s Lynn (Mayes 2002, 15; Chapman 2010, 383; Goodall and Carter 1977).

The Archaeology of Windpower

In the year 1185 two references to the existence of windmills appear in the English written sources. The first of these was at Weedley in the East Riding of Yorkshire, the second is to another mill, already in existence since 1180, at Amberley, Sussex. By the 1190s at least twenty windmills were at work in England (Holt 1988, 20): in around 1300 it is estimated that upwards of four thousand windmills were in operation in Britain (Langdon 1992). The earliest documented windmill in Ireland was at work at Kilscanlan, near Old Ross, Co. Wexford, in AD 1281, but given the generally poor survival of records from the medieval lordship of Ireland, their introduction could have been much earlier (Rynne 1998). And, while there has been much debate, mostly of the naive diffusionist type (e.g. Hills 1994; Kealey 1987), about the European origins of the vertical windmill, there is really nothing to suggest that they may not have developed first in Britain (Holt 1988, 20).

There is a marked concentration of sites in eastern England, owing to a general lack of streams with sufficient volume to power watermills (Langdon and Watts 2005, 698). However, while generally a useful supplement to watermills where sources of hydraulic energy were either unavailable or unsuitable, windmills suffered from the disadvantage of being unable to store their energy. As is evident from the documentary and archaeological record, before the early 1290s, the vast majority of the windmills at work in Britain were *post-mills* (Figure 31.7) in which the actual mill building is rotated about a central wooden pivot in order that the wind sails can face into the prevailing wind (Zeepvat 1980). The entire structure could be rotated through 360 degrees by means of a *tail pole*, which enabled the miller to adjust the position of his sails to accommodate changes in wind direction, by the simple expedient of rotating the entire mill building. The mill machinery was contained within a wooden framework, and the entire structure was usually erected on high ground, often on a specially prepared mound.

Thus far around fifty post-mill sites, dating from the early thirteenth to the sixteenth centuries, have been identified in Britain (Watts 2013, 48), along with a further five probable windmill mounds recorded in Ireland, all in Co. Meath (Rynne 1998). In the main, these mounds tend to be around 11.5–24 m in overall diameter, and vary somewhat (p. 504) in height. They are commonly surrounded by C-shaped ditches, as at Manor Farm, Humberstone, Leicester (Thomas 2009), which are both wide and shallow, and the material upcast from them was used to construct the mound. One, and occasionally two causeways, extended across the ditch to facilitate access. When later medieval windmill mounds are excavated, as at Bridlington, Yorkshire (Earnshaw 1973), Tansor Crossroads, Northamptonshire (Chapman 1997), Great Linford, Buckinghamshire (Mynard and Zeepvat 1992), the foundation trenches in which the cross-trees or trestles were laid are commonly revealed. At Lamport, Northamptonshire, the cross-trees had been laid on stone cross walls (Posnasky 1956). Excavation at many sites has also demonstrated that the foundation trenches, in which the cross-trees were laid, were packed with clay and/or stones, to either counteract penetration of water from the surface or to assist in drainage (Watts 2013, 50). However, while a number of windmills mounds show modifications to their height over time, and were thus not operating over a single phase, many later medieval sites were not re-used by later mills (Watts 2013, 51–2).



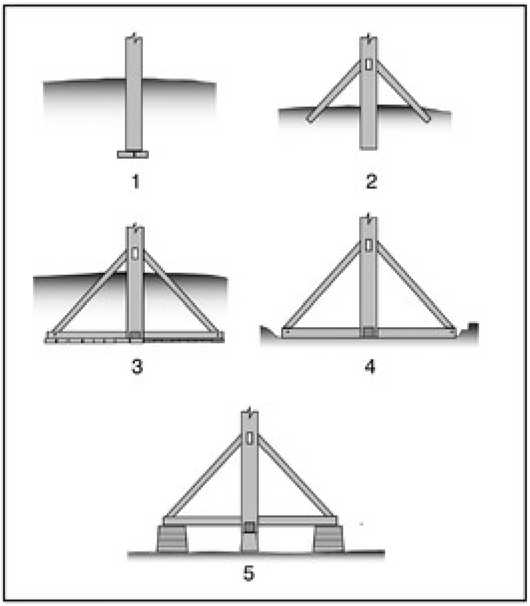
Click to view larger

Figure 31.7 Reconstruction of the later medieval post windmill at Great Linford, Buckinghamshire (after Mynard and Zeepvat 1992)

(© Colin Rynne)

During the excavation of the windmill mound at Manor Farm, two relatively well-preserved cross-trees of box heart oak were investigated *in situ*. The longest cross-tree was 5.4 m long and around 40 cm square, and the two cross-trees had joined at the centre by halving. Pottery recovered from the construction slots for these beams would indicate a twelfth- to thirteenth-century date for the mill's construction (Thomas 2009, (p. 505) 119). Excavation of a windmill mound at Bridgewater Without, Somerset (Webster and Cherry 1972, 212), also produced a large section of a cross-tree, along with near-complete section of a *quarter bar* (a raking strut morticed at an angle into the trestle, by which means it provided lateral support for the main pivot post of the mill). Surviving sections of the cross-trees from the Great Linford mill are C^{14}-dated to AD 1200 ± 70 (Mynard and Zeepvat 1992), while pottery from Tansor Crossroads suggests a date of *c.*1225–50 (Chapman 1997, 20). However, at many later medieval sites the timber substructure of the post-mill was often deliberately dismantled when the site went into disuse. The cross-trees of the Tansor Crossroads mill would have been 5.6–5.8 m long (Chapman 1997, 35) and their salvage and recycling for uses, structural or otherwise, would have saved the expense of the felling and carriage of new timbers of the same scantling. As many authorities have posited, one of the principal technical developments associated with later medieval post-mills is the gradual abandonment of the practice of burying the substructure of the mill (Crossley 1990; Watts 2013). This enabled both increased structural stability for the mill structure and considerably reduced the likelihood that the buried cross-tree would be susceptible to un-monitored decay (Figure 31.8). Furthermore, (p. 506) with the trestle frame now above ground, taller post-mills with longer sails (which could create greater power) could now be built, while the condition of the cross-trees could be more easily monitored (Watts 2013, 50–1). Very little is known about the machinery of the later medieval post-mill, save what can be gleaned from contemporary and frequently stylized representations in medieval manuscripts.

Thus far a single piece of windmill machinery—a pivot stone for a vertical driveshaft—has been recovered at the Bridlington post-mill site (Earnshaw 1973).



Click to view larger

Figure 31.8 A suggested evolution of English windmill foundations (after Watts 2002)

(© Colin Rynne)

A number of recorded sites, as one might expect, are located close to, and likely serviced, contemporary settlements. There is a possible windmill mound at Barton Blount, Derbyshire, close to the earthworks of a deserted medieval village (Watts 2013, 53). Aerial photography has also demonstrated that these mounds can also be sited either within or occasionally over ridge-and-furrow field systems, as was the case at the excavated thirteenth-century windmill mound at Great Linford (Mynard and Zeepvat 1992). Considerably less is known about the buildings associated with later medieval windmills in general. However, a number of excavated sites around Eastbourne, Sussex, have uncovered functionally related structures such as a bolting house (in which the flour and meal was sieved and dressed) and even a miller's dwelling (Stevens 1982, 91–3).

In the post-medieval period post-mills tended to become rarer and were gradually replaced by more powerful *tower-mills*, so-called because the mill machinery was contained within a typically cylindrical masonry tower. In the tower-mill the building is a fixed entity and the moving portion containing the sails and the driveshaft (or *windshaft*) are carried in a rotating *cap* section set on top of the tower. A *tailpole* with a tiller wheel at its lower end was connected to the cap portion, a movement of the pole in any direction enabling the miller to turn the cap and thence the sails into the prevailing wind. This indeed is the precursor of the multi-storeyed windmills with which most people today would be more familiar. However, from at least the late thirteenth century, a small number of these mills were beginning to be erected in England. The 'stone windmill' recorded at Dover castle in 1294–5 would appear to have been a tower-mill, while a further example was in existence at Turweston, Buckinghamshire, in 1303 (Langdon and Watts 2005, 701, 707). All told, there are around six recorded example of later-medieval tower-mills in Britain, three of which, Burton Dassett, Warwickshire, Fowey, Cornwall, and Tidenham, Buckinghamshire, have standing remains (Langdon and Watts 2005, 712;

Watts 2002). The high cost of their construction, for the most part, would appear to have acted as a brake on their widespread adoption in Britain during this period, although other factors such as a reluctance from contemporary carpenters to build them may also have played a part (Langdon and Watts 2005, 717).

Conclusion

The archaeology of water power in Europe in general and in Britain and Ireland in particular exhibits marked continuity from the Roman period onwards. This applies to both (p. 507) the hydraulic systems employed to power individual mills (whether they used horizontal or vertical waterwheels) and the mechanisms actuated by them. Even the diameter of the millstones turned by them, it is now clear, changed little until the fourteenth century. The same continuity can be demonstrated for the long-distance trade in millstones made from German lava, which continued in most of Europe and in mainland Britain (with the exception of Scotland).

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