The Introduction of the Vertical Watermill into Ireland: Some Recent Archaeological Evidence

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THE IMPORTANCE of the archaeological evidence for the horizontal-wheeled mill in Ireland has tended to obscure and inhibit research into the introduction of its counterpart, the vertical-wheeled mill. The latter is normally associated with the coming of the Cistercians and the Anglo-Normans to Ireland, although no-one has ever attempted to explain why this was so. The validity of these claims is re-examined below in the light of recent archaeological evidence from Ireland, where it can now be demonstrated that both horizontal- and vertical-wheeled mills were in use as early as the 7th century A.D.¹

INTRODUCTION

The origins of water-powered machines in Ireland were considered worthy of serious inquiry by many Irish 19th-century antiquarians, a number of whom made important contributions to their study. This is hardly surprising given the frequency with which early watermill sites have occurred in the Irish archaeological record, and the prominence afforded to them in early Irish law. Indeed, the contemporary existence in the west of Ireland of mills similar to those recovered from Irish bogs provided further food for thought; whilst the striking similarities between the Irish horizontal-wheeled mills and those of Mediterranean Europe did not go unnoticed.² All that was needed to complete the picture (or so it seemed) was the discovery of artefacts at these sites diagnostic of the early medieval period, thereby confirming what nearly all of the 19th-century commentators had, in any case, always suspected. Yet such evidence was not forthcoming. As late as the 1950s in the pioneering studies produced by A.T. Lucas³ and E.M. Fahy⁴ it was still not possible to demonstrate conclusively that any of the known sites were early medieval. The breakthrough in terms of the date range of these sites did not come until the 1970s, when it became possible to date a large number of them by dendrochronology. And in this regard the publication of the Drumard site in Co. Derry by Dr M.G.L. Baillie,⁵ which was dated to the 8th century A.D., was in many ways a turning point. It was now possible to date the Irish sites with great accuracy, and Baillie was to continue to document the extension of the Belfast master chronology to the rest of
RECONSTRUCTION OF CLOONTYCARthy WATERMILL C.A.D.833.

FIG. 1

Suggested reconstruction of Irish horizontal-wheeled watermill at Cloontycarthy, Co. Cork
Ireland, an exercise in which structural members from early mill sites have figured prominently.\textsuperscript{6} There can now be no doubt that the known early Irish mill sites were built between the 7th and the 10th centuries A.D. and are demonstrably the most accurately dated structures of the early medieval period in Ireland.

The majority of the early sites were clearly horizontal-wheeled mills, similar to that shown in Fig. 1, which is a reconstruction of a 9th-century example from Cloontycarthy in Co. Cork. Incoming water was directed into a hollowed-out wooden trough splayed internally so as to develop a concentrated water jet, which discharged against the waterwheel. As the mechanical arrangement of these mills did not involve gearing, the drive from the waterwheel's axle to the upper millstone was direct. All the available evidence suggests that these mills were known in Ireland no later than the second half of the 6th century.\textsuperscript{7} The introduction of the vertical-wheeled mill, however, is believed to be much later, even though both varieties of mill are likely to have been common elsewhere in post-Roman Europe. The received wisdom about the introduction of the vertical-wheeled mill into Ireland is that this was a 12th-century development (see below). Although both horizontal- and vertical-wheeled mills seem likely to have been common elsewhere in post-Roman Europe, the introduction of the latter to Ireland has usually been attributed to the 12th century, despite lack of evidence. It will be shown below, however, that recent archaeological data from Little Island, Co. Cork, and Morett, Co. Laois, establishes beyond all doubt that both horizontal- and vertical-wheeled mills were used in Ireland before the 10th century.

The problem of the antiquity of the vertical-wheeled mill in Ireland has either been completely ignored or inadequately dealt with in the existing literature. As to its introduction, two completely different hypotheses have been put forward to account for its development. Dr W. A. McCutcheon, on the one hand, argued that the horizontal-wheeled mill was introduced into Ireland from Scotland in the 3rd century A.D.\textsuperscript{8} The vertical-wheeled mill, he asserted, was introduced from northern Britain a century later and both types were, by the 7th and 8th centuries A.D., ‘widely distributed throughout the country’;\textsuperscript{9} whilst Lucas suggested that the vertical-wheeled mill may have been introduced by the Cistercians and the Anglo-Normans in the 12th century.\textsuperscript{10} The archaeological and historical evidence, however, belies both arguments. To begin with, the hypotheses proffered by McCutcheon for the introduction of both types of mill are wholly improbable. For not only has no 3rd-century mill site yet been found, but there is absolutely no evidence (historical or otherwise) which would indicate that horizontal-wheeled mills were used in 3rd-century Scotland, whereas at least two Roman vertical-wheeled mill sites, Chesters and Haltwhistle Burn Head,\textsuperscript{11} have been investigated in N. Britain. But again, there are no Irish vertical-wheeled sites dating to the 3rd century and even if there were they need not, of necessity, have arrived from northern Britain. A number of Roman vertical-wheeled sites have in fact been excavated in southern England,\textsuperscript{12} whilst the existence of further sites can be adduced from stray finds such as millstones.\textsuperscript{13} Moreover, as the early Irish law tracts dealing with watermills and watercourses are clearly concerned with horizontal-wheeled mills,\textsuperscript{14} and the remains of the pre-10th-century watermills investigated in Ireland are almost exclusively of this type,
McCUTCHEON'S BELIEF THAT BOTH TYPES OF MILL SHARED A WIDE DISTRIBUTION IN THE 7TH AND 8TH CENTURIES IS TOTALLY UNFOUNDED.

THE SECOND HYPOTHESIS, CONCERNING THE 12TH-CENTURY INTRODUCTION OF THE VERTICAL-WHEELED MILL INTO IRELAND, IS ALSO LARGELY UNTENABLE. WHILE THE CISTERCIANS IN BRITAIN AND ON THE CONTINENT FOUND MANY USES FOR WATER-POWERED MACHINERY IT IS, NONE THE LESS, UNREALISTIC TO SUGGEST THAT THE FIRST VERTICAL-WHEELED MILL IN IRELAND WAS BUILT UNDER THEIR AUSPICES. THE THIRTY-FIVE CISTERCIAN HOUSES ESTABLISHED IN IRELAND ARE ALL KNOWN TO HAVE POSSESSED AT LEAST ONE WATERMILL,15 AND NEARLY ALL OF THEIR EXTANT MONASTIC SETTLEMENTS STILL EXHIBIT TRACES OF CAREFULLY EXECUTED MILL CANALS.16 Indeed the vertical waterwheel, and other industrial processes and power transmission systems associated with it, are also likely to have been used on Anglo-Norman manors. But Ireland had not previously been completely isolated — monastic contacts with the Continent are well-attested in the pre-Norman period — and as vertical-wheeled mills are likely to have been used in pre-Cistercian European monasteries there is every reason to suspect that new developments reached Ireland before the advent of the Cistercians.

THE ARCHAEOLOGICAL RECORD

The starting-point of all our considerations must be the archaeological record or, rather, a thorough reassessment of it. In his discussion of the Mashanaglass horizontal-wheeled mill Fahy drew attention to a number of structural anomalies in another mill site at Morett, Co. Laois,17 which was claimed by its excavators to be a horizontal-wheeled mill.18 The site has recently been dated by dendrochronology to A.D.770.19 The Morett mill comprised two V-shaped channels each lined with oak soleplates and floored with neatly overlapping boards (Fig. 2a), which were connected at their narrow ends by a central wooden penstock, 14 ft. (4.22 m) long, 2 ft. (0.61 m) wide and 1 1/2 in. (0.29 m) deep. Fahy's observations on this structure may be summarized as follows:

(a) As the Morett penstock was nearly horizontal it could not have directed water efficiently onto a conventional horizontal waterwheel. Its narrow end had in any case been set at floor level leaving, it would appear, no provision for the clearance of the waterwheel from what Lucas interpreted as the 'wheelhouse' floor.

(b) In the vast majority of Irish horizontal-wheeled mill sites, the requisite water jet was developed through an orifice cut at one end of a hollowed-out tree-trunk (see Fig. 1). No attempt had been made to do so on the Morett penstock, whilst the normal type of Irish mill flume would have been positioned some distance above the floor of the mill undercroft, and was inclined steeply in relation to the waterwheel. While both the Irish and foreign horizontal-wheeled mills known to Fahy conformed in these respects, the Morett mill clearly did not.

(c) The above factor and what Fahy saw as 'the unusual plan and small size of the wheelhouse'20 suggested that it could not have been what he called a 'pressure-jet mill', i.e. where the water jet was developed under the pressure of a head of water.
Excavation plans of (A) Morett (after Lucas, op. cit. in note 3) and (B) Little Island watermills

maintained in a cistern behind the wheelhouse, and where the orifice was set at paddle level.

(d) Finally as regards the identification of the structure as a horizontal-wheeled mill, the discovery of pivot stones, which were believed to be footstep bearings for the waterwheel’s driveshaft, could not be considered diagnostic.\textsuperscript{21}

Clearly the Morett remains could not have been those of a horizontal-wheeled mill, and while Fahy suggested elsewhere that it may have operated with a vertical waterwheel positioned over the central penstock,\textsuperscript{22} he did not pursue the idea further. The latter is by far the best if not the only explanation for the Morett phenomenon, and is one that is largely confirmed by the evidence from Little Island.
At Little Island, a wooden-framed head-race channel converged upon a slightly inclined, two-piece penstock, 3.11 m long, 1.30 m wide at rear end and 0.80 m wide at its fore end (Structure II, Fig. 2b). Internally the Little Island penstock was 0.26 m deep, though its depth as investigated was largely the result of damage by a digger bucket. However, it is unlikely that it would have been appreciably deeper owing to its mode of manufacture, in which the two sections of the penstock were stitched together along their undersides by three sets of flimsy dovetail clamps. A wattle floor had, in addition, been laid in the area immediately in front of the penstock, presumably to counteract the scouring action of incoming water. The structural remains of a second mill at Little Island (Structure I, Fig. 2b) were more in accordance with those of other recorded examples of Irish horizontal-wheeled mills, and it is assumed that the two mill flumes recovered out of their original positions were associated with this mill. By comparing Figs. 2a and 2b it will be seen that there are obvious similarities between Structure II at Little Island and the Morett mill; whereas the two-piece penstock from Little Island presents a stark contrast to flumes I and II from the same site which, though crudely manufactured, are recognizably of the type normally associated with Irish horizontal-wheeled mills. The Little Island mills have both been dated by dendrochronology to c. 630 and are the earliest examples of either type yet to come to light in Ireland.

The two-piece penstock from Little Island was clearly not intended to discharge a concentrated water jet, and we may conclude that this structure was not a horizontal-wheeled mill. And further, on the analogy of the Morett mill, we may conclude that the remains of one of Ireland’s earliest watermills are in fact those of an undershot vertical-wheeled mill: a conclusion upon which the full weight of the evidence for the early and subsequent development of the undershot vertical waterwheel can now be brought to bear.

THE VERTICAL UNDERSHOT WATERWHEEL: EARLY DEVELOPMENTS

Of both overshot and breastshot waterwheels, during the early stages of the development, there is abundant evidence for the use of horizontal or nearly horizontal penstocks. Both utilize the potential energy of falling water, the penstock being positioned so as to direct water into the buckets at the top (overshot) or in the middle (breastshot) of the waterwheel, where in each case a series of buckets on the periphery of the wheel set it in motion by taking up the weight of the water directed into them. The breastshot wheel is less well documented in classical antiquity, although the overshot variety has appeared quite frequently in the archaeological record from the Roman period onwards. A specialized term for the penstocks or ‘launders’ appears in the English language at a relatively early period in the O.E. mylentroh, and Professors P. Rahtz and D. Bullough, who have examined the etymology of troh, concluded that this was a ‘hollowed-out or planked wooden construction (which may be open or covered over) ...’. The term falltrogh/fallogh is used in later medieval account rolls to describe the penstocks of what can only be overshot waterwheels, whilst examples of these wheels have been excavated at Chingley, Kent, and Batsford, Sussex. Furthermore, illustrations of overshot
waterwheels (usually with penstocks) are relatively common in manuscript illuminations of the same period.\textsuperscript{31}

Vertical undershot waterwheels, on the other hand, utilize the kinetic energy of falling water, the impact of the water striking paddles providing the motive force. As has already been seen, a steeply angled flume was employed in early Irish horizontal-wheeled mills both to increase the velocity of the incoming water and to regulate its discharge onto the waterwheel. But although both horizontal and vertical undershot waterwheels are actuated by the impact (i.e. kinetic energy) of the water striking them, the methods employed to direct the full force of the incoming water against them are quite different. In horizontal-wheeled mills the water jet issues from a point \textit{above} the waterwheel, leaving the rim of the wheel centrifugally, whereas water directed against the paddles of an undershot wheel strikes them at the level of the lowest part of the wheel's circumference, flowing out \textit{beneath} the wheel and along its long axis of rotation. In vertical undershot waterwheels, therefore, the entry and exit of the water occurs at floor level, which in practice usually meant that in addition to being carefully channelled so as to increase its velocity prior to impact with the wheel, it was also necessary to take steps to prevent incoming water from escaping around the sides of the wheel. Thus the headrace and tailrace channels were tapered inwards and outwards, respectively, from the wheel area itself, and the lower part of the waterwheel was provided with either a penstock or a wooden

\textbf{FIG. 3}

Reconstruction of 3rd-century A.D. Roman undershot watermill at Haltwhistle Burn Head, after R.J. Spain
casing. These practices are widely attested in the archaeological, ethnological and
documentary evidence for vertical undershot waterwheels, which will be reviewed
below.

The earliest excavated example of a vertical undershot watermill at Haltwhistle
Burn Head on Hadrian’s Wall, which was dated to the 3rd century A.D., produced
the remains in situ of what was termed a ‘wheel casing’.32 The remains as inves­ti­
gated consisted of three planks, which would originally have formed part of a
composite wooden trough (Fig. 3) whose function ‘was to concentrate the full flow of
the mill stream into the paddles of the waterwheel’.33 One of the Gallo-Roman mills
investigated at Lösnich in the Moselle valley may also have been provided with an
undershot waterwheel, where the outfall of the upper, overshot mill was directed via
a rock-cut channel and a steeply inclined penstock onto the floats of an undershot
waterwheel.34

Lower penstocks are also occasionally depicted in medieval manuscript
illuminations of undershot waterwheels, as in the Hortus deliciarum of c. A.D. 1202
(Fig. 4).35 A number of English medieval account rolls also refer to the existence of
such penstocks. The bailiff's account for the manor of Kingsland in Herefordshire for the years 1389–90, for example, records that 6s. 8d. was expended on the cost of '24 oxen hired for one day for carrying one alder from the park of Penbrugge as far as the mill, required for the watercourse under the wheel'. Similarly, in the account of the Manor and Borough of Leeds for the years 1323–24, 13s. was spent on 'remaking one wheel for the fulling mill (apart from the axle), covering it and sawing the boards needed for this'.

Archaeologically, medieval and post-medieval undershot mills are less well documented, although the evidence presently at our disposal does tend to reinforce the impression given by the earlier sources. A late medieval undershot mill at Ahrensfeld near Hamburg is likely to have been provided with a lower penstock. Indeed, undershot mills with lower penstocks were common in central Europe up until quite recent times. The 17th-century undershot mills at Caldecotte, Buckinghamshire, had a stone-lined headrace channel, which tapered inwards with respect to what was termed the 'waterhouse', a rectangular structure 4.2 m long. Internally the waterhouse was divided into three separate sections: a central, inclined two-bay channel 2.6 m long and two narrow flat-bottomed channels each 0.80 m wide. The floors of the narrow channels had been lined with boards. The tailrace channel (as at the Morett site) was splayed outwards from the waterhouse, its southern portion being covered with two large boards. The central conduits were interpreted as bypass channels and the narrow channels adjoining the side walls of the waterhouse as likely emplacements for undershot waterwheels. In its essentials the Caldecotte mill presents an interesting parallel for the contemporary 'double mills' of the Netherlands, which were equipped with lower penstocks. Similar mills were also formerly in use in the Rosia-Tal region of Romania, where again the expedient seems to have been to prevent water from escaping around the sides of the waterwheel. The evidence from the 18th-century fulling mill at Ardingly, Sussex, at which a lower penstock and the timber-lined channel feeding it were investigated in situ, is also in line with what has been suggested above. As might be expected, the more conventional form of undershot waterwheel was also quite common in colonial and post-colonial America. The American millwright, Thomas Ellicott, prescribed the dimensions for the various types along with their water requirements in Oliver Evans's Young Millwrights' and Millers' Guide of 1867. Each of the three undershot wheels illustrated by him is equipped with lower penstocks which are inclined, respectively, at angles of c. 10, 25 and 40 degrees to the horizontal. Nor can it be assumed that the latter were an indigenous American development for, as a recent survey of the development of American water-powered mills has concluded, this technology was simply 'an extension of the technology prevalent in the old world, reflecting in its details usages characteristic of other countries of emigrant origin'. Finally, the traditional undershot waterwheels of the Carpathians (cauripi or lopeti) also had lower penstocks while more recent examples in Britain have been provided with lower casings.

Thus far it has been established that vertical undershot waterwheels, at all stages in their development, were equipped with lower penstocks in order to maximize the impact of the water directed against them. Given then that the troughs
investigated at Little Island and Morett could not have serviced horizontal waterwheels, and in view of the evidence presented above, can the remains from these sites be safely identified as those of vertical-wheeled mills? With regard to the Morett mill, a problem still exists in establishing the position of the millhouse building, although the beam supporting the rear end of the penstock is likely to have been associated with such a structure. Nor can we assume that this building need necessarily have been parallel to the central trough. Certainly the excavator’s suggestion that the beams that funnelled outwards from the fore end of the Morett penstock represented the remains of an undercroft for a horizontal waterwheel cannot be accepted, and this becomes all too apparent if one attempts to extend this interpretation to structure II at Little Island. It is clear that in both cases horizontal waterwheels ‘housed’ in such positions would have very little freedom of movement, even if the fact that neither conduit was designed to develop a waterjet could be explained away. There can be no doubt, therefore, that the remains investigated at Morett and Little Island II are in fact those of vertical-wheeled mills; and as these sites have been soundly dated to the 7th and 8th centuries the introduction of this type of watermill into Ireland can no longer be considered a 12th-century development.

NOTES

1 I communicated a brief summary of the results of my investigations into the antiquity of the vertical undershot in Ireland to Dr Orjan Wikander of Lund in 1985, in compliance with a request for an update on research on early water-power in Ireland for a forthcoming paper by him. Dr Wikander’s excellent account of the archaeology of early watermills, ‘Archaeological Evidence for Early Water-Mills — an Interim Report’, History of Technology, 11 (1986), 151–79 (esp. 155 and 159 n. 22) makes a passing reference to the existence of vertical undershot watermills in Ireland before the 12th century, and is cited by R. Holt in The Mills of Medieval England (London, 1988), 5. The following paper, however, is the first full statement of the evidence collected by me for the existence of vertical-wheeled mills in Ireland before the 12th century.


9 Ibid., 67.

10 Lucas, op. cit. in note 3; this idea was accepted by G. Bowie, ‘Corn drying kilns, meal milling and flour in Ireland’, Folklife, 17 (1979), 5–13, at 5.


13 See Wikander, op. cit. in note 1.

14 See Ryne, op. cit. in note 7, ch. 1, 17 seq.

15 G. Carville, The Heritage of Holycross (Belfast, 1973), 70.

16 G. Carville, The Occupation of Celtic Sites in Ireland by the Canons Regular of St Augustine and the Cistercians (Kalasazoo, Michigan, 1982), 28–47.

17 Fahy, op. cit. in note 4, 41–42.

18 See Lucas, op. cit. in note 3, 15 seq.

19 See M. G. L. Baillie, Tree Ring Dating and Archaeology (London, 1982), 182.

20 Fahy, op. cit. in note 4, 42.
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21 Ibid.
24 Baillie, op. cit. in note 19, 182.
25 See Wikander, op. cit. in note 11, 82.
26 For a summary of the recent evidence see Wikander, op. cit. in note 1.
33 Ibid., 30. See reconstruction in R. J. Spain, *Romano-British Watermills*, *Archaeologia Cantiana*, 100 (1984), 101–28, and Fig. 3 above.
40 Ibid., 72. More recent examples of these mills (again provided with lower penstocks) have been photographed by A. Jespersen, e.g. ‘Windpower as carrier of the early Industrial Revolution in Holland’, *Trans. Int. Molinological Soc.*, 4 (1978), 131–41, fig. 9.
44 Ibid., 32.