The First Kidwelly Tinplate Works: An Archaeological and Technological History

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The opening of Kidwelly Tinplate Works as an industrial museum in 1984 was the culmination of a project conceived 10 years previously when the site was purchased by Llanelli Borough Council. The surviving buildings and machinery were saved from further demolition to form a unique monument to an industry once widespread in South Wales. Conservation work began in 1980, and two years later the Kidwelly Heritage Trust was founded, now co-managers of the museum with Llanelli Borough Council. The guiding force throughout was W. H. (Bill) Morris, Chairman, of the Trust, without whose enthusiasm the enterprise would not have been possible. In October 1985 (and as a further development of the museum activities) I was invited by Llanelli Borough Council in conjunction with Dyfed Archaeological Trust to direct what was to become a two-year excavation at the works. The project concentrated upon the 'Lower Works' – site of the earlier, waterpowered tinplate rolling mill. The excavation owed much to the interest and support of Bill Morris – not least the generous contribution of the results of his own, hitherto largely unpublished, documentary research. Thanks are offered to the Kidwelly Heritage Trust and Dyfed Archaeological Trust. I am greatly indebted to Llanelli Borough Council and their former Manpower Services Commission Agency which funded the excavation and provided a workforce of 30 over the two year period. In particular the two site assistants, Gwilym Bere and Phil Burt, deserve special thanks.

INTRODUCTION

Founded in 1737, the Lower Works at Kidwelly was only the second tinplate rolling mill established in Britain, and was powered solely by water until the 1860s. It closed down in 1896 to be subsequently totally demolished. Tinplate production was however maintained in the steam-powered 'Upper Works' established in 1879 on a virgin site 100m upstream. This in turn closed in 1938 and now forms the core of the industrial museum.

The museum management soon recognised that development of the site and the industrial processes occurring within could only be fully understood through reference to the earlier rolling mill. And because of its early foundation the Lower Works provided a valuable opportunity to explore the origins of the tinplate industry — particularly within a regional context. Accordingly, archaeological excavation of the Lower Works began in 1985 with the aim of establishing the history of the site and its technological development — with particular regard to water power.

Because the steam powered works had been built on a new site, the demolished and abandoned earlier works had potentially undisturbed below-ground remains. A deep and complex sequence of archaeological deposits were revealed during the excavation, which provided evidence for the construction and finally the destruction of the Lower Works. In addition, the site was eminently suitable for 'open-area' excavation, which provides the best opportunity for recovering the plans of earlier structures. The project was not a rescue dig; the need to preserve, for display, all upstanding structures and major surfaces necessarily limited the opportunity to excavate earlier material to restricted areas.

The excavation archive includes 545 context forms, 92 finds record sheets, 1217 detailed 1:20 plans, elevation and section drawings and 12 total area plans. Archive copies will be deposited with both the Museum and Dyfed Archaeological Trust. An interim report was produced for internal circulation in February 1986, and further summaries appeared in *Archaeology in Wales.*[1]

The main purpose of this paper is to summarise the excavation results and place them within their technological and historical context. For a history of site ownership, the reader is referred to W. H. Morris' official history,[2] within which full accounts of the brief summaries provided herein can be found.

Fundamental to an understanding of the development of the works are the site topography, its geographical location, and the processes of tinplate manufacture summarised below and illustrated in fig. 1.

TINPLATE MANUFACTURE

Tinplate manufacture — the production of thin iron sheets and their coating with tin — was from the first a complex process. It required both engineering expertise and financial investment in suitable sites and machinery. The hand-milling method of sheet production remained basically unchanged from the early eighteenth century onwards until superseded in the 1930s by the hot strip mill; however, it became increasingly complex and mechanised. Below is a general description of the process and its development.[3]

The dynamic and heaviest part of the process — converting iron bars into sheets — took place in the Rolling Mill (fig. 1:1). After being heated in 'reheating' furnaces, wrought iron bars were repeatedly passed between pairs of large cast-iron rollers to produce thin sheets or 'black plates'. The roll pairs were powered by water, or later steam, and were mounted within upright frames termed 'standards'. (In later years a number of pairs could be mounted in lines or 'trains'.) At least from the mid-eighteenth century the black plates were obtained by successively heating, rolling and doubling the sheet, normally until it was an eight-thick pack ('rolling in eights'). The pack edges were then clipped off with shears; the latter were at first worked manually but were later also power driven. The entire process is termed hot rolling.

At first the plates were then merely scrubbed with sandstone or a similar abrasive ('descaling' — fig. 1:2), and cleaned by steeping in a dilute acid ferment ('pickling' — fig. 1:3) prior to tinning. But from the mid-eighteenth century onwards the plates were given a further pass between a different pair of powered rolls ('cold rolling' — fig. 1:4). In preparation for cold rolling the plates after pickling were annealed or softened in furnaces ('black annealing' fig. 1.:2). Cold rolling made the plates brittle, so they were afterwards annealed again ('white annealing' fig. 1:5). The plates were pickled once more in preparation for tinning ('white pickling' fig. 1:6).

Pickling and annealing normally took place in a separate building, as did tinning itself (fig. 1:7). A cast iron 'tin pot' heated by a fire contained molten tin within which the plates were immersed. An even coat was obtained by then dipping the plate into the 'wash pot' of cooler tin, and finally into the 'grease pot' containing hot oil. At first entirely manual, tinning had by the later nineteenth century become a continuous mechanised process. After a scrub with bran the finished plates were separated, inspected and then packed in boxed (fig. 1:8), ready for use in the manufacture of a variety of domestic utensils.

WATERPOWER

Until the widespread introduction of steam power tinplate rolling, like most industrial processes, was powered by water. The requisite prime movers, waterwheels, and the method by

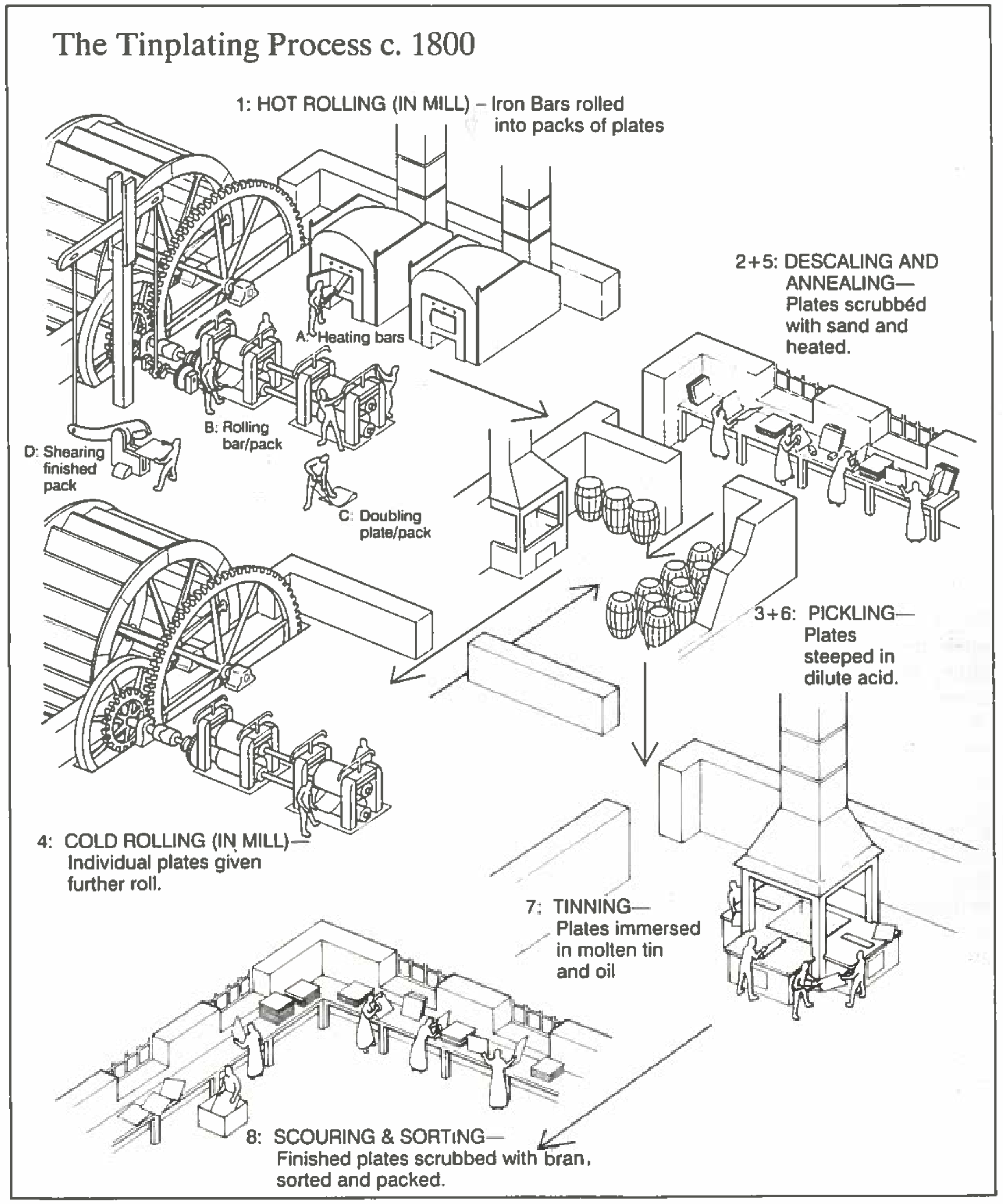

Fig. 1.

which they were supplied with water had undergone gradual development in Western Europe and Asia Minor since classical times. Their design was increasingly refined during the Industrial Revolution.[4] (fig. 2)

The first requirement was a steady supply of water. An existing watercourse might be used directly (fig. 2:1), or a supply be taken from it by means of an upstream weir and leat (or headrace — fig. 2:2). In many mills, including those utilising tidal water, the water was held in an artificial millpond (fig. 2:3). Potential power was harnessed when the water was allowed to turn a waterwheel.

This could be achieved in either or two ways. In the earlier impact wheel (fig. 2:4), first recorded in 27 BC, moving water was permitted to strike paddles projecting from the rim, turning the wheel. Such wheels were normally fed from below axle level ('undershot'), while later 'pitchback' wheels were fed from above.

By the third century AD the gravity wheel had been introduced (fig. 2:5). Here water was allowed to fill buckets located between the wheel rims; thus it was the weight of the water rather than its impact that drove the wheel around. Early gravity wheels were all 'overshot' (fig. 2:5a). A trough or 'launder' conveyed water to the far side of the wheel to turn it in the opposite direction to the flow. During the later eighteenth century important modifications in Western Europe and the USA led to the introduction of pitchback and 'breast-shot' gravity wheels. The latter were normally used by heavier industries and were fed at around axle level (fig. 2:5b). During this period too iron was increasingly used in waterwheel construction.

Primitive undershot wheels might be merely mounted within an existing watercourse and allowed to rotate. However, increased efficiency was obtained with the provision of a sluice, an opening controlled by a gate or hatch according to requirement or water supply. Earlier sluice hatches were normally simple open/shut affairs rising within the sluice to allow the water to pass beneath. From the early nineteenth century, however, breast-shot wheels might be shot over or through a hatch whose position was adjustable according to the level of the water supply. For example, Fig. 2:5b shows the 'depressing' sluice hatch, which descended within the sluice as the water level receded, permitting the water to flow over it and onto the wheel as a thin flat sheet.

The rotation of the waterwheel generated power which was transmitted to machinery according to need. In heavier industries like tinplate rolling, direct connection through gear wheels between waterwheel and machinery was the rule. Alongside the wheel and sharing its axle a large spur gear wheel ('pit wheel') was often employed, whose teeth engaged with further step-up gearing to the rolls and shears. Alternatively, the waterwheel itself might be equipped with gear teeth in the form of a rim drive. The latter method permitted lighter waterwheel construction, and later iron wheels were often slender spoked and held in suspension. Ideally one wheel drove each major piece of equipment; however, by means of clutch couplings different items of machinery might be engaged alternately. Regular motion and the torque produced were maintained by flywheels.

The success of advanced watermilling technology is demonstrated by its continued use long after the introduction of steam power.

FOUNDATION, 1737

The Lower Works was founded on an area of level ground known as Bank Broadford, on the east bank of the River Gwendraeth Fach, 3.5km. upstream of the estuary and 1km. north of Kidwelly town. The site lay at the northern end of a roughly rectangular spit of land between the river to the west and north, and an established corn mill leat to the east and south (figs. 3 and 4).

The site was chosen for both topographical and locational considerations. The adjacent stretch of the Gwendraeth Fach had had a long tradition of water powered activity and from the Middle Ages had supported a dense concentration of corn and fulling mills.[5] An iron forge lay just upstream,[6] next to a paper mill,[7]

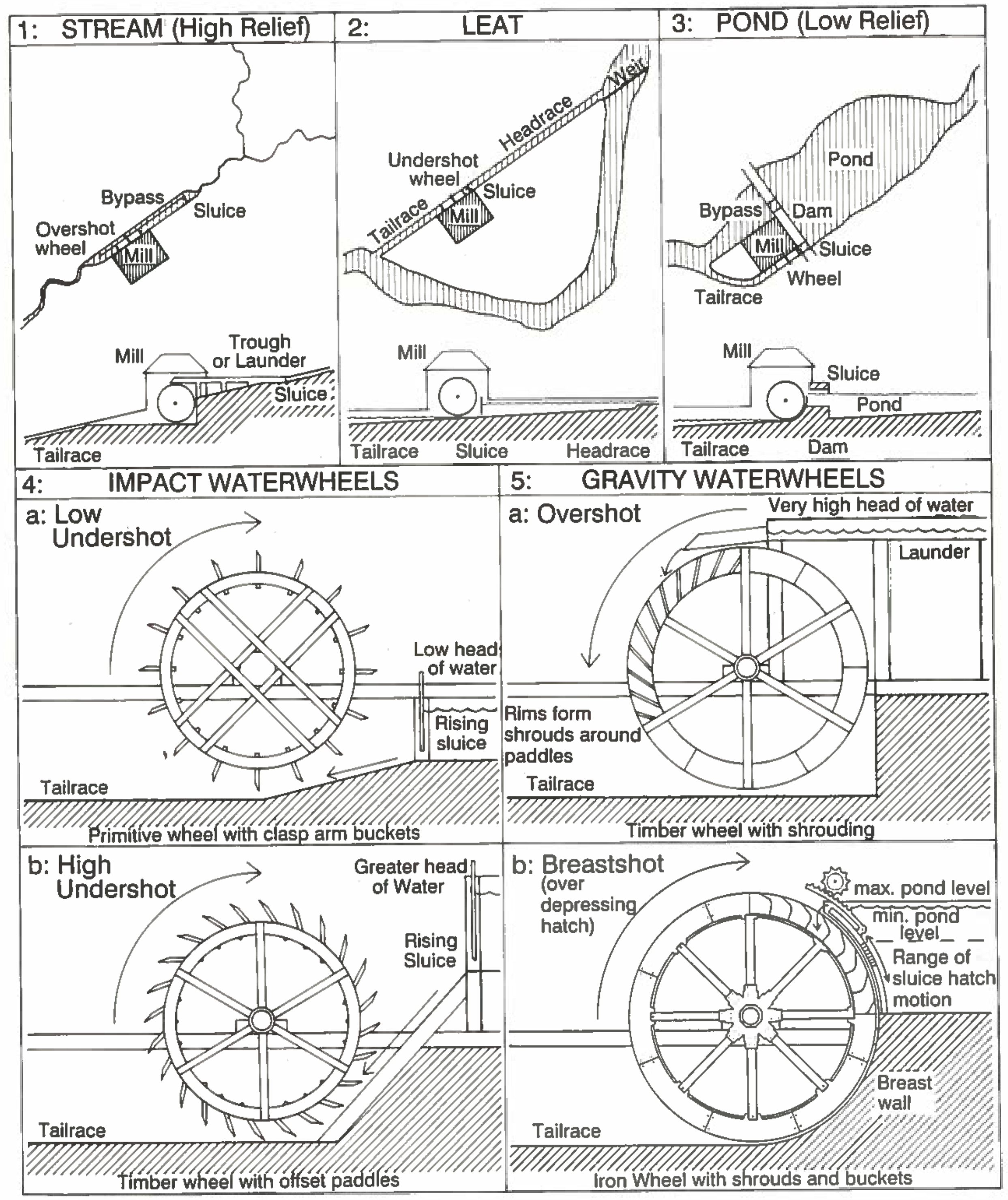

Fig. 2.

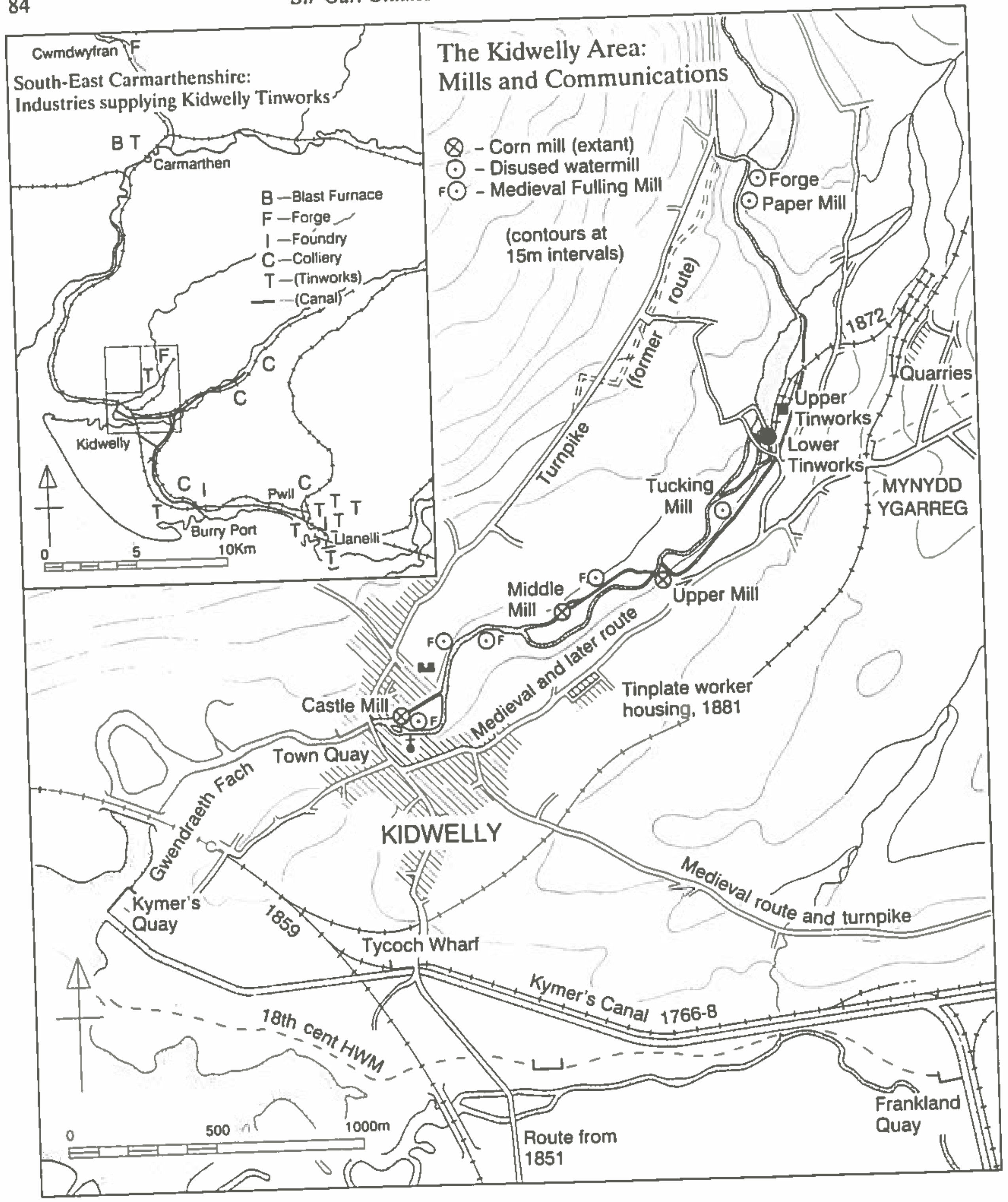

Fig. 3.

while a tucking mill had been established 150m to the south.[8] Such was the suitability of Bank Broadford that the tinworks had in fact supplanted an ore stamping works on the same site.[9]

Within a wider context, Kidwelly was an established port with ample warehouse space by the town quay, and was located directly opposite the tin mines and ports of South West England. From the mid-eighteenth century onwards a system of canals would provide link with both the coalfield and local iron foundries, and in 1872 the Works was incorporated into the local rail network. The site was also crossed by a routeway connecting two long established roads.[10]

Documentary Evidence

The founder of the tinworks was Charles Gwynn, a local man. Bank Broadford was part of the common lands of the town of Kidwelly and was leased to Gwynn in August 1737. The terms of the lease entitled him to 'take down the old Stamping Mill of Dr. John Lane [at] Bank Broadford', and to rebuild it 'in what use [he] thinks fit'.[11] Dr Lane's works, established by 1721, had foundered within five years and by 1737 was apparently in 'ruins'.[12]

It may be 'reasonably assumed that the stamping works would require little alteration for a change of use as a tinplate rolling mill. It would have possessed at least one waterwheel, driving a hammer or hammers to crush copper ore that was mined on nearby Mynyddygarreg. However, a clause in Gwynn's lease entitled him to build 'a Wear . . . to Dam and pond the water' and 'two courses . . . to convey the water from the . . . dam to the mill'.[13] In October of the same year, moreover, Gwynn was granted liberty to quarry limestone from Mynyddygarreg 'for the building of a Rowling Mill'.[14] The extent to which Lane's work was obscured by the rolling mill is thus debatable; at any rate Gwynn's works was operational as early as Spring 1738.

Excavation and Survey Evidence

Millpond and Dam: The dam across the Gwendraeth Fach is the most substantial and possibly the earliest structure still standing at the Lower Works site. It is suggested that at least the core of the of the fabric is Gwynn's work, being a magnificent limestone construction incorporating three floodgate arches separated by cutwaters. The dam extends as a revetment bank for another 70m., the whole retaining a millpond that stretched 500m. upstream. Though narrow, the dam was from the first required to carry a roadway[15] (figs. 4 and 5).

Millraces: Excavation revealed two millraces issuing from the pond, and Gwynn's lease suggests that both were employed from the first (figs. 4 and 5).

The eastern millrace runs N-S along the eastern wall of the rolling mill, upon which the waterwheel was mounted. The surviving features of the sluice area suggest that the wheel was always large, and undershot through a rising hatch. Part of the long tailrace can still be seen returning to the river 150m. downstream.

The western millrace lies at right angles to the above. Though much altered by late work, it essentially consists of a sluice within the dam wall immediately adjacent to the north wall of the rolling mill, which leads into a well defined waterwheel pit. The short tailrace curves back into the Gwendraeth Fach after only 50m. Few features of the wheelpit can be attributed with any certainty to the early eighteenth century, but it may be assumed that during this period this waterwheel too was undershot.

Under normal conditions the dam floodgates were closed and the millrace sluices open, the wheels turning to drive the rolling machinery within the mill. When work had ceased or the millpond had emptied the sluices were closed while the pond refilled. The dam floodgates were only opened as a relief to prevent flooding during rough weather.

Mill: The excavated area — and the works as a unit — had as its core the rolling mill itself (fig. 5). This was a large square building,

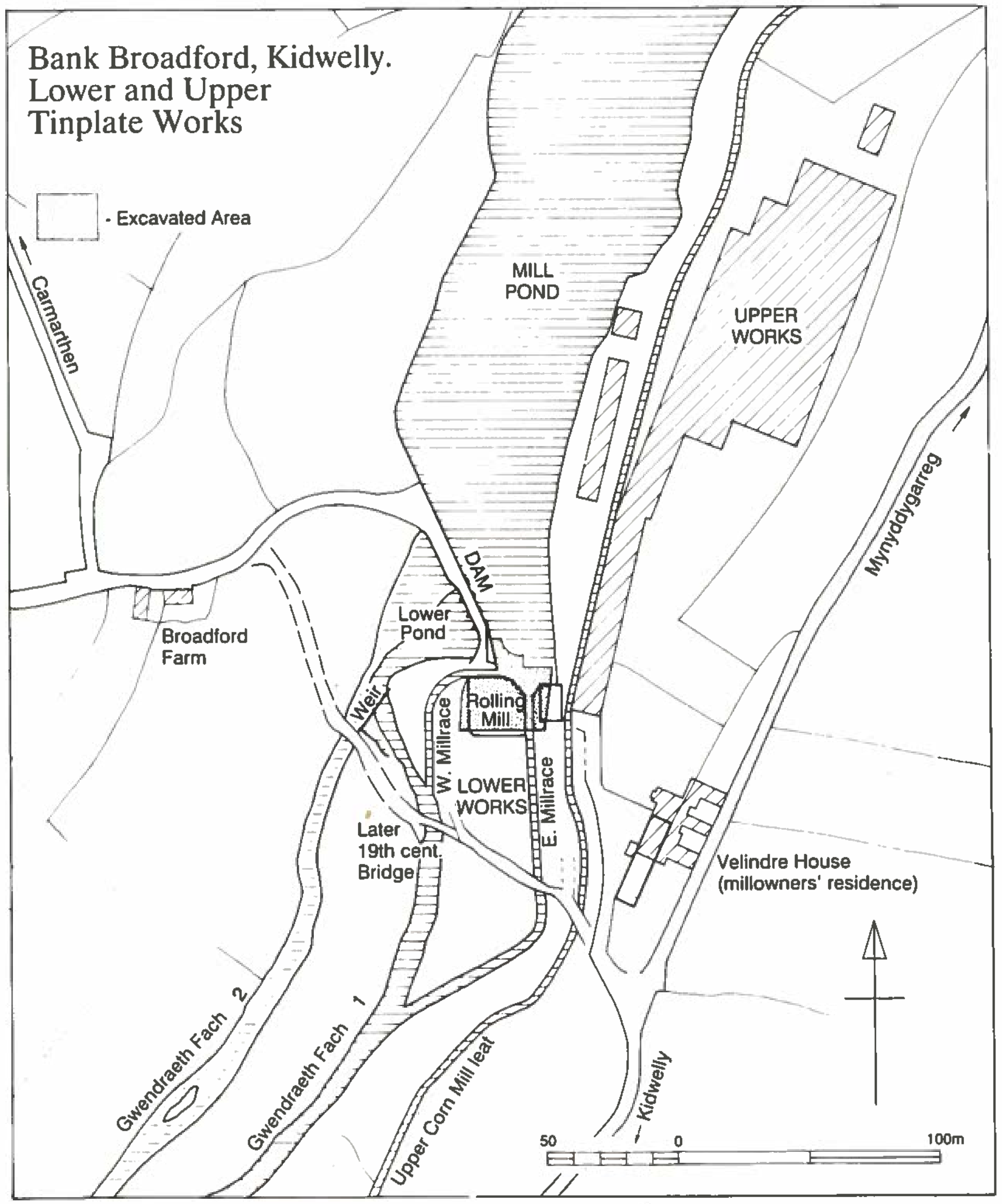

Fig. 4.

variously truncated or robbed to the extent that only one short stretch of its northern wall now stands above ground. The wording of Gwynn's lease suggests that the mill, like the dam, was substantially his work. Physically too, in terms of their massive construction and common use of local Carboniferous limestone, mill and dam appear to be of contemporary build. However, no architectural detail from the mill survives. Both SW and NE corners of the building bore considerable chamfers, the latter incorporating part of an earlier structure that resembles a cut-water, and may represent part of the earlier stamping works.

The footings of a N-S internal wall were excavated and appear to be of one build with the outside walls. The wall divided the building into two unequal halves, each presumably associated with one of the waterwheels. Perhaps each area, and wheel, was associated with hot and cold rolling respectively and this may in fact suggest that cold rolling was practised very early on at Kidwelly.

Other Buildings: Part of another truncated limestone building was excavated to the east of the eastern millrace (fig. 5). It appears to be integral with the construction of the millrace, and hence with the mill and dam. The eastern wall of the millrace may at this time have formed the western wall of this building, and its chamfered NW corner mirrors the angle on the mill's NE corner. The area was crossed by two masonry drains emptying into the eastern mill-race, and a complex of walls which may not all be contemporary. By the nineteenth century at least, however, the southern area was used as a tinhouse.[16]

CONSOLIDATION, 1738-1801

In order to finance the completion of the works Charles Gwynn had in 1738 taken into partnership one Anthony Rogers — who was later to buy him out. Rogers held a lease on the above mentioned iron forge upstream and in this partnership we see the beginnings of an integration under one man of all the plant and processes involved in ironworking and tinplate manufacture. This culminated in 1758 when Roger's son Lewis, who had acquired the works, took as his senior partner the redoubtable Carmarthen ironmaster Robert Morgan.

Tinworking was a logical extension of Morgan's industrial interests. His blast furnaces at Carmarthen produced pig iron which was converted into bars at his forges at Kidwelly and elsewhere. The bars were in turn rolled and tinned at the Lower Works. Indeed he was to found his own tinworks at Carmarthen upon the dissolution of the partnership in 1761, after which Morgan ceased to have an interest in the Kidwelly works.[17]

Lewis Rogers died in 1776 and the works was sold some twelve years later to Leonard Bilson Gwynn, who held it until his death in 1798.

The sale catalogue of c. 1788 lists two pairs of hot rolls and one pair of cold rolls amongst the equipment.[18] Confirmation that packmilling was practised is provided by the mention of a shearing house, though this suggests that the packs were sheared manually. The same catalogue makes reference to only one water-wheel. It has been argued above that both mill-races were present from 1737, and thus presumably both wheels; indeed a sale catalogue of 1801 specifically mentions 'waterwheels'.[19] The omission of a second waterwheel from the former catalogue is not readily explainable.

DEVELOPMENT, 1801-1838

In June 1801 the Lower Works was sold to the partnership Haselwood, Hathaway and Perkins. They immediately commenced a programme of repairs that was rather ambitiously styled a rebuild in the commemorative plaque erected upon its completion.[20] As this was in place by the end of the year the 'rebuild' can have done little to alter the existing layout.

Severe mismanagement led to a takeover in 1808 by a former trustee, Thomas Waters. Waters in turn sublet the works from 1814 until his death two years later, when a renewal of the lease was granted to Philip Protheroe of Bristol.

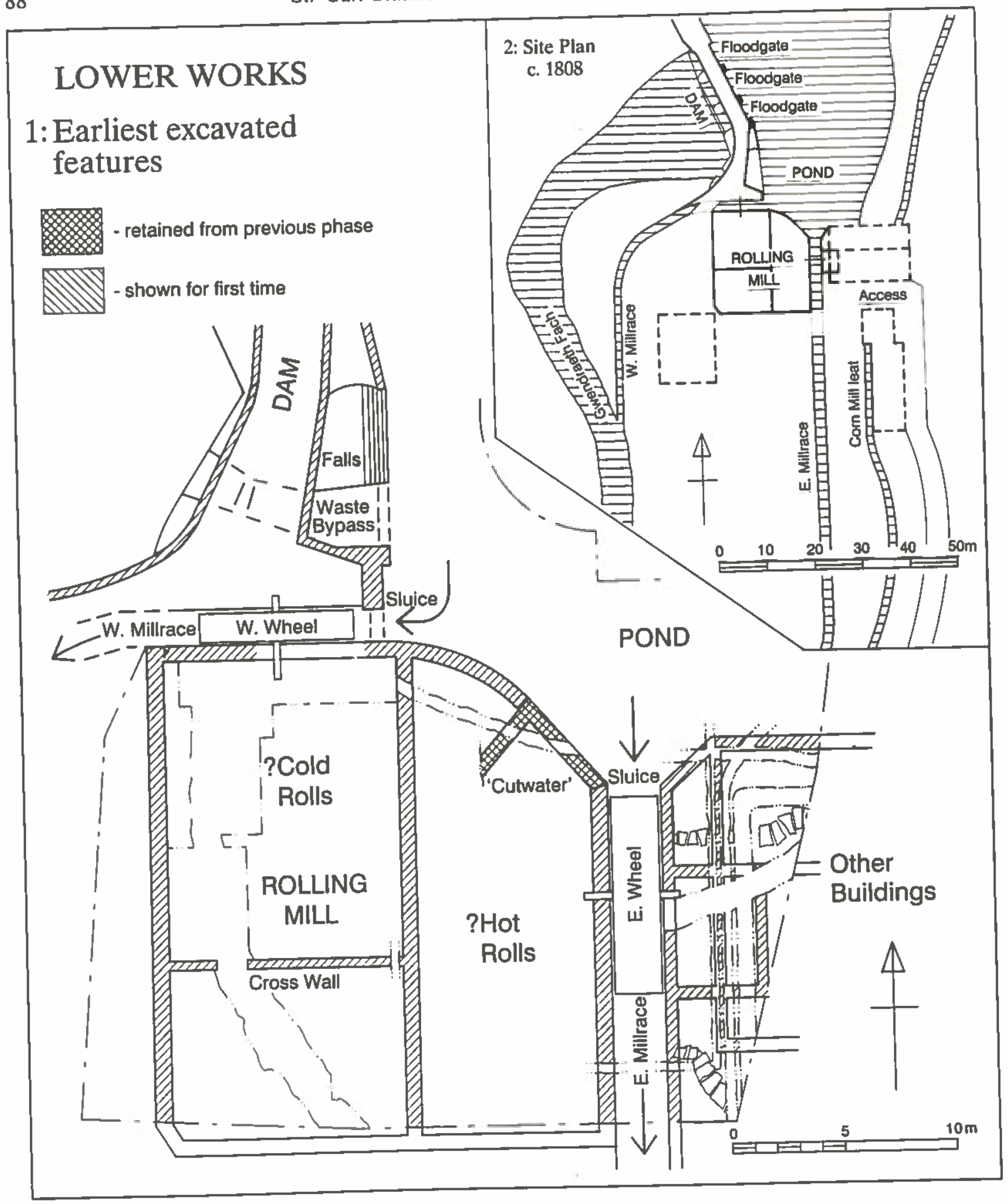

Fig. 5.

The leasehold renewal of 1816 was complicated by the long-standing problem of seasonal unreliability of the water supply to the works. This was in fact one of the reasons why Robert Morgan had left Kidwelly in 1761.[21] Waters' executors became involved in litigation with Colonel Pemberton, owner of the two corn mills immediately below the Lower Works.[22] Pemberton argued that he had to wait for the tinworks pond to fill up before his mills could become operational. (In fact the claim was only applicable to one mill, the Middle Mill; the Upper Mill's leat began upstream of the tinworks pond (fig. 3). Indeed under an agreement made seven years previously between Waters and the mills' then lessee William Morris, Waters was permitted to tap water from the Upper Mill leat — which ran through the Lower Works — 'as the occasion required'.[23]) A factor contributing to the water shortage was the immense quantity of silt deposited in the tinworks pond as the river slowed down at the dam. The silt reduced the capacity of the pond and was later to choke it completely.

Dam, pond, rolling mill and millraces are all depicted in a plan of c. 1808[24] (fig. 5:2), the earliest plan of the works and which includes the eastern block and two ancillary buildings. Not shown, however, are either the pool downstream of the dam (the 'lower pond'), or the two channels of the Gwendraeth Fach beyond it (cf. fig. 4 and fig. 5:2). A downstream tailrace pond was often employed in association with the millpond to take the large quantities of water discharged from the millraces without flooding. However, at Kidwelly neither tailrace actually discharged into the pond and its formation may be associated with that of the bifurcation of the river.

Two branches of the Gwendraeth Fach are mentioned in documents relating to the litigation of 1816;[25] only one is shown on the plan of 1808 (fig. 5.2.). This strongly suggests that the second western channel was created between these two dates, perhaps as a result of ineffective discharge of water from the western millrace. Its short tailrace, of insufficient fall, may have caused backflow preventing the wheel from turning efficiently.

Traces of a weir on the bed of the Gwendraeth Fach can still be seen at the junction of the two courses (figs. 4, 6 and 7). This was probably constructed when the two channels were formed. The weir would effectively lower the water level of the older course (whilst raising it upstream) facilitating more efficient flow down both tailraces.

The works was again offered for sale in 1829. Instead a tenant was found in the civil engineer Thomas Hay who remained at Kidwelly until 1838. The sale catalogue of 1829 contains the first direct reference to furnaces,[26] whilst under Hay the first, apparently tentative, moves were made to add ironworking equipment at the Lower Works. Before 1838 a 'balling' furnace to convert iron pigs into wrought iron had been built, but afterwards removed.[27]

CHANGES, 1838-1860

The tenure of the Downman brothers, beginning in 1838, was a period or radical change at the Lower Works. Under the brothers the expansion into ironworking anticipated by Thomas Hay was completed.[28]

Such major restructuring required a range of completely new equipment, at considerable cost. Yet both excavation and documentary evidence make it clear that it was all crowded into the existing rolling mill building. No attempt was made to add further prime movers and this placed an intolerable burden on the millwork, resulting in considerable inefficiency. Nevertheless, by 1839 Hugh Downman was importing pig iron from Neath Abbey Ironworks for conversion into bars at Kidwelly and operating as the 'Kidwelly Iron and Tinplate Co.'[29]

By 1841 Downman, declared bankrupt, was forced to sell the works, his 'improvements' unfinished. His brother Henry, equally inexperienced, took over the works. After two years of further alterations he too withdrew and offered the works for sale in 1846. In 1848 Hugh Downman returned to Kidwelly, later

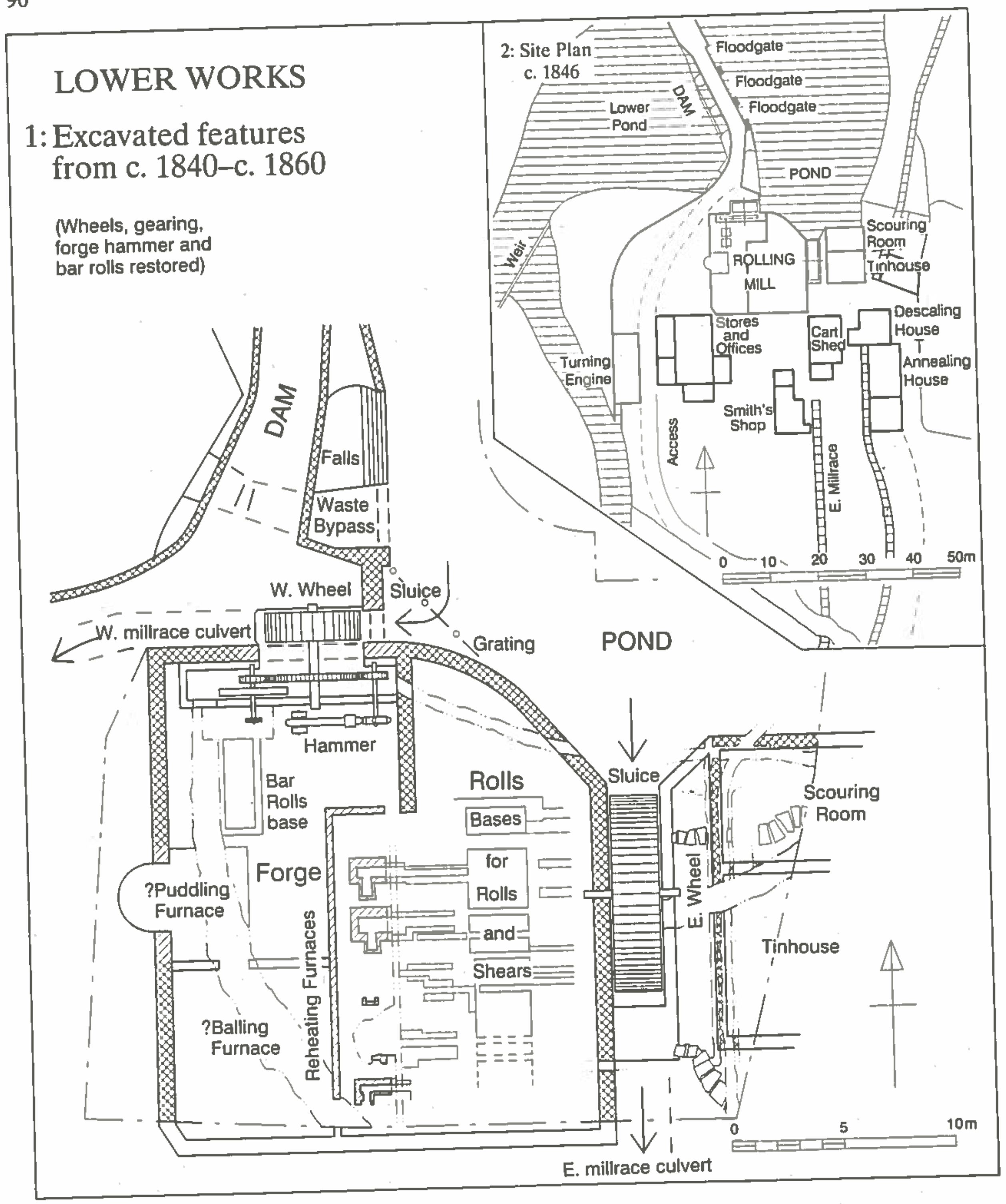

Fig. 6.

acquiring a senior partner in William Briggs of Bristol. Nevertheless, the Downmans' interest ended in 1858 when the works was again put up for sale.

Documentary Evidence

The excavated evidence for this period of conversion is complemented by a considerable body of documentary material which includes sale catalogues, letters and plans. In particular a Bill of Complaint from 1857 confirms that tinplate rolling and ironworking were carried out in separate halves of the rolling mill. The insertion of the iron forge into the mill appears to have been begun in 1840; after this date both the hot and cold rolls were located within the eastern half of the mill (fig. 6). Both were now driven by the eastern waterwheel which was rebuilt in anticipation .[30] The hot rolls were replaced by two new pairs — with the cold rolls alongside.[31] By 1846 a second pair of cold rolls had been installed.[32]

The most extensive changes however occurred within the western half of the rolling mill, which was entirely given over to ironworking (fig. 6).[33] Thomas Hay's balling furnace was replaced in 1841[34] and later a puddling furnace was added;[35] excavation located the possible site of one of these furnaces. The western wheel pit was rebuilt to house a completely new waterwheel, obscuring the earlier evidence. The new wheel, entirely of iron, was built by John Ferguson at Burry Port foundry, and was conveyed by barge on the Kidwelly and Llanelly company's canal to Tycoch Wharf[36] (fig. 3). It was equipped with gearing for both a pair of 'bar rolls',[37] replacing what were probably the cold rolls, and a forge helve hammer.[38] Both the rolls base and indications of the hammer mounting were excavated adjacent to the western wheelpit[2] (fig. 6).

A third waterwheel was apparently present, driving a lathe for turning the rolls.[39] It seems to have been located within one of the tailraces — perhaps the western tailrace, adjacent to and over which a long building is depicted in contemporary plans.[40]

The Downmans were responsible for the introduction of steam power to the works, albeit on a modest scale. To the south of the mill lay a blacksmith's forge which was, by 1857, equipped with a blower driven by a 20-30 hp Cornish expansion engine.[41]

Excavation and Survey Evidence

Dam: An 1839 list of repairs to the mill, dam and sluices suggests that the dam possessed by then three sets of three floodgates, a waste bypass gate and 'falls'. These complex and elaborate arrangements may be seen as a response to the problems of flooding while still maximising water supply. The falls at the southern end of the dam had a stepped profile and a pitched stone floor, later substantially altered. The top of the falls (fig. 6) was presumably a little lower than the maximum height of the waterwheel sluice hatches to allow egress of water here rather than onto the wheels during periods of inactivity. Water flowed from the falls under the carriageway to share an outfall with the adjacent waste bypass (fig. 6). The latter lay immediately next to the wheel sluice and was used as an overflow under normal conditions. All gates appear to have been of timber with iron frames.

In the later nineteenth century a road and bridge were established immediately south of the works. It was thus no longer necessary for traffic to cross through the site and over the dam.

Millraces: The eastern millrace had always housed the 'main' (or 'large') waterwheel. The excavated sluice indicates that despite its rebuild the wheel remained undershot through a hatch rising diagonally within the sluice framing. Since the *Llanelly Mercury* report of 1934 (see note 36) stresses the uniqueness of the western iron wheel it is reasonable to assume that the rebuilt eastern wheel was still largely constructed of timber. Over 8m. in diameter and 2.5m. wide,[42] it fitted snugly within the millrace which then ran through a culvert beneath a pathway and ancillary buildings (fig. 6).

The western waterwheel pit was extensively adapted to take the new iron wheel mentioned above. A breast-shot gravity wheel with buckets, it was nearly 2m. in width and 4.5m. in diameter,[43] and probably replaced a high undershot wheel. The sluice was rebuilt to house a 'depressing' hatch; during the excavation a curved iron plate representing part of the hatch structure was retrieved from the wheelpit. The sluice wall was adapted (rather poorly) to hug the face of the new wheel as a 'breast', retaining water within the wheel buckets (cf. fig. 2:5b).

Either side of the sluice opening can still be seen a vertical row of V-shaped iron brackets. They appear to mark the positions of louvres forming part of a timber shroud which was, in effect, an upwards extension of the breast wall. Water spillage was thus prevented regardless of the height at which the wheel was being shot.

Careful and removal of silt to the pond side of the sluice revealed three timber uprights representing part of a diagonal grating, newly erected (or replaced) in 1841,[44] to prevent flotsam fouling sluice and wheel (fig. 6).

The western tailrace was culverted below the roadway through the site, its riverside revetment continuing upwards as a perimeter wall (fig. 6:2).

Mill: The rolling mill remained the central element of the works, but was, as we have seen, extensively altered during the Downmans' tenure. The former N-S dividing wall (fig. 5) had, apparently some time prior to 1838, been rebuilt as a thinner and probably lower wall further west (fig. 6) over the truncated E-W cross wall also shown in fig. 5. Excavation confirms that the western half of the mill now received iron forging equipment.

(*Forge*) A large square feature excavated in the middle of the wester half of the mill may be the robbed out base of either the puddling or balling furnace. It was situated opposite a curved brick wall extending beyond the western wall of the mill (fig. 6). This is arguably the remains of a brick stack associated with the furnace; the size and location of the features cannot be otherwise explained. The other furnace may lie south of the former E-W wall in an area not fully excavated. Both types of furnace were large and normally charcoal fuelled. Iron pigs were decarburised within both types of furnace rendering them malleable for forging into bars.

The conversion of the western waterwheel pit included its extension right into the mill building, within which it was further laterally extended to receive an entirely new gearing arrangement. Formerly having driven just one roll train the wheel now also powered a helve hammer.

Whilst the arrangements for transmission of power from the wheel to the hammer cannot be conclusively demonstrated, it is likely that a large pit wheel shared the waterwheel's axle turning a smaller follower gear lying on its eastern face. This in turn drove a tappet wheel which, as it rotated, lifted the head of the forge hammer. The hammer 'shingled' impurities out of the molten ball of iron and slag produced in the furnaces. A number of bedding trenches next to the eastern wheel pit extension may represent the hammer mounting (fig. 6:1).

A second follower wheel lying in the opposite wheel pit extension drove a large flywheel. A deep groove cut into the wheel pit wall shows the diameter of the flywheel to have been 2.5.m. Its purpose was to relegate the motion of the new bar roll gearing to which it was linked via a clutch coupling. Blooms shingled by the hammer were passed between these grooved rolls to produce iron bars. A plinth defined by four bedding trenches was excavated adjacent to the flywheel groove and doubtless represents the rolls base (fig. 6:1).

Considerable plant was thus run from just the one wheel. The constant switching of power from forge hammer to rolls created damaging levels of stress. In addition, much of the power generated by the waterwheel was lost keeping the gearing itself in motion. The same situation now prevailed in the eastern half of the mill.

(*Rolls*) At this stage in the process the forged iron bars were taken to the eastern half of the mill where they were again heated and rolled for tinning.

Moving the dividing wall further west had effectiveley created an enclosure down the middle of the building, within which were located what were the bases of five reheating furnaces. All were similar with long flues, ash pits, and their superstructures carried on bolts. Like the enclosure wall itself, the furnaces were clearly the work of one of the Downmans' predecessors; the sale plan of 1846[45] indicates that by that date only two were operational. This suggests a reduction in hot rolling equipment to provide room for the introduction of cold rolls.

A plethora of sleeper impressions set in a rectangular rubble plinth were excavated opposite the furnaces. They may be interpreted as having carried the rolling machinery, which by 1857 included two pairs of shears, two pairs of hot rolls and one pair of cold rolls — all powered by the eastern waterwheel.[46] The narrowness of the millrace suggests that the main spur was a rim drive on the wheel itself. The rolling machinery could not be precisely located and so the gearing arrangements must remain uncertain. However, two follower wheels must have been required and they probably rotated within the circumference of the rim gear, their shafts entering the building to engage with bevel gearing to rolls lying N-S on the plinth. A system of crank shafts, connecting rods, and rocker beams normally operated the shears.

Other buildings: The buildings east and south of the rolling mill housed the less mechanised stages in the tinplate process. The excavated masonry block immediately east of the eastern millrace was by now at least divided internally into two unequal areas (fig. 6).[47] The northern third represents the 'scouring room' where finished tinplate was cleaned. The tinhouse occupied the remainder (annealing and pickling having been performed in a separate building to the south) which by 1857 possessed the full complement of three pots — tin, wash and greasepot.[48]

TRANSFORMATION 1860-c.1887

The works was purchased in 1860 by Jacob Chivers, under whom it was radically transformed. In a seven year campaign[49] Chivers introduced extensive new buildings, and the works' 120 year old dependence upon water power was broken.

Documentary Evidence

Fig. 7:2 is based on the 1900 sale plan which, in great detail, depicts the Lower Works in its final form. No such detail is present in earlier plans but the same overall layout is shown in examples from the 1880s.[50] Careful comparison of this plan evidence reveals the great changes intiated by Chivers during the 1860s. To the south of the rolling mill the ancillary buildings were demolished to make way for the steam mills block. Brick walls, piers and columns of iron carried timbers supporting a corrugated iron roof, beneath which two hot roll trains of four pairs each worked at right angles to one another. Each train was driven by a large vertical single cylinder engine and flywheel mounted together in a T-shaped pit; they also operated the shears. Alongside each train was a line of four reheating furnaces.

West of the old mill, the enclosure wall was levelled and the works extended towards the river. Arranged around a yard were the brick built, slate-roofed smithy and fitter's shop. Within the former were three forges supplied with blast pipes from a small vertical steam engine; a similar engine powered two lathes in the fitter's shop.[51]

Water continued to drive the cold rolls in the eastern half of the old mill for over twenty more years — in addition to the forge and bar rolls in the western half.[52] Their furnaces were supplemented with new puddling furnaces and a hollow fire apparently on the site of the old pickling and annealing house.[53] But by the mid 1880s the use of Siemens steel bars became widespread and forging ended at Kidwelly.[54] The western half of the rolling mill soon went out of use, as did Chivers' more recent furnaces.

By 1872 the works, now operating as the 'Gwendraeth Iron and Tinplate Works', was connected with the local rail network via a line

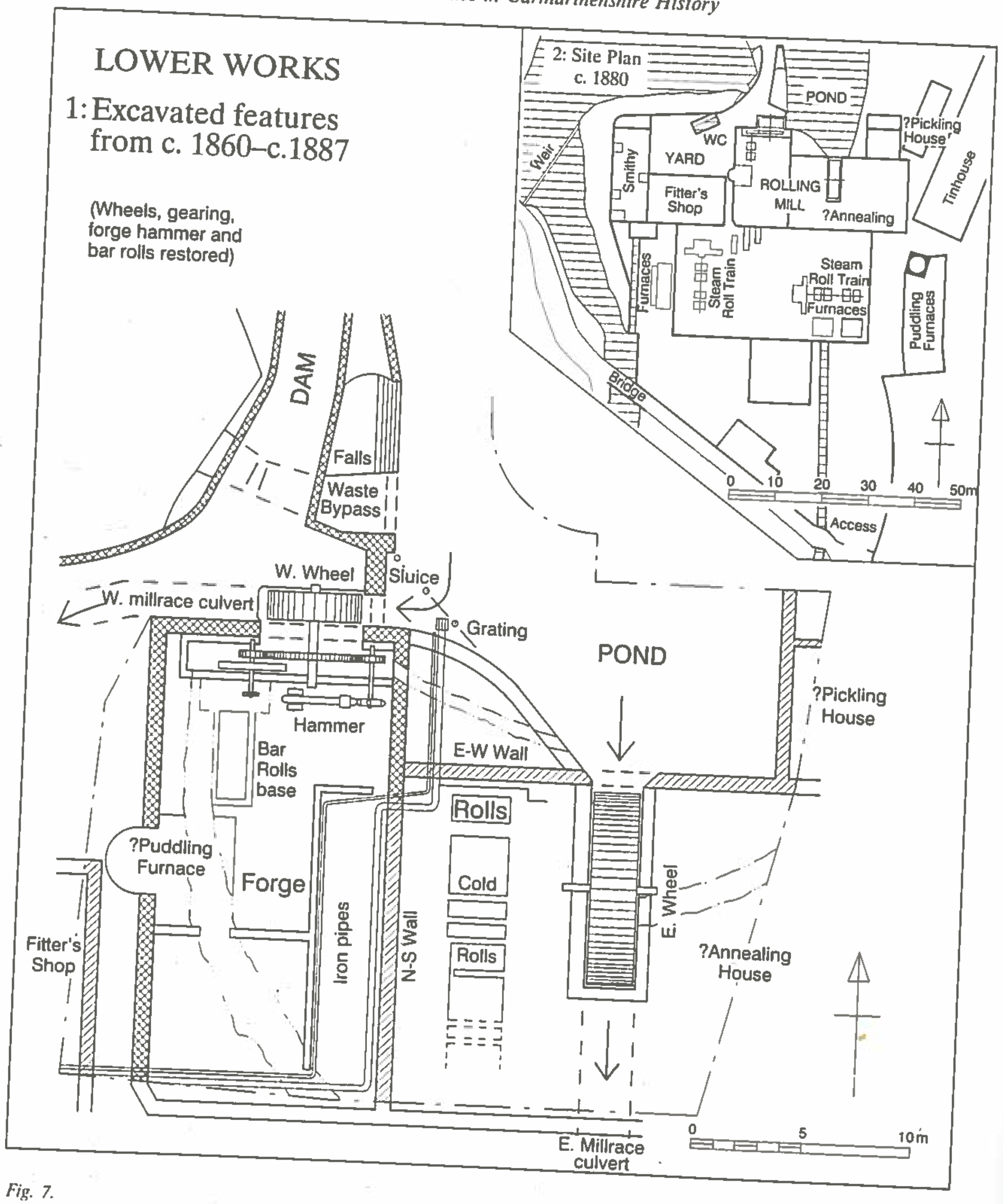

Fig. 7.

from Mynyddygarreg. Chivers' son Thomas took over the works in 1877 and within two years initiated a second major building programme which more than tripled its extent. This was achieved by building on a virgin site upstream — the 'Upper Works' — where a large hot rolling mill was built. Within it two vertical steam engines built by Edwin Foden drove six pairs of rolls in a continuous train. These are still to be seen at the museum.

Excavation and Survey Evidence

Chivers' campaign also initiated changes to the water-powered rolling mill — within the excavated area. The main plan (fig. 7:1) is thus the product of archaeological investigation.

Mill: Water powered cold rolling continued despite the increasing burden of silt that periodically denied water to the eastern millrace completely — a factor that was eventually to lead to its disuse. This perennial problem is graphically illustrated in the Kidwelly work reports from the strike year of 1874, when in July the 'third mill [was] not working for want of water', while the forge was working 'full and steady'.[56] The western millrace, then, was less affected by the water shortage.

(*Rolls*) There was undoubtedly a reduction in the amount of plant located in the eastern half of the rolling mill under Chivers. Probably only two pairs of cold rolls now ran from the eastern waterwheel. The excavated sequence demonstrates that the disused reheating furnaces were taken from their brick bases, and their enclosing wall truncated. A tarry levelling layer was laid down, prior to the construction of a new N-S internal wall on the line of the pre-Downman division (fig. 7:1). A brick floor was subsequently laid down in this half of the mill against the new internal wall.

Two iron water pipes were then laid down. They entered the mill from the pond, passing across the central area to turn west — possibly to supply the steam engine located in the smithy. At the point of entry from the pond the mill's chamfered north east wall was reduced in height to lie outside a new E-W wall which had been built 5m. to the south (fig. 7). The wall formed the north wall of an entirely new building, situated partly over the demolished tinhouse and scouring room (see below).

(*Forge*) As we have seen, bar production ceased at Kidwelly in the mid 1880s. Excavation demonstrated that the forge was then immediately dismanted. The furnaces were demolished, the hammer and bar rolls removed, and their bedding trenches backfilled. The western wall of the building itself was truncated and replaced with a open arcade of brickwork piers communicating with the suite of buildings added further west. A brick floor was laid down, areas of which were revealed during excavation. Whilst the western wheel was not immediately removed, its sluice was blocked with limestone rubble probably derived from the demolition debris.

Waterpowered cold rolling and forging then, terminated more or less together — though for different reasons — anticipating major changes in the second half of the 1880s.

Other buildings: A new building was constructed east of the old rolling mill from masonry obtained through the demolition of the tinhouse and scouring room, the footings of which were buried beneath a considerable depth of material (fig. 7). Later evidence[56] suggests that the annealing house was sited here but evidence of furnaces was lacking and they may have been situated just outside the excavated area.

The small annexe to the north of the new building may represent a pickling house. Tinning henceforth was now carried out in an entirely new building to the north, towards the Upper Works (fig. 7:2).

DECLINE c. 1887-1904

The later 1880s and 90s were a period of decline at the works as a whole. In 1887 Thomas Chivers was forced, through debt, to close the works and offer it for sale. 'The Gwendraeth Tinplate Co. Ltd.' was founded early the

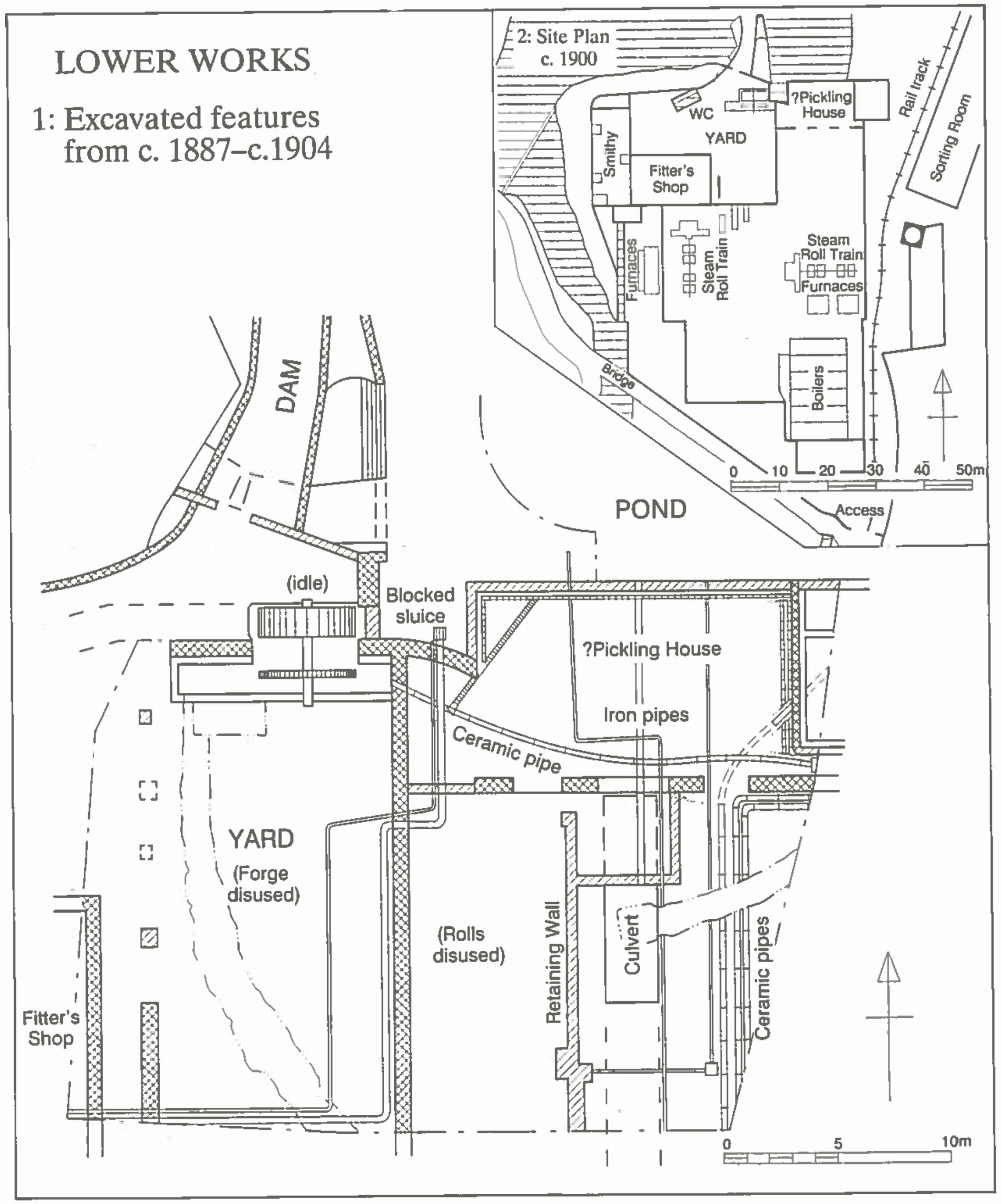

Fig. 8.

following year, retaining Chivers as one of six directors and 'production had resumed by summer 1889. However just two years later the Mackinley tariff was introduced in the USA dramatically limiting export of tinplate which had provided a market for three-quarters of British production. The ensuing recession forced many works to shut down, some of them forever. Kidwelly closed in 1896.

However changes and new building projects were in the meantime initiated at both the Lower and Upper Works.

Documentary Evidence

Abandonment of waterpower accompanied a general shift in interest from the Lower Works towards the unrestricted Upper Works site, which was to result in the final obliteration of the pre-steam layout.

The sale plan and catalogue of 1900 (fig. 8:2) show that the old rolling mill was more or less entirely demolished and the forge area had become a mere extension of the fitter's shop yard.[57] Six Lancashire boilers were erected at the south end of the site. At the same time an entirely new building had been constructed against the north wall of the old mill/annealing house — over a millpond so completely choked with silt as to provide a level surface.

Excavation and Survey Evidence

Mill: Surviving from the demolition of the old rolling mill were two piers and a length of its western wall, possibly supporting a roof while separating the yard from the steam mills (fig. 8:1). The floor of this half was resurfaced with iron plates. The fitter's shop yard itself was given a brick surface.

In the eastern half all walls were levelled except that on the northern pond side, and the internal dividing wall now became an outside wall of a large block created from this area and the annealing house. The eastern waterwheel was removed, its sluice blocked and the whole culverted for most of its length. The culvert arch stood fairly high so a low wall was built just to the west to retain the considerable thickness of material necessarily deposited over the area to make a level surface.

After a time the northern wall was pierced to form an arcade communicating with a new brick building being built alongside. During its construction, a series of small gauge iron pipes were laid down leading from the pond through the works (presumably to supply water to the new boilers), and a larger one flowed into the eastern millrace. At the same time three ceramic drainage pipes were directed along the same alignment from the east (fig. 8:1).

The lower level west of the retaining wall received a brick and iron plate floor, while the revetted area and new building were floored with iron plates alone. Such was the instability of the silt upon which the latter had been constructed, however, that the plates were successively lifted and replaced as more and more make-up was deposited to compensate for subsidence. These episodes were punctuated by the provision of a number of drains directed into the western waterwheel pit. None of the features present, however, give any clues to the function of the building. The plan of 1900 indeed suggests that by this time it may have been disused, being therein termed 'Old Annealing'.

The northern building enclosed the eastern annexe built under Jacob Chivers, which had been reduced in height and filled with material to form a raised platform. The whole, like the building to the south, was roofed with pantiles, which account for a large proportion of the demolition debris. A mechanised pickling plant was present at the Lower Works in 1900[58] and may have been located here.

DEMOLITION, 1904

The Lower Works never operated again after the shut-down of 1896. When the site was purchased in 1899, production was restricted to the Upper Works. In 1904 the Lower Works was entirely dismantled, and the buildings levelled.

Within a few years the Upper Works had fully recovered from the recession; it continued to operate until the Second World War. How-

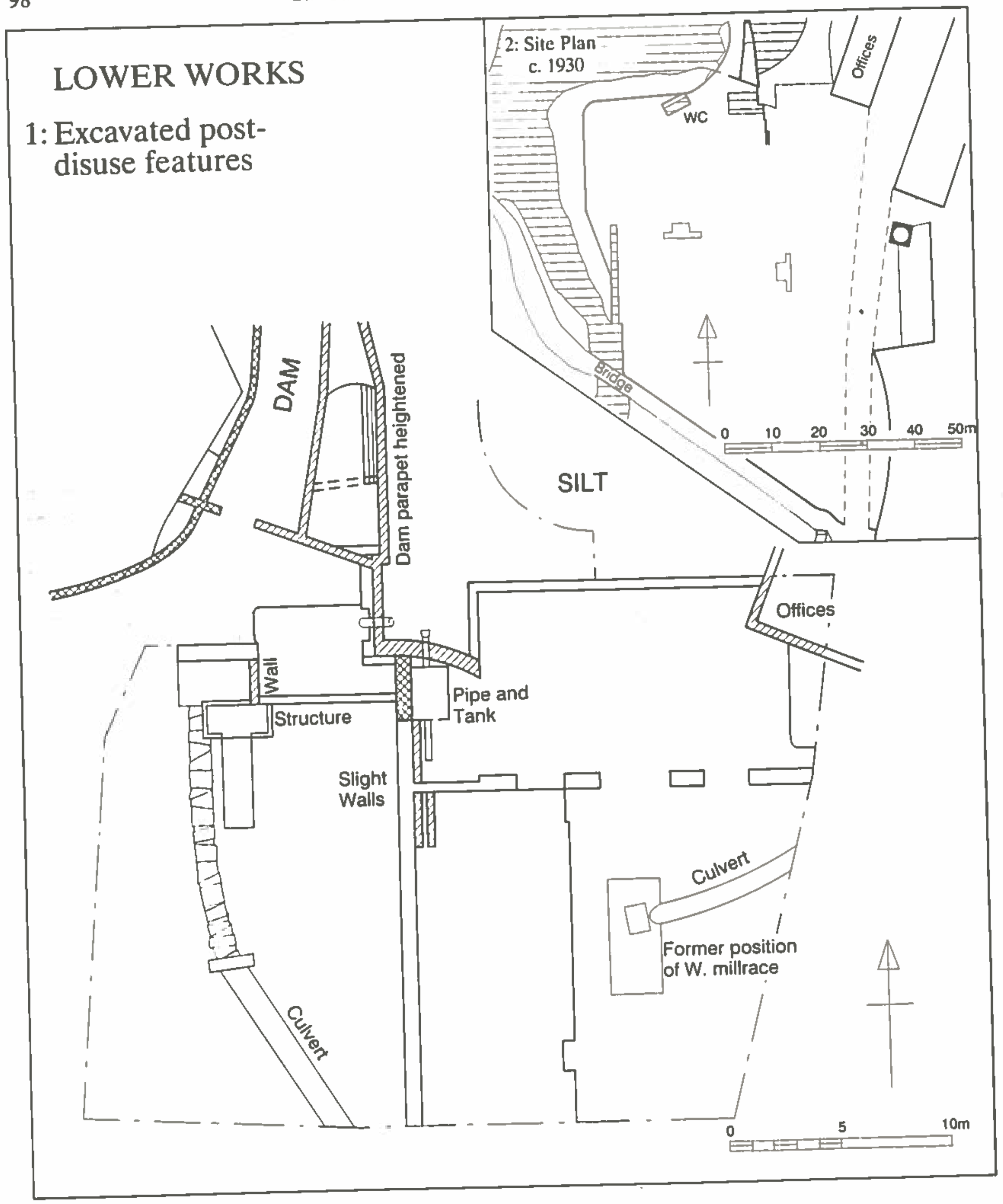

Fig. 9.

ever, American competition, and in particular the introduction of the continuous hot strip mill, finally put an end to the Welsh hand-milling industry. In 1946 the works closed for good and was purchased by Messrs. J. P. Zammit of Llanelli to be used for storage.

Excavation and Survey Evidence

Just prior to the dismantling of the Lower Works two massive culverts were cut through both halves of the former mill, one emerging from the east to empty into the eastern millrace, the other issuing northwards into the western waterwheel pit. A structure was subsequently built between the latter pit and the re-exposed bar rolls base, the plinth for which was excavated but of unknown function (fig. 9:1).

The 1904 demolition was complete. Nothing was left of Jacob Chivers' steam mills nor the ancillary buildings, except the brick built latrine which continued to be used well into the twentieth century. Of the old mill, only a stretch of the rebuilt internal wall was left standing to any height, and whilst the northern building was retained (in a much reduced condition), it was buried beneath destruction debris and the subsequent dumping which considerably raised the ground level here.

The western waterwheel was eventually removed, and the western extension of its pit was walled off and backfilled. Two slender retaining walls were built over the former internal dividing wall to retain dump material to the east, which may have been a deliberate flood prevention measure. Some further minor structures were erected (fig. 9:1).

Silting in the millpond remained considerable. Though the dam floodgates had for some time been left permanently opened the millpond was, by the second decade of the century, completely choked. Flood prevention work thus included the complete reconstruction and infill of the long-disused waste bypass and falls area in brick, and the heightening of the western waterwheel's infilled sluice — incorporating an open iron pipe to flush the latrine. Just prior to the final abandonment of the works, the dam was heightened throughout and equipped at the southern end with iron sluices running along the top of the pondside parapet.

CONCLUSION

It can be seen that the above account is based on the study of a combination of documentary material, archaeological evidence and surviving physical features. Whilst the documentation furnishes an overall picture of the development of the site, and occasionally lists the machinery present, the precise location of all the various elements was only resolved through excavation. However, as most of the structural features had been entirely robbed out, it is the dimensions of the remaining features, assessed alongside the sequence of operations that form the tinplate and ironworking processes, that permit an interpretation of the evidence.

ACKNOWLEDGEMENTS

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NOTES

Not all the following references are as complete as I would have wished; the mss. sources are based on transcripts and photocopies given to me by W. H. Morris.

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Naming of Seams in the Llanelli Coalfield

MALCOLM SYMONS

INTRODUCTION

The commercial exploitation of any coalfield involved the granting of mining leases and, in every case, it was important that both lessor and lessee knew exactly which coal seams were being included in the demise. There was, therefore, a need to distinguish seams one from the other, a task most easily and logically achieved by allocating a different name to each individual seam. The Llanelli Coalfield, in common with all of Britain's coalfields, adopted this apparently simple naming practice, but examination of the area's historical mining and, geological documentation reveals the existence of a surprisingly complicated naming pattern, with many seams known by a large number of different names, different seams known by the same name, and with the names themselves varying from the mundane to the exotic. Confronted with this vast array of alternative names for a limited number of coal seams one is bound to ponder on the rationale, or lack of it, behind the naming of seams in the Llanelli Coalfield.

THE GEOLOGICAL STRUCTURE OF THE LLANELLI COALFIELD IN TERMS OF PRESENT KNOWLEDGE

In order to understand how this complicated seam name pattern came into being and subsequently evolved, it is necessary to gain a brief appreciation of the present understanding of the geological structure of the Llanelli Coalfield in terms of coal seam and fault occurrences.

The Llanelli Coalfield of this study comprises some 21 square miles (5,500 hectares) centred around the township of Llanelli, Dyfed (Figure 1). It was a coalfield in its own right, with a separate development from those based around the neighbouring townships of Burry Port and Loughor which, in terms of pre-twentieth century parochial trading practices, were regarded as rival areas. The Coalfield extends from National Grid line SNO4 in the north (delineating a barren zone between bituminous and anthracite surface coal where little exploitation has taken place), to the shoreline of the Burry Estuary in the south. The major Moreb and Plas Isaf Faults, which formed natural barriers to mining between the Llanelli Coalfield and the adjacent Burry Port and Loughor Coalfields, are taken as the western and eastern boundaries, respectively.

Mining was carried out to a maximum depth of about 1300 feet (396 metres)[1] and was confined to the Upper Coal (or Pennant) Measures. Within this depth range, the Measures consist of a succession of sandstones, siltstones, shales and mudstones containing some thirty coal seams. More than twenty of these seams, varying in thickness from 1 to 9 feet (0.3 to 2.7 metres), were exploited in the Grovesend, Swansea and Hughes Beds of the Upper Pennant Measures and in the Brithdir and Rhondda Beds of the Lower Pennant Measures. The sequence of known coal seams over the exploited depth range is given in Table