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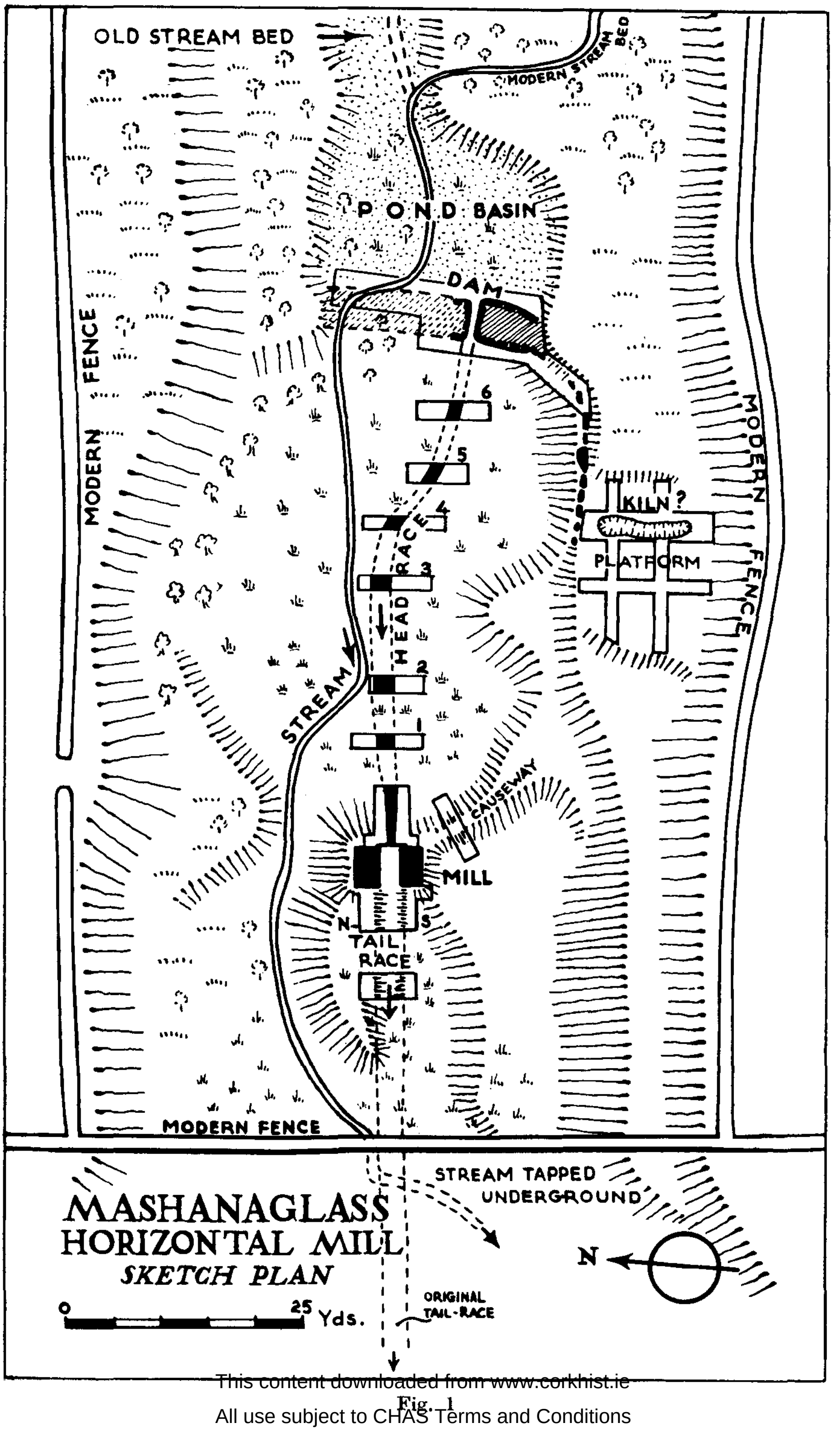

Fig. 1

A Horizontal Mill at Mashanaglass, Co. Cork

By EDWARD M. FAHY, M.A.

A number of archaeological sites will be affected, directly or indirectly, by the flooding of two areas of the Lee valley in connexion with the hydro-electric development scheme now nearing completion. The lower dam, that at Inishcarra, will create a lake extending almost nine miles westward to Carrigadrohid, while the lake behind the upper dam will extend a further eight miles to Drumcarra. In the former, land below the 165′ *contour will be affected, and in the latter, flooding will rise to the* 215′ *contour. In all a total of five and a half square miles* (3,500 *acres*) *will be directly affected by the scheme.*

When the project was initiated, the council of this society pressed strongly for an examination of any ancient structures which might be interfered with. Consequently, after a detailed survey of the reservoir basins had been made, the following monuments were investigated: Castle Inch, Carrigadrohid Castle, Inishleena Abbey, two standing stones at Carrigadrohid, a fulacht fiadh and a horizontal mill at Mashanaglass, a bullán at Macloneigh and a standing stone at Dunisky. Apart from these, no other monuments were observed in the area.

The Mashanaglass mill proved to be the most interesting of these structures and a full report on it is given below. It is hoped that it will be possible to publish the other sites in subsequent issues of the Journal—*Hon. Editor.*

This site, traditionally known as a holy well and locally called *Toberbaun*, is situated in a narrow steep-sided glen running east–west some one hundred yards from the eastern bank of the Sullane River two miles east of Macroom.[1] The glen floor slopes rather gently from east to west and is drained by a stream, which, even in the height of the 1955 summer's drought never ran dry. When the site was first visited in the spring of 1955 a considerable stream of water some three feet wide and over six inches deep flowed through the glen, the floor of which in the main was very marshy. This was especially true of the area immediately west of the site where the overflow from the 'well' had caused extensive waterlogging. Here, and to the east of the structure, the ground was thickly carpeted with marsh vegetation.

The stream, which traversed the glen, flowed past the 'well' at a distance of seven yards from its northern side and then disappeared underground at a point twenty-six yards to the west. From there it ran southwards in an underground channel for some fifty yards and finally swung westwards, once again in an open channel, to join the Sullane. In this way it flanked the southern end of a long narrow ploughed field in which could be distinguished an irregular meandering hollow running westwards from below the 'well' site to the river bank. This hollow was the natural original stream bed and the underground channel was obviously designed in modern times to draw water off the field.

[1] The exact location will be found on the 6″ O.S. Sheet, Cork, No. 71. N.14; W.23.2 cm. Td: Mashanaglass; Ph: Aghina; By: East Muskerry.

As the site has long been frequented as a holy well it is desirable here to describe its general appearance before excavation. Briefly, it consisted of a three-walled dry-stone structure of rectangular plan open to the west but enclosed in a mound on the other three sides. The north and south walls of dry-built stone, and the eastern wall of stone slabs on edge, rose some five feet above the enclosed pool which measured 12′ by 7′. The north and south walls, which were eight feet thick, were built of large sandstone slabs. The eastern face of the upper standing slab of the east wall protruded 1′ 9″ above the turf. Stone slabs taken from the side walls had been laid as stepping stones on the marshy ground outside the mouth of the 'well.'

The entire structure was overgrown with brambles and ivy, and an ash tree grew against the western face of the northern side wall. This tree greatly obstructed the 'well' and had been cut back where necessary from time to time in the past. Its roots had penetrated the adjoining parts of the structure and had caused an inward bulge to develop on the inner face of the northern wall. Religious objects and personal mementoes were affixed to the tree, while cups and other containers were placed on the stones in front of the 'well'.

The site was frequented by pilgrims up to recently, but the custom has been dying out for some years past. Previously large numbers of persons visited the 'well' and it is said locally that the principal visiting days were Easter Sunday, Palm Sunday and Whit Sunday.

The water from the 'well' was said to cure infirm children, one of the old customs being to immerse the infant in the water. Should the child turn pink it would live but if it became pale it would die! In common with other sites of this nature it was said that the water would not boil. O'Donovan, who visited the site in 1839, reported[2] that it was 'A remarkable spring well which is said to possess the power of either speedily killing or curing infirm children. This well is also said to have cured many diseases in adult persons. It appears to be very ancient being raised 4 feet high with large stones overgrown with ivy, and on the west side of it there is a small tree growing.'

During the excavation large numbers of white pebbles were found in the turf about the 'well'.[3] The workmen unhesitatingly identified these pebbles as 'Hail Mary Stones.' Apparently it had been the custom for pilgrims to deposit these mementoes at the site. The pebbles were also found in the back fill behind the side stones of a french drain which was uncovered over two feet below the turf to the west of the site and were also found beneath the roots of the ash tree mentioned above. These circumstances indicate that both the french drain and the ash tree post-date the commencement of the 'rounds' to the 'holy well'.

It was apparent that this massive structure built of sandstone slabs up to 9′ long by 4′ wide was not an ordinary well. The only analogous structure known to the writer was the Killogrone horizontal mill in Co.

[2] O.S. Name Books: Co. Cork; Ph. Aghina.

[3] The name 'Toberbaun' (*An Tobar Bán*—The White Well) seems to have been derived from this feature of the site.

The wheel-house, from the west, during clearance of superficial debris

The wheel-house floor, from above, showing the bridge (the diagonal plank) in position

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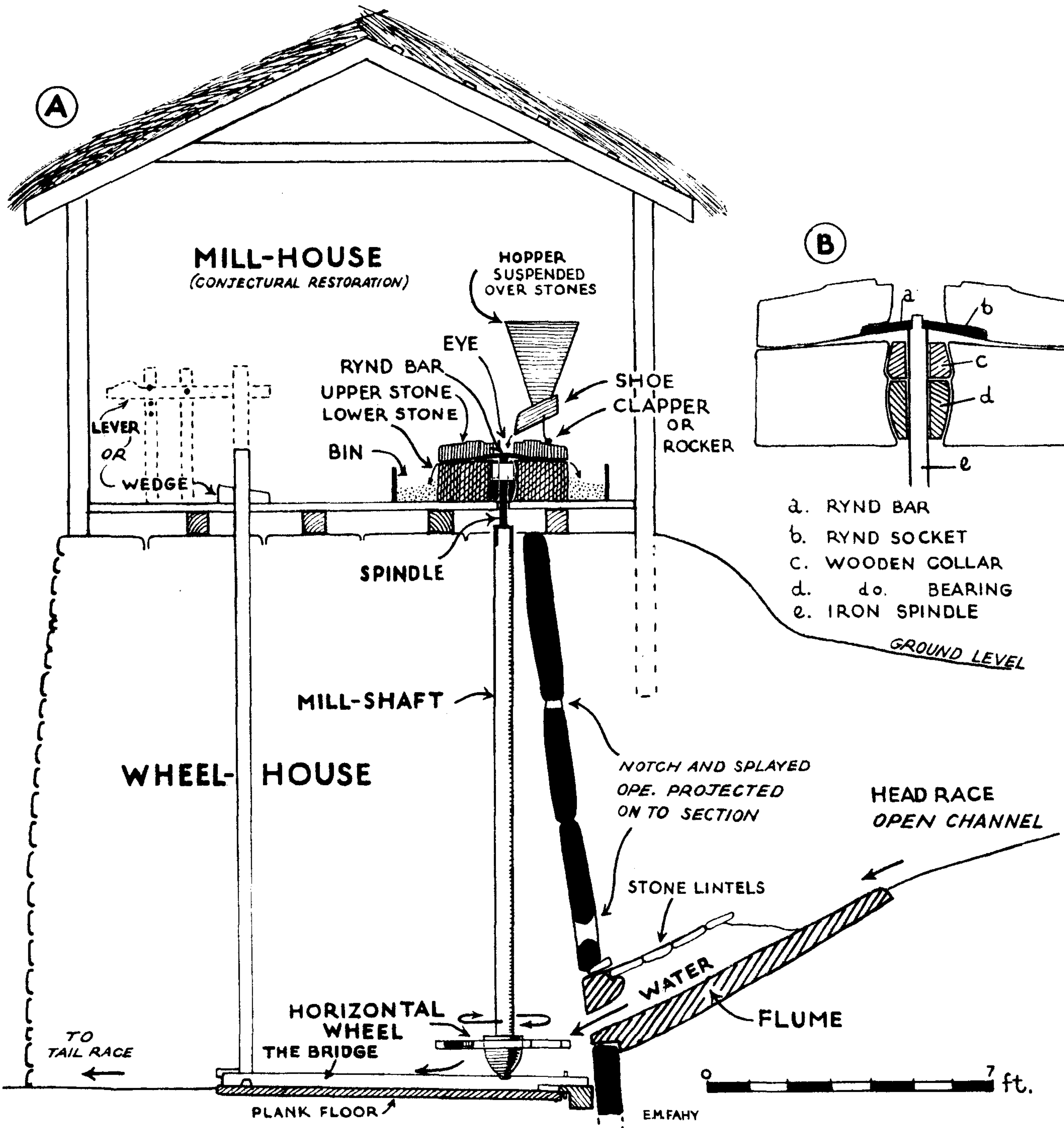


Fig. 2. Conjectural restoration of the Mashanaglass horizontal mill

Kerry. The similarity between the sites was sufficient to indicate that Toberbaun was also the wheel-house of a horizontal mill. This conclusion was further strengthened by the fact that an obviously artificial causeway-like ridge extended from the mound at the back of the 'well' to the southern side of the glen. This bank could have been a built causeway leading to the working floor of the mill. Some twenty-five yards further up the glen the slope had been levelled to form a large platform, the northern side of which showed traces of dry-stone walling. There was no superficial indication of either head or tail-race channels, but if such had existed the adjacent stream would have provided motive power for a mill.

Excavation revealed that *Toberbaun* was, indeed, the wheel-house of a horizontal mill. The stream which traversed the glen had been ponded behind an earthen dam, with stone revetments, in order to provide the quantity of water necessary to work the mill. The dam originally extended across the floor of the glen some fifty-five yards east of the mill, and was provided with a narrow water channel which, no doubt, was equipped with a regulating sluice. The water was led from the sluice through an artificial head-race into the upper end of a sloping wooden flume buried in the ground immediately behind the wheel-house. The lower end of the flume was set into an aperture in the rear of the wheel-house, and the water, which developed velocity as it ran through the sloping flume, played, in the form of a jet, upon the left side of the horizontal water-wheel and set it in motion. A vertical wooden shaft affixed to the wheel transferred (without intermediate gearing) the clockwise rotary motion of the wheel to the upper one of a pair of mill-stones placed on the floor overhead.

The adjustment of the gap between the mill-stones was controlled by raising or lowering the wheel and shaft by means of a horizontal lever on which the water-wheel rested. The spent water was led away from the wheel-house through an artificial tail-race which discharged into the natural stream bed at a point lower down the glen.

The ridge extending from the wheel-house to the southern side of the glen proved to be an artificial causeway designed to give easy access to the floor of the mill-house proper. On the southern side of the glen, also, were what appeared to be the ruins of the flue of a grain drying kiln.

The mechanism of the mill and the general lay-out of the site will be readily understood by reference to figures 1 and 2. The special interest of the site is that it constitutes the most complete horizontal mill yet excavated in Ireland, and that the evidence therefrom adds considerably to our knowledge of a type of mill which, in all probability, has been in use in Ireland since early Christian times.

It is proposed to describe the structure under the following heads: the dam, the head-race, the flume, the wheel-house, the tail-race, the causeway and the grain drying kiln.

THE EXCAVATION

The Dam (fig. 3, A, B and C)

The presence of the dam was indicated by a slight mound running north and south across the floor of the glen some fifty-five yards east of the wheel-house. Excavation revealed that the dam originally consisted of two earthen banks with dry-stone revetments. A water-channel, 14′ long by 1′ 4″ wide, passed through it from east to west. The southern arm of the dam, 21′ long by 14′ wide, was well preserved to a maximum height of 3′ 9″, but the northern arm was almost completely destroyed. Only the stone revetment, flanking the water channel and backed by a mound of earth, remained in position. The rest of this northern arm was eroded away by the stream, the present bed of which lay 33′ to the north.

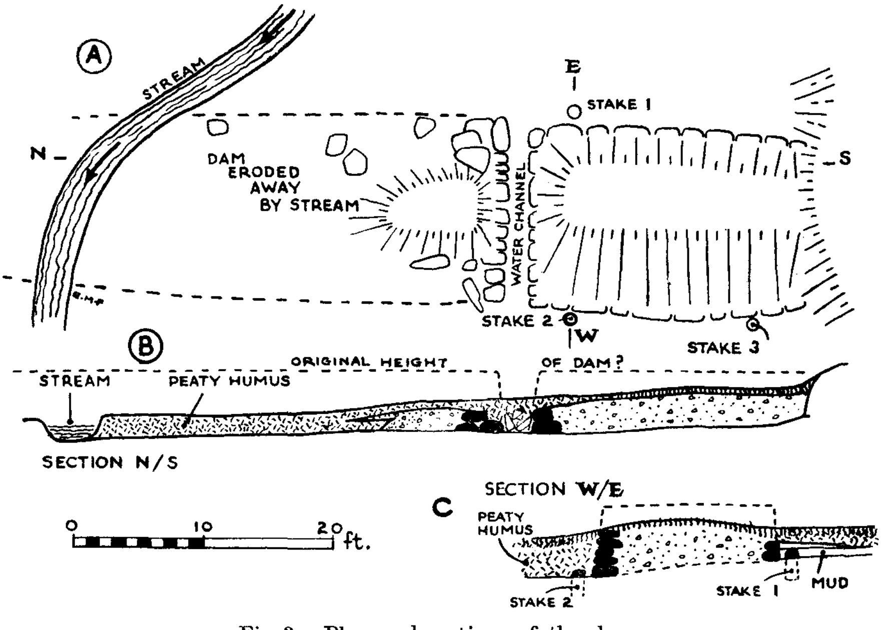


Fig 3. Plan and sections of the dam

Three substantial wooden stakes (1, 2 and 3, fig. 3, A) were set in the ground about the southern arm of the dam. Two of them stood immediately in front of the western face of the structure, while the third was 8″ from the eastern face. All of the stakes were about 12″ in diameter and were set deeply into the ground. None of them protruded more than 6″ above the foundations of the revetment walls. The ground around the northern arm of the dam was examined for post holes but none were found. No traces of the sluice gate itself survived.

The evidence obtained indicated that the upper parts of the revetment walls of the channel through the dam had collapsed into it after the abandonment of the site. The stream, thus choked, must have overflowed the northern arm and gradually eroded it away, so that, no trace remained of the original overflow channel which must have existed on this side of the dam. It will be seen from the section (fig. 3, B) that the entire earthern core of the northern arm of the dam had been swept away by the stream.

The Head-race (fig 1)

As previously pointed out there were no superficial indications of either head or tail-race channels. However, a series of six cuttings in the floor of the glen established the exact course and nature of the head-race channel. It was 150′ long, 2′ 6″ wide and 1′ 2″ to 2′ 10″ deep, was dug into the gravel bed of the glen and followed a slightly curving downhill course from the dam to the wheel-house. The stratification of the cuttings clearly showed that after the channel had become choked with mud and silt it had been sealed down beneath a growth of over 12″ of peaty matter which completely obliterated all signs of the original channel.

The Flume (fig 4)

Excavation of the area immediately east of the wheel-house revealed an 8′ long wooden flume set at an angle of 30 degrees in the ground. Its lower end, which was penetrated by an orifice, was set into an aperture in the rear wall of the wheel-house. The flume was of rectangular section and its upper or open side had originally been roofed over with sandstone slabs, but these, in the course of time, had collapsed into it and were embedded in the gravelly silt which choked it. A clearly marked channel of U-shaped section, choked, like the flume, with gravel and mud formed the junction between the head-race and the flume.

A total depth of 9′ 4″ of soil overlay the flume (see fig. 4). This consisted 9″ of surface humus containing white quartz pebbles ('Hail Mary Stones'); 4′ of red-brown charcoal flecked earth in the upper level of which was a posthole 2′ 2″ in diameter and 2′ deep narrowing to 6″ in diameter at its base; and finally 4′ 3″ of fine textured charcoal flecked blue-grey clay. This latter deposit extended in an unbroken mass all round the flume and backwards and upwards for a distance of 7′ 6″ beyond the upper end of the flume. The U-shaped junction channel described above was cut into this mass of blue-grey clay.

The Wheel-house (fig. 4)

As will be seen from fig. 4, section W/E, the floor of the wheel-house was almost 7′ 6″ below modern water level within the structure. When the surface water was drained off, a tangled mass of twigs and other rubbish was exposed. A depth of 2′ of this material was raked out and dumped clear of the entrance. A 1′ 9″ thick layer of mud was then encountered but its removal was hindered by the constant inflow of ground water through the side walls. It was necessary to bail and pump the water from the site during excavation. This enabled the layer of compacted mud to be excavated, and during its removal the neck of an eighteenth century glass bottle was found embedded in the lowest level of the deposit. The upper end of a wooden beam lying at a steep angle was also uncovered. Its lower end was embedded in a 1′ 6″ deep layer of gravel and mud which lay below. Other wooden objects were found in this layer, and two wooden stakes were found protruding into it from below. Finally a 6″ deep layer of putty-like mud overlay the entire area of the wheel-house floor.

Removal of the layer of mud revealed the plank covered floor of the wheel-house as well as the remains of the water-wheel. The nave of the latter was trapped beneath the collapse from the wheel-house walls which choked the western area of the structure. This dump of collapse was, in the main, allowed to remain in position during the excavation of the wheel-house as it formed a barrier which prevented the fill of the tail-race from backsliding on to the excavated area.

The drystone side walls of the wheel-house (fig. 4) existed to a height of 12′ 3″, were 8′ thick, and were, respectively north and south, 13′ 6″ and 12′ long. Both walls were built of sandstone slabs, some of which were over 6′ long and 6″ thick. Several slabs showed chisel or crowbar marks on their quarried edges. They were laid in courses which dipped outwards through the body of the walls. Both walls obviously splayed outwards by about 6″ from base to top originally, but some distortion had taken place, particularly in the north wall where the roots of the ash tree had caused a bulge to develop some 5′ above floor level (fig. 4, elevation). A lesser bulge had developed midway up the southern wall. Close examination of the inner faces of the walls failed to reveal any joist sockets so we may conclude that the mill floor spanned the walls at a higher level.

The rear, or eastern, wall of the wheel-house was built of four slabs standing, one on the other, on edge (fig. 4). These slabs extended across the full width of the wheel-house and were bedded against the eastern ends of the side walls (fig. 4, elevation). The rear wall sloped inwards from base to top, the overhang being 1′ 8″. Slab A was 9′ long, 8″ thick and 4′ 2″ high. Slabs B, C and D were similar to slab A in length and thickness, but varied in height as follows: B, 2′ 10″; C, 4′ 8″; D, 2′ 3″. This latter slab was sunk a further undetermined distance into the ground.

The end of the flume was housed in a rectangular opening 2′ 4″ wide by 1′ 10″ high cut partly out of slabs C and D, and the sides of the opening were splayed outwards towards the flume. The face of the flume measured 1′ 8″ high by 1′ 11″ wide. Its base was rabbeted so that it locked against the sill of the cut in slab D (fig. 4, section W/E). The space between the other three sides of the flume and the top and sides of the housing was packed with stones. The stones above the top had been inserted there as wedges, while those about the sides were merely a packing which prevented the blue-grey clay in which the flume was set from silting into the wheel-house. The orifice of the flume was 14½″ above the surface of balk A, and was 5″ high by 7″ wide. It was centred 2′ 2″ from the southern side wall, and was thus 1′ south of the east-west axis of the wheel-house (fig. 4, plan and elevation).

Two other features of the rear wall must be noted. These are the rectangular notch in the upper edge of slab B, and the splayed circular opening in slab C (fig. 4, section and elevation). The 3″ by 2″ notch was roofed by the bottom edge of slab A. The rectangular socket so formed showed no sign of wear. It was probably meant to house some horizontal member of wood or metal, which, we do not know. If the notch were in line with the mill-shaft we could suggest that it held a guide to steady the shaft. However, it was centred 7½″ from the central axis of the shaft, and unless our supposed guide were L-shaped it could not have had any contact with the shaft. Because of the wear it would have caused it would not seem desirable to have a metal band loosely encircling the shaft unless as a safety precaution in case the shaft kicked out of position. One might suggest that the notch housed the tenon of a large wooden horizontal beam, but there seems to have been no structural need for such a beam.

The splayed circular opening penetrated slab C, and its inner surface showed no sign of wear. It opened obliquely towards the floor of the wheel-house. Its design made it most unsuitable to house a wooden beam, movable or otherwise. Since the perforation was splayed on both inner and outer faces it is clear that it was cut in the slab before the latter was placed in position in the rear wall. Four small stones were placed outside the perforation, apparently to prevent the clay backing from silting into the wheel-house in any quantity.

It is possible, though unlikely, that the slab was at first intended to be used as a flag for the mill floor and that the perforation would have housed the spindle of the mill-shaft. A change in plans would then have seen the slab transferred to its final resting place in the back wall. Such a theory is not readily acceptable, and it would seem that the splayed perforation did have some special significance. There is, however, insufficient comparative material available to suggest that this feature was a normal occurrence on other sites, so that for the present at least it must remain unexplained.

The Floor (fig. 4, plan and pl. I)

The wheel-house floor comprised five oaken planks, B to F on plan, laid side by side parallel to the long axis of the structure. Their upper surfaces were smooth and their edges quite straight. They fitted closely together, and their eastern ends were inserted under a protruding ledge on the upper surface of balk A which lay transversely at the eastern end of the wheel-house. Three of the planks (D, E and F) were of almost uniform dimensions—8′ 3″ long, about 1′ wide and 3½″ thick. Their western ends were skew shaped and showed axe cuts. Plank C was shorter and narrower than the others, and had a square cut western end. It was 3½″ thick. Plank B was larger than the others. It was 9′ 7″ long by 2′ 6″ wide and 3½″ thick. A wooden plank 8′ 11″ long, 10″ wide and 4″ thick lay diagonally across the wheel-house floor. The underside of the eastern end of the plank had been cut away so that a 15″ long tongue remained. This tongue overlapped balk A and was connected thereto by a wooden peg which passed through a 1½″ hole in the tongue and a similar hole in the protruding ledge on balk A.

We can readily explain certain features of the wheel-house floor. The diagonal beam (plank A on plan, fig. 4) was the horizontal lever, or bridge, upon which the water-wheel spun and by which the wheel and shaft were elevated when adjustments were to be made to the mill-stones. Holes *a* and *b* in balk A were probably trial holes made while the millwright was finding the most suitable lie for plank A. Hole *d* in balk A held an oak peg and wedge (fig. 9, J) when found. This peg and peg *b* (fig. 9, L) in plank B prevented plank A from moving out of position. Mortice *a* in plank B must have held a substantial vertical peg, now gone, which limited the backward movement of plank A. Such precautions were necessary to counteract any lateral swing which might develop in plank A once its western end was raised clear of the floor during the process of setting the gap between the mill-stones.

Mortice *b* ($4\frac{3}{4}''$ by $4''$), and rabbets *a* and *g* in plank A must be considered together. Mortice *b* obviously housed the lower end of the vertical shaft used to raise or lower plank A. Rabbets *a* and *g* must have accommodated wedges which secured the vertical shaft into position.

Hollows *c*, *d* and *e* on plank A must be associated with the positioning of the wheel, which spun in one of them. In experiments with a scale model it was found that hollow *d* was the most suitable one for this purpose.

The use of stake G, and sockets *f* and *g* in balk A, holes *c* to *f* in plank B, and mortices *a*, *a* in planks D and F cannot readily be explained.

As will be seen (fig. 4, elevation and plan) stake G was tenoned into chase *e* immediately in front of the southern side of the flume housing. It is a substantial alder stake of subrectangular section, $10\frac{3}{4}''$ high, $6''$ by $4''$ at its base narrowing to a $4''$ by $2\frac{1}{4}''$ flat top which is just below the level of the base of the flume. It is obvious that this stake was meant to withstand a considerable amount of use, and no small amount of care was taken to mortice it into position at this point. Obviously it was not meant as a stop in front of the flume as the latter was securely held in position by the step on its underside resting against the rear of the slab D. The sturdiness of the stake, coupled with its flat top, suggests that some beam or plank may have rested on it; there are no marks which would suggest that the stake was morticed into such a plank.

During the series of experiments conducted with the model various arrangements of beams were tried out in the sockets and mortices discussed above, but no clue could be gained as to their original use. Speculation in that connection is hampered by the very meagre knowledge available regarding the finer details of the known horizontal mills.

Plank A (fig. 4, plan and fig. 5)

The overall dimensions of plank A have been given above. Its eastern end, which was skew cut, had a $2''$ deep $15''$ long segment cut from its underside forming a tongue or tenon which overlapped balk A immediately below the rectangular opening which housed the end of the flume in the rear wall. The overlapping tenon of plank A was penetrated by a $1\frac{1}{2}''$ circular hole (f) which exactly coincided with a similar hole in balk A (fig. 5), and which held a wooden peg (fig. 9, M) when found.

Three hollows, discussed above, were cut into the surface of the plank $1'\ 8''$ to $2'\ 10''$ from its eastern end (fig. 4, plan and fig. 5, F). Hollow *c* was almost $4''$ long, $3\frac{1}{2}''$ wide and $\frac{1}{2}''$ deep; its sides were splayed and its floor was almost flat. Hollow *d* was sub-rectangular in plan, $2\frac{1}{2}''$ long by $2\frac{3}{4}''$ wide and $\frac{3}{4}''$ deep. Its sides sloped steeply and its floor was almost flat. The northern side of the hollow was more irregular than the other three sides—it bulged outwards by almost $\frac{1}{2}''$ midway along its length. The third hollow, *d*, was almost kidney shaped in plan, its sides measuring respectively 4, 5 and 6 inches long. It was $1\frac{1}{2}''$ deep. The western end of plank A was penetrated by a $4\frac{3}{4}''$ by $4''$ vertical mortice, *b*, which was transversely intersected by a $\frac{3}{4}''$ wide, $2''$ high rabbet, *g*, cut into the underside of the plank. A V-shaped groove, *a*, was cut from the upper surface of the plank between the western edge of mortice *b* and the end of the plank.

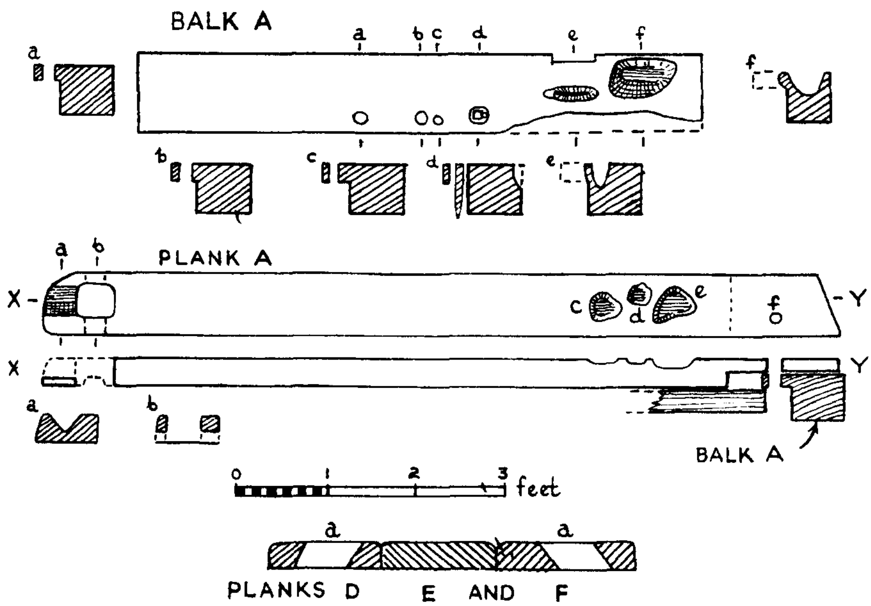


Fig 5.

Balk A (fig. 4, plan and fig. 5)

Balk A lay across the eastern end of the wheel-house and was almost in contact with the base of that wall. It measured 6′ 4″ long and was 7″ square with the exception of a 2″ thick, $3\frac{1}{2}''$ wide nosing which ran the full length of the western upper edge of the balk. We have previously seen that the ends of the floor boards were partly overlapped by this nosing, but they did not butt against the main balk of wood. The surface of the balk was penetrated by four holes (*a* to *d*), two hollows (*f* and *g*) and one mortice (*e*). Holes *a* to *d* were cut through the nosing of the balk. Holes *a* to *c* were roughly cylindrical and were respectively 2″, 2″ and 1″ in diameter. Holes *b* and *c* were covered by the tenon of plank A, and hole *c* coincided with hole *f* in that tenon. Hole *d* was almost rectangular in plan with rounded corners, and measured $3\frac{1}{4}''$ by 3″. It held a tapered peg of rectangular section (fig. 9, J) which was wedged into position with a short stick of circular section. Hollow *g* was 7″ long, $2\frac{1}{4}''$ wide and 3″ deep, its long axis being parallel with that of the balk. The sides of the hollow were curved, and tapered to its base so that its sections were of a rounded V shape. Hollow *f* was oval on three sides, but was straight on its eastern side which also had an almost vertical profile. The other three sides of the hollow sloped downwards to its base and showed axe marks. Chase *e* was cut into the eastern edge of the balk to hold the tenon of stake G.

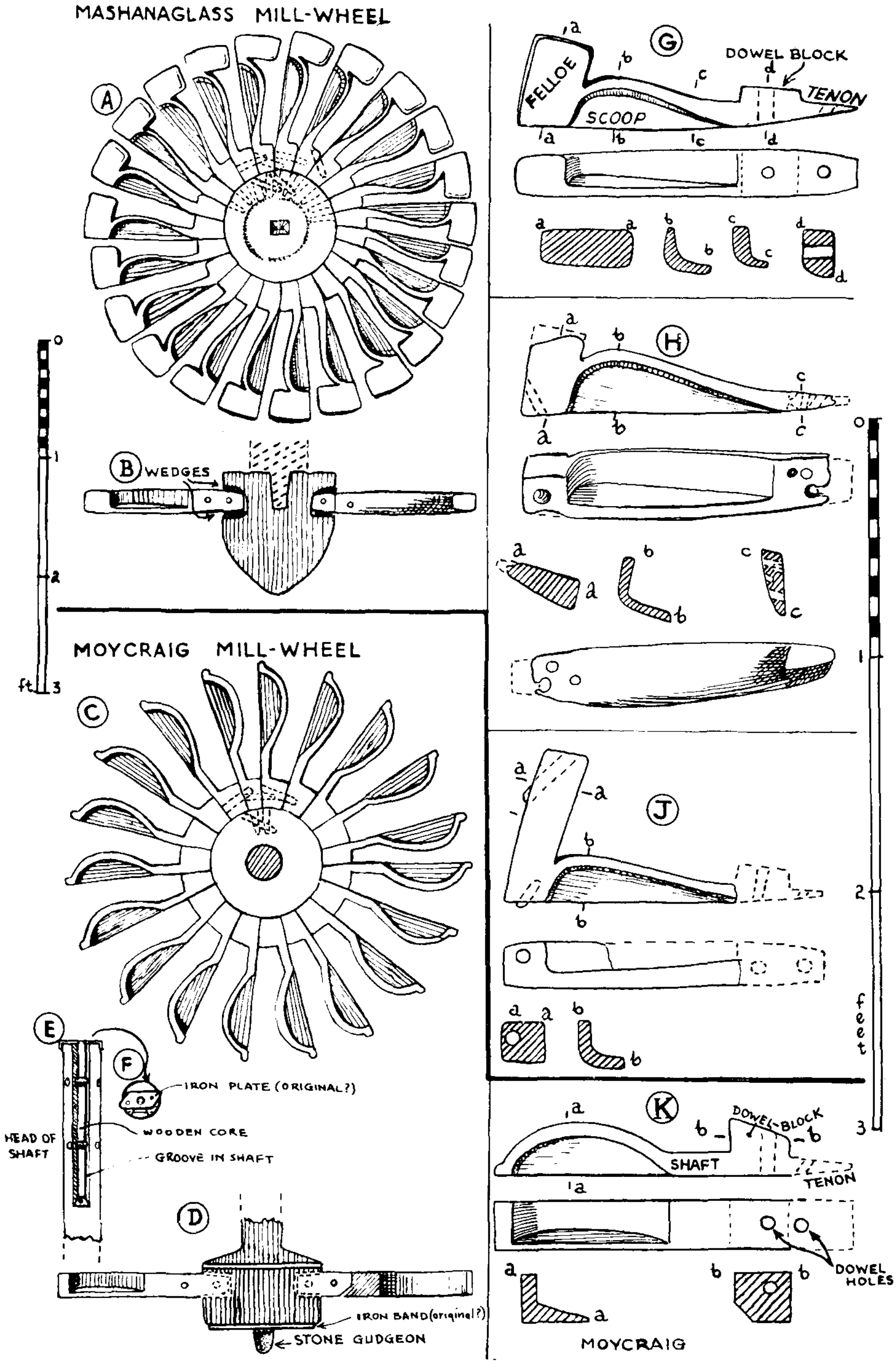
The Water-wheel (fig. 6, A and B and pl. II)

Originally the water-wheel consisted of an oaken hub or nave into which twenty-three scoop paddles had been morticed, and locked into position with dowels. When found, however, no complete paddle remained attached to the nave. After the abandonment of the mill the wheel had apparently been left lying on its side on the wheel-house floor. In this position at least half of its total number of scoops would have protruded from the water, and these in the course of time apparently decayed away. Eventually too the weight of the nave would have become too much for the scoops, which, radiating like spokes, kept it propped up until weakened by decay. The scoops then snapped, and were found criss-crossed and jumbled beside the nave. In all, fragments of eleven scoops were found.

The Nave

The nave was $11\frac{1}{2}''$ in diameter and $12\frac{1}{2}''$ high. It is probable that the latter measurements would have been slightly greater originally but decay of its point has shortened it somewhat. It was cut from a cylindrical log, and trimmed to a conical shape so that it resembled an extra large spinning-top. A mortice, $2''$ by $1\frac{5}{8}''$ by $3\frac{1}{2}''$ deep, narrowing to $1\frac{1}{4}''$ by $\frac{1}{2}''$ at its base, was cut into the centre of the upper surface. This mortice would have accommodated the wedge shaped tenon of the vertical mill-shaft. A shallow depression $\frac{3}{4}''$ wide concentric with the mortice clearly indicated the resting place of the shaft on the surface of the nave (fig. 6 A and B), so that it is possible to state that the shaft was $6''$ in diameter. Experiments with the scale model showed that when the wheel was spinning at its normal working speed, a rotating collar of water remained permanently lodged around the base of the mill-shaft. This was rather surprising as one would have expected the centrifugal reaction to throw the water clear. At any rate, it may be that it was this 'collar' of water (which would normally contain some grit) that caused the groove to be worn on the top of the hub. It is therefore unlikely that the shaft was greater than $6''$ in diameter.

The twenty-three vertical mortices of the paddle tenons encircled the nave in a horizontal band approximately $1\frac{1}{8}''$ below its top surafce. The mortices were not quite radially set; they were off radius by a few degrees. The mortices averaged $\frac{3}{4}''$ to $1''$ in width, $3\frac{3}{8}''$ to $4''$ in height and $2\frac{1}{2}''$ to $3''$ in depth. The partitions between the mortices were $\frac{1}{2}''$ thick where best preserved, and showed holes where they had been pierced for dowelling; two dowels were actually in position in the hub holding the stubs of the paddle tenons. The slight off-vertical lie of the mortices was conditioned by the grain of the wood. There was no evidence of a stone or iron gudgeon nor was there any mortice which would have accommodated such a gudgeon in the apex of the hub.



MASHANAGLASS MILL-WHEEL
A
B
WEDGES
MOYCRAIG MILL-WHEEL
C
D
E
F
IRON PLATE (ORIGINAL?)
WOODEN CORE
HEAD OF SHAFT
GROOVE IN SHAFT
IRON BAND (original?)
STONE GUDGEON
G
FELLOE
SCOOP
DOWEL BLOCK
TENON
H
J
K
DOWEL-BLOCK
SHAFT
TENON
DOWEL HOLES
MOYCRAIG
feet
ft

Fig. 6

The Paddles (fig. 6, G, H and J)

In all, fragments of eleven paddles were found. Ten were with the nave, and one was found several feet away on the wheel-house floor. All of the paddles were of the scooped or dished variety, and each was cut from a single piece of wood. Two of the paddles differed in detail from the others.

Each of nine paddles may be said to have consisted of four distinct parts; tenon, dowel-block, scoop and 'felloe.' In no case was the tenon complete, but fragments of two were found dowelled into mortices in the hub. The average overall length of each paddle was 1′ 5¼″, allocated as follows: tenon 2⅝″, dowel-block 3⅜″, scoop 8¾″, and rim segment or 'felloe' 2½″. These are average measurements taken along the length of the paddle on its open face, that is, the side of the paddle on which the water jet impinged. While this face of the paddle was almost straight in outline the back of the paddle was not. The rim 'felloes' which were 4¼″ to 4½″ long protruded over 2″ beyond the backs of the scoops, but did not touch one another, so that the wheel did not have a continuous rim. A block of wood 3″ long protruded a maximum distance of ⅞″ from the back of each shaft. These blocks on the paddle shafts were trimmed in such a fashion that when the paddles were assembled in the hub each block contacted the face of the shaft of the preceding paddle. Dowels penetrated the dowel-blocks so that the paddles were rigidly united outside the periphery of the hub. The tenons of the paddles were 2⅝″ long, 2¼″ high and ⅞″ thick, but narrowed to 1½″ high by ¼″ thick at their extremities. The tenons were thus smaller than the vertical dimensions of the nave mortices, but were wedged above and below where necessary to ensure a perfectly rigid fitting. The dowels average 3″ in length by ⅝″ thick narrowing to ⅜″ at their points. Each dowel penetrated at least two and sometimes three tenons. Thus most paddles were triple dowelled within the nave, and as indicated above, all were also dowelled together immediately outside the periphery of the nave.

The scoops were 1¾″ deep at their inner ends, but were only 1½″ deep at their outer extremities, where too the scoops attained their maximum width of 2″. When the paddles were in position their sloping floors ensured that the water did not lodge on them (fig. 6, G, *b*, *b*). Furthermore, the back of each scoop was carefully rounded, or streamlined, so that it offered no resistance to the dead water falling from the preceding scoop (fig. 6, G section *b*, *b*).

One paddle (fig. 6, J) was found several feet away from the hub on the wheel-house floor. The scoop section of this paddle was slightly smaller than the others, but the 'felloe' was 8″ long—that is, almost twice as long as those on the other scoops—and was pierced diagonally by two dowel holes. The dowels were in position when found.

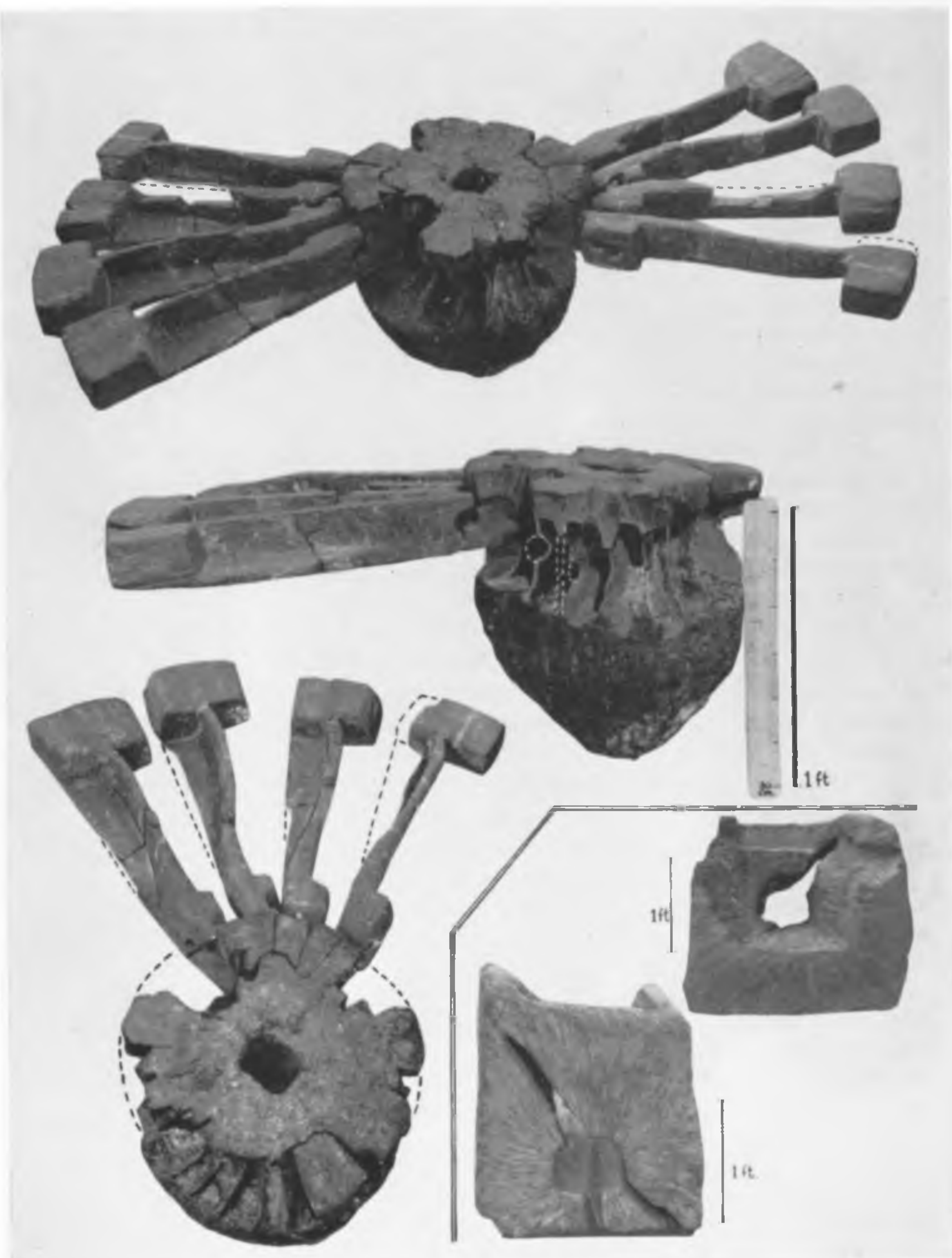
A second paddle (fig. 6, H) was in general similar to the others, but it did not have the protruding block on the back of its shaft. Its scoop was 10½″ long. The shaft and tenon were cut in such a fashion that when the paddle was inserted in the hub its scoop section was tilted downwards (fig. 6, H, b). The 'felloe' of this paddle was also pierced diagonally to take a dowel, but in this instance the dowel was not in position. The shaft-tenon of the paddle was fully penetrated by two dowel holes, and partly penetrated by two others.

It is significant that both of the above paddles were apparently dowelled to other paddles through their 'felloes.' We have seen that the normal paddles were dowelled together only at their dowel-blocks and tenons. Therefore we must conclude that both paddles were insecurely fixed at their tenon ends, and that the secondary dowelling was necessary in order to ensure that they remained in the wheel. This suggests that we are dealing with any one of three possibilities. In the first instance it is possible that having fixed twenty-one of the twenty-three paddles into the nave the mill-wright was compelled, by the limited working space remaining, to adopt a different technique for fixing the final pair of paddles into position. Thus it may be that our odd paddles could not have been secured into the nave as easily and as effectively as the others, and that the millwright was forced to take the added precaution of dowelling their 'felloes' to the next adjoining paddles. It is possible too, that the extra long 'felloe' on paddle J was found necessary in order to bridge an unexpectedly large gap between it and the first paddle inserted into the hub, paddle J being the last to be inserted.

The second possibility is that the odd paddles represent repairs to the original wheel. In that event paddle H, which has no protruding block on the back of its shaft, may be the work of a later millwright. Certainly, when it is fitted to the nave its scoop occupies a different angle to all the others. Finally, this and the other paddle may represent totally different wheels which had been in use at an earlier date, and the remains of which had been allowed to lie about the floor of the wheel-house.

Owing to the decayed condition of both paddles and nave it is not possible to assemble the wheel without first submitting it to a prolonged treatment of repair and preservation. Fig. 6 A and B show the wheel fully restored without introducing paddles H or J which are separately illustrated.

We have seen that the nave of the wheel shows no sign of ever having had a stone or metal gudgeon fixed into its base. The diagonal beam or bridge (plank A) was not fitted with a pivot stone or metal plate when found nor was any pivot stone found on the site. This negative evidence does not however preclude the possibility that a pivot stone was placed below the base of the nave. However, as there is no evidence of either pivot stone or gudgeon pin at Mashanaglass it is conceivable that the oaken nave did, in fact, spin directly in one of the hollows in plank A. As this plank was 4″ thick, and since both nave and plank were constantly wet, this arrangement could have given quite satisfactory service for a considerable length of time. Some of the older *vertical* mills are known to have had their horizontal oaken shafts working in oaken bearings. In situations where both shaft and bearing were continuously wetted, as by splashing in the case of an overshot wheel, no other form of lubrication was necessary and both shaft and bearings lasted indefinitely. On the other hand, where the wooden shaft was dry, i.e., in the case of an undershot wheel, the bearing was made of stone, and tallow or graphite had to be used as a lubricant.



The Mashanaglass water-wheel partly re-assembled.
Inset. Views of the flume showing, *above,* the interior looking towards the water orifice and, *below,* the outer face showing the diagonal split across the orifice.

In having a wooden nave and scoop paddles, the Mashanaglass water-wheel is similar to those from Moycraig [4] and other Irish sites as well as to those from Salonika, Comillas and Lampsaki, all of which will be referred to again. Unfortunately, published details of all, except the Moycraig wheel, are inadequate for purposes of really close comparison. It would appear, however, that all the other known hubs are either barrel-shaped or cylindrical with special gudgeon pins of either stone (Moycraig) or metal set into their undersides. The Mashanaglass hub was shaped like a spinning top, and did not have a gudgeon pin. There is so little of the apex of the hub missing that we should certainly find the socket of the gudgeon pin if had ever existed.

The Mashanaglass paddles show a refinement of design which places them in a class above the Moycraig wheel (fig. 6, C) in fact, we might suggest that they represent a more virile craftsmanship than that exhibited in the latter example. Apart from the subtle lines of the Mashanaglass paddles one of the finer points of difference between the wheels is the deliberate streamlining of the backs of the Mashanaglass scoops. The Moycraig scoops have vertical backs, (fig. 6, K). The 'felloes' on the tips of the Mashanaglass paddles do not occur on the Moycraig wheel. These substantial blocks of wood perhaps served a twofold purpose ; firstly, the outer extremity of the paddle was thereby given greater solidity, and secondly, the weight of the blocks may have helped the wheel to develop a smoother motion, flywheel fashion, when it rotated. There is no evidence of similar blocks on any other Irish water-wheel.

In size and general dimensions the Moycraig and Mashanaglass wheels are, indeed, remarkably similar :

		Mashanaglass	*Moycraig*
Overall diam.	....	40½″	41½″
Nave diam	....	11½″	12″
Nave height	....	12½″	10½″ (incl gudgeon pin of 2½″)
Length of Paddle	....	14½″	15″
Length of scoop	....	8 to 9″	8″
Depth of scoop	....	1½″	1½″
Width of scoop	....	1¾″ to 2″	2″
Number of scoops	....	23	19

The only other excavated Irish wheels of which we have fairly complete measurements are those which were found at Banagher and Milverton. The former had 'scoop like pieces each about 14″ long, and perforated at the extremity, dished at one end, and having a projecting ledge or step at the back, near the perforation' [5]. In size and general design the Banagher scoops were, then, similar to the Moycraig and Mashanaglass paddles. The paddles were 'each about 2′ by 14″, scooped out of a solid piece of oak rounded

[4] *U.J.A.*, 4, (1856), pp. 6–15

[5] Wilde : *Catalogue of the Antiquities in the Museum of the Royal Irish Academy*, Dublin, 1857, pp. 207, 208

at the end.'[6] Eight of these paddles were morticed into a mill-shaft. This wheel seems to have been a more cumbersone product than the others. Finally, MacAdam, who was familiar with the details of the Moycraig wheel reported the finding of 'portions of a precisely similar wheel to Moycraig' at Killinchy.[7] Two modern water-wheels, described by Knox (see below) are in principle similar to the foregoing examples, but it will be seen that they were the products of a very decadent craftsmanship, and are not to be classed with the earlier wheels.

The Flume (fig. 7, A to E and pl. II, inset)

The flume was cut from an 8′ long oak log. It was dressed to an external rectangular outline. Internally it was hollowed out to carry water and the final 15″ of its length was left solid except for a subrectangular orifice, 5″ by 7″, running through to the end of the log. The body of the flume was 1′ 10″ square externally, and was internally 1′ 3″ deep, by 9″ wide at floor level. The walls of the flume were preserved to their full height of 1′ 3″ for a distance of almost 3′ from the orifice face; thereafter they broke down to floor level some 2′ from the opposite end of the flume. The plane of the orifice face of the flume made an angle of 16° with the long axis of the flume.

The flume, as we have seen, was set in a packing of blue grey clay, and had a series of stone slabs roofing its upper, or open, side. Of the other sixteen flumes found in Ireland only three (Inchidoney, Knockrour and Kilmagar) had wooden lids. It is possible that the remaining thirteen were roofed with stone slabs as at Mashanaglass. The slabs, if they had collapsed into the flumes, would not have been recognised as such when accidentally encountered. Whether that be so or not the available evidence tends to show that the wooden-lidded flume was the exception rather than the rule.

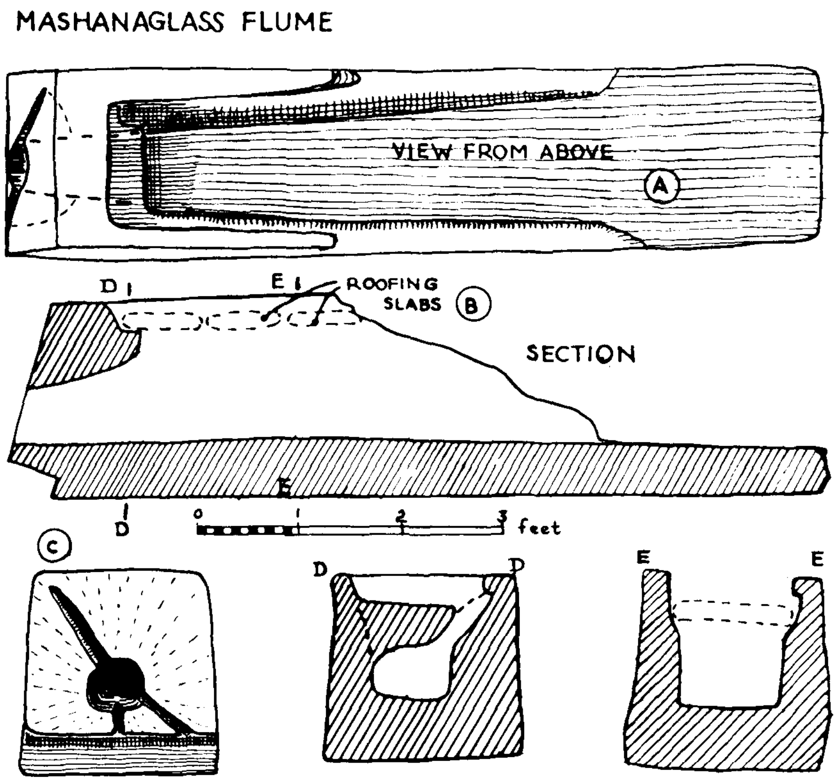
The diagonal fissure in the face of the flume must next be considered. This extended across the orifice from the top left hand corner to the bottom right hand corner (see fig. 7, C). The upper arm of the fissure was 2½″ wide at the edge of the orifice and tapered away to a slightly rounded apex. It extended backwards into the body of the flume and opened into the water channel of the same. It was smoothed by water action. The lower arm extended a short distance only into the wood, but swung downward to break through the bottom of the flume. This lower arm was far more like an accidental split than its counterpart on the upper side of the orifice though, indeed, its inner surfaces were also scoured and smoothed by water action.

Either the fissure was a deliberate cut or an accidental split and arguments can be advanced in favour of both interpretations. One cannot base any consideration on tool marks as none were preserved on either the inner face of the flume or in the fissure—in fact, both presented identically smooth surfaces as if equally subjected to the scouring action of the water.

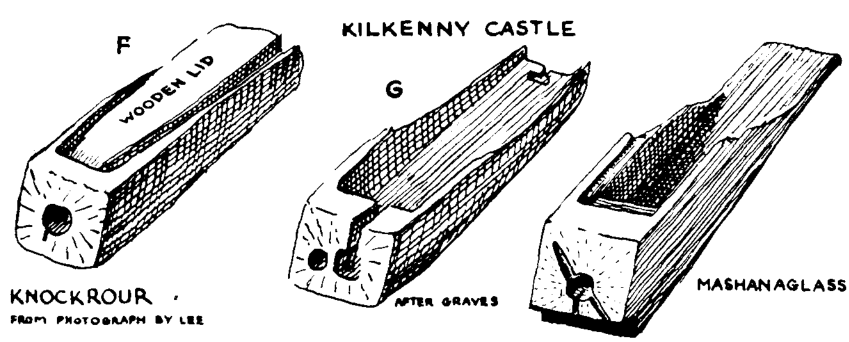
If we regard the fissure as being a deliberate feature it could have served one of two purposes. Firstly, if and when the flume flowed excessively full

[6] *J.R.S.A.I.*, V (1858–1859), p. 252

[7] MacAdam: *U.J.A.*, IV (1856), p. 6



MASHANAGLASS FLUME
VIEW FROM ABOVE
A
D
E
ROOFING SLABS
B
SECTION
E
D
0
1
2
3
feet
C
D
D
E
E



F
WOODEN LID
KILKENNY CASTLE
G
KNOCKROUR
FROM PHOTOGRAPH BY LEE
AFTER GRAVES
MASHANAGLASS

Fig. 7

[To face page 27

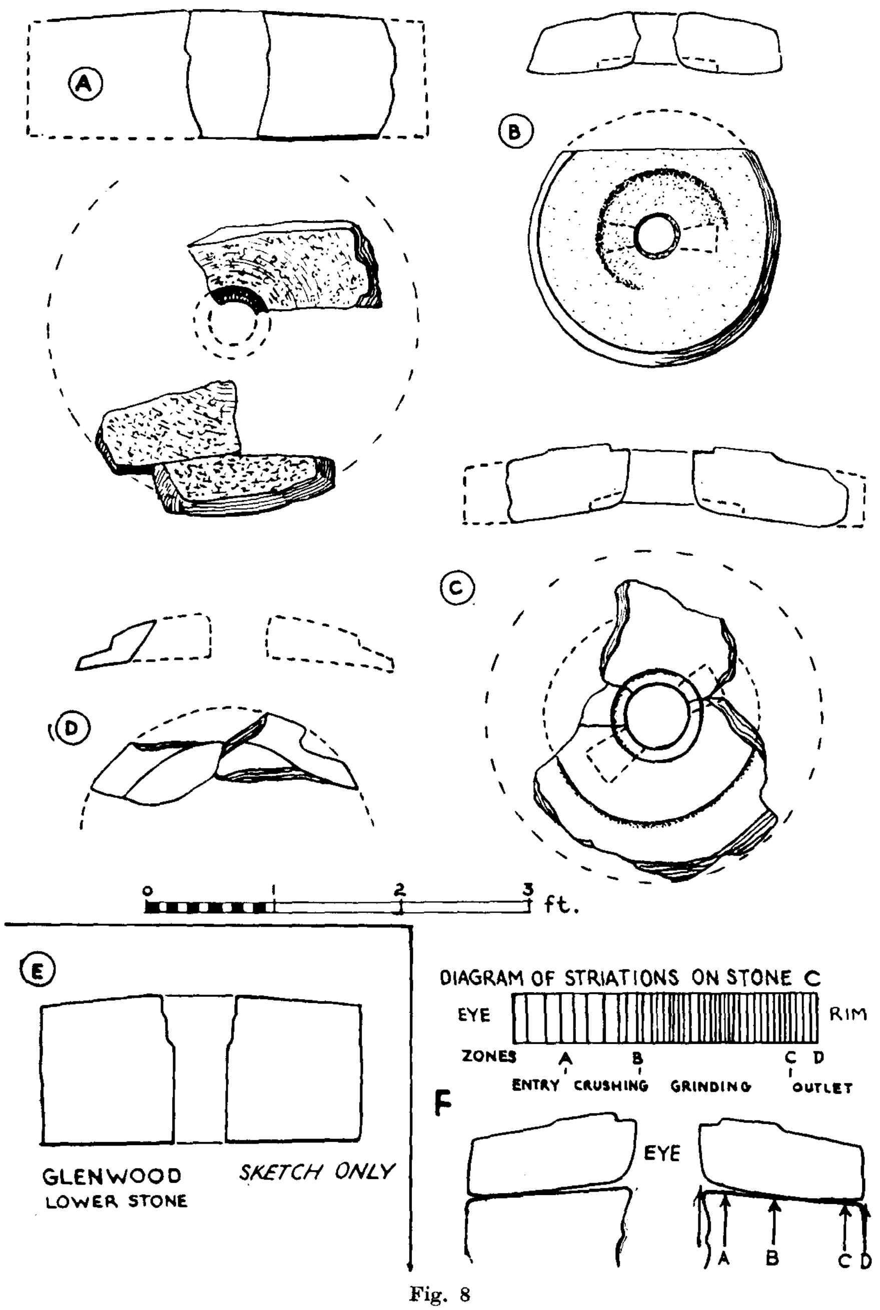


Fig. 8

it would have caused the development of a 'winged' jet. This would have played more extensively on the paddles which would thus in all probability have derived more power from the water supply.

Secondly, though it seems unlikely, it might have accommodated a butterfly valve. Such a valve could have been used either to deflect the jet from the wheel altogether, or to reduce the volume of the jet or, finally, to stop the jet. Which, if any, of these purposes it may have served is very debatable. Certainly, it would have been far more convenient and normal to control the water supply at the dam. It is unlikely therefore that a butterfly valve was used at all.

Even if the fissure were accidental, its water worn surfaces indicate that it existed in the flume during the use of the mill. The winged jet may therefore have been developed fortuitously rather than deliberately.

No other flume of which we possess detailed knowledge displays a diagonal fissure similar to that at Mashanaglass. The Kilkenny Castle flume (fig. 7, G) had two separate orifices. One was 6″ by 8″ oval, and the other 9″ by 12″ subrectangular. The roof of the rectangular opening was intersected by a fissure a few inches wide which extended right through the upper part of the flume. This fissure seems to have been an accidental split.

The sloping face of the Mashanaglass flume is not just a residual feature of the tree felling operation, but a deliberately designed feature which ensured that when the flume was placed in its sloping position its face was in the same plane as that of the rear wall of the wheelhouse. Similar sloping faces are attested at Knockrour and Kilkenny Castle (fig. 7, F and G). At present there is no evidence that the underside of any other flume found in Ireland was stepped in the manner of the Mashanaglass flume.

The Mill-stones (fig. 8, A to D and pl. III)

The remains of the four mill-stones were uncovered on the site—three upper stones and one lower. Stones A and C were found on the bed of the tail-race and stone D came from the tail-race fill (see below), and stone B was found in the head-race fill.

Mill-stone B (fig. 8, B)

This upper mill-stone is made of coarse red sandstone, has two rynd sockets, and is striated from use. A segment some four inches wide is missing. The overall diameter of the stone is 2′ and it is $4\frac{3}{4}$″ thick. The upper surface is uneven, and it is partly encircled by a rudimentary hollow $\frac{3}{16}$″ deep, 2″ wide, and 2 to 3″ from the lip of the eye. The eye of the stone is $4\frac{1}{4}$″ in diameter at its lip, narrows to $3\frac{3}{4}$″ midway through the stone, and expands again to $4\frac{1}{2}$″ at its base. The eye is thus constricted by a low ridge at approximately half its depth, and expands rather asymmetrically to the upper and lower surfaces of the stone. The rynd sockets are dovetailed in shape, $3\frac{1}{2}$″ long, $2\frac{1}{4}$″ wide at the eye, expanding to 3″ wide at their closed ends. The long sides of the sockets are slightly splayed outwards from roof to base while the end walls are almost vertical.

The under surface of the stone at first glance appears to be concave, but the actual grinding surface is itself convex. This slight convexity of the grinding surface which also occurs on stone C is carefully designed. It may be divided into four specific functional zones (fig. 8, F). The first zone, which passes from the base of the eye to point A, shows no significant striation. This sharply curved surface allowed the grain to enter between the stones. In the next zone, area AB, the grain was spread over the surface of the lower quern, and crushed or burst by the rotating stone. The crushed grain then passed into zone BC where it was ground, and finally, passed out through zone CD. The recurved surface of the stone provided a sufficiently wide gap to allow an air current to develop between the stones. This air current would have helped to draw the flour out from between the stones and deposit it in the encircling container. In discussing Gannon's and Flatley's mills, Knox[8] refers to the fact that the draught set up by the rotating stone helped to blow the flour into the container.

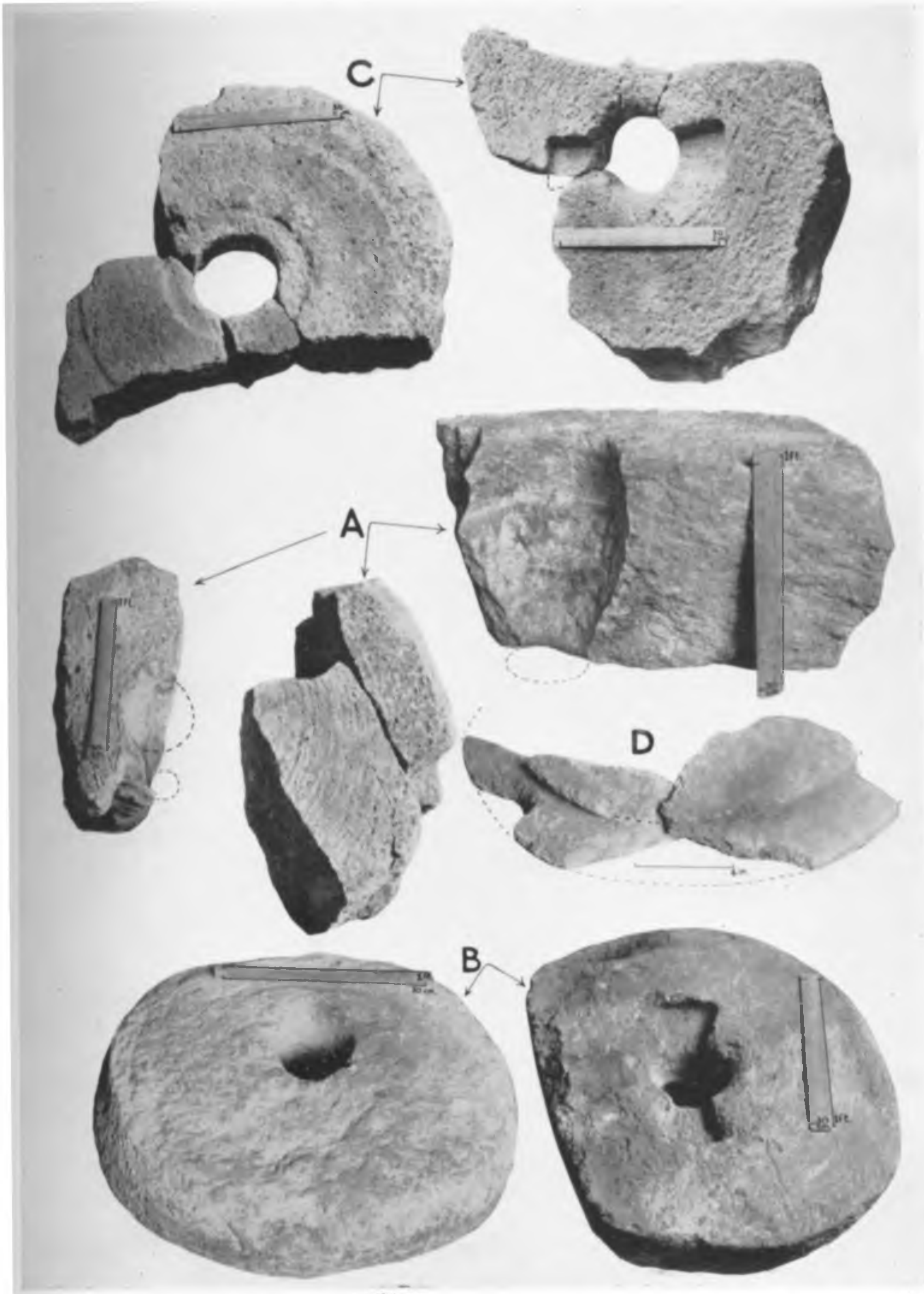
Mill-stone C (fig. 8, C)

Only three fragments of this stone were found. Together they make up the entire central area of an upper stone, but no one piece extends to the periphery. The mill-stone was carefully made from a silicious sandstone. It is striated from use, is $5\frac{5}{8}''$ thick, and has two rynd sockets. The assembled fragments show that the diameter of the mill-stone was at least, 33″, but the indications are that it was hardly greater than 40″. The eye which is $5\frac{7}{8}''$ in diameter, is encircled on the upper surface by a finely cut hollow area $1\frac{1}{2}''$ wide and $\frac{1}{2}''$ deep. From this the surface of the stone slopes gently outward for almost 6″ to a point where it is again cut away to a depth of $\frac{1}{4}''$, over the remaining surface of the stone. The combined effect of the central and outer cut away areas is to leave a 6″ wide low flat ridge encircling the eye $1\frac{1}{2}''$ from its lip.

We may readily explain the central hollow as being a provision to ensure that stray grains which failed to fall directly into the eye from the hopper would be trapped in this 'cup'. Such grains would from time to time be brushed into the eye by the miller. Even if a hopper were not used the 'cup' would have served the same function.

We must consider whether or not the flat raised band, already described, had any functional purpose. It seems unlikely that so much careful dressing would have been carried out for purely artistic reasons when the finished feature did not, in fact, have any real decorative effect. The surface of the stone shows certain inequalities in its polishing which may have some significance. The surface of the raised band is polished to a lesser degree than the outer cut away area, while the zone of junction of this outer surface with the edge of the ridge is highly polished. There is no evidence of polishing on either the floor or the wall of the central hollow, or 'cup,' which encircles the eye. The polish, where it exists, could have been imparted by the stone-cutter or else it developed accidentally while the stone was in use.

[8] Knox, H. T: *P.R.I.A.*, XXVI, C (1906–1907), pp. 265–273



The Mashanaglass mill-stones

Fragments of upper stones B and C, showing top and under surfaces, with fragments of upper stone D and lower stone A. Note the inverted bell-shaped central perforation in stone A, the rynd sockets in stones B and C and the depression, or cup, encircling the eye of stone C.

It is likely that if the stone-cutter were responsible he would have polished the entire surface of the stone. But if the stone acquired the polish during use it significantly acquired it in those areas which should have been passing beneath the hopper if such had been used. Accepting that a hopper was used we could suggest that the polish was caused by the stone rocker trailing on the surface of the mill-stone between the raised band and the periphery. This, of course, is not conclusive proof that a hopper and stone rocker were used at Mashanaglass.

The eye of the stone has vertical walls, is 5⅞″ wide and 2½″ deep. As in stone B the base of the eye opens sharply back to the under surface of the stone thus giving the wide opening for the grain to enter between the stones. As the outer perimeter of the mill-stone is missing we do not know whether or not it was curved upwards as in stone B. The rynd sockets are shaped as on stone B but in the case of stone C are somewhat larger. One of the sockets in stone C is slightly shorter than the other. On neither mill-stone are the roofs of the sockets horizontal, but slope some few degrees to the horizontal, that is, almost parallel with the radial dip of the mill-stones themselves. The depths of the rynd sockets indicate that the rynd bar was not more than $\frac{15}{16}$″ thick.

The silicious grit from which this mill-stone is made contains many quartz pebbles, is brittle and is rather open in texture. The result is that the grinding surface of the stone is liberally sprinkled with irregular concavities—much like the usual millstone grit. In the absence of the special grooves, which are a feature of the later mill-stones, these small natural concavities considerably aided the breaking down of the grain.

Mill-stone A (fig. 8, A)

Three fragments of this massive lower stone were found. One, fortunately, preserved a segment of the central perforation and one shows part of the periphery of the stone. From the fragments available we can estimate that the original diameter of the stone was at least 30″ and it is improbable that it was greater than 40″. The stone is 1′ thick at the centre, and is of the same material as mill-stone C. Its surface is striated from use and tilts down from the horizontal by a few degrees. This gives the stone an appearance of convexity. The principal feature of the mill-stone is the central perforation which would have housed the spindle of the rynd bar. The hole is not cylindrical. Its upper part splays downward to form a shoulder while below this the diameter decreases again to give the hole an inverted bell shaped section. The diameter at the upper surface is 6¾″ expanding to 8″ just above the shoulder. At the shoulder the diameter is 7½″ and at the bottom it is 5½″. The sides of the perforation are both irregular and rough, and show no signs of wear. It is obvious then that the rotating axle, or spindle did not contact the walls of this curiously shaped perforation. It would appear that a wooden bearing in which the spindle rotated was inserted in the stone and occupied the bell shaped portion of the perforation. Above this, in the splaying portion, a second wooden collar was inserted in order to prevent the grain falling down through the lower stone. It is unlikely that both bearing and collar were cut fron one piece of wood. The bearing could easily be placed in position as a unit, but the collar could not if it were to occupy fully the space designed for it. We must visualise the collar as consisting of two or more segments which, after being placed in the stone, were wedged tightly into position. The effect of these wooden fittings was to ensure that the spindle was held correctly centred in the lower stone.

Mill-stone D (fig. 8, D)

Two fragments, forming an incomplete segment of an upper mill-stone, were found. The stone is a brittle, light coloured, laminated sandstone. The upper surface is very finely dressed to a smooth finish, but the grinding surface is striated and coarse. A gap in the periphery of one of the pieces is fortuitous, though at first it is suggestive of a deliberately made notch. As closely as can be calculated the original diameter of the stone was about 2′ 6″. The maximum thickness of the existing parts is $4\frac{9}{16}''$, but when complete the stone may have attained a thickness of about 5″. In outline the stone differs from both B and C. Its outer rim is one inch thick, and the upper surface of the stone slopes rapidly upwards from this to a one inch step at a point 3″ from the rim. Thereafter the stone continues to increase in thickness until it attains a thickness of $4\frac{9}{16}''$ only $7\frac{1}{2}''$ from the rim.

The grinding surface of the stone, though only a little of it is preserved, is very different from that of stone B. We have seen that the latter was convex and that its outer edge was curved slightly upwards to give a gap at the periphery of the stones. Stone D, by contrast, has a concave surface and its outer edge is not up-curved but is worn smooth where it contacted the surface of the lower stone.

If stones B, C and D were used in conjunction with the same lower stone we should expect that stone D, by reason of its concave surface giving a greater gap between the stones, should deliver a far less finely ground product than either of the other stones. In that event it could be suggested that apart from normal adjustments, mill-stones of dissimilar design were used to produce different grades of meal. On the other hand, stone D may have been used with a bottom stone other than the one found on the site. Be that as it may, it is in any event evident that upper mill-stones of different sizes and designs were used at Mashanaglass.

Other Finds (fig. 9, A to P)

Board A:

This board lay at the western end of the wheel-house floor, and protruded diagonally up through the mud and gravel which overlay the floor. It could only have come to lie in this position as a result of disturbance or by reason of the fact that it was part of the overcroft structure, and having fallen into the wheel-house after the abandonment of the mill, floated for a time, and, after a certain amount of silting had taken place, was buried under a fall of slabs from the side wall.

It was 4′ 6″ long, 1′ 6″ wide and 3″ thick. It was apparently part of a slotted plank, the slot being 6″ wide and at least 14″ long. It was provided with a protruding ledge or tongue on one of its long edges. Other features of the plank were a V-shaped 4½″ deep cut on one edge, and a splayed 7½″ deep, 6½″ wide cut in the tenoned edge. The original length of the plank cannot be determined. If this were one of the floor boards of the mill proper it could have accommodated the upper end of a vertical member which might well have been the lever attached to the western end of plank A.

Board H:

Board H existed to a length of 2′ 10″ and was 7″ wide. It was 2¼″ thick and was extensively charred. It was found above the gravel layer within the wheel-house. One or two pieces of similarly charred wood were found trapped beneath plank A (the bridge) on the wheel-house floor. These, and board H, were unquestionably parts of the superstructure of the wheel-house. Board H was part of a slotted plank, the remains of the slot being 6″ long by 4½″ wide. The other end of the plank showed traces of a circular perforation about 2½″ in diameter.

Board C:

This short and curiously worked board was found above the gravel layer which overlay the mud on the wheel-house floor. It was 17″ long, 12″ wide and 1½″ thick. One face was flat but the long edges of the other face had grooved rabbets 2″ wide. A somewhat irregular perforation 3″ in diameter penetrated the board. Cylindrical holes, ½ to ⅜″ in diameter were drilled at the four corners.

This wooden object almost certainly belonged to some feature of the mill works. The four small holes in its corners could have been dowel sockets, or alternatively, they may have held cords. The grooved rabbets would normally be provided to hold side boards, but in this instance they were not sufficiently pronounced to provide more than a casual resting place for the lower edges of such boards.

The underside of the board, which was otherwise smooth, had a shallow groove (fig. 9 C, aa) of 7½″ radius worn into its surface. This groove was obviously imparted accidentally by some rotating object which intermittently contacted the board. The groove is rather deeper in its central area than at its extremities. From the position of the groove it is obvious that the rotating object was not centred on the board itself. The groove could have been imparted by the upper mill-stone or the water-wheel—these being the only rotating objects of the mill. Of these we must suggest that the upper mill-stone is the more probable agent. If this be so, we can regard board C as probably being part of a hopper, possibly its base board. The grooved rabbets would then have accommodated side boards, and the four small holes in the corners of the board may have held cords by which the hopper would have been suspended over the mill-stones.

Lever B:

Only a 2′ 9″ length of this lever was found. Its stem measured 2½″ deep by 1½″ wide. It was found above the gravel which lay on the wheel-house floor and probably belonged to the works situated on the mill floor. One is tempted to assign it to the mechanism for lifting plank A (the bridge).

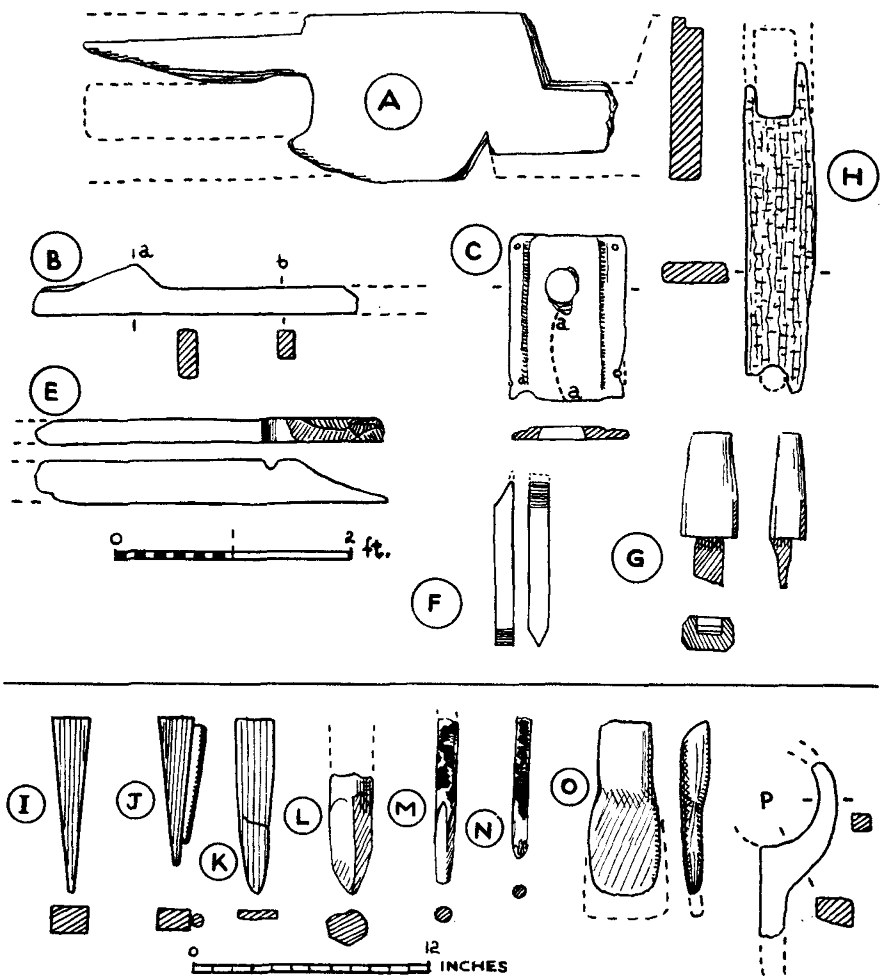


Fig. 9. Wooden objects from the Mashanaglass mill

Lever E:

This incomplete wooden lever was found at floor level beneath the rubble at the western end of the wheel-house. It was 3′ long by 4½″ wide and 2½″ thick. The first 9″ of its length had been cut away to a diagonal slope. The surface of this sloping cut still shows axe or adze marks which had not been abraded to any extent. Two inches away from the upper end of the slope, a 1″ deep, $1\frac{1}{2}$″ wide cut extended across the full width of the lever. If we visualise this lever working up and down in a vertical plane we could suggest that such a groove would have been of use in locking the lever into position by means of a peg projecting horizontally from a suitable upright. In that event either this lever or lever B (described above) could have formed part of the apparatus for adjusting the gap between the mill-stones.

Peg F:

This wooden peg was found in the gravel deposit overlying the floor. It was 1′ 5″ long and 2″ square. One end was chisel-shaped for $2\frac{3}{4}$″ of its length, while the other end was trimmed on two opposed faces to give a wedge shaped 2″ long point. None of the holes or mortices in the wheel-house floor could have housed this peg. It shows no sign of wear and its use remains obscure.

Peg I:

This peg was found in the gravel deposit overlying the wheel-house floor. It was 9″ long by 2″ square and was tapered on all four sides to an elongated pyramidal shape. This peg may have occupied hole *a* in balk A at the east end of the wheel-house floor.

Peg K:

This peg was found in the layer of mud which lay on the wheel-house floor. It was almost 9″ long, 2″ wide and $\frac{1}{2}$″ thick. It tapered to an oval point.

Pegs M and N:

Both of these pegs are cut from twigs. Their ends were roughly whittled to blunt points. Peg M was $8\frac{1}{2}$″ long and 1″ thick, while peg N was somewhat shorter and only $\frac{3}{4}$″ thick. Peg M was found in hole f in plank A. Peg N was found in the layer of mud which overlay the wheel-house floor.

Wooden Shovel or Scoop O:

This object was found sealed down beneath plank E at the eastern end of the wheel-house floor. It must have lain there since the floor was placed in position. It could not have fallen between the closely laid floor-boards during the use of the mill. Only the stump of the object remains. It is 9″ long and, of this, 5″ constitutes part of the blade which remains to a width of $3\frac{3}{4}$″.

Wooden Object P:

It is impossible to say what this may have been. It was obviously incomplete and showed sign of wear. It was 9″ long, and varied in thickness from $\frac{3}{4}$″ to $1\frac{1}{2}$″. The internal diameter of the semi-circular portion was approximately 5″.

The Tail-race (fig. 10 and fig. 4, section W/E)

A 12′ square area was excavated immediately west of the wheel-house. Removal of the first 1′ of marshy sod revealed large numbers of white pebbles similar to those found elsewhere on the site. The lintels of a french drain were encountered at a depth of 2′ 5″. The back fill behind the side stones of the drain contained white pebbles ('Hail Mary stones'), but the surrounding ground at this depth was absolutely free of such finds. The french drain extended to a depth of almost 5′ below the surface and was dug into the peaty mud which overlay the bed of the tail-race to a depth of 4′ 3″.

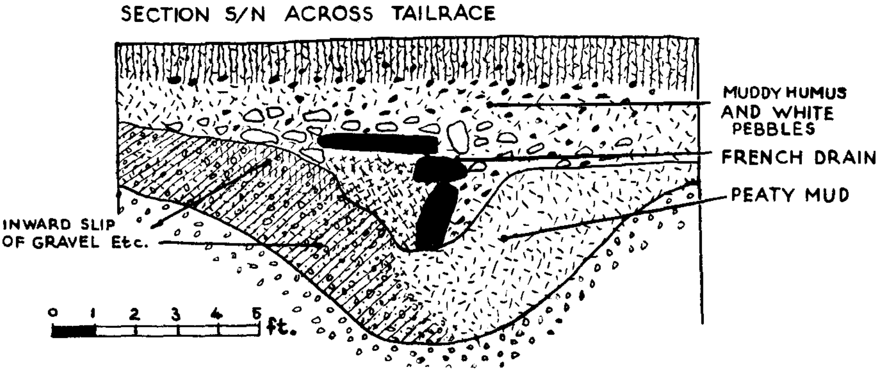


Fig. 10. Section across the tail-race showing inserted french drain

We had previously noted the dump of debris which lay in the tail-race immediately west of the wheel-house. During the removal of this accumulation, two fragments of a mill-stone (fig. 8, D) were found, while fragments of two other mill-stones (fig. 8, A and C), one upper and one lower, lay beneath on the bed of the tail-race.

A second section was cut across the tail-race 10′ further west, but this produced no finds. The information obtained from both sections indicated that the tail-race was cut into the natural gravel bed of the glen, and was originally over 12′ wide and 4′ deep measured from old ground level. In other words, the bottom of the tail-race was 7′ 6″ below the modern turf.

The Causeway (fig. 1)

A 4′ wide strip of the causeway was excavated, and it was found to consist of brown soil containing flecks of charcoal to a depth of 3′ 6″. It is clear that this artificial bank was constructed in order to provide a raised pathway to the working floor of the mill.

The Kiln (figs. 1 and 11)

Four cuttings were opened at right angles to each other across the platform on the southern side of the glen. In the most easterly cutting a deposit of charcoal-flecked earth was encountered 1′ 3″ to 2′ below the surface. Excavation revealed an elongated shallow pit lying almost north-south across the platform. The pit was 22′ 6″ long, 3′ 9″ wide at its northern end, 2′ wide about midway along its length, and 5′ 9″ wide at its southern end. It was 1′ 6″ deep at its northern end, and 2′ deep at its southern end, and 19″ deep in its central area. A 2″ thick layer of charcoal covered its floor at the northern end and spread rather thinly over the remainder of the pit floor. Several large stones were found lying within the pit but were mainly concentrated on its southern half.

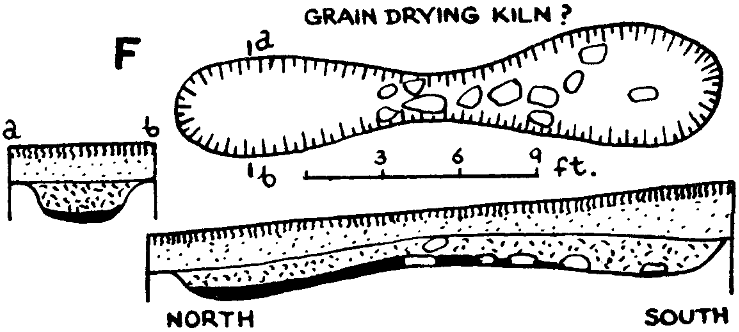


Fig. 11

This pit may have been the ruins of the flue of a grain drying kiln, the northern end of the pit accommodating the fire. The stratification of the pit indicated that it was deliberately infilled with soil after the kiln and flue had been dismantled.

THE MODEL

Since it was not possible to reconstruct the Mashanaglass mill on the site and put it into working order once again, it was thought worth while to build a scale model based as closely as possible on the evidence obtained from the excavation. Accordingly, this was done, the scale being 1″ to 1′. All the parts of the wooden floor of the wheel-house were copied exactly including the various holes, pegs and other features. The nave of the wheel was carved in oak and all of the twenty-three paddles were individually carved and morticed into place. The actual diameter of the finished wheel was 3⅓″. Much experimentation was necessary in order to provide mill-stones which were correct both as to size and weight. The upper stone finally used had an actual weight of 2½ oz. representing a weight of 2 cwt. 70 lbs. The T-shaped rynd bar, originally probably made of iron, was made in copper for the model. The shank of this spindle was passed through a wooden collar and bearing fitted in the perforation of the lower stone.

The flume was an exact copy of the original, and included the diagonal fissure across the orifice. It was set into the model at the correct slope of 30 degrees. Water was led to the model via a head-race from a small clay dam.

Working with the model it became clear that of the three hollows in the bridge (fig. 4, plan, plank A, c, d, e) the central one (d) gave the best results. When in this hollow the wheel was obviously in the optimum position with respect to the water jet. To ensure that the model worked satisfactorily it was necessary to centre the eye of the upper mill-stone, the spindle and the lower mill-stone exactly over the apex of the hub. Furthermore, the upper stone had to be perfectly balanced on the rynd bar to prevent erratic working of the mill.

When the flume flowed at less than half full the mill would not work. When the water supply was increased so that the flow half filled the orifice of the flume the jet played on the outer ends of the scoops, and the mill-stone was set in motion. It was, however, necessary to overcome starting friction by moving the mill-stone through quarter of a revolution. When the water supply was further increased so that the flume ran full, the power of the jet was sufficient to set the mill in motion without manual assistance. A further increase in the supply of water caused the jet to build up into the diagonal fissure in the face of the flume. A 'winged' jet was thus developed, and it played more extensively on the scoops. The mill-stone then attained a high speed.

At first it would appear that the adjustment of the gap between the millstones by means of the bridge (plank A) was a cumbersome and ungainly process, but that was not so. The experiments with the model showed that by elevating the bridge through $\frac{1}{3}''$, a clearance of $\frac{1}{12}''$ was obtained between the stones. Thus, in the original structure a gap of $\frac{1}{4}''$ could be obtained by raising the western end of the bridge through $1''$.

When all adjustments were correct, and the stones were set so that the revolving stone brushed lightly and evenly over the lower stone it was not possible to obtain a stone speed of less than 84 revolutions per minute. A stone speed of 140 r.p.m. was obtained when the flume flowed at slightly more than half full, and, depending on the amount by which the jet was increased, speeds greater than 140 r.p.m. could be obtained.

It was difficult to obtain suitable fodder for milling experiments. Eventually, finely ground oats, though relatively coarse to the scale of the model, was used. This was fed to the stones while they were revolving at 140 r.p.m. and the stone speed immediately dropped to 90 r.p.m. However, the fodder did pass between the stones and was thrown out around their perimeter. As has been pointed out above, a slight increase in the water supply was sufficient to increase the speed of the mill-stone once more. The results of the experiments, though allowance must be made for a margin of error, compare favourably with the statement of Knox [9] that stone speeds of 150 to 180 r.p.m. were the normal grinding speeds of the Cullentra and Meeltraum horizontal mills.

Various arrangements of beams were tried out in the socket holes in balk A, the floorboards, and in the splayed perforation and rectangular

[9] Knox, H. T: *P.R.I.A.*, XXVI, C. (1906–1907), pp. 265–273

notch in the rear wall of the model. No conclusions could be drawn from these experiments, but it is to be hoped that future excavations may provide answers to the unsolved problems.

SUMMARY

The excavation and the experiments with the model together provide us with the most complete picture yet recorded of an Irish horizontal mill.

At Mashanaglass the narrow steep sided glen was dammed fifty-five yards upstream from the mill. The water from the stream was thereby impounded, and released, into an artificial head-race, which conducted it, through a fall of 8′, to a point behind the wheel-house where it entered the open end of a wooden flume, 8′ long. This was lintelled over with stone slabs and buried in the ground at an angle of 30 degrees to the horizontal. This arrangement gave the water a further fall of four feet. The lower, or wheel-house end of the flume had a 5″ by 7″ orifice through which the water jet played on the horizontal wheel.

The wheel was affixed to a vertical shaft the upper end of which passed through the mill floor overhead and carried a vertical spindle which locked into the upper mill-stone by means of a rynd bar. Thus, when the water-wheel was caused to revolve by the water jet playing on one side, the rotary motion was transferred directly through the mill-shaft to the upper mill-stone.

A wooden bearing set in the stationary lower mill-stone prevented lateral movement of the spindle, and thereby enabled the upper mill-stone to rotate evenly and smoothly over the lower stone. The latter must have rested on the mill floor proper.

The adjustment of the pressure of the upper stone upon the lower is of the utmost importance in the process of milling the grain. At Mashanaglass this adjustment was made by lowering or raising one end of the horizontal lever or bridge (fig. 4, plan, plank A) on which the water-wheel rested. The wheel and vertical mill-shaft were thus raised, as consequently was, of course, the upper mill-stone. The lifting mechanism consisted of a vertical beam, the lower end of which was affixed to the horizontal lever, or bridge, mentioned above. The upper end of the vertical beam passed through the floor of the mill where, of course, the miller controlled the necessary adjusting mechanism. At Mashanaglass this may have consisted of a system of wooden levers attached to the upper end of the vertical beam.

It is suggested that board C, fig. 9, may have been part of a wooden hopper. This would have been suspended over the mill-stones, and may have been agitated by means of a string attached to a stone which joggled on the surface of the rotating mill-stone. A trickle of grain would thus have been caused to fall into the eye of the mill (fig. 2, A). The flour or meal discharged from between the stones would have fallen into a container, placed about the stones, on the mill floor.

Because of the angle at which the flume was set in this mill, it is proposed to use the term 'steep flume class' to describe similar mills in which this feature occurs.

IRISH HORIZONTAL MILLS

In view of the Mashanaglass evidence and of additional information which has come to light regarding the Bantry, Mallow and Knockrour mills it is necessary here to undertake a review [10] of the known Irish mill sites.

During the past hundred years, or so, the fragmentary remains of horizontal mills have been discovered in various parts of Ireland. Many writers have attempted to solve the problems raised by such finds. O'Donovan [11] and Petrie [12] were early in the field. Windele [13] in 1844 read a paper, to the Cork Cuvierian Society, concerning several sites in Co. Cork. This was followed by reports of similar sites in Co. Kilkenny.[14] Next came MacAdam's report [15] of finds in the Down and Antrim areas. In the following year Wilde [16] identified wooden objects from Banagher as being parts of a mill. Not long after this another site was discovered in Co. Kilkenny.[17] Towards the close of the 19th century Macalister [18] reported two sites, one at Fahan, in Co. Kerry, and the other on the island of Ardoilean, off the Galway coast. O'Reilly [19] discussed all of the foregoing evidence. Knox [20] reported on two horizontal mills then actually working Mayo and Roscommon. In 1926, O'Conlon reported on a site at Knockrour [21] in Co. Cork, and some time later Power [22] published further information concerning the same site. The most recently published works on the subject are by A. T. Lucas.[23] In his first paper he reviews all the foregoing evidence as well as ancient literary references, and quotes statements concerning further mill sites in Co. Mayo and Co. Galway. He describes the Killogrone mill in Co. Kerry, and discusses the results of excavations carried out by him at Morett, Co. Laoighis. In his second paper [24] he describes the results of an excavation at Ballykilleen, Co. Offaly.

[10] In this matter I am deeply indebted to Mr A. T. Lucas. His comprehensive paper (*J.R.S.A.I.*, LXXXIII (1953), pp. 1–36) contains, in addition to his own research on the subject, an invaluable list of references to the earlier discoveries which greatly facilitated the re-examination of the original records. For the sake of convenience the relevant details of the more important early sites as well as of those reported by A. T. Lucas in the above are included in Appendix I to this paper

[11] O'Donovan : *Dublin Penny Journal*, I, No. 36, 1833, p. 282

[12] Petrie : *T.R.I.A.*, XVIII (1839), pp. 162–165

[13] Windele : *The Cork Constitution* (1844), Dec. 21

[14] *T.K.A.S.*, I (1849–1851), pp. 154–164

[15] MacAdam : *U.J.A.*, IV (1856), pp. 6–15

[16] Wilde : *A Descriptive Catalogue of the Antiquities in the Museum of the Royal Irish Academy.* Dublin, 1857, pp. 207–208

[17] *J.R.S.A.I.*, VI (1860–1861), pp. 347–348

[18] Macalister : *T.R.I.A.*, XXXI, pt. 7 (1899), pp. 251–253

[19] O'Reilly : *P.R.I.A.*, XXIV, C, (1902–1904), pp. 55–84

[20] Knox : *P.R.I.A.*, XXVI, C, (1906–1907), pp. 265–273

[21] O'Conlon : *J.C.H.A.S.*, XXXI (1926), pp. 96–101

[22] Power : *Cork Examiner*, 27 Sept. 1928

[23] Lucas : *J.R.S.A.I.*, LXXXIII, (1953), pp. 1–36

[24] Lucas : *J.R.S.A.I.*, LXXXV, (1955), pp. 101–113

Of the many Irish sites which have thus up to the present time produced material evidence, Mashanaglass is the most complete. Four other sites (Kilnagross, Bantry, Knockrour and Mallow)[25] have yielded sufficient material to identify them as steep-flume mills quite comparable with Mashanaglass in their basic lay-out. The Kilnagross flume had a slope of 5′ while that of the Bantry mill 'conveyed the water from a large wooden cistern to the works standing considerably beneath.' The Knockrour flume is recorded as sloping at forty degrees and the Mallow flume extended to within a few feet of the surface from a 'floor of oak planks.' The Kilnagross mill also had a wooden floor. Both Mallow and Kilnagross produced the remains of water wheels and in addition two pairs of mill stones were found at the latter site. The back wall of the Knockrour wheel-house consisted of slabs on edge and the flume was housed in a cut slab which was in every way similar to slab D at Mashanaglass. Unfortunately the Knockrour wheel-house was not completely excavated.

It can be deduced that a further four sites (Kilkenny Castle, Kilmagar, Shanacashel and Kilbarry) were provided with sloping flumes similar to the foregoing sites. The Kilkenny Castle flume[26], was found 5′ below the surface; it had a solid end which was perforated by two orifices (fig. 7G) and was thus intended to develop a jet. It rested on a 'sort of frame of wooden planks and beams' which may have been the remains of the wheel-house floor. The face of the flume was skew-cut to a few degrees from the vertical. This feature occurs on the Knockrour and Mashanaglass flumes both of which were steeply inclined towards the floor of the wheel-house. When the flume was placed in such a position its skew-cut face lay in the same plane as that of the back wall of the wheel-house (see fig. 4, section W/E).

The only find from Kilmagar[27] was a 14′ long wooden flume fitted with a lid which was caulked with moss when found. There is no doubt that the flume, like the Knockrour one which also had a wooden lid, was intended to be buried in the ground and utilised to develop a jet. Under the circumstances it seems reasonable to suggest that the Kilmagar flume belonged to a steep-flume mill. Shanacashel[28] provides a more complete story. A wooden flume, a morticed mill-shaft and two broken mill-stones were found at that site. The floor was found beneath 8′ of bog and the 12′ long flume was dug up two years earlier, having apparently been encountered at a higher level than the floor and immediately excavated by the finders. There seems little doubt that this was a steep-flume horizontal mill.

The Kilbarry[29] find consisted of a 12′ square, 3′ deep 'tank' of oak planks resting on four pillars or legs, 2′ high by 1′ square. A wooden flume with a 1′ wide orifice entered the tank which was 11′ below ground level. The finders dismantled the structure. It is very probable that the 'tank' was a

[25] See Appendix 1, Nos. 1, 2, 3 and 5

[26] *J.R.S.A.I.*, VI (1860–61), pp. 347–348

[27] *T.K.A.S.*, I (1849–51), pp. 154–164

[28] See Appendix I, No. 6

[29] *The Gentleman's Magazine*, March, 1843, pp. 303–304. I am indebted to Mr D. Clarke, National Library, Dublin, for the details quoted here.

wooden wheel-house the side walls of which had decayed away to a height of 3′. We have evidence from Aunahincha [30] of the construction of elaborate walls of vertical planks. The Kilbarry flume was correctly surmised by the finders to have conveyed water into the tank. Now, since the tank was 11′ below ground the flume must have sloped down from the surface in order to convey the water into the tank, hence, if Kilbarry was a horizontal mill it follows that it was equipped with a sloping flume. If, on the other hand, we were to regard Kilbarry as a cistern-fed mill with a horizontal delivery (see below) we should expect to find an 11′ deep cistern behind the wheel-house. There is no evidence that such a cistern existed there.

A further group of eight flume-producing sites (Muskerry, Banagher, Inchidoney, Killynumber, Killyscolban, Coumshinagaun, Smithstown and Morett) must next be considered. Windele's description of the Muskerry [31] site is most ambiguous, but in his opinion the remains were those of a horizontal mill. This, we have no reason to doubt as Windele had previously seen the Bantry steep-flume mill and was familiar with such structures. On the Mashanaglass analogy it could be suggested that one of the artificial banks noted by Windele may have been part of a dam while the other could have corresponded to the mound behind the Mashanaglass wheel-house. The wooden uprights may have been parts of the wheel-house walls and the pair of flumes, each 12′ long by 1′ 9″ deep, might have constituted a head-race channel; alternatively one may have been the mill flume while the second was part of the head-race. It is regrettable that more specific information is lacking.

In 1838 Petrie reported the discovery at Banagher [32] of a large wooden reservoir for water, with two flumes, one to conduct the water into the reservoir and one to carry the water off. Again the details are insufficient for positive identification of the site. It is likely, however, that the reservoir may have been the cistern of a pressure jet mill similar to Meeltraum (see page 46). There seems to be no logical reason why a 'sewer' should be fitted to a wheel-house, but, since the published details are so scanty one can but record the site. It is possible that the three 14″ long scoop-paddles described by Wilde [33] in 1857 may have come from the Banager site, since they came from a townland of that name. It may be therefore that the Banagher 'reservoir' was part of a horizontal mill.

The 14′ long Inchidoney [34] flume was lidded and had a hole at one end and so was obviously intended to develop a jet. While we have no details of the two flumes from Killyscolban [35] and Killynumber,[36] it is recorded that millstones were found at the former (as well as at Inchidoney) and that

[30] Townsend: *Statistical Survey of the County of Cork,* Dublin (1810), pp. 272–274

[31] See Appendix I, No. 7

[32] Stokes: *The Life and Labours in Art and Archaeology of George Petrie.* London, 1863, pp. 125–126

[33] Wilde: *A Descriptive Catalogue of the Antiquities in the Museum of the Royal Irish Academy.* Dublin, 1857, pp. 207–208

[34] *T.K.A.S.*, I (1849–51), pp. 154–164

[35] MacAdam, *U.J.A.*, IV (1856), pp. 6–15

[36] O/S Letters, Co. Derry, p. 224.

there were the ruins of a Danish mill at the latter. The Coumshingaun [37] flume was fancifully described as being used for extracting 'liquor from the mountain heath.' The flume was 12′ long, 2′ wide and 2′ deep and had 'holes at the end.'

While it cannot be stated that any or all of the above flumes belonged to steep-flume mills it does seem reasonable to suggest that at least the Inchidoney flume probably belonged to that class.

Finally there are two sites (Smithstown and Morett) which produced horizontal flumes. The Smithstown[38] flume (14′ long, 8″ deep, 3′ wide at one end and 2′ at the other) was morticed on one of its long sides to the footbeam of a wooden platform. In such a position it could not have discharged on to the platform, or floor (?), as it should have done in the case of a horizontal mill, and without further information regarding the site it is difficult to speculate as to its use.

A. T. Lucas has pointed out that the Morett [39] wheel-house would not have accommodated a wheel of more than 28″ in diameter. Such a wheel would have been very much smaller than the Mashanaglass or Moycraig wheels, which were respectively 40½″ and 41½″ in diameter. Even if a small wheel were used at Morett, it does not, however, eliminate the difficulties. It must be remembered that the *height* of the wheel is another vital factor, for the jet, whether delivered from a steep or a horizontal flume, must of necessity be delivered at paddle level in order to set the wheel in motion. At Mashanaglass the paddle level was 16″, and the lowest point of the flume orifice was at that height *above floor level.* The Meeltraun [40] pressure-jet flume, which lay in a horizontal position, was also set at paddle level. The illustrations accompanying the description of that site indicate that the flume orifice was at least 12″ above floor level. In that event the Morett flume, which rested *at floor level*, could not, apparently, have delivered a jet to a horizontal wheel of the normal type.

Lucas [41] suggests that the end of the Morett flume may have been fitted with a device 'by which the mouth of the trough was constricted and the exit of water diverted to the left, or east side, and forced thereby to strike the left side of the wheel with increased force.' However, this would not be sufficient without, at the same time, raising the jet from floor to paddle level. To estimate minimum paddle level we must allow at least 2″ for the thickness of the movable beam, or bridge, on which the wheel spins, at least 2″ more for the height of the pointed nave, or stone or metal gudgeon, and a further 2″ for the thickness of the paddles, in all, a minimum total of 6″ (the like measurement at Mashanaglass was 16″). In that event the Morett flume, if fitted with the proposed device, would have had at least 6″ to 16″ of its internal slope of 18″ negatived. Thus, since the millwright appears to have designed the internal slope of the flume so that ' . . . the

[37] See Appendix I, No. 8

[38] *T.K.A.S.*, I (1849–51), pp. 154–164

[39] Lucas, A. T : *J.R.S.A.I.*, LXXXIII (1953), p. 27 (See Appendix I, No. 9 for a brief summary of this site)

[40] Knox, H. T : *P.R.I.A.*, XXVI, C (1906–1907), pp. 265–273

[41] Lucas, A. T : op. cit., p. 27

main impetus of the water from the dam to the wheel was supplied by the internal configuration of the trough itself . . . ,' it appears unlikely that he would, at the same time, introduce a device which would, apparently, have counteracted his prime intentions.

If it is allowed that the end of the flume were constricted in the manner suggested, it must follow that the sides of the flume would have to be increased in height so that an additional head of water could be contained within it. In that event greater significance could be attached to the excavator's suggestion that the height of the flume walls had been increased in such a manner.

But, be that as it may, Morett does not appear to conform to the majority of the Irish horizontal mills of which we have evidence. All known flumes, except Morett, appear to have had solid ends penetrated by an orifice through which the water jet played on the wheel. The Mashanaglass, Cullentra, Meeltraun flumes and the flumes of foreign mills were set at an appreciable distance above the wheel-house floor. At least five Irish sites (Mashanaglass, Kilnagross, Mallow, Bantry and Knockrour) had flumes which sloped steeply towards the wheel-house floor. The Morett flume was horizontal. The Meeltraun flume was also horizontal, but the jet was generated under pressure of a head of water maintained in a cistern behind the wheel-house and the flume rested at paddle level.

The question arises, could Morett have been a pressure jet horizontal mill ? If the V-shaped 'dam' were regarded as a lead-in structure behind which a canal-like head race was maintained, a pressure jet could have been developed. If the device discussed above had been fitted to the flume, and the walls of the latter, as suggested by A. T. Lucas, had been increased in height, with as well, the addition of a lid, it is conceivable that the jet would have been delivered to the wheel in the correct manner.

There are, however, objections to such an interpretation. Firstly there would be no need for a 14′ long flume in a pressure jet mill, secondly there is no indication that the flume was ever fitted with a device for developing a jet, and finally, the position of the flume, the unusual plan and small size of the wheel-house as well as the smallness of the proposed water-wheel all tend to argue against its being a mill of the pressure jet class.

Two pivot stones were found on the floor of the Morett wheel-house. Though every effort was made to locate similar finds at Mashanaglass nothing was found which would indicate that pivot stones had ever been used on the site. The fact that the water-wheel was not fitted with a gudgeon pin, suggests that pivot stones were not used on the site. None of the other Irish horizontal mill sites produced pivot stones, though it must be allowed that in some instances they may have been overlooked. At Killinchy a pivot stone was 'found nearby' but, even so, it is clear that, for the present at least, pivot stones, by themselves, cannot be accepted as conclusive proof of the identity of a mill site.

Nine sites (Kilnagross, Bramblestown,[42] Mallow, Ballindeasig,[43] Shanacashel, Glenwood,[44] Killyscolban, Inchidoney and Mashanaglass) have produced millstones. In those instances where measurements are supplied, upper stones are found to average from 2′ to 3′ 4″ in diameter and 4¾ to 6″ in thickness. Lower stones were 12 to 14″ thick.

Four of the above sites (Kilnagross, Mallow, Shanacashel and Mashanaglass) have revealed the remains of water-wheels, and similar finds have been made at a further five sites (Banagher, Milverton, Moycraig, Killinchy and Ballykilleen). Of the early finds only the Moycraig wheel has been preserved.[45] Details of the finds are as follows : Mallow, a 'wooden stock with portions of the spokes of a wooden wheel which latter had been fastened with wooden pegs' ; Kilnagross, 'the shaft of a mill-wheel', Shanacashel, 'six foot long shaft of a wheel, with mortices for mill-fans' ; Banagher, 'three scoop-like pieces, each about 14″ long, and perforated at the extremity, dished at one end, and having a projecting ledge or step at the back, near the perforation' ; Milverton, 'a mill-shaft about 4′ long, into which were morticed . . . eight large wooden spoons each about 2′ by 14″, scooped out of a solid piece of oak rounded at the end' ; Moycraig, nineteen 'buckets or ladles of wood morticed into the nave, and dowelled so that each dowel passed through the inner ends of three ladles.' The shaft and nave were cut from a solid piece of wood and together measured 6′ 6″ long ; the wheel was 3′ 5½″ in diameter. The Killinchy find is described as being similar to Moycraig. Ballykilleen [46] yielded the remains of two scoop paddles, and Mashanaglass produced a morticed nave and several scoop paddles which formed a water-wheel 3′ 4½″ in diameter.

As previously noted by Lucas [47] and Curwen,[48] the earlier evidence indicates that scoop paddles were used extensively in Ireland. Mashanaglass gives further confirmation of that fact. It is now evident, however, that in some instances (Moycraig, Milverton and Shanacashel) the shaft and nave of the wheel were cut from a solid piece of wood while in at least one instance (Mashanaglass) the shaft and nave were separate units. The only wheel recorded as being fitted with a gudgeon pin is that from Moycraig, though it is possible that the Killinchy wheel was also fitted with a similar stone gudgeon. The Cullentra and Meeltraun mills were fitted with metal gudgeon pins and pivots.

Stone-walled wheel-houses are recorded at Killogrone,[49] Knockrour,[50] Fahan,[51] Mashanaglass and probably at Glenwood.[52] The Killogrone

[42] *T.K.A.S.*, I (1849–1851), pp. 154–164
[43] ibid
[44] See Appendix I, No. 10
[45] Belfast Museum and Art Gallery
[46] Lucas, A. T : *J.R.S.A.I.*, LXXXV, (1955), pp. 101–113
[47] Lucas, A. T : *J.R.S.A.I.*, LXXXIII (1953), p. 33
[48] Curwen, C. E : *Antiquity*, XIX (1945), pp. 211–212
[49] Lucas, A. T : *J.R.S.A.I.*, LXXXIII, (1953), p. 9
[50] O'Conlon : *J.C.H.A.S.*, XXXI (1926), pp. 96–101 and Power : *The Cork Examiner*, 21 December, 1844. See Appendix I, No. 3
[51] *T.R.I.A.*, XXXI, pt. 7 (1899), pp. 252–253
[52] See Appendix I, No. 10

wheel-house has been described by A. T. Lucas. This writer has also visited the site. Briefly, it may be described as consisting of two drystone side walls, each 13′ long by 6′ 6″ wide, with a rear wall (3′ 8″ wide) of slabs on edge—one of these protrudes above ground level and has a 4″ by $4\frac{3}{4}$″ notch cut out of its upper edge. A similar notch occurs in slab B at Mashanaglass at a height of 6′ 6″ above the aperture which housed the flume. It can then be suggested, on the Mashanaglass analogy, that the like notch at Killogrone did not house the flume on that site. The recessed inner faces of the Killogrone side walls are unlike those at Mashanaglass, but there is no doubt that the broad principles of both wheel-houses are the same.

Two low banks which diverge from the southern end of the Killogrone wheel-house may represent a lead-in to the flume from a canal like head race; somewhat similar to the lay-out at Knockrour. It seems likely that excavation would reveal that the Killogrone mill is of the steep-flume class.

The Knockrour wheel-house was not excavated but it is abundantly clear that it followed the Mashanaglass plan very closely. Only one of the rear wall standing slabs was recorded and that was in all respects similar to slab C at Mashanaglass. In the published account of the site[53] it is stated that the flume rested on top of the slab. However, Mr J. Lynch, who discovered the flume in position, informs me that it was housed *in* the U-shaped cut in the slab, and that dry-stone walling was exposed beside the slab. It is regrettable that further investigation was not undertaken at this site.

The Glenwood site, which produced several millstones, was situated in a narrow glen through which a stream flowed. A dried up headrace extended back along the glen and 'building stones' were found in the cutting which produced the millstones. It seems very probable that the building stones must have belonged to a stonewalled wheel-house.

Macalister reported the remains of a rectangular stone structure at Fahan in Co. Kerry. The measurements supplied by him (5′ 6″ by 9′) must be the internal dimensions of the structure and the 'doorway' at one end can only have been the water exit from the mill. Macalister suggested that a nearby stream had been 'diverted to pass through the mill.'

There are many other sites which, while they did not produce flumes or stonewalled wheel-houses, are almost undoubtedly the remains of horizontal mills. In considering them it is well to remember that none of the early sites was completely investigated and that in any event the mills would have been exposed to interference for a considerable time after abandonment. So it is that the entire structure or any part thereof could have been removed in antiquity.

In this connexion we can instance Bramblestown, Ballymartin, Lodge Park, Timahoe, and Ballykilleen where wooden floors or frameworks were found without associated flumes. Six feet deep in a bog at Bramblestown[54] an 11′ square framework with mortices for uprights was found. The uprights were missing. The finding of broken millstones on the ground within the

[53] O'Conlon: *J.C.H.A.S.*, XXXI (1926), 96–101

[54] *T.K.A.S.*, I (1849–51), pp. 154–164

framework suggests that the floorboards had been removed and the stones allowed to fall into their find place. Again at Ballymartin [55] an 11′ by 6′ floor of planks with mortices for uprights was found 6′ below ground. The uprights were missing. Lodge Park [56] was 'analogous to Ballymartin.' At Timahoe [57] an 11′ 6″ long floor with mortices for uprights was found. The uprights were missing. At Ballykilleen [58] a plank floor measuring about 14′ by 10′ was discovered 3′ below the bed of a stream. The ends of the planks were bedded beneath a substantial wooden beam which corresponds very closely to balk A at Mashanaglass. In each case the balk was intended to lock down the planks at the upstream end of the wheel-house. The remains of two scoop paddles were found on the site. Each of the foregoing sites appears to have had a wooden rather than a stonewalled wheel-house and all of them appear to have been extensively dismantled at an early date.

It has been suggested that the above floors and frameworks were the remains of wooden dams.[59] Without sufficient evidence it is hard to be certain of their purpose but in view of the later evidence from Mashanaglass it now seems more likely that they were the remains of wheel-houses. The wooden floor was an essential part of a wheel-house as it prevented the running water from gouging away the underlying clay or gravel and, at the same time, supported the works of the mill. It would appear that a wooden floor would be desirable in the cistern of a pressure fed mill or in a wooden lead-in structure and it is, of course, possible that the above mentioned structures belong to such features of horizontal mills.

One site, Morett,[60] produced pivot stones. These it is suggested were bearings upon which the horizontal wheel spun. Though none of the other Irish horizontal mill sites produced pivot stones the possibility must be allowed that they were used in some instances. At Killinchy a pivot stone was found 'nearby'. The Ardmore [61] and Ballyshannon[62] pivot stones were not associated with mill structures. Knox [63] says that pivot stones were used on the older horizontal mills but he gives no authorative source for his information. He also says that the only pivot stones he had seen in use were in breast wheel (vertical) mills.

Knox [64] has supplied an eyewitness account of two horizontal mills (Cullentra and Meeltraun) which were actually working in 1906, and in view of the Mashanaglass evidence it is desirable to quote their details here.

[55] *T.K.A.S.*, I, (1849-51), pp. 154-164
[56] ibid
[57] ibid
[58] Lucas, A. T : *J.R.S.A.I.*, LXXXV, (1955), pp. 101–113
[59] ibid
[60] See Appendix I, No. 9
[61] O'Reilly : *P.R.I.A.*, XXIV, C (1902–04), pp. 55–84
[62] Lucas, A. T : *J.R.S.A.I.*, LXXXIII (1953), p. 14
[63] Knox, H. T : *P.R.I.A.*, XXVI, C (1906–07), pp. 265–273
[64] op. cit.

Meeltraun, Co. Roscommon

This information, Knox says, 'was supplied to him'. He also states that in the Ballyhaunis district the tendency was to convert surviving horizontal mills into vertical mills.

The Meeltraun mill is also called Gannon's Mill, for such was the name of the family who had operated it for 'seven generations'. The mill was powered by a jet of water delivered 'almost horizontally' from the lowest point of a cistern in which a 5′ head of water was maintained. If the head of water fell below 1′ 9″ the mill did not function satisfactorily. The horizontal wheel was 5′ 6″ in diameter and consisted of fourteen scoops set closely together. The backs of the scoops were rounded. Iron stays connected to the outer ends of the scoops were fixed to the shaft. This latter was shod with an iron gudgeon pin which rested on a steel plate fixed to the upper surface of the adjustable beam. From one end of this beam a vertical post extended upwards to the mill floor. By raising or lowering this post it was possible to produce a corresponding movement in the adjustable beam; this in turn affected the mill-shaft and altered the gap between the millstones by raising or lowering the upper stone as the case may be. The grinding speed of the stone was 150 to 180 revolutions per minute.

We may note here that the illustrations which accompany Knox's article are schematic and are inaccurate in some details.

Cullentra, Co. Mayo

This mill was powered by a jet of water delivered to the wheel from a flume sloping at 30 to 40 degrees. The water aperture from the cistern to the flume is stated to have been 1′ 6″ square and the flume was also 1′ 6″ square narrowing to 1′ at the wheel-house end. The fall of the flume was about 1′ 6″ but its length, so far as one can see, was very short. The head of water above the flume was about 5′. The building measured 20′ by 10′. The wheel consisted of thirteen ladles 'in the form of long narrow boxes with no side boards towards the water. Formerly the ladles were made of sally-wood'. The ladles were bound into position by a thin iron hoop. The mill-shaft was 4′ 6″ long. The millstones were 4′ 4″ in diameter and their grinding speed was 150 to 180 revolutions per minute—that is identical with Gannon's Mill. Knox gives an interesting description of the method of feeding the grain to the stones.

In his discussion regarding this site Knox says that the 'chute system is an innovation here', i.e., at the Cullentra mill, and that the binding of the ladles with a thin iron hoop was 'a late and ineffective innovation'.

DATING EVIDENCE

Curwen [65] and others have discussed the available evidence regarding date and place of origin of the horizontal mill. In the late first century B.C.,

[65] Curwen, C.E: *Antiquity*, XVIII (1944), pp. 130–146

Strabo [66] and Antipater [67] refer to structures which probably were horizontal mills. Antipater exhorted the 'grinding-maids' of Thessalonica to cease work at the querns, 'For Demeter has laid the toils of your hands upon the water-nymphs, and they, leaping down upon the top of the wheel, turn the axle which by its whirling spokes causes the heavy, hollow Nisyrian mill-stones to revolve . . .' It is clear from the foregoing that the mill was an innovation in that region at the time Antipater described it. If this be so the knowledge of the mill must have spread with great rapidity for Steensberg [68] in 1946, excavated at Bolle, Denmark, the remains of a dam which he claims belonged to a horizontal mill of iron age date. However, in the absence of structural evidence for a mill on that site, the excavator's claim must be treated with reserve.

The earliest historical references to mills in Ireland occur in three of the annals—Four Masters, Ulster and Tighernach—where we find mention of Maelodran's mill under dates varying between 647 and 651 A.D. Amongst other references we find that a passage in Cormac's Glossary, one of the earliest of our sources, likens the whirlpool of Coire-Brecáin to the whirling of mill-paddles—an analogy which can only be applied to a horizontal wheel. The Senchus Mor [69] lists the essential parts of a mill and both Lucas and Curwen, while disagreeing on the interpretation of certain of the terms used in that list, agree that the parts named are those of a horizontal mill. Thus it is thought that the horizontal mill was in use in Ireland from about the 7th century A.D.[70]

No Irish mill site has so far produced dating evidence. We know from O'Donovan (page 14 above) who visited the site over a century ago that the ruins of the Mashanaglass wheel-house were then venerated as a holy well. We know too from local tradition that this veneration is reputed to have gone on for almost two centuries. We have seen that an ash tree grew on the debris outside the western end of the wheel-house. A growth-ring count indicated that the tree was about one hundred and fifty years old. The only find of dating value from the site was the neck of an 18th century glass bottle which lay in the mud deposit 2′ above floor level. This layer was of putty–like consistency and the bottle is unlikely to have sunk through it in recent times. In fact it must have been thrown there during the accumulation of the deposit.

[66] Strabo : XII, 3, p. 30

[67] *Greek Anthology*, IX, p. 418, quoted by Curwen, op. cit.

[68] Steensberg, A : *Bondehuse og Vandmoller i Denmark gennem* 2000 *Aar*, Copenhagen (1952)

[69] *Ancient Laws of Ireland*, I, 125, 141

[70] 'An 11th century poem ascribes the introduction of the first water-mill to Cormac Mac Art, King of Ireland (254–277 A.D.)'—Curwen, C. E : *Antiquity*, XVIII (1944) p. 138

The above considerations then prompt us to suggest that the mill had been abandoned more than two hundred years ago. In light of this, the following extract from the Civil Survey of 1654 [71] is of interest :

Mashanagliss—by estimation 3 ploughlands
Proprietor—Owen McSwiney, Irish Papist
The said land is bounded on the East with Aghinagh and Curraghanerly lands on the South with ye River Lee on the West with ye Rivers Sullane and ye River Lany running into the same, on the north with ye Brook or spring of Glassinagowne . . . on the p^r^misses is a demolished Castle and a grist mill in repair val^d^ at £3. There's a yearly chief rent of £4 0 with suit of court Leet & Barron to the Manor of Macroomp, answerable out of ye p^r^misses to the Ld. of Muskerry.

It is possible that the mill referred to above is, in fact, our horizontal mill. The site is no more than a half mile from the ruins of Mashanaglass Castle, and there is no record or tradition which would indicate any other mill site in the townland. There is, however, one point which must be borne in mind and that is that the townland boundaries mentioned in 1654 are far more extensive than the modern ones. For instance, the Laney River is over one mile away with Ummera townland lying between. Similarly, the Clashavoon stream (Glassinagowne in 1654) is about a mile away to the north. Thus the grist mill mentioned above may have been elsewhere in the district outside the present townland.

If, however, we accept that the Mashanaglass horizontal mill is identifiable with the grist mill of 1654 we find that our previous suggestions regarding its date fit rather closely with this literary evidence. On that basis we can suggest that the Mashanaglass mill was in working order in 1654, had been built before that date, and was abandoned late in the 17th century.

Jespersen [72] states that by 1600 the vertical mill had superseded the horizontal mill in the majority of the areas where before the horizontal mill had served for centuries. If we accept the 17th century date for the abandonment of Mashanaglass we find that the change over in milling technique had been accomplished rather slowly in the Lee valley. Not so slowly, however, as in Connaught where the horizontal mill continued in use until the early 20th century. It is notable that Curwen records this type of mill was in common use in the country districts of Norway in 1944, and we will see that it was also in use in areas of Spain, Greece and China as well as in the Western Isles of Scotland in the 19th century, so that we can group our Connaught mills with these far flung remnants of a two thousand year old milling tradition.

DISCUSSION

The horizontal mill was widely distributed in Europe and Asia. Its place of origin is, so far, unknown, but it is generally accepted as having been invented in either Greece or China. Jespersen [73] who has extensively

[71] I am indebted to Mr C. Ó Cuileanáin, Irish Placenames Commission, Dublin, for this reference

[72] Jespersen, A : *Gearing in Watermils* (Gangtojet i Vandmoller), Virum, 1953

[73] Jespersen A : op. cit.

studied the development of milling in Europe assigns the origin of the horizontal mill to Greece in the 1st century B.C., but O'Reilly [74] and Curwen [75] do not preclude the possibility that it may have entered Europe from central Asia or China at that early date. It is generally agreed that the horizontal mill predates, by a short period, the invention of the Roman one-step mill with vertical water-wheel as described by Vitruvius in 25 B.C. [76]

Horizontal mills in working order have been recognised in China,[77] Persia,[78] Turkestan,[79] the Holy Land,[80] Roumania,[81] the Dardanelles,[82] Greece,[83] Italy,[84] the Garonne region of France,[85] Spain,[86] the Isle of Man,[87] the Western Isles,[88] Caithness and Sutherland, Orkney and Shetland,[89] the Faroes,[90] Norway [91] and Ireland at dates ranging from the sixteenth and seventeenth centuries to modern times.

The distribution of the mill in Europe and Asia indicates that it follows two ancient trade routes. To the east along the ancient trans-continental caravan route and westwards along the Mediterranean–Atlantic sea-trade route to Ireland from where the knowledge of the mill was apparently taken by the Vikings who introduced it into their dominions of the north.[92]

From the extant accounts we know that the basic principles of the horizontal mill remained the same in all regions—that is, a water powered horizontal wheel affixed to the lower end of a vertical shaft the upper end of which carried the upper mill-stone. The mill building consisted of two parts; the undercroft which housed the spinning water-wheel and shaft, and the overcroft or working floor on which the mill-stones rested and, of course, where the grain was ground. The mill-stones were set at the desired gap by raising or lowering a horizontal lever on which the water-wheel rested.

[74] *P.R.I.A.*, XXIV, C (1902–04), pp. 55–84

[75] *Antiquity*, XVIII (1944), p. 145

[76] Vituvius: *De Architectura*, X. Book 10, Chap. 5, pt. 2. Rome. 20 B.C.

[77] Bennett, R. & Elton, J: *History of Corn Milling*, Vol. 2, p. 26 London & Liverpool, 1899

[78] Goudie, G: *P.S.A.S.*, XX (1886), pp. 295–296

[79] Curwen, C. E: *Antiquity*, XVIII (1944), p. 136

[80] Darvieux: *Des Arabes*, Paris (1717), quoted by Bennett & Elton

[81] Bennett & Elton: op. cit.

[82] Castellan, A. L: *Lettres sur Constantinople*, Paris (1811)

[83] Bennett & Elton: op. cit.

[84] *The Scotsman*: 24 August 1885, quoted in *P.S.A.S.*, XX (1886), pp. 295–296

[85] Henzer, P: *Itin. Gall.*, LVI, p. 262, quoted by Bennett & Elton

[86] O'Reilly: *P.R.I.A.*, XXIV, C (1902-04), p. 76

[87] Gibson's *Camden*, II, p. 1448

[88] *P.S.A.S.*, XV (1881), p. 135–136

[89] Goudie, G: op. cit.

[90] Landt: *Faroe* (1810), p. 293, quoted by Bennett & Elton

[91] Curwen, C. E: *Antiquity*, XVIII (1944), p. 145

[92] Curwen, C. E: *Antiquity*, XVIII (1944), p. 144

The available evidence, however, indicates that two types of water-wheel were used. In Ireland, the Isle of Man, the Mediterranean region and, as far as we know, in Asia the wheel consisted of a nave with radiating wooden scoops, whereas in the northern regions—Orkney, Hebrides, Norway, etc., the scoops were discarded in favour of flat wooden boards fixed obliquely, or in some instances vertically, into the nave. In Persia, the Levant and Spain the wheels were caused to rotate in an anti-clockwise direction, whereas in the region from Ireland to Norway the mill worked in a clockwise direction.[93]

In most of the known sites both of the northern province and of the Mediterranean region the water was normally led to the mill from an artificial channel and directed on to the wheel through a sloping flume. From the illustrations of mills in Norway, the Western Isles, Spain and the Mediterranean region it is possible to estimate the slope of the flumes as ranging from 17 degrees with respect to the horizontal at Lewis (fig. 12 C), to about 30 degrees at an unspecified site in Norway [94] and 40 degrees at Lampsaki in the Dardanelles (fig. 12, A).[95]

Alternative methods of developing the required water jet are exemplified in Greece [96] and Spain.[97] At the site in Greece the water was led from an elevated stream or aqueduct into a tank shaped as the frustum of a cone. A horizontal tube near the base of this tank and at the level of the water-wheel conducted a jet of water from the tank on to the wheel. Secondly, O'Reilly described a horizontal mill at Comillas (fig. 12, B) in the north of Spain which was worked by impounding tidal water behind a dam and releasing it through a sloping flume on to a wheel of 'radiating buckets' or scoops.

In the Mediterranean region it appears to have been the normal practice to construct a raised aqueduct (see Lampsaki, fig. 12, A) while in the northern regions a known procedure was to lead some water from a suitable stream and to conduct it, through an open chute, to a mill standing a little distance downhill on the bed of the same stream.[98] Alternatively a covered in flume was led through the otherwise solid rear wall of the wheel-house. In this case, the mill could be built beside the rivulet or stream which, when diverted, supplied the motive power for the mill.

It is a surprising fact that none of the early Irish discoveries was investigated fully or reported upon coherently in the appropriate journals. In fact there is a division of information between the journals and the newspapers with, remarkably enough, some of the more vital details concerning two important sites, Knockrour and Bantry, published in the newspapers. The omission of this information from the journals has inevitably caused a misinterpretation of the typology of those sites and a consequent misreading of the evidence from several other sites.

[93] Curwen, C. E: *Antiquity*, XVIII (1944), p. 143

[94] Curwen, C. E : *Antiquity*, XVIII (1944), fig. 5, p. 141 and pl. 4

[95] Castellan : *Lettres sur Constantinople*, Paris (1811). Illustration used by O'Reilly in *P.R.I.A.*, 24, C (1902–04), pl. 31

[96] Bennett & Elton, quoted by O'Reilly, op. cit. p. 73

[97] O'Reilly : op. cit., p. 75, and pl.3.

[98] Curwen, C. E : op. cit., pl. 4

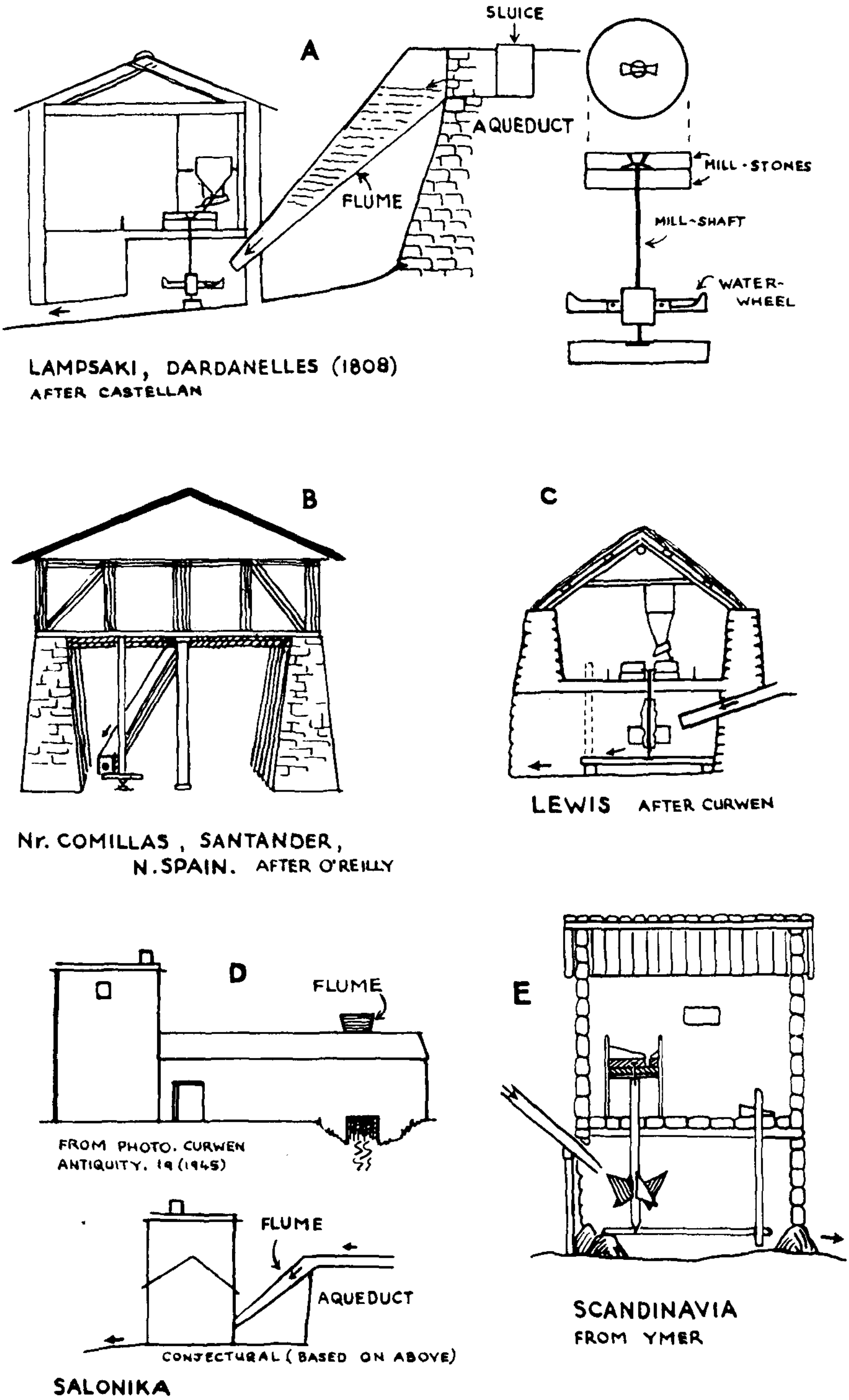

A
SLUICE
AQUEDUCT
FLUME
MILL-STONES
MILL-SHAFT
WATER-WHEEL
LAMPSAKI, DARDANELLES (1808)
AFTER CASTELLAN
B
C
Nr. COMILLAS, SANTANDER, N. SPAIN. AFTER O'REILLY
LEWIS AFTER CURWEN
D
FLUME
FROM PHOTO. CURWEN ANTIQUITY. 19 (1945)
FLUME
AQUEDUCT
CONJECTURAL (BASED ON ABOVE)
SALONIKA
E
SCANDINAVIA
FROM YMER

Fig. 12

So it is that the most recently published views concerning the horizontal mill in Ireland [99] must now be revised in light of the Mashanaglass evidence, and of the additional information available regarding the Knockrour and Bantry mills.

It is now clear that at least five Irish sites (Mashanaglass, Knockrour, Bantry, Mallow and Kilnagross) were equipped with flumes which sloped at from 30 to 40 degrees to the horizontal. Such sloping flumes are quite comparable with those on Scandinavian and S. European horizontal mills which sloped at from 17 to 40 degrees to the horizontal.

At least one Irish site, Meeltraun, was worked by a horizontal delivery. But, it must be emphasised that the jet in that instance was generated under pressure of a 5′ head of water maintained in a cistern behind the wheel-house. A minimum head of 1′ 9″ of water was needed to work the mill efficiently. The lowest point of the flume orifice was level with the blades of the water-wheel so that the relationship between the wheel and the jet was quite similar to that at Mashanaglass. However, the salient difference between the two mills was that in one instance the force of the jet was mainly developed by gravity as the water descended the *sloping flume* while in the other, Meeltraun, the force was developed under pressure from the head of water in the cistern, and delivered through a near *horizontal flume*. Incidentally, as far as one can judge, the Meeltraun flume was quite short. The Meeltraun wheel was 5′ 6″ in diameter, and the stone speed was 150 to 180 revolutions per minute so that there is no reason to suppose that it was less efficient than its steep flume counterpart.

Knox [100] appears to have confused the issue when he stated that scoop paddles were best adapted to a jet of water delivered horizontally, and that the introduction of the flume inclined at from 30 to 40 degrees 'was an innovation here'. It must be remembered, however, that Knox was discussing a particular site, Cullentra, and was not laying down a general dictum regarding Irish horizontal mills. He observed that the inclined jet tended to beat the paddles downwards and tear them out of their sockets. Again he was referring to the Cullentra mill where 'long narrow boxes made of inch boards had replaced the sallywood paddles of the earlier days'. These boxes were bound into position with a thin iron hoop. Had the water-wheel been made by the Moycraig or Mashanaglass wheelwrights we may be sure that no extraneous supports would have been needed. It is, indeed, obvious that both the Cullentra and Meeltraun mills were the end-products of a dying craftsmanship.

The system of dowelling the shafts into the nave and again dowelling the paddle stems together immediately outside the perimeter of the nave gave a wheel of great stability which needed no other supports or binding. However, the secret of assembling such sturdy wheels appears to have been lost, in Ireland at any rate, before Knox's time. That was not so on the continent for Curwen [101] recently illustrated a horizontal mill, near Salonika,

[99] Lucas, A. T : *J.R.S.A.I.*, LXXXIII (1953), pp. 1–36
[100] Knox, H. T : *P.R.I.A.*, XXVI, C (1906–1907), pp. 265–273
[101] Curwen, C. E : *Antiquity*, XIX (1945), pp. 211-212

the wheel of which was remarkably similar to the Mashanaglass and Moycraig wheels, and accommodated almost forty scoops without stays or bands of any sort. It was worked by a jet delivered from a steep flume to which water was led by an aqueduct (fig. 12, D). Similarly, O'Reilly,[102] illustrates a horizontal mill from Lampsaki (fig. 12, A) which was worked by a 40 degree flume discharging on to a wheel with wooden scoop paddles. Here again there was no evidence of stays or bands. Finally, O'Reilly [103] described and illustrated a horizontal mill at Comillas in north Spain. This was also worked by water delivered through a steeply sloping flume to a wheel with scoop paddles, for which there were no extraneous supports. In view of this foreign evidence, as well as the evidence from Mashanaglass and other sites, we must conclude that Knox made an insecure deduction when he said that 'The delivery from above [steep-flume] seems suited to oblique boards . . . Horizontal delivery as near as possible to the wheel seems better suited to the ladles'.[104]

The fact that the remains of many of the Irish horizontal mills were found buried beneath four to eight feet of bog has also led to a certain amount of confusion. Windele, for instance, in discussing Shanacashel was under the impression that the bog had grown up after the mill had been abandoned. Thus it seems that it was not fully realised that the wheel-house, or undercroft, of the mill had been constructed below ground level in order to provide for the necessary fall of water to the water-wheel, or in the case of a cistern feed, to allow for the accumulation of a sufficient head of water to work the mill.

The *sunken* wheel-house differentiates the Irish mill from its S. European counterpart. Both the Lampsaki and Salonika mills were fed from raised aqueducts through flumes which were, of course, *above* ground and their wheel-houses were built in the normal way on the surface of the ground. (See fig. 12, A and D).

As pointed out by Lucas, the Irish evidence indicates that the mills were built near but not on the natural water supply.[105] Water was brought to the mill through an artificial head-race and directed thereby into the sloping flume or cistern as the case may be. The advantages to be derived from such a system are manifest : firstly the mill could be provided with a *controlled* supply of water, secondly, either when the mill was not in use or the stream was in flood, the unwanted water could be caused to bypass the mill via the natural stream bed, and finally, the construction of the sunken wheel-house could only be conveniently undertaken on a site which was not directly in the path of a flowing stream. So it is evident that the construction of the mills on artificial channels was in certain respects a necessity, but above all it was a procedure which was entered upon in order to facilitate the provision of a regulated *fall* of water to the wheel in the case of a steep-flume mill, and the maintenance of a controlled *head* of water in the case of a pressure-jet cistern-fed mill.

[102] *P.R.I.A.*, XXIV, C (1902–04), pp. 68–73, quoting Castellan : *Lettres sur Constantinople*, Paris (1811)
[103] *P.R.I.A.*, XXIV C (1902–04), p. 76 and pl. 3
[104] Knox, H. T : *P.R.I.A.*, XXVI, C (1906–07), pp. 265–273
[105] Lucas, A. T : *J.R.S.A.I.*, LXXXIII (1953), p. 32

Much has already been said concerning the development of the requisite water jet. Summarising this we find that, apparently, four separate methods were employed. At Mashanaglass the glen was dammed in the normal way, and a head-race carried the water directly to the sunken flume. At Knockrour a dam does not appear to have been used, instead the mill pond was accumulated within a wooden lead-in channel immediately above the open end of the flume, where, apparently, the water supply was regulated by a sluice. A similar system seems to have been used at Bantry but, in this instance, the water was ponded in a sunken cistern (?) from which it descended the flume 'to the works standing considerably beneath'. Finally, at Meeltraun, a cistern was again used but, in that instance, in conjunction with a near horizontal flume which delivered a pressure-jet to the wheel.

Three separate types of nave are recorded. The gudgeonless 'spinning-top' Mashanaglass nave (fig. 6, B.), the stone-gudgeoned blunt-based Moycraig nave (fig. 6, D.) and the metal-gudgeoned Meeltraun and Cullentra naves. It may be that these represent a developmental series of water-wheels in which the stone-gudgeoned wheel is intermediate between the Mashanaglass and Meeltraun wheels.

Again, the scoop paddles as exemplified on these sites seem to indicate a gradual decline in craftsmanship. Those from Mashanaglass display a degree of subtlety and skill far beyond that of the Moycraig paddles while, at Meeltraun, the scoop paddles of the earlier days had been discarded in favour of long narrow boxes open at one side. The most evident difference between the Mashanaglass and Moycraig paddles is that the 'felloes', (fig. 6, G) which occur on the former are absent from the latter, (fig. 6, C). These 'felloes' ought to have set up a sort of fly-wheel action when in motion, thus perhaps leading to a more efficient wheel than that from Moycraig. Another noticeable difference between the paddles is that whereas the Mashanaglass scoop blends directly into the dowel-block (fig. 6, A, G and J) the Moycraig scoop is separated from the dowel block by a distinct shaft (fig. 6, C and K). Finally, the Mashanaglass paddles have rounded or streamlined backs (fig. 6 G, bb) whereas the Moycraig paddles have vertical backs (fig. 6, K, aa). Since the rounded backs of the paddles lessened the resistance to the dead water falling from the preceding paddle as the wheel spun, it is clear that the Moycraig paddles, which lacked this refinement, were less skilfully designed than those at Mashanaglass; in other words, the Moycraig paddles appear to represent a declining craftsmanship. In conclusion it must be noted that the Mashanaglass wheel was fitted with a detachable shaft whereas the Moycraig nave and shaft were cut from a solid balk of wood.

Present evidence indicates that the millstones, normally of siliceous sandstone, varied in diameter from 2′ to 3′ 4″, the upper stones being $4\frac{3}{4}$ to 6″, and the lower 12 to 14″ thick. Normally the eye of the upper stone was cylindrical (one from Mashanaglass was slightly constricted) for most of its depth but splayed outward to the under surface of the stone. The eye diameter, at its narrowest, varied from $4\frac{1}{2}$ to 6″. The lower stones were equipped with wooden bearings which centred and steadied the spindle (fig. 2, B). The earlier millstones (Mashanaglass) were equipped with two rynd sockets but the later ones (Meeltraun and Cullentra) had four.[106]

It must be noted that the working surfaces of the upper and lower Mashanaglass millstones together form specific functional zones (fig. 8, F) and this again reflects the high degree of skilled craftsmanship so evident in the other aspects of the Irish horizontal mills.

A. T. Lucas [107] has already drawn attention to the coastal distribution of the horizontal mill in Europe. It is also worthy of note that the known Irish sites show a distinct adherence to the hilly coastal regions—Kilkenny, Waterford, Cork, Kerry, Galway, Mayo, Down, Antrim and Dublin. By far the greater number of discoveries has been made in Counties Kilkenny and Cork, and the reporting of these indicates that by the mid 19th century the horizontal mill had then become a thing of the past in the south of Ireland. However, that was not so in Connaught where the mills functioned, in a debased form, until 1906, at which time, according to Knox, the tendency was to convert them into vertical mills.

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[106] Knox, H. T: *P.R.I.A.*, XXVI, C (1906–07), pp. 265–273
[107] Lucas, A. T: *J.R.S.A.I.*, LXXXIII (1953), p. 2

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APPENDIX I

Kilnagross [1]

A flume with a slope of 5′, a wooden floor 8′ by 5′, two pairs of quern stones, and the shaft of a mill-wheel were found beneath a 'considerable depth of clay'. It had been discovered two months before it was reported, and in the interval 'much of the structure had been carried away'. However, the local man, who reported the discovery to Windele, saw the floor in position and is quite clear about the details. He also states that he had seen four other sites similar to this one, and that they were locally called *baisin* mills. Furthermore, he says that the wheel should be very small 'with open floats'— a fact that suggests he had seen the remains of a wheel with scoop paddles, which are, in several instances, referred to as 'floats'. The term *baisin* mill is unusual and may refer to the ponded water behind the dam—as at Mashanaglass. There is, however, no recorded evidence of a dam at Kilnagross.

Bantry [2]

Windele visited this site and described it as follows: '. . . a water channel and a square timber cistern from which the collected water was conveyed by a large oaken chute to the works standing considerably beneath. There was scarcely any iron used in the construction, the fastenings were generally of wooden pegs . . . and a stream ran beside it'.

This obviously conforms to the other sites in its general aspects. The 'cistern', apparently to the rear of the wheel-house may have been similar to the 'lead-in' at Knockrour. The sloping oaken trough is, however, the most important item to note, as it places the site in the steep-flume class without any shadow of doubt.

Knockrour [3]

O'Conlon's report records the discovery of a large wooden trough (with lid) in a marshy field on the hillside at Knockrour, Co. Cork. Two plank walls, some 4′ high, diverged fanwise for over 20′ in north easterly and north westerly directions from the northern end of the trough. The southern end of the trough, in which there was an 8″ orifice is recorded as having rested *on* a large upright slab of stone. This slab, a few inches thick and almost 6′ long, was penetrated by an inverted U-shaped cut, 2′ wide.

Power [4] who also visited the site, gives further information, notably, that the 'trough tilted to the south at an angle of 40 degrees, and that at outlet of water from the chute are large stones, apparently the remains of an uncemented building'. The trough, or flume, was 13′ 2″ long and 1′ 8″ square.

The writer has also visited the site. Mr J. Lynch, who discovered the flume, informs me that it was from 4′ to 8′ deep in the ground and that, when found, the lower, or southern end of the flume was housed in the U-shaped cut in the slab mentioned above. He confirms the fact that the site was not fully explored.

Mallow [5]

Windele records that this structure was similar to the Bantry site, discussed above. He reports the finding of fragments of a quern, and 'a wooden stock with portions of the spokes of a wheel which latter had been fastened with wooden pegs.' Berry [5a],

[1] *T.K.A.S.*, I (1849–1851), pp. 154–164

[2] *The Cork Constitution*, 21 December 1844. See also *T.K.A.S.* I (1849–1851), pp. 154–164

[3] O'Conlon: *J.C.H.A.S.*, XXXI (1926), pp. 96–101

[4] Power: *Cork Examiner*, 27 September 1928

[5] *The Cork Constitution*, 21 December 1844

[5a] *J.C.H.A.S.*, II (1893), p. 25

quoting the Windele MSS, tells us 'he found some planks of oak within four feet of the surface, and a cellar containing a quantity of heath and oak leaves. The floor was of oak planks, from which a balk of same extended to within a few feet of the surface, having a grove from end to end 2′ wide in the centre,"as if to convey liquid to a vat." '

Shanacashel [6]

This site is described as being in 'low moorland between high rocky elevations.' About 8′ of peat had been cut away, and below it, resting on the clay, what is described as a wooden cistern, was found. This cistern consisted of a floor of 'sawed planks' apparently enclosed within a framework of four large beams. The cistern was 20″ deep, 14′ 8″ long, and 6′ 10″ wide. There were several mortices 1′ 6″ long, some of which held upright boards about 3′ long. These were charred at that level, as was the 6′ long shaft of a wheel, with mortices for 'mill-fans', which was found on the floor of the cistern. A broken 'upper stone, 2′ in diameter and 8″ thick, a broken lower stone 3″ thick falling away to 1½″ at the edge', and a wooden shovel lay within the cistern. About two years earlier a trough 12′ long was dug up 'at one end of the cistern'.

Windele did not see the shovel, which had been carried away, nor did he see the trough. Furthermore, he states that the site was not fully explored.

Muskerry [7]

Windele describes this site as follows : '. . . one side of the watercourse at the head of the bank was formed of a wall of drystone masonry about 20′ in length. The bank, the sides of which consisted of square beams, placed on each other, with a superstructure of drystone work was 20′ in length and of similar breath in its upper part, but narrowed to 11′ at its lower. From this last, two chutes, each 12′ in length and 1′ 9″ deep extended in a standing position and communicated with a second bank of nearly similar extent to the first. Indications of upright timbers appeared below this but were not explored. The length of the structure down to the unexplored position was 92′.'

The description of this site is most ambiguous. Apparently a water course, an artificial bank, two troughs, a second artificial bank, and finally, the wooden uprights of a wheel-house (?) were arranged one behind the other in sequence.

Coumshingaun [8]

'Thomas Kennedy on whose lands on the Comeragh Mountains is the celebrated lake of Coomshingane has recently discovered below the surface of his land, a large trough 12′ long, 2′ wide and 2′ deep, having holes at the end from which, it is supposed, chutes led to carry off the liquor extracted from the mountain heath from whence the Danes made their beer.

The trough was made of black bog-oak and was filled with the tops of this heath. It is not far from the lake and parties come daily from far and near to inspect it.'

Morett [9]

This site was discovered in May 1952, and was investigated by A. T. Lucas and K. Danaher. The structure lay in a shallow depression which was formerly filled with bog. The remains consisted of a central wooden flume (14′ long, 2′ wide and 11½″ deep internally) from both ends of which radiated two diverging wooden frameworks. The V-shaped areas enclosed by these frameworks were floored with wooden planks. In one instance, the north V (15′ 10″ long, 6′ 3″ wide narrowing to 2′ 10″ where it met the flume), the boards lay transversely, and in the other, the southern V (15′ 4″ long, 2′ 3″ at the flume expanding to 3′ 4″), the planks lay parallel with the long axis of the structure.

The excavator concludes that the northern V was the dam from which the water was conveyed, via the flume, to the southern V or wheel-house on the floor of which two pivot stones were found. The flume lay horizontally in the ground ; internally

[6] *T.K.A.S.*, 1 (1849–51), pp. 154–164
[7] *The Cork Constitution*, 21 December 1844
[8] *The Cork Constitution*, 5 September 1849
[9] Lucas, A. T : *J.R.S.A.I.*, LXXXIII (1953), pp. 1–36

its floor had been hollowed so that a slope of about 1′ 6″ was obtained between the dam and the wheel-house. The lowest point of the flume was level with the wheel-house floor.

It was concluded that Morett was a horizontal mill in which water was delivered almost horizontally to the wheel.

Glenwood [10]

This site was discovered in 1948 while excavations for the foundations of a building were in progress near the bank of a stream which flows through a narrow glen in the above townland. No mill structure was exposed, but six broken mill-stones were unearthed at depths ranging from 2′ to 5′. The area excavated was 13′ 6″ long by 8′ 6″ wide; much soft dark soil was encountered and what appeared to be an ancient head-race extended for some distance up the glen. The nearby stream could readily have been dammed to provide a water supply.

The interesting point about this site is that the mill-stones are similar to the Mashanaglass ones. One millstone was 2′ 6″ in diameter, 6″ thick and had a cylindrical eye 5½″ in diameter. It had two rynd sockets. One lower stone measured 2′ 6″ in diameter and was 14″ thick. The central hole was tapered or funnel shaped for 5″ and cylindrical for the other 9″. The diameters were 7″ and 5″ respectively (fig. 6, E). It lay on limestone bed rock 5′ below the surface. A further lower stone 2′ 7½″ in diameter, with a central eye 4½″ in diameter was found at an unspecified depth. Its maximum thickness at the centre was 7″ and the eye was cylindrical. A group of five fragments of upper mill-stones was found at an unstated depth. One fragment was decorated with a raised band similar to that of mill-stone C at Mashanaglass. A further group of three fragments was found at a depth of 4′ 6″ and finally a complete stone was excavated, again at an unstated depth. Thus a minimum of six mill-stones was found.

APPENDIX II

Report on the wood specimens submitted by Miss M. J. P. Scannell, M.Sc., National Museum, Dublin :

Specimen	A (nave of the water-wheel) :	*Quercus* (oak)
,,	B and E (paddles) :	*Quercus* (oak)
,,	C and D (dowels from water-wheel)	*Taxus* (yew)
,,	F (stake G, fig. 9)	*Alnus* (alder)
,,	G (stake L, fig. 9)	*Alnus* (alder)
,,	H (shovel ?) fig. 9, 0)	*Prunus* (cherry)
,,	I (peg J, fig. 9)	*Quercus* (oak)
,,	J (peg M, fig. 9)	Wood structure not well preserved but probably *Prunus* (cherry)

[10] The information of this site is taken from a MS report made by G. Pennefather, Esq., which is in the files of the Cork Public Museum.