ROLLING TO MECHANISATION: EXCAVATIONS AT LYMM SLITTING MILL

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Abstract

An archaeological excavation at Lymm slitting mill in Cheshire was undertaken by Oxford Archaeology North in 2005 as a key component of the Lymm's Life Project, which was financed by the Heritage Lottery Fund. The slitting mill was established in the second quarter of the 18th century, and was one of a group of important iron-working sites in the area that were managed by a local Quaker family. The remains probably represent the best surviving example of a slitting mill in England, and one of a very small number that has been subject to archaeological study and consolidation. The slitting mill had been excavated by a local group between 1968 and 1974, although the site was eventually backfilled before a detailed survey was produced and a full synthesis of the results was never published. This paper discusses the archaeological work undertaken on this important early mechanised iron-working site, and places it in its context of 18th-century slitting mills in north-west England.

Key Words

slitting mill, rolling mill, Lymm, Titley, Quaker

Notes on Contributor

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Introduction

Slitting mills were introduced to England during the final years of the 16th century to roll wrought-iron bars into thin sheets and then cut, or silt, into narrow strips for use by a range of craft-working trades. With the exception of the mechanical hammer, the slitting mill was the first piece of powered machinery to be used in the iron-processing trades, and was of great importance to the progress of iron-making from a craft-based trade to a mechanised industry. It also formed the basis for the rolling mill, which was fundamental to the development of the iron industry during the 19th century.[1]

In essence, a typical slitting mill had two rolls, placed horizontally and arranged one above the other, each driven by a waterwheel. Iron bars were sheared into short sections and passed between a set of plain rollers and flattened into small sheets. These were then fed through a pair of slitting cutters that sliced the iron into narrow strips (Figure 1). The resultant strips of iron had numerous end uses, although they were used primarily for making nails, and their introduction eliminated the laborious process of splitting wrought-iron bars by hand.[2] This reduced the cost of nails, allowed a dramatic expansion of production, and helped to stimulate the nail-making trade.[3] Following the introduction of slitting mills to Cheshire in the mid-17th century, the manufacture of nails became one of the most important industries in Warrington, and also formed a significant element of the local economies of Lancashire towns such as Wigan, Leigh, and Atherton.[4] As with other aspects of the early iron industry in England, there is evidence to show that Quaker families played a key role in the development of slitting mills in Cheshire, and this is clearly demonstrated through the present study of one such mill, established at Lymm, near Warrington, in the second quarter of the 18th century.

It is uncertain precisely how many slitting mills were built during the 18th century, although the agricultural travel writer Arthur Young calculated in 1785 that there were 16 such mills operating in England, with each slitting between 800 and 1500 tons of iron per annum.[5] At the time Young was writing, however, the decline of the slitting mill had been signalled with the development of the iron rolling mill that led from Henry Cort's grooved rolls, patented in 1783, which made it possible to roll wrought-iron rounds, squares, and other shapes.[6] Cort's ground-breaking innovation coincided broadly with the application of a steam engine to drive machinery for rolling and slitting iron, thereby severing a dependence on water power and allowing larger works to be established remote from a river.[7]

Despite the key role in the development of the iron industry that they fulfilled, surviving physical remains of slitting mills are very rare, with the best example in England being that at Lymm. This is also one of the very few slitting mills to have been subject to comprehensive archaeological excavations; the only other example in the North West is at Stanley Bank in St Helens, Merseyside.[8] The excavations at Lymm slitting mill were commenced between 1968 and 1969 by members of the Lymm and District Local History Society. Excavation was continued by the Society in 1971, with further stages carried out by the North Cheshire Archaeology Group between 1973 and 1974. Some of the walls of the mill were rebuilt following these excavations with the intention of creating a monument to Lymm's rich industrial heritage, but the site was eventually backfilled due to safety reasons, and became

overgrown and inaccessible. A measured survey of the site was not produced, and whilst summaries of these excavations were published by several authors between 1968 and 1978, the detailed interpretation was often inconsistent.[9]

In 2003, a steering group convened by Warrington Borough Council secured funding from the Heritage Lottery to deliver *Lymm's Life Project*, a scheme that was intended to improve public access and interpretation of important natural and historic features of the village. The site of the slitting mill formed a key element of the project, which aimed to re-expose those areas examined by the earlier excavations, identify any additional remains, and produce the first detailed plan of the mill. The surviving foundations of the mill were consolidated upon completion of the excavation, and a new footpath was laid to provide public access to the site. The excavation was carried out in 2005 by Oxford Archaeology North and, for the first time, exposed the entire footprint of the slitting mill, providing evidence for several phases in the development of this important iron-working site, and permitted some re-interpretation of the conclusions drawn from the earlier excavations.

Early Development and Mechanism of Slitting Mills

The origin of the iron-slitting mill is not well understood, although they are known to have been in use in the Liège district of Belgium shortly after 1500.[10] The adoption of slitting-mill technology in England, however, has been attributed to Sir Bevis Bulmer who, on 4 December 1588, obtained a patent that gave him the exclusive right for 12 years to erect and operate a water-powered machine to cut iron into small bars or rods.[11] This appears to have been first put into practice by Godfrey Box of Liège, who established a slitting mill at Dartford in Kent in 1590, probably working under the patent granted to Bulmer.[12] There is evidence to indicate that a second slitting mill was established in south-east England at Crayford some seven years later,[13] although the technology does not appear to have been adopted elsewhere in the county until the 17th century; the first slitting mill to be established in the Midlands, for instance, was built by Walter Colman and Thomas Chetwynd at Rugeley in *c* 1610, and was modelled on that at Dartford, which Colman and Chetwynd had visited several times.[14] It has been suggested that these pioneering slitting mills were capable of flattening wrought iron bar into strips by narrow plain rollers (although these may have been hand-powered), and then utilised water-powered oscillating shear blades, which probably cut two or three iron rods at a time. Thus, the circular cutters, which constituted the most essential component of the developed slitting mills, were unlikely to have been used in these early mills.

One of the most celebrated of the English slitting mills was that established by the Stourbridge ironmaster Richard Foley at Kinver, Staffordshire, in *c* 1627.[15] It seems that Foley's mill utilised iron cutters rather than oscillating shear blades, thereby representing a type of slitting mill described briefly by Robert Plot in the late 17th century, who noted that 'the new invention' of slitting mills presented iron-workers with a 'vast advantage'.[16] Plot's observations, which represent the earliest known description of an English slitting mill, were reiterated in greater detail in 1758 by William Emerson, who also provided a useful illustration of the slitting mechanism, and the associated power-transmission system (Figure 2).

According to Emerson, the bars of iron were normally sheared into short lengths upon arrival at the mill. The pivoting arm of the shears was edged with steel, and raised by a cam attached to the waterwheel axle as it rotated. As the arm rose, it clipped the bar of iron into two pieces, each measuring approximately 0.3m long.[17] The clipped bars of iron were then heated red hot (*c* 850^0C) in the forge furnace to make them malleable and easier to work; the forge and its furnace were essential components of a slitting mill. A characteristic feature of the English slitting mill was the use of a single furnace, whereas many mills on the continent were equipped with several furnaces for heating the iron bar.[18]

Once heated, the clipped iron bars were passed between a pair of rollers; the end of the bar may have been hammered flat to help the rollers draw it through. The heated bars will have been fed through the rollers several times, and on each occasion the gap reduced via a screw-down mechanism, eventually creating strips of iron that would probably have been about 1.5m long, and as thin as 3mm. For many years, the flat strip was the only rolled wrought-iron produced in a slitting mill until certain innovations were adopted in the 18th century, notably the introduction of wider rolls by John Hanbury in *c* 1720 that allowed iron sheet to be produced.[19]

The flattened sheets were then fed through a pair of slitting cutters, which were again on two rolls. Each roll may have incorporated three or four cutting discs, which inter-locked, with guides between the top and bottom to ensure that the slit rods did not get entangled around the mechanism (Figure 3). The cutting discs would have been some 0.3m in diameter, and made of wrought iron, edged with hardened steel. The iron passing between the revolving discs was sheared into a series of strips, the width of which was determined by the thickness of the discs and the distance between them. It was not uncommon for slitting mills to incorporate a plating forge, where a steel tip for edge tools was welded to the iron body of the tool, thus economising on expensive steel.

The number of slitting mills in England increased gradually during the late 17th and 18th centuries, the greatest concentration being established in and around the Black Country, reflecting the importance of the nail-making industry to that region.[20] Nevertheless, it has been suggested that there were probably not more than 20 slitting mills as a maximum operating simultaneously in the early 18th century.[21]

Many of these mills were established by various partnerships, which also controlled iron furnaces and forges, forming part of a larger network of iron production.[22] Hence, ironmasters slit iron produced in their own forges in mills that they also owned. In some cases slitting mills were attached to forges, as at Kirkstall near Leeds, but in general the iron was taken to sites specifically built for the purpose. A study of slitting mills in Staffordshire, for instance, concluded that they operated under a type of 'putting out' system, by which an ironmaster or ironmonger sent bar iron to an independently owned mill for slitting, receiving back the same iron in rods on payment of an appropriate fee.[23]

An important group of slitting mills centred on the Trent Valley was built from the 1730s onwards, including those at Derby, Wychnor, and Borrowash.[24] It seems likely that these were established to take advantage of cheap iron bar that was imported from Russia during the 1730s, as these mills were situated on the transport route from Hull, the port of import, and the Black Country, the place of consumption.[25] Russia and Sweden were the principal sources of bar iron for the English iron industry for most of the 18th century.[26] It was advantageous to import bar iron and have it rolled and slit in England, rather than importing rod iron, as iron drawn or hammered into bars less than ¾ inch (19mm) square was considered to be manufactured iron, and was thus subject to a higher rate of import duty.

Slitting Mills in Cheshire and Lancashire

Awty considered that slitting mills were introduced to Cheshire and Lancashire during the Commonwealth (1649-60), when new ironworks were being built in large numbers.[27] The principal components of the iron industry by the end of this short period were the blast furnace, forge, and slitting mill. One of the earliest blast furnaces in Cheshire was established at Church Lawton in 1658 by John Turner.[28] Two years later, in 1660, a forge that processed some of the iron from this furnace was established at Cranage, near Holmes Chapel, situated 13km to the north of Church Lawton.[29] Cranage Forge incorporated a slitting mill, and is likely to have been the first to have been built in Cheshire, and was almost certainly intended to supply iron to nail-makers in Warrington and Lancashire in addition to consumers in the Midlands.[30] The forge lay at an important junction of roads leading north to Warrington and

Lancaster, south to Staffordshire, and east to Manchester, and was thus a good centre for the distribution of bar iron for the next century.[31]

Further north, an important group of slitting mills was established during the late 17th and 18th centuries, including those at Brock Forge, Great Sankey, Lymm, Bidston, Wigan, Birkacre, Partington and Stanley Bank, although the exact dates at which many of these mills were established is uncertain (Figure 4). The slitting mill at Brock Forge in the narrow valley of the River Douglas, a short distance to the north of Wigan, is though to have been established by Spencer & Co in 1665.[32] The origins of the slitting mill at Great Sankey are not documented, and whilst it has been suggested that it opened in 1727[33], it may actually have been established by the Squire family in the late 17th century. In 1700, however, Esther Squire married Joseph Titley, a Quaker iron merchant from Warrington, who took responsibility for this slitting mill, and was able to bequeath it to his eldest son, Thomas, in his will of 1731.[34] This included 'the timber and poplar and other wood which I have lately bought for the mill', implying that Joseph had been investing in his premises; it is notable that the detail of his will makes no reference to a slitting mill at Lymm. It is also of interest to note that Joseph Titley's youngest son, Benjamin, inherited a farm in Atherton that incorporated a nail-making shop.

Thomas Titley and Lymm Slitting Mill

Following his inheritance of the slitting mill at Great Sankey in 1732, Thomas Titley married Esther Rawlinson, whose family had established Caton Forge near Lancaster in 1727 and were part of a group of Quaker families with considerable business interests in the Lancashire iron trade. They were also heavily involved in the slave trade; between 1752 and 1762, more Rawlinson slave-trading vessels were registered with the Liverpool Port authorities than any other Lancaster merchants. The family also traded out of Liverpool in partnership with Alexander Chorley, a Quaker from Warrington.[35]

It was probably shortly after his marriage into this very prosperous Quaker family that Thomas Titley established another slitting mill in the secluded, steep-sided gorge of the Slitten Brook, a short distance to the north of Lymm village in Cheshire (centred at SJ 6815 8740), and some 12km to the east of Great Sankey (Figure 4). Hughes and Thomas cited title deeds purportedly dating to 1720 from which they drew reference to the slitting mill at Lymm,[36] but this document cannot now be traced, and there is no other primary evidence to corroborate that the mill was in existence by this date. The earliest surviving reference to the slitting mill is provided by the Land Tax Returns Register for 1751, which itemises the mill

and lists Thomas Titley as the occupier, although it is likely to have been established prior to that date.

Thomas Titley's ambitions in the iron-slitting trade did not stop at Great Sankey and Lymm and, in 1747, he bought the remainder of the lease of Brock Forge for £400, which included the slitting mill. The following year (1748), Thomas bought the freehold of a site at Partington, on the River Mersey some 7km to the north-east of Lymm, and established another slitting mill there.[37]

Thomas Titley is mentioned in the journal of the Swedish industrial spy, RR Angerstein, during his mid-18th-century tour of manufacturing sites in England. Angerstein visited Warrington in July 1754, and noted the main industry to be the manufacture of pins. He also noted that the town and its surrounding area consumed 250 tons of iron annually, the majority of which was supplied by Liverpool merchants. Angerstein goes on to mention a slitting mill owned by a 'Mr Tittly', located 'some six miles from Warrington', where wrought iron bars were rolled and slit. Angerstein was of the opinion that 'Mr Tittly' consumed 100 tons of iron per annum for slitting, the majority of which was obtained from Russia.[38] This is supported by records of the Titleys importing 722 bars of iron through the port of Liverpool in 1771.[39]

It is probable that the raw materials were transported from Liverpool to Lymm slitting mill via the River Mersey. This had been made navigable as far as Warrington before 1697 by clearing away the fish weirs, and an Act passed in 1721 authorised a company to make the river navigable as far as Manchester. The resultant Mersey and Irwell Navigation was opened to boats sailing between Liverpool and Manchester by 1734, taking a course approximately 1.5km to the north of Lymm.[40]

Thomas Titley died in 1753, and ownership of his four slitting mills passed to his son Abraham. During Abraham's period of ownership, the Bridgewater Canal was constructed through Lymm. A survey of the route by James Brindley in 1762-3 marks the position of the slitting mill in the valley immediately to the north of the canal; the mill is similarly annotated on a slightly later survey of the canal by Arthur Young in 1769.[41]

The occasion of Abraham Titley's marriage in December 1765 to Sally Fothergill, from a Quaker family based in Liverpool, was celebrated in regional newspapers, which described Abraham as an 'eminent iron master'.[42] Abraham managed the family's slitting mills until his death in July 1772,[43] but his entire estate was auctioned thereafter as he had no heir. Lymm slitting mill appears to have passed to Walter Wilson, who continued to slit iron; in 1781 it was a reported in the local press that 'Brice Grant, Slitter, late foreman to Mr Wilson of

Lymm…has taken and entered upon the Slitting Mill at Bidstone in Cheshire, which he intends to work in all its branches, etc'.[44]

An account of 1795 described Lymm slitting mill as 'slitting iron and flatting it into hoops for the cooper's use', but provides little additional information.[45] The slitting mill lay within an estate owned at that time by Domville Poole Esq, who resided at Danebank, a mansion house that stood on the higher ground just to the east, overlooking the Slitten Brook. Following his death, the estate was advertised for sale by auction in 1795. Lot 1 comprised Danebank, together with several plots of land, cottages and buildings, including 'a slitting mill with a good stream of water' and 'a barn, stable and cow house in the occupation of Mr Walter Wilson'.[46] This lot was purchased by James Wilde Esq, who is listed at Danebank in a survey of Lymm dated 1796; the survey also lists a 'slitting mill dam etc' in his possession, but doesn't refer specifically to the mill buildings.[47] Whilst this may suggest that the slitting mill had been abandoned, the site's association with the iron industry had certainly finished by January 1802, when Walter Wilson died at the age of 75 years.[48]

In February 1800, James Wilde agreed to lease the site to Godsalve Robinson of Lancaster, James Foster and Samuel Foster of Warrington, who had formed a partnership as textile manufacturers. The lease authorised Robinson and the Fosters to 'enlarge and improve the buildings and other conveniences belonging to the said mill for the more convenient and beneficial occupation thereof'. It also gave permission to 'put the buildings into tenantable repair and condition' (suggesting dilapidation through disuse) but 'shall not erect a fire or other engine'. The layout of the site at this time is shown on a plan that accompanied the lease (Figure 5).

The subsequent history of the site is uncertain. Lyson and Lyson, writing in 1810, noted that the mill 'was formerly used for the splitting of iron, but it has not been applied to that purpose for many years'.[49] However, they make no mention of the use of the mill for textile manufacturing, and it seems likely that the Fosters and Robinson's new venture did not last long, assuming that it had even gone into production, and Robinson died in Warrington in 1825.[50] Early maps of the area are lacking in detail and do not mark the slitting mill, although Christopher Greenwood's survey of Cheshire in 1820-21 shows the dam across the Slitten Brook. Interestingly, Bryant's county survey of 1831 marks a 'factory' on the site of the slitting mill, and shows a waterwheel symbol indicating that it was still water-powered (Figure 6). The tithe map of 1837, however, provides a detailed plan of the area and depicts the millpond, but the mill buildings had seemingly been cleared and the area landscaped as part of the gardens of Danebank.[51] A plan of the Danebank Estate from 1845 shows a similar

arrangement, with no mention of the slitting mill apart from the mill dam and pond.[52] The dam was evidently still in place as late as 1896, and is identified as the 'Slitten Dam' on the Ordnance Survey map published in that year (Figure 7), although it is absent from the next edition of mapping, published in 1907, as it is thought to have been breached in 1905, allowing the mill pond to drain.[53]

The Early Excavations (1968-74)

The first archaeological excavations of Lymm slitting mill were undertaken by members of the Lymm and District Local History Society in 1968-9. The initial phase of work concentrated on exposing a waterwheel pit in the centre of the mill, which was found to be 8.3m long and 1m wide, with a wear mark indicating that it had been fitted with a waterwheel measuring 4.88m in diameter. The remains of sluices and other water-management features were also revealed, and finds recovered from the wheel pit were considered to have an 18th- or 19th-century date.[54] The results of this initial investigation encouraged further excavation, which was carried out by the same society in 1971 under the direction of Barry Johnson, and continued thereafter by members of the North Cheshire Archaeology Group in 1973-4.[55] In total, seven discrete parts of the site were excavated (Areas A1 to A7), as shown on a sketch plan produced upon completion of the work (Figure 8).

Excavation to the east of the waterwheel pit exposed the foundations of two large rooms (Areas A1 and A2). No fixtures or fittings that could be associated with the slitting process were identified in either of these rooms, although an Irish half-penny dated 1766 and a cartwheel penny of 1797 were discovered.[56] The foundations of another room were exposed immediately to the north (Area A4), the component walls of which were of brick construction, set on a stone foundation. These were interpreted as an extension to the building, associated with its 19th-century use as a textile mill. Excavation to the east of these rooms revealed the remains of a small brick-built structure, abutting the eastern elevation of the mill buildings, which was interpreted as a 'metalwork repair shop'.[57]

Much of the area to the west of the waterwheel pit was opened using a mechanical excavator. The southern part (Area A5) yielded little physical evidence for the slitting mill, although the area to the north (Area A7) was considered to be the 'rolling room'. This included a semi-circular brick base, 1.5m wide, forming the foundation of a structure interpreted as a furnace. This was surrounded by a flagstone floor, which was marked with traces of molten iron, and below the furnace were the remains of another, although little of this survived.

The published accounts of these excavations also describe three 'tunnels'. The first of these (T1) formed the tailrace from the central waterwheel pit, and was 1.5m high internally, with walls built of sandstone blocks and an arched brick roof. The base was finished with timber planks, and the north end had been extended by 3.2m, where it was also 0.15m wider.[58] The second tunnel (T2) was interpreted as a 'flushing sluice' for the millpond, used to clear it of silt. It was constructed in a similar manner to the first tunnel, although the brick arch had been rebuilt. The third tunnel (T3) was of unknown function, and whilst it was of similar construction to the others, it was blocked at both ends. It was suggested that it might have been intended for trapping air that could then be piped into the furnace, although the rationale for this interpretation was not given and it is difficult to understand how it may have worked.[59]

The excavations also uncovered the foundations of a former cottage, situated to the east of the mill (Area A3). Only part of this building's footprint was exposed, as a large, modern sewer pipe cut across its centre. Buried structural remains were limited to a flagstone floor and the vestiges of the western and southern walls, the latter incorporating the base of a fireplace. The foundations of the cottage comprised sandstone blocks, whilst elements of the fireplace were of brick construction. Finds dating to the 17th and 18th centuries were recovered.

Upon completion of the excavations in 1974, the exposed walls were consolidated and the site was subject to landscaping works (Figure 9). However, in the absence of a regular maintenance regime, coupled with safety concerns, the site was eventually backfilled and became overgrown, precluding any public access to this important historic site.

The Later Excavation (2005)

In June 1999, an application was made to the Heritage Lottery Fund on behalf of Lymm Parish Council and Warrington Borough Council for a project to improve access to the natural history and heritage of the village and enhance areas of Lymm Dam, The Dingle and Slitten Gorge, including the site of the slitting mill. This application was rejected for several reasons, including its lack of adequate provision for archaeological recording of the slitting mill. A revised application, entitled *Lymm's Life Project*, was prepared by a steering group, convened by Warrington Borough Council, and included representatives of Lymm Parish Council, Lymm and District Local History Society, the Countryside Agency, the Mersey Valley Partnership, and several local amenity groups. This application allowed for a comprehensive archaeological investigation of the slitting mill, and was intended to re-expose those areas examined by the earlier excavations, identify any additional remains, and produce

the first detailed plan of the mill. The surviving foundations of the mill were to be consolidated upon completion of the excavation, a new footpath laid to provide public access to the site, and interpretation panels were to be installed. The revised application was successful, and the Heritage Lottery agreed to fund the programme of archaeological investigation and enhancement of the site.

The re-excavation of the site was carried out by Oxford Archaeology North in 2005, and uncovered further important elements of the slitting mill. This enabled a reinterpretation of some of the conclusions of the earlier investigations, and allowed an accurate plan of the site to be drawn up (Figure 10). In particular, it became clear that one of the 'tunnels' identified during the 1970s (T2) was actually a second waterwheel pit, which had formed an essential component of the slitting mill.

Five principal phases of the site's development were recognised during the excavation in 2005, commencing with the initial construction of the slitting mill (Phase 1). By the end of the 18th century, the mill had expanded and incorporated an additional room (Phase 2). Phase 3 represented the remodelling of the building for use as a textile mill, and Phase 4 its demolition and associated landscaping in the 1830s. The final phase of activity (Phase 5) represented the excavations of the site between 1968 and 1974, and the associated consolidation and landscaping works.

Phase 1 (c 1735 - 80)

A large part of the mill was erected in a single phase, comprising the main working area that housed the rolling and slitting mechanism, a forge and two ancillary rooms, together with two waterwheels and their associated water-management features, including a weir across the Slitten Brook and the resultant mill pond.

The eastern part of the original mill was occupied by two rooms of unequal sizes, which may have provided storage or workshop spaces. The largest, with an internal area of 6.72m by 4.74m, formed the south-eastern part of the mill (corresponding to Area A1 during the earlier excavations). The room had been excavated completely during the 1970s, and no internal floor, fixtures or fittings remained, although none were reported from the previous excavations. It was separated from the main working areas by the central waterwheel pit (Figure 10). The eastern wall of the building had also been removed entirely, although large, freestone blocks forming the southern wall represented the original fabric.

The northern part of the room was defined by a 0.30m-wide wall, set in a foundation trench that was cut into the natural geology, and formed a partition with the adjacent room. This

survived as a single course of large, worked blocks of fine-grained yellow sandstone, each with a decorative tooled finish, set on an offset foundation course of similar stone blocks (Figure 11). The western end of the wall was keyed into the original fabric of the central waterwheel pit, indicating that it was of a contemporary build. The remnants of a 1.24m-wide doorway survived towards the western end of the wall, affording access into the adjacent room.

The northern room (referred to previously as Area A2) measured 6.1m by 4.1m internally but, as with that to the south, did not retain any internal features or a floor (Figure 12). The surviving foundations of the northern wall were composed of worked stone blocks, again displaying a decorative tooled finish, with two offset foundation courses that had been laid in a 0.5m-deep foundation trench to enable the wall to be set on top of the solid bedrock.

The central waterwheel pit lay immediately to the east of room A1, and had an internal length of 8.25m and width of 1m. Its lower part had been hewn out of the sandstone bedrock, and faced with worked stone blocks. Only two irregular courses of original masonry survived above ground level, with overlying stonework deriving from the consolidation works carried out in the 1970s (Figure 12). Several courses of hand-made bricks had been added to the north end of the wheel pit, representing a remodelling of the structure in the late 18th century (Phase 2). Excavations in 1968-69 concluded that the central waterwheel had a diameter of 16 feet (4.88m) and, whilst all evidence for the position of the wheel axle had been removed, there is no reason to doubt this calculation.[60] The position of the housing for the sluice board at the head of the wheel pit implies that it had contained a breast-shot waterwheel, and evidence from the excavation showed that the second waterwheel was of the same size and type.

The second waterwheel pit lay along the western side of the slitting mill, parallel and 8m to the west of the central waterwheel, but was offset to the north (Figure 10). Each side wall was composed of large freestone blocks, with a narrow stepped offset built into lower courses to improve the flow of water onto the waterwheel and provide additional protection from erosion (Figure 13). The walls were 7.3m long, set 0.94m apart, and survived to a maximum height of seven courses (1.7m), but had been reduced by at least two courses, which evidently removed any trace of the wheel axle housing.

The profile of the wheel pit at its southern end mirrored the curvature of the waterwheel, terminating at a stone slab that formed the base of the short headrace from the mill pond. The long edge of the stone slab had been rounded off carefully, again probably representing an

attempt to improve the flow of water to the wheel. This was controlled by a sluice board, the position of which was marked by a narrow slot in each elevation at the head of the wheel pit.

A series of oak planks, treated with linseed, formed the base of the waterwheel pit. The planks continued part way up the curved slope to the head of the wheel pit, although the upper part was formed by three sandstone blocks which, in turn, lay beneath the planks that held the sluice board. At its northern end were the remains of a 1.64m-long section of a brick-arched tailrace. This was keyed into the masonry of the wheel pit, and appeared to be part of the original build.

Excavation immediately to the west exposed the intact capping of a large culvert, which was the same width as the waterwheel pits (Figure 13). The stone-built side walls were of a similar character to the waterwheel pits, but with an arched brick capping and a stone floor. However, the brick component represented an early 19th-century modification to the structure (Phase 3), which may originally have been an open stone-lined channel, or perhaps a third waterwheel pit, although there was no firm evidence to support this suggestion. The exposed western elevation comprised large stone blocks set in a lime-based mortar, which survived to a height of five courses (1.2m). The external face of many of the stone blocks was dressed in a similar herringbone fashion as the walls on other parts of the site, although this decorative finish had not been applied to the internal faces (Figure 14). The culvert was open at the northern end, whilst the position of its southern end was marked by an iron sluice mechanism, fixed to the masonry of the dam wall. However, this sluice was clearly a later addition, perhaps installed during the late 19th century as part of the Victorian landscaping of the area (Phase 4).

Excavation immediately to the west, in the channel of the Slitten Brook, exposed the collapsed remains of a by-wash (Figure 15). The eastern side of this structure was formed by the western wall of the culvert, whilst its western wall had collapsed, with only a single foundation course surviving *in-situ*, an event that, anecdotally, resulted from a flash flood in the 1960s. The flagstone floor of the by-wash survived entirely *in-situ*, although it was covered at the southern end by the collapsed remnants of an arched brick capping, identical to that over the adjacent structure, and probably of a contemporary build.

The outflow from the wheel pits and by-wash originally passed through arches in the northern retaining wall of the mill site, and fed back to the Slitten Brook via an open channel that was approximately 30m long. This retaining wall had evidently been rebuilt since the mill was demolished, and the tailrace from the wheel pit and the by-wash blocked up, leaving only the

aperture from the culvert open (Figure 16). The retaining wall forming the southern edge of the mill had also been subject to some remodelling, although the original cutwater situated between the two wheel pits at the head of the mill pond was retained largely unaltered.

The main processing area that will have housed the rolling and slitting machinery lay between the two waterwheels, in what was originally a single room. This was sub-divided by the insertion of a substantial brick wall in the 19th century, representing a remodelling of the mill for textile manufacture (Phase 3). The northern part of the processing area (Area A5) had been excavated thoroughly in the 1970s, and few remains pertaining to the original function of the room survived. The area to the north (Area A7) had also been fully excavated during the 1970s, although several structural components survived *in-situ*. These included elements of an L-shaped, brick-built wall situated adjacent to the western waterwheel, representing the vestiges of a substantial internal structure. It seems possible that it was designed to house a pit wheel or gear wheel connected to the western waterwheel axle. A spread of closely packed, large stone blocks was also unearthed, immediately adjacent to central waterwheel pit. These lay beneath the level of the mill floor, and were probably intended to provide a solid foundation for the rolling or slitting machinery (Figure 17).

Situated to the north of the main processing area were the fragmentary remains of the forge. This comprised a north/south-aligned brick wall, an east/west-aligned sandstone structure, a partition, and fragments of another brick wall to the west (Figure 18). Remnants of sandstone slabs, abutting the vestiges of a cobbled surface, probably represented the base of the forge hearth identified during the 1968-74 excavations.

Phase 2 (c 1780 - 1800)

Lymm slitting mill evidently benefited from sufficient commercial success during the later 18th century to warrant some investment and expansion, attested by the addition of a large room across the northern end of the mill (Area A4). This lay above the outflow from the central waterwheel, and necessitated an extension of the brick-arched tailrace. As with the original components of the mill, the walls of the extension employed freestone blocks with a decorative herringbone tooled finish for the foundation courses, although the fabric of the upper four courses comprised hand-made bricks. No solid floor was found inside the room, although several discrete deposits of metal-working debris and dumped material overlay the natural geology. These deposits were up to 0.10m thick, and contained numerous small, corroded fragments of iron objects, including nails, bars, and smithing slag, together with abundant but degraded charcoal, consistent with the room's use as a forge (Figure 19). The

evidence from the excavation suggests that the new building was at least two-storeys high, as an external staircase had been built against the eastern wall.

Phase 3 (1800 - 1835)

Documentary evidence indicates that the slitting mill closed in *c* 1800, and the mill was converted for use as a woollen factory. Many textile mills were established on pre-existing water-powered sites in the late 18th and early 19th centuries, and the availability of an abundant and managed water supply will undoubtedly have been a prerequisite for the site's purchase by textile manufacturers. The adaptation of the building for new use clearly demanded some remodelling, which included the erection of the substantial, brick-built partition across the centre of the slitting and rolling room. The textile mill evidently only required a single waterwheel, as the western wheel pit was abandoned during this period. It is likely that the adjacent stone-lined channels were capped with brick at this time, perhaps to allow for an expansion of floor space within the mill, on what was a site of restricted space.

The paucity of available documentary references to the woollen mill suggest that this enterprise was short lived. This is perhaps unsurprising, as the early 19th century saw the widespread adoption of steam power to the textile industry, and its concentration in Lancashire and Yorkshire. The remoteness of Lymm from the emerging centres of factory-based textile production may suggest that the mill was not particularly suited to this purpose. Indeed, physical evidence for it ever actually having been used for textile manufacturing is limited to a wooden bobbin that was recovered from an 'occupation layer' during excavation in 1972.[61]

Phase 4 (1835 - 1968)

By the 19th century, Lymm was developing a growing reputation as a tourist destination. Indeed, towards the end of the century, George Ormerod described the village as 'a vale…of most exquisite beauty and a waterfall of great beauty and boldness'.[62] It was during this period that the site was landscaped for recreational purposes, with the mill pond forming the centrepiece of a pleasure garden in the grounds of Danebank House.

The retaining wall between the southern edge of the mill site and the mill pond was rebuilt at this date. This wall essentially sealed the entrance to the wheel pit and the former by-wash, whilst the central culvert was retained for water-management purposes and was fitted with a sluice gate to regulate the water level in the mill pond.

Phase 5 (1968 - 1974)

The final phase pertains to the series of excavations carried out at the site between 1968 and 1974. These investigations involved the excavation of much of the mill footprint, and the removal of most occupation layers associated with earlier phases of activity. Some of the surviving walls, including the upper courses of the central waterwheel pit, were consolidated or rebuilt.

Discussion

The precise date at which Lymm slitting mill was established remains uncertain, and there is no independent documentary evidence to support the previous suggestion that it was in operation by 1720.[63] The earliest surviving reference to the mill is provided by the Land Tax Returns Register for 1751, but it seems entirely possible that it had been in operation for several years previously, and was probably established by Thomas Titley during the late 1730s-40s following his union through marriage with the Rawlinson family. The opening of the Mersey and Irwell Navigation in 1734 may have improved the commercial viability of erecting a slitting mill at Lymm, as it provided a new trade route to the port of Liverpool and access to imported iron bar. The excavation confirmed that the water-power potential of the site had not been exploited prior to the slitting mill, although there was a corn mill upstream in the centre of Lymm. The requirement to build the slitting mill on a previously undeveloped site in a steep-sided gorge will have demanded resolution to a suite of engineering challenges, particularly in respect of creating a water-management system.

A key aspect of the iron industry in England after the mid-17th century was the influence of Quaker families, with perhaps the most famous including the Darbys and Richard Reynolds for their innovations at Coalbrookdale, together with Charles Lloyd and his descendants of Dolobran in Wales, John Pemberton and Isaac Spooner of Birmingham, Richard Parkes, John and Samuel Fidoe of Wednesbury, and Booth Hodgetts of Dudley.[64] Indeed, as noted by TS Ashton, 'the more important chapters in the early history of the iron industry might be written almost without passing beyond the bounds of the Society of Friends.'[65] The contribution of the Titley family to the early iron industry in Cheshire has hitherto largely escaped the attention of historians, although they evidently played a significant role in the region's iron-slitting trade. Thomas Titley, in particular, accelerated the family's interests in the trade, having married into the Rawlinson family of Quakers and taken on four slitting mills by the late 1740s. Shortly after his death in 1753, and the accession of Abraham Titley as head of

the family business, an eyewitness account describes 'Mr Tittly' (*sic*) obtaining wrought iron from Russia at a rate of 100 tons of iron per annum for slitting at his mill near Warrington.[66]

There are no documentary references to the markets for the iron rods that were slit by the Titleys. England was the world's largest manufacturer of nails in the mid-18th century, and the principal customers for iron rods slit at Lymm will have been nail makers, not only in Warrington and the surrounding area, but perhaps also American markets, which had limited domestic production. The growth of the industry in the American colonies was theoretically held back by the prohibition of new slitting mills in America by the Iron Act of 1750. It has been estimated that there were just four slitting mills in the American colonies at that date (two in Massachusetts, one in Pennsylvania and a fourth, reported in 1750 to be out of use, in New Jersey), and it has been claimed that the Act of 1750 'was pretty generally enforced in the colonies, and the further erection of rolling and slitting mills prevented'[67]. Whether this was actually the case is perhaps debatable, although the investment expended on Lymm slitting mill through the small expansion of the site implies that business was profitable. Whilst the archaeological record cannot furnish a firm date at which this expansion to the workshop facilities occurred, it is likely to have been under Abraham Titley's direction during the mid-18th-century prosperity of the trade. However, Abraham seems to have focused his attention on the family's slitting mills at Lymm and Partington, leaving those at Great Sankey and Wigan to close in *c* 1755 and 1761 respectively.

There are multiple factors that contributed to the demise of slitting mills as an instrument of the iron industry, not least the introduction of Henry Cort's patent grooved rolls for rolling iron bars in the 1780s and the concomitant growth of rolling mills. The changing character of the nail-making industry and its market towards the end of the 18th century will also have had an impact on slitting mills. Following the American Declaration of Independence in 1776, the former English colony developed its own industries, leading to a contraction of the export market for iron and nails; whilst the ensuing war stimulated growth of the English iron industry, the cessation of hostilities in 1783 'found the industry with a productive capacity in excess of demand at remunerative prices', and the years 1783-5 was characterised by a widespread depression in the iron trade.[68]

Attempts to mechanise the nail-making process were made from 1790 onwards, when various machines were invented to automate and speed up the process of making nails from bars of wrought iron. A breakthrough was attained in 1809, when Joseph Dyer set up machinery at the Britannia Nail Works in Birmingham to cut nails from sheets of iron.[69] Before that date, however, Lymm slitting mill had diversified into supplying barrel hoops, with the gunpowder

works at Thelwall (opened in 1755) being one of their customers by the mid-1790s.[70] The Titley family were no longer associated with the Cheshire iron industry at that time, in consequence of Abraham Titley dying without an heir in 1772. Titley's slitting mill on the Mersey and Irwell Navigation at Partington, some 7km upstream of Lymm, was advertised for sale by auction after Abraham's death, but does not appear to have continued in operation thereafter.[71] Lymm slitting mill, however, passed to Walter Wilson and continued in production, perhaps reflecting a positive effect on the local economy that derived from the opening of the Bridgewater Canal to Lymm in 1776.

The archaeological excavation has provided a complete plan of the layout of Lymm slitting mill during this period, which may be seen as a 'type site' for an 18th-century slitting mill in the North West. The only other slitting mill in the region that has attracted archaeological work is that at Stanley Bank, which was established in 1773, and was thus the last of the group of slitting mills in Cheshire and Lancashire to be built. One of the founding partners of this slitting mill was Alexander Chorley, a Quaker businessman who had formed a partnership with Esther Rawlinson's family in Liverpool, and was a member of the same Warrington Meeting as Thomas and Abraham Titley.[72] Like Abraham Titley, Chorley was also related through marriage to the Fothergills, a Quaker family based in Liverpool.

The site was subject to an initial excavation and partial conservation through the work of Manpower Services, volunteers and St Helens Ranger Service in 1981-2, and became the focus of a community-based excavation in 2004-7,[73] with a further phase of excavation in 2008.[74] Stanley Bank provides a useful comparator to Lymm slitting mill, and was similarly driven by two waterwheels that were estimated to have been between approximately 4-5m in diameter and 1.7m wide. Whilst of a similar size to those at Lymm, excavation concluded that they were probably of overshot or pitch-back design, rather than breastshot.[75] The waterwheel pits excavated at Stanley Bank were built of sandstone ashlar, which was mirrored in the fabric of the wheel pits at Lymm; the tailraces at Stanley also received an arched brick capping at a later date.

The two wheel pits excavated at Lymm had been designed to house breastshot waterwheels. John Smeaton is credited by both contemporary and modern authors as being singularly responsible for the widespread application of breastshot waterwheels to industry during the second half of the 18th century.[76] Smeaton's contribution to improving waterwheel efficiency is widely acknowledged, having performed the first scientific evaluation of the waterwheel in the mid-1700s and developed methods for determining the efficiency of different types. His work led to changes in design, with the advantages of both the undershot and overshot types

being incorporated into the breastshot waterwheel, leading to a dramatic increase in their performance.[77] The breastshot wheels at Lymm slitting mill, however, preceded Smeaton's work and their design will not have benefitted from his improvements, at least initially. The excavation concluded that the wheel pits had been remodelled slightly, although there was no evidence to suggest that a breastshot waterwheel had not been fitted to the mill originally. The application of two waterwheels at Lymm, together with a by-wash, conforms to what appears to be the typical layout of an 18th-century slitting mill, although it is difficult to understand the rationale for the third water channel that was used subsequently as a culvert. It is tempting to suggest that this may have housed a third waterwheel for the slitting mill, based on its size, position and fabric, although supporting evidence is wanting.

Conclusion

The archaeological and historical significance of Lymm slitting mill has been recognised since the 1960s, although the physical remains were neglected and inaccessible until the inception of the *Lymm's Life Project*. The excavation of the slitting mill, which formed a key component of the wider project, has allowed well-preserved structural remains of the mill to be exposed, and has facilitated an understanding of the chronological development of what is probably the most intact 18th-century slitting mill in England.[78] The work has also provided an example of Quaker investment in the Cheshire iron industry. Most importantly, however, the project has allowed the surviving remains to be consolidated, and the site to be interpreted and presented to the public as a monument to the area's important industrial heritage.

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Image Captions

Figure 1: An 18th-century engraving of a French slitting mill, showing the rolling and slitting mechanism. As was typical for a European slitting mill, the engraving appears to show that the machinery was powered by a single waterwheel (taken from Diderot 1765)

Figure 2: The mechanics of English rolling and slitting machinery which, in contrast to European slitting mills, was powered by two waterwheels (taken from Emerson 1758)

Figure 3: Detailed drawing of the slitting mechanism (taken from Diderot 1765)

Figure 4: Distribution of 18th-century slitting mills in Cheshire and Lancashire

Figure 5: Plan of Lymm slitting mill based on a lease of 1800

Figure 6: Extract from Bryant's plan of Cheshire in 1831, marking a 'factory' in the position of Lymm slitting mill

Figure 7: Extract from the Ordnance Survey map of 1896

Figure 8: Composite plan of Lymm slitting mill based on the excavations carried out between 1968 and 1974 (© Lymm & District Local History Society)

Figure 9: Lymm slitting mill during the landscaping works in 1974 (© Lymm & District Local History Society)

Figure 10: Plan of the remains of Lymm slitting mill excavated in 2005

Figure 11: South-facing elevation of the partition wall, showing tooled finish of the component blocks (© Oxford Archaeology Ltd)

Figure 12: The two rooms forming the eastern part of the mill, and the rebuilt central waterwheel pit (© Oxford Archaeology Ltd)

Figure 13: The east-facing elevation of the western waterwheel pit, with brick-capped culvert to the rear (© Oxford Archaeology Ltd)

Figure 14: The interior of the stone-lined, brick-arched channel adjacent to the western waterwheel pit (© Oxford Archaeology Ltd)

Figure 15: The excavated remains of the culvert and collapsed by-wash channel (© Oxford Archaeology Ltd)

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