William Colles (1702-1770), Kilkenny Mayor, Entrepreneur, and Marble Necromancer

Dermot O'Dwyer
Department of Civil, Structural and Environmental Engineering, Trinity College Dublin

Introduction

William Colles (1702-1770) was an entrepreneur, inventor, mill owner and building contractor who lived in Kilkenny in the south-east of Ireland. William was the son of an English surgeon who moved to Kilkenny about 1690 and, through a friendship with the 2nd Duke of Ormonde, bought large estates of confiscated property [1]. In about 1730 he established the Kilkenny marble mills, which remained in the control of the Colles family until they closed in 1920. He was the grandfather of Abraham Colles (1773-1843) a leading Irish surgeon of the nineteenth century after whom the Colles fracture is named [2].

William Colles was a man of many talents. In his early life he was reputed to have written poetry, and throughout his life he participated in local administration. He was an Alderman, the city Treasurer, and was twice Mayor of Kilkenny city [3]. He owned and constructed a number of mills for the production of flax, flour and marble. He was central to the attempt to extend the navigation of the river Nore upriver from Inistioge to Kilkenny. William Colles was also a contractor who build many fine houses in the Kilkenny area and was contracted to construct the Kilkenny canal and the replacements for some of the principal masonry bridges across the Nore following the destruction of most of the bridges over the river in the flooding of 1763 [4]. He is was also identified as the person who constructed the current, third, Tholsel in Kilkenny [5]. A Tholsell is an Irish term for a type of building that functioned as a town hall, toll house, and courthouse. In this case it was the town hall raised on arches.

Many of William Colles' enterprises were significant and are worthy of detailed study. This paper concentrates on his development of machines to cut, bore and polish marble. Colles' work in this field is celebrated in Kilkenny, which is known as "The Marble City", but is little known elsewhere. It predates similar developments in the working of stone in the United Kingdom. Colles is a classic example of a highly talented entrepreneur who developed, or progressed, a technology largely independently of others, but who was part of the simultaneous technical advancements of the early industrial revolution.

Working of Stone in Ancient Times

Stone has been worked since antiquity [6]. It is appropriate to consider the achievements of the Egyptians, Greeks, Romans and other ancient civilisations before expressing amazement at the achievements of construction workers and engineers in later centuries. For example, Fontana's achievement in moving the obelisk in Rome about a quarter of a mile in 1590 is put into context by the more significant achievement of the Romans who transported it from Egypt and the achievements of the Egyptians who quarried, erected and transported it and other obelisks [7]. Similarly, Colles's achievement in boring water conduits from solid Kilkenny marble (a variety of limestone that appears black when polished) should be assessed against the Romans' ability to turn large columns on a lathe, the evidence of Roman and Byzantine water-powered mills for sawing stone, and later medieval marble mills [8].

The reference to Roman quarrying technology, and to Pliny in particular, is of particular relevance to William Colles's mechanical developments for the cutting, boring and polishing of Kilkenny marble. In his *Encyclopaedia of Natural History* Pliny describes the process by which marble is sawn [9].

> "The cutting appears to be done by iron, but really it is achieved by sand: the saw exerts pressure on the sand along a very thin line and it is the sand's movement to and fro that actually does the cutting."

This is the same basic process, albeit mechanised, that was used in Colles' marble mills.

Colles's other innovations

William Colles is most famous for his marble works, but he introduced innovations in many other industries. Tighe's 1802 account of the marble mills, written after William Colles' death, contains a description of his development of the machinery used in the mill, stating that, "He first tried a model in a small stream, and finding it succeed, took a perpetual lease of the marble quarry" [10]. This development and testing of prototype mechanisms is in keeping with the description of Colles' other works. Tighe described Colles as,

> "A man of great mechanical abilities and abounding in a variety of those eccentric schemes which mark original genius, though success only, in the eyes of the world can stamp them with rationality; one of which was an attempt to make dogs weave linen by turning wheels; …Such was the impression that his abilities made on the common people, that to this day his feats are proverbial among them, and they speak of him as a necromancer…He amused the populace by various devises, such as that of a musical instrument which played by itself, as it floated down the stream of the river, and many others,…He applied himself to the construction of useful machinery for different purposes; and invented a water mill and an engine for dressing flax, simple and efficacious, but now no longer used." [11]

Colles' interest in flax was significant. His entry in the dictionary of Irish biography describes the machinery he developed for processing flax and notes that in 1751 he was awarded a Dublin Society prize for the most flax grown [12]. Tighe states that,

> "Alderman Colles raised great quantities of flax; he invented a water machine to take off the bows of flax, and break them at the same time, which was attended by children, without danger of damage; and also an engine into which he threw the broken bows, and separated the light chaff from the seed, which was brought out finished and perfectly clean for sowing; these machines were plain and simple: he used a Dutch oven for drying Flax; and had it dressed by hand, instead of a mill, which he found injurious and wasteful." [13]

Colles also constructed, and operated, a three-storey flour and oat mill at Abbeyvale, a few hundred yards down-river from the marble works at Maddoxtown [14]. This mill was the largest industrial building in the country at the time of its construction in 1762 [15]:

> "…mills three stories high, whereby oats are shelled, winnowed from the shellings, ground to meal and shifted, by a regular and easy course of progression, and wheat is in like manner ground and completely dressed into flour, all of which are of a new, firm and convenient structure, many parts of which were invented by the petitioner [Colles] on much and long attention after several expensive trials with kilns and granaries necessary; and are fully supplied with water at all seasons of the year, and so much out of the reach of floods that they receive but little damage from the last extraordinary floods in that part of the country [16]."

The mill at Abbeyvale was one of a number of very large multi-storey mill buildings constructed in Ireland around this time, including the large mill at Slane completed in 1766 [17]. The development of these mills predate Arkwright's mill by about thirty years [18].

Detailed Description of Colles' marble works

The Kilkenny marble mills founded by William Colles continued in family ownership for many years and finally ceased operations in 1920 [19]. The full history of the marble works is described in detail by Hand [20]. Hand's thesis also covers William Colles' involvement in the Kilkenny Canal [21]. Kilkenny had a long history of marble quarrying and production and the Black Quarry, which was used as a source of marble by Colles was described by Bishop Roth writing in the seventeenth century [22].

William Colles' letter to the Dublin Society

The first mention and description of William Colles' marble works is his letter to the Dublin Society, a society that had been established in July 1731 by the members of the Dublin Philosophical Society with the aim of promoting improvements in animal husbandry, manufacturing, the sciences and other useful arts. The Dublin Society was later renamed the Royal Dublin Society, the name it is known by today. The letter, or a summary of it was written directly into the minutes at a meeting in February 1731. The text reads,

> "As I have seen a Paper inviting all Persons to comunicate to the Dublin Society, Improvements in Arts, & Manufactures, I thought it might not be unacceptable to let them know, That there being within ¼ of a Mile of Kilkenny, a Quarry of Excellent black marble, beautifully Veined, with great Variety of White, if tedious & expensive Methods of sawing, & polishing which, in the common Way, rendered the Trade for the said Marble less extensive that it might be, if wrought by a more expeditious Manner, induced me to try some Experiments in relation to sawing the same by an Engine, w[hi]ch appearing practicable, I obtained an Interest in the Quarry, & some Mills, on the River near adjoining thereunto, where I have now ten saws, w[hi]ch are moved by Water, & going night & day, & saw the Marble more true, and expeditious, than it can be otherwise be done, And have also erected an Engine that grinds the s[ai]d Marble with sand so as to fit it for polishing, whereby I employ upwards of thirty Hands in polishing & finishing Marble Chymney Peices, Tables, Cisterns, Mortars, Tombstones, & w[hi]ch I sell at more reasonable Rates, then heretofore they were sold.
>
> These Experiments Led me farther to the trying others, in relation to the Boring Pipes of the s[ai]d Marble, w[hi]ch I have brought to such Perfection, that I can bore Pipes of any reasonable Length from 2 to 10 inc[he]s Diam[eter]. fit for conveying water under Ground, or from the tops of Houses, for the Latter of which uses, some of them are set up at Mr. Sean Tighs Merch[an]t on Ushess Quay [23]."

This letter succinctly describes the nature of Colles's mechanical innovations in sawing, grinding and boring marble. The letter refers to the mills being adjacent to the quarry but may also refer to Colles's marble works at Abbeyvale, also called Maddoxtown. Colles is thought to have started his marble works at Maddoxtown, which is about two miles down-stream from the Black Quarry, in the 1730s [24].

Unfortunately, there are no surviving drawings of the machinery developed by Colles to saw, bore, true, grind or polish marble. However, Ramelli's 16th century text (Fig. 1), shows an animal-powered marble saw [25] that probably shows the key components of Colles' saw. Such illustrations show the key concepts involved in a mechanism but would not be sufficiently detailed to build the machine unless one was an experienced mill wright. This illustration shows a gearing

system, a crank, a saw frame and a method of adjusting the motion of the saw frame relative to the stone that is being cut. Ramelli's text also contains images of similar water-driven saws.

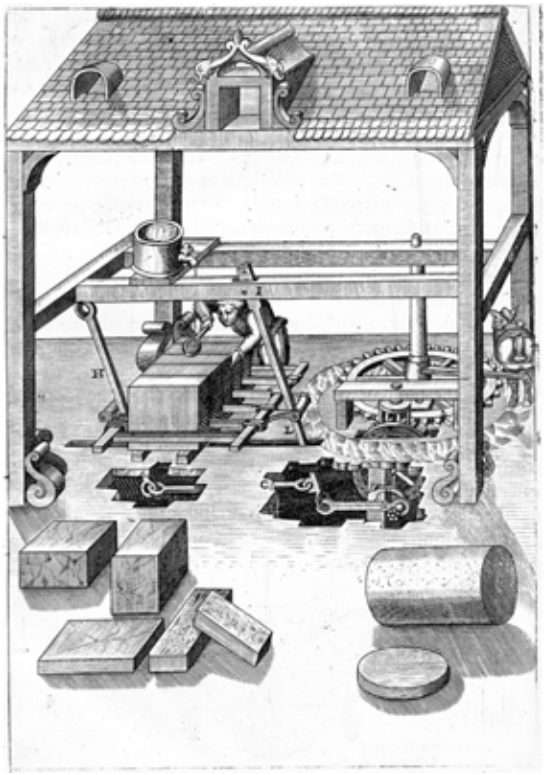

Figure 1: Animal-powered marble sawing mill from Ramelli 1588 [25].

The boring of marble pipes was probably achieved by a mechanism similar to the machine for boring wooden pipes illustrated by Isaac de Caus, (Fig. 2) [26]. A surviving piece of Colles' marble piping shows a female socket similar to the coupling system used in the timber pipes shown in the background of de Caus' illustration [27]. In practice it is difficult to build a machine to bore long pipes with precision. Similar machine arrangements were used to bore or true cannons but it was not until Wilkinson improved boring technology in 1775 that precision boring of metal cylinders was achieved [28]. Colles' achievement in being able to bore limestone pipes is impressive.

Two further accounts of the marble mills at Maddoxtown and of Colles' mills adjacent to the Black Quarry date from the time of William Colles. The first comes from *A tour through Ireland…by two English Gentlemen*, William Chetwood and Philip Luckombe, which was published in 1748 [29]. Their account of Colles' mills, was summarised by Tighe but is short of technical details. They describe seeing warehouses full of "such a diversity of chimney-pieces, cisterns, buffets, vases, punch-bowls, mugs of different dimensions, frames for looking glasses, pictures, etc." This combined with a newspaper advertisement for Colles' marble products confirms that he was turning a variety of smaller marble items at his mills [30]. Production of these products and of the bored pipes seem to have ceased by 1802 when William Colles' grandson, Richard Colles, had ownership of the mills.

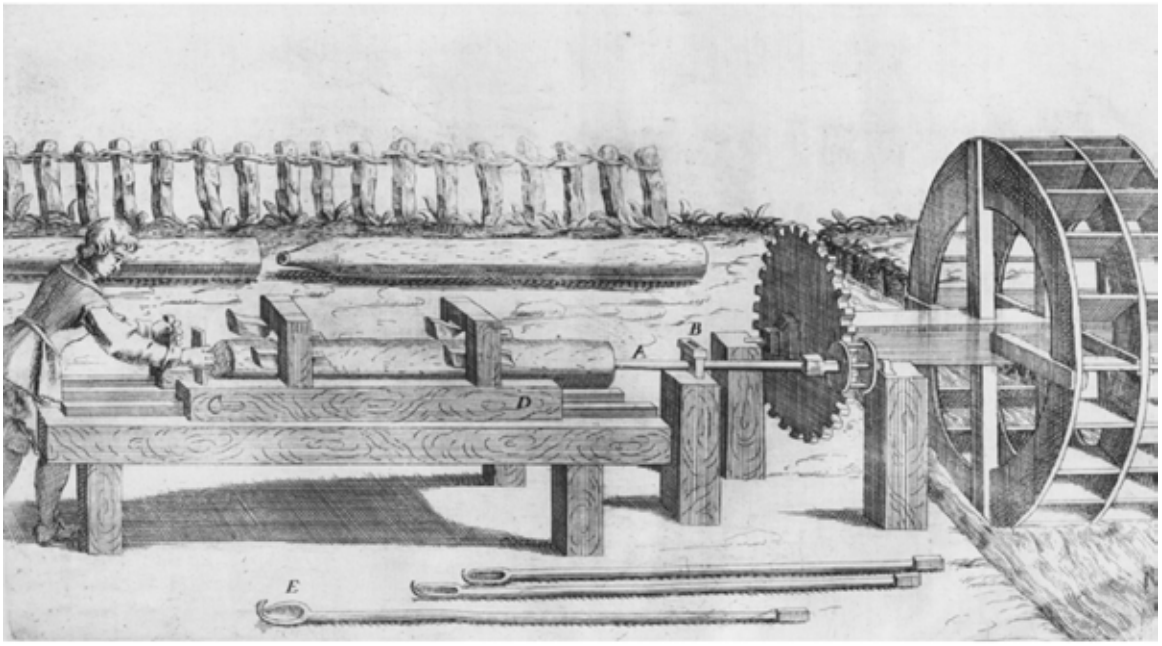

Figure 2: Illustration from Isaac de Caus' text on mechanical devices [26]

Hugh Dawson's account of Colles' grinding Mill

The second account of the marble mills is far more detailed. This account is by Hugh Dawson, from near Kilkenny, who gave a description of the Black Quarry and the marble mills to the Physico-Historical Society. This society was founded in 1744 but was wound up by 1752. It was founded with the objective of publishing county surveys covering industry etc. Dawson's unpublished account is held in the Robinson Library in Armagh. The following extracts are taken from Hand's account of these manuscripts [31].

Dawson states that Colles had erected mills on the river Nore where iron saws moved by two waterwheels sawed the marble "with Much more Expedition and Truer than by Mens Hands". This adds little to the picture painted by Colles himself, however; Dawson also includes an interesting description of Colles' system for truing the marble blocks. This involved first grinding one surface of the block, presumably a cut face, flat. Dawson states that the blocks were:

> "Ground to bring it truly out of winding by a waterwheel fixed horizontally which is moved by a current passing by one side of the wheel while the rest wades in an eddy:"

Horizontal waterwheels had been in use in Ireland since early Christian times but Dawson's description of the wheel being moved by a current passing by one side of the wheel while the rest wades in an eddy may not tally with the traditional horizontal mill described by Rynne [32]. The text suggests that the mill building straddled a channel or mill race. Above the waterwheel,

> "Is a circular bed of the sawed marble of 27 feet in diameter laid level and bedded in sand on which are laid a parcel of marble Slabbs Less than the Breadth of the Bed w[hi]ch by an arm Passing from the Shaft are Moved Round over the Bed and by a Small wheel fixed on said arm are so Shifted to and from the Center That they Every round change their Possision so as to Make no Hollows In ye Bed"

Both the blocks that make up the circular bed and the "parcel of marble Slabbs" are being ground flat. This would have required considerable care when laying the blocks in the circular bed in the sand bedding. If the arm that projected from the drive shaft had simply dragged the upper blocks in a circle over the bedded blocks, then the lower blocks would not have been ground flat. Instead circular paths would have been worn into the lower bed and the bottom surface of the upper blocks would have been ground to match. For the mechanism to work it was essential that the blocks moved both circumferentially and radially. Figure 3 shows a simple potential mechanism that tallies with Dawson's description. A is the shaft, shown rotating anti-clockwise, B is the arm, C the small wheel, D is a "wheel" that surrounds the shaft but doesn't rotate and E is a belt or chain to which the marble pieces are attached. There are many other methods of achieving the required motion: there is no implication that the mechanism described is the method Colles used.

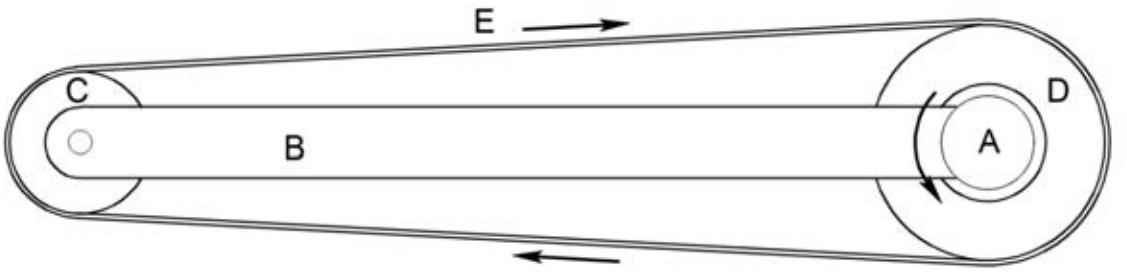

Figure 3: Mechanism to move blocks both radially and circumferentially.

Dawson commented on the time that it took to grind the blocks,

> "the Bed Stones take a fortnight or 3 weeks to Rubb Sufficiently but the Upper Stones w[hi]ch are always In Motion are Rub'd twice in a Day Here the Marble after being Rub'd on the fface is alsoe Rub'd on the Edges w[hi]ch Makes It as True as if Chiselled and free from Gapps:"

This makes sense as the upper blocks are constantly in motion whereas the lower bed is only ground when the upper blocks pass. Dawson also describes the next step in the process whereby the blocks are honed to remove the sand tracks. This confirms that, as one would expect, a sand slurry was used in the trueing process and further, that Colles did not attempt to rotate the upper blocks as they were dragged across the lower bed. Dawson describes the honing process thus,

> "where 3 or 4 Peices being Laid Side by Side there and fixed on Each of Them a piece of a Kind Greet Stone Called Black Hone found at a place called Chappel in the Libertys of ye Citty of Kilkenny which being moved by ye Mills Backwards and forward the whole Length of the Marble Slabb Takes out ye Tracks of the Sand & Leaves the Marble Smooth Skin'd and Black:"

The description of the grit stone as been moved back and forward by the mill implies that a crank was used to turn the rotary motion of the mill wheel into a back and forward motion in much the same way as the saw frames would have been moved. Dawson describes a final polishing sequence with emery and putty that is again driven by the mill and which achieves a finish on the flat surfaces, "no hand being able to give it a Higher Gloss that this do's" in a manner similar to the honing machine.

Dawson also comments on

> "Boring Pipes of Marble…and Making Pumps for all w[hi]ch uses they are Excellent He alsoe Turns & Polishes Marble Punchbowls, by the Same Mills. and Has thereby Made Engines for Extinguishing fires In one Solid Stone of 2ft 2in Long 1ft 10 In Deep and 1 foot 1 Inch Broad w[hi]ch Is a Valuable Improvement of these Kinds of Engines being less In Bulk more Durable Incapable of Rusting & Subject to fewer Repairs."

Dawson too makes the comment that Colles' mills were his "own Invention & Contrivance".

This combined with the description of the items in Colles' warehouses by the English gentlemen confirms that Colles was using a lathe to turn marble items and was still boring pipes in the late 1740s. The description of the pump cylinder block is interesting.

Tighe's account of 1802

The final description of the eighteenth-century mills from comes from Tighe, who published his account in 1802. William Tighe's *Statistical Observations relative to the County of Kilkenny* was addressed to the Dublin Society and was described as being made, for their consideration and under their direction [33]. By this time William Colles had died, and the mill was being run by his Grandson Richard Colles. Tighe gives a lot of information on the operation of the mills in general including details of costs and the quantities exported abroad. By Tighe's account some course work was finished at the Black Quarry close to the city with some of the blocks being split in the town by handsaws and a little polished work and the cutting of tomb-stones. However, the principal work was carried out at the marble mill at Maddoxtown, requiring the marble to be drawn across John's bridge. Tighe noted that the Carrara marble was also being imported and worked at the marble mills.

Tighe describes the Maddoxtown marble mill as having one wheel, ten feet in diameter and with twelve floats or ladles. A crank at one end of the wheel's shaft moved a frame containing twelve saws, and it was described as doing the work of about twenty men. Another crank at the other end of the wheel's axis drove a frame of five polishers, which did the work of about ten men. There was a further note that Mr. Colles had recently fitted a frame beneath the polishers with eight saws. The power of the machine was found to the equal to the additional frame. Tighe reported that the strength of the stream did have some effect on the working of the wheel, but not much, and the mill could reliable do the work of forty-two men daily. Tighe reported that the mill is stopped at night as constant attention was required to supply the saws with sand and to attend the polishers. This differs from the original night-and-day descriptions of William Colles and the English gentlemen. Tighe gives information on the marble saws stating that,

> "The saws are made of soft iron, and last about a week; they are constantly supplied with water and sand, the latter is taken out of the bed of the Nore, well washed and riddled until nothing remains but very fine and pure siliceous particles. A saw cuts ten inches in the day, and twelve when the water is strong; it would require two men to do the same with a hand-saw [34]."

His description of the honing and polishing of the marble describes three stages: first boys use a cove-stone, a brown sandstone imported for Chester; next it is polished with a hone-stone, which is "a smooth nodule of the argillaceous iron ore, found in the hills between Kilkenny and Freshford", and finally it receives its last polish in the mills with rags and putty.

By 1802, it seems that the production of smaller turned items and the boring of pipes had ceased. Tighe's account is of particular importance with regard to Colles' marble water pipes and may explain this sessation. Tighe states that Colles' plan to supply Dublin Corporation with,

> "bored marble tubes, as pipes for distributing water through the city, was defeated only by a combination of pump-borers and other mechanics, who rose in a mob and destroyed them on their arrival".

This reaction to the progress of the industrial revolution predates the activities of the Luddites in the 1810s by many decades.

Although William Colles, the founder of the marble works, was clearly particularly mechanically gifted it would be a mistake to assume that his facility with machines was the key to the development of the mills. Kilkenny had a very long tradition with milling that dated back to the coming of the Normans in the twelfth century. Part of the original Norman contingent comprised Flemish speakers who brought milling technology from the Netherlands [35]. Later accounts of the mills, and a study of the ordnance survey maps, show that the mills at Maddoxtown were repurposed many times by the later family, showing that the expertise to modify the works as necessary was available [36].

Sherrard and Brownrigg 1777 Survey of Millmount

Figure 4 shows a 1777 survey of the marble works at Maddoxtown by Sherrard and Brownrigg [37]. The survey was commissioned by William Colles (1745-1779) who designed and built Millmount at Maddoxtown and who was the son of the original William Colles. William Colles (1745-1779) was educated at the Shackelton's Quaker school in Balitore [38].

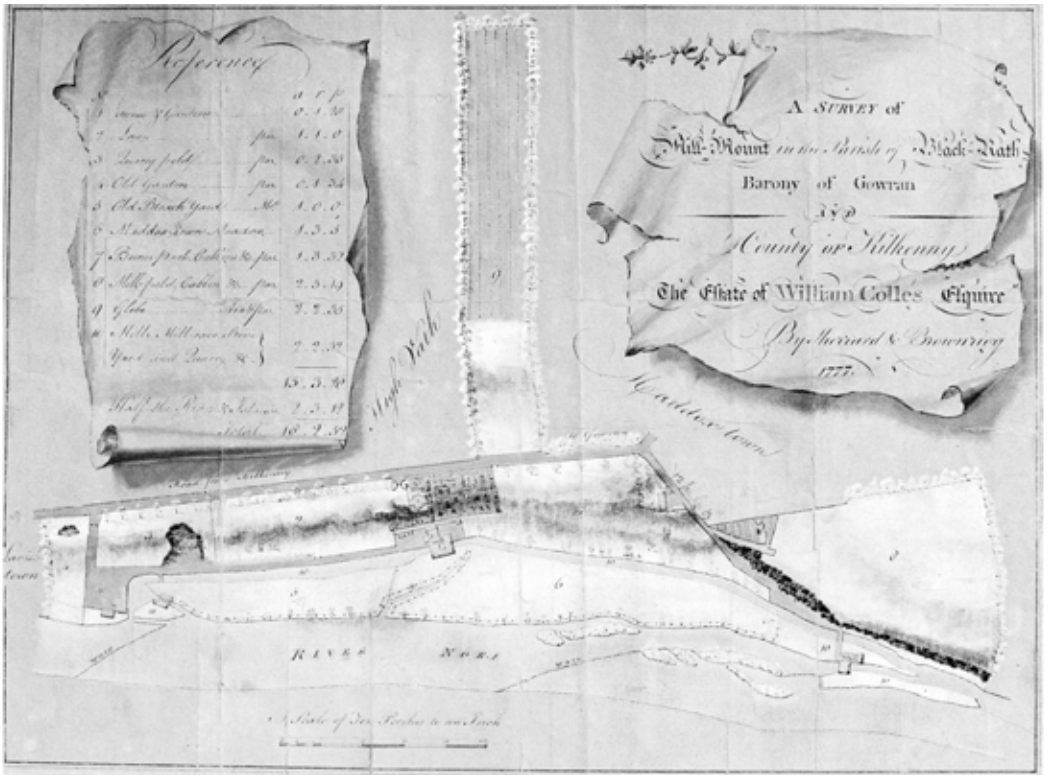

Figure 4: Survey of Mill-Mount house and the marble works by Sherrard and Brownrigg [37].

The survey shows three mill buildings. The mill on the left was the marble sawing mill. That in the centre was originally an old flour mill associated with an Abbey that was located at Maddoxtown. It is shown in William Petty's Down Survey of 1655-1656. The mill on the right of the survey is William Colles' three-storey Abbeyvale mill. By the time Tighe was writing in 1802 the central mill was a paper mill and later accounts showed that it was subsequently used as the main marble sawing mill. The marble works remained in the ownership of the Colles family until 1920 when the mills closed. The mills are in the parish of Clara and a recent social history of the parish gathered accounts of the last workers at the mill and their families [39]. They described a system of horse-drawn railways operating between the mills and the publication also includes a sequence of photographs taken from the marble mills' catalogue that illustrate some of the stages in the quarrying, transportation and sawing of the marble shortly before the marble works closed.

William Colles' contractor and the Kilkenny canal

William Colles was also a successful building contractor who constructed many fine houses and bridges in the Kilkenny area [40]. The skills necessary to operate a quarry, undertake building works and develop machinery are complementary.

William Colles was at the heart of promoting, planning and constructing the Kilkenny canal. He was involved with the canal throughout the second half of his life and his death coincides approximately with the end of substantial works on the canal [41]. The history of the Kilkenny canal has been detailed many times but deserves further work on its engineering aspects. This paper gives brief summary of William Colles' involvement.

The river Nore, which flows through Kilkenny, is navigable upriver from New Ross as far as Inistioge but from Inistioge to Kilkenny the river has sections of shallow rapids. Despite this shallow-draft flat bottomed local "cots" were used to ferrying goods by hauling them upriver [42].

Colles was actively involved in an official capacity in promoting the canal [43]. He was not a disinterested party because his marble produce was being transported to Dublin and exported to England and Scotland. A canal from Killkenny to Inistioge would have been of considerable advantage in reducing Colles' transportation costs as it would have facilitated transporting the marble by river to New Ross or Waterford and would have tied Kilkenny to the Barrow Navigation and Dublin. In the absence of the canal, Colles had to transport his goods by road to Leighlinbridge, which was on the Barrow navigation. The construction of the Kilkenny canal would also have linked the Black Quarry, and his mills adjacent to the quarry, with the marble mills about two miles down-river at Maddoxtown.

Construction of the canal was begun in 1755 to the design of William Ockenden, who was involved in many of the canals being constructed at the time [44]. Unfortunately, Ockenden proved to be a poor engineer and many of his canals experienced problems. At the time the Irish Parliament wanted to minimise the amount of the surplus funds that were sent to the English Exchequer. Thus, the political circumstances facilitated the initial funding.

Ultimately the Kilkenny canal was a failure and the general consensus is that one of the primary causes was the decision to start work on the canal to Kilkenny and work downriver. Colles is usually blamed for pushing this approach. The reason given at the time was that construction costs would be minimised as the quarries and other building materials were located in Kilkenny and the cost of moving materials would be minimised. The second reason, which is often surmised, is that once substantial works had been completed it would be easier to lobby for additional funds so that the money already spent would not be wasted.

The actual progress in the construction of the canal is difficult to assess. There is clear evidence of a level of purposeful misreporting of progress as part of the overall attempts to continue to secure funding [28]. However, there is physical evidence to support the accounts that the canal was constructed as far as Bennetsbridge. Thus, the map that was published

in the Journal of the Irish House of Commons, (Fig. 5), can be taken as an accurate account of the route of the canal and the location of the locks that were constructed [45].

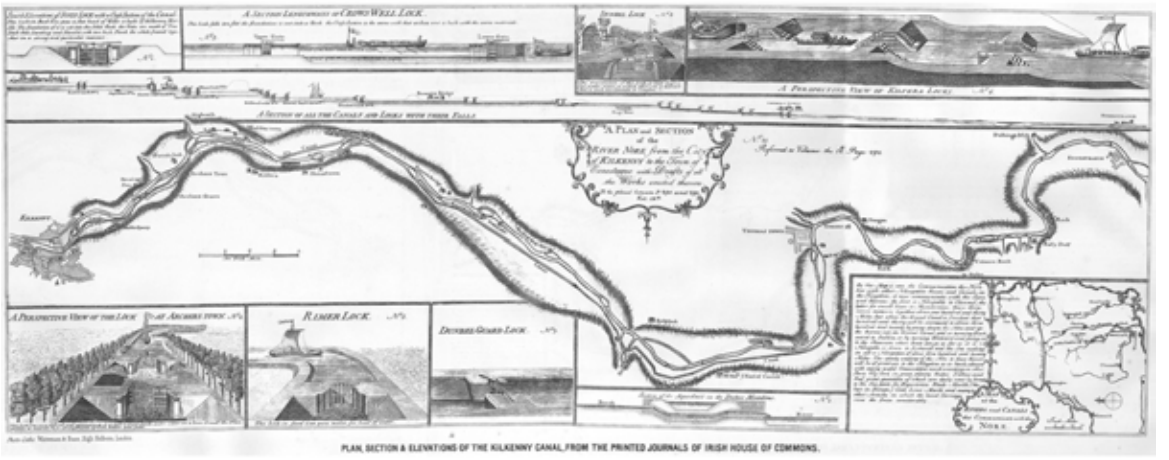

Figure 5: Plan of the Kilkenny Canal from the Journal of the Irish House of Commons [41]

In 1763 there was a very significant flood on the Nore that washed away most of the masonry arch bridges including both of the Bridges in Kilkenny city [46]. The Clara Heritage Society publication contains a letter written by William Colles immediately after the flood that lists the bridges that were swept away and commenting on the damage to the canal [47]. Today the Nore has a collection of particularly fine masonry arch bridges that were all constructed to replace those lost in 1763 [48]. The considerable expense of replacing so many bridges took from the funding that was earmarked for completing the canal and Colles, who was the contractor for the canal, and George Smith, who had taken over as the engineer for the canal on Ockenden's death, were diverted to the reconstruction of the bridges.

Figure 6: Green's Bridge designed by George Smith and constructed by William Colles.

Green's Bridge, (Fig. 6), which is based on Palladio's drawings of the Bridge at Rimini, was designed by George Smith and constructed by William Colles [49]. This was the event that appears to have ended the canal works.

Although contemporary accounts state that the canal works were not adversely affected by the flooding this may not be correct. Furthermore, the major flood of 1763 was followed by a number of severe floods in the next few decades [50]. The locks were largely of earthen construction and David Chapman's estimate for a renewed and extended navigation in 1787, which is included as an appendix in Tighe, includes significant work repairing and dredging the canal [51]. Chapman's commentary also highlight that some aspects of the original canal were poorly designed.

Conclusions

William Colles was an entrepreneur of considerable mechanical ability. He applied this ability to flax production, milling flour and oats and working marble. His mechanical skills also extended to contracting and he is associated with the construction of significant bridges and buildings. His development of marble water pipes was notable not only as a novel technology, but also as an early example of "Luddite" resistance. Colles' inventions are significant as an example of how new building technologies emerged in the eighteenth century. When writing about the construction of three-storey mills in Ireland in the 1760s, when large scale mills were few, Cullen commented that they could be regarded as the precursor of the textile mills which became common in the 1770s and later [52].

Colles was a particularly skilled mechanic. However, others were also progressing rapidly in the same fields at the same time. Thus, the reason for the rapid technical developments were not due to Colles' mechanical genius alone. The machines that Colles developed were not all new inventions and the early reference to his production of a music-playing machine, when taken with some of the other mechanisms he produced, suggest that he may have had access to one of the sixteenth or later mechanics texts that showed such machines. This is not to detract from Colles' skill, but simply to acknowledge that his skill-set was not unique.

In Colles' letter to the Dublin Society written in 1731, he makes the point that his motivation in developing his marble mill was the realisation that he could reduce the cost of producing finished marble by developing machines. This clearly shows the role of economics in allowing the adoption of new technologies. Similarly, his construction of the three-storey mill at Abbeyvale was a direct response to the introduction of the Irish Parliament's corn bounties in 1758. The example of William Colles' reinforces the idea of the spontaneous development or reinvention of technologies when the economic conditions are ripe.

References

[1] K. M. Lanigan & G. Tyler, eds., *Kilkenny: its architecture & history*, Kilkenny: An Taisce, Kilkenny Association, 1977.
[2] C.J. Woods in *Dictionary of Irish Biography*, ed. by James McGuire and James Quinn, 9 vols., Cambridge: Cambridge University Press, II, 2009, pp. 665-666.
[3] W. Tighe, *Statistical observations relative to the county of Kilkenny: Made in the years 1800 & 1801*. Dublin: Graisberry and Campbell, 1802.
[4] Dictionary of Irish Architects, entry of William Colles' works, retrieved 02/04/2021, https://www.dia.ie/architects/view/1187/COLLES-WILLIAM%5B1%5D%2A#tab_works; Lanigan and Tyler, Kilkenny, (Note 1).
[5] Archaeological Impact Assessment, Proposed Restructuring and Renovation of the Tholsel (RMP KK019-026061), High Street/St Mary's Lane, Kilkenny, Kilkenny Archaeology, 18E413, December 2018; Lanigan and Tyler, *Kilkenny,* (Note 1).

[6] J.P. Oleson, ed., *The Oxford Handbook of Engineering and Technology in the Classical World*, Oxford: Oxford University Press, 2008.
[7] D. Fontana, *Della traspolieatione dell'obelisco Vaticano et delle fabriche di papa Sisto V. Libro Primo*, Rome, 1590.
[8] Pliny the Elder, *Natural History, A Selection: Translated with an Introduction and notes by John F. Healy*, London: Penguin Classics, 2004; P. Kessener, 'Stone Sawing Machines of Roman and Early Byzantine Times in the Anatolian Mediterranean', *ADALYA*, XIII, 2010, pp. 283-303; F. V. Sánchez Martínez et al., 'Marble cutting processing used in 16th century for building the "El Escorial" monastery altarpiece', *Procedia Manufacturing*, 13, 2017, pp. 1381-1388.
[9] Pliny the Elder, *Natural History,* (Note 8).
[10] Tighe, *Statistical observations relative to the county of Kilkenny,* (Note 3).
[11] *Ibid*.
[12] Woods in *Dictionary of Irish Biography*, (Note 2).
[13] Tighe, *Statistical observations relative to the county of Kilkenny,* (Note 3).
[14] C. Rynne, Industrial Ireland 1750-1930: An Archaeology, Cork: Collins Press, 2006; L.M. Cullen, 'Eighteenth-Century Flour Milling in Ireland', *Irish Economic and Social History*, vol. 4, 1977, pp. 5–25.
[15] Woods in *Dictionary of Irish Biography*, (Note 2).
[16] Cullen, 'Eighteenth-Century Flour Milling in Ireland', (Note 14).
[17] Rynne, Industrial Ireland 1750-1930, (Note 14); Cullen, 'Eighteenth-Century Flour Milling in Ireland', (Note 14).
[18] Rynne, Industrial Ireland 1750-1930, (Note 14).
[19] J. C. J. Murphy, "The Kilkenny marble works", *Old Kilkenny Rev*ue, ii, 1949, pp. 14–19.
[20] Tony Hand, "'Doing Everything of Marble wch can be Done with it': some descriptive accounts of the Kilkenny Marble Works", *Irish Architectural and Decorative Studies,* 11, 2008, pp. 74-99; T. Hand, *The Kilkenny Marble Works: A Family Business Enterprise*, PhD Thesis submitted to the History of Art and Architecture Department, Trinity College Dublin (TCD Thesis 9650.2), 2012.
[21] Hand, *The Kilkenny Marble Works*, (Note 20).
[22] W. Carrigan, and Most Reverend Dr. Brownrigg. *The History and Antiquities of the Diocese of Ossory*, 4 vols., Dublin: Sealy, Bryers & Walker, 1905.
[23] W. Colles, 'Letter of William Colles of Abbeyvale to the [Royal] Dublin Society', RDS Archives, *Minute Book 1*, 3rd February, 1731/2.
[24] Tighe, *Statistical observations relative to the county of Kilkenny,* (Note 3).
[25] Agoarino Ramelli, *Le Diverse Et Artificiose Machine Del Capitano*, Paris, France, 1588.
[26] Isaac de Caus, *Novvelle invention de lever l'eau plus haut que sa source avec qvelqves machines movvantes par le moyen de l'eau, et un discours de la conduite d'icelle ...*, Londres, 1657.
[27] Hand, *The Kilkenny Marble Works,* (Note 15).
[28] E. A. Forward, 'The Early History of the Cylinder Boring Machine', *Transactions of the Newcomen Society*, 5:1, 1924, pp. 24-38.
[29] W. R. Chetwood and P. Luckombe. *A Tour Through Ireland. In Several Entertaining Letters.: Wherein the Present State of That Kingdom Is Consider'd... By Two English Gentlemen*. London: J. Roberts, 1748.
[30] Advertisement by William Colles, *Dublin Journal*, Tuesday 7th, 1734, p. 2.
[31] Hand, *The Kilkenny Marble Works,* (Note 15).
[32] Rynne, Industrial Ireland 1750-1930, (Note 14).
[33] Tighe, *Statistical observations relative to the county of Kilkenny,* (Note 3).
[34] *Ibid.*
[35] Carrigan, *The History and Antiquities of the Diocese of Ossory*, (Note 22).
[36] The Clara Heritage Society, *Clara County Kilkenny: A Social History of People and Places in the Parish*, Kilkenny: The Clara Heritage Society, 2006
[37] T. Sherrard and J. Brownrigg, *A Survey of Mill-Mount in the Parish of Black-Rath, Barony of Gowran and County of Kilkenny: The Estate of William Colles, Esquire*, (recently gifted to the Geology Museum, Trinity College Dublin,

Mrs. Alexandra Mallaghan, whose uncle, Michael O'Dwyer, owned The Rocks, Millmount and the disused marble works in the 1960s), 1777.

[38] M. Leadbetter, *Leadbetter Papers*, London: Richard Davis Webb, 1862.

[39] The Clara Heritage Society, *Clara County Kilkenny,* (Note 36).

[40] Dictionary of Irish Architects, (Note 4).

[41] R. Delany, *Ireland's Inland Waterways: Celebrating 300 Years*, Belfast: Appletree Press, 2004; N. Stopford, 'The Kilkenny Canal 1755-1786', *Old Kilkenny Review*, 1954, pp. 25-29; P. Watters, 'The History of the Kilkenny Canal', *The Journal of the Royal Historical and Archaeological Association of Ireland*, vol. 2, no. 1, 1872, pp. 82–98.

[42] Delany, *Ireland's Inland Waterways,* (Note 41).

[43] Watters, 'The History of the Kilkenny Canal', (Note 41).

[44] Delany, *Ireland's Inland Waterways,* (Note 41).

[45] Watters, 'The History of the Kilkenny Canal', (Note 41).

[46] P.M. Egan, *The Illustrated Guide to the City and County of Kilkenny*, Kilkenny: P.M. Egan, 1884.

[47] The Clara Heritage Society, *Clara County Kilkenny,* (Note 36).

[48] T. Ruddock, *Arch bridges and their builders, 1735-1835*, Cambridge: Cambridge University Press. 1979.

[49] *Ibid*; A. Palladio, *I quattro libri dell'architettura [The Four Books of Architecture]*. Venice. 1570.

[50] Tighe, *Statistical observations relative to the county of Kilkenny,* (Note 3).

[51] *Ibid*.

[52] Cullen, 'Eighteenth-Century Flour Milling in Ireland', (Note 14).