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COALMILLS IN TYNE AND WEAR COLLIERIES : THE USE OF THE WATERWHEEL FOR MINE DRAINAGE 1600-1750

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Abstract: In the later decades of the 16th century large-scale coalmining made intensive mechanical drainage increasingly necessary. This was done in the main by waterwheels driving bucket or disc chains, the "coalmill". Conflict from 1600 to 1650 over demand for water hastened industrial concentration. After 1650 maximum power was extracted, but largely wasted in transmission, in a sophisticated treble-shaft system. Efficient suction pumps worked by rodding appeared quite suddenly around 1700; how, and why so late, we do not know. With these the waterwheel remained in common use in established Durham collieries until the mid century.

THE POWER DEMANDS OF THE COAL INDUSTRY

By 1600 the scale of its operations put coalmining in a world apart from that of the extraction of metals. Every year from that date onwards at least a quarter of a million tons of coal was exported from the Tyne; by 1622 this had increased by 51%, and what was actually raised at the pits was probably greater by half.[1] Merely to move this from pithead to riverside required energy of the order of three or four million kilowatt hours, at first of necessity provided by draught animals. Though we have no means of calculating it, draining collieries may well have demanded a power input almost as high.[2] For this owners could usually turn to those ubiquitous motors of early industry, watermills, which appear in deeds of the time as "coalmilns" but have been given little attention by coal historians, and none by industrial archaeologists.[3] Indeed there has been so little archaeological enquiry into coal that the quasi-totality is contained in a single article in the present volume, Fred Hartley's *The Tudor Miners of Cole Orton, Leicestershire*. His investigation revealed that pillar and stall working was in use 150 years earlier than the date historians had given it; existing accounts of mine drainage are plainly even more inadequate, and similar archaeological evidence is even more badly needed.

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The documents clearly show a spreading use of the coalmill hastening both technical advances and change in the structure of ownership, and falling into three phases, 1600-1650, 1650-1690 and 1690-1730. However though the dating of the structural changes is secure, that of developments in drainage techniques leaves large and important questions to be answered.

In the most important coalfield, that upstream of Newcastle, the River Tyne carved a gorge through a 500-foot plateau, exposing the crop of half a dozen seams of coal. Tributary streams cut the plateau into blocks to like effect, and these valley sides in turn were indented by denes, so that miles of free-draining coal were laid bare. These exposed seams had already been much depleted by 1492 when we first hear of powered drainage. However more typical of 16th century working was the watergate or adit driven in 1551 from halfway down Winlaton Hill. The hill was a layer-cake of seams; by the 1630s the recovery of what coal remained at its foot was to require a battery of coalmills[4].

After 1600 the working of seams lying below the water table became unavoidable, and it brought a general demand for energy for pumping such that only waterpower could meet it. The engineering problem has been much misunderstood by the economic historians, who have shown a curious faith in the ability of horses to solve it. By 1700 on the Tyne a "great colliery" was to cover half a square mile or more, between 300 and 400 acres, and merely to remove the rainfall seeping from its own surface demanded a rate of clearing of up to 135 gallons a minute, and at a depth of 240 feet and 40% efficiency a constant primary input of the order of 25 h.p; using horses for this would require a stable of over 80. Nef was able to cite only 15 coalmills in all Britain, of which only 3 were on Tyneside where at least 25 now seem probable, a striking demonstration of the dangers of economic history unsupported by adequate industrial archaeology. More recent accounts of drainage have not remedied his defects; John Hatcher's 600-page volume of the NCB history adduces only five cases, and Flinn none.[5]

THE CONTESTED COALMILL, 1600-1650

Water was not lacking; the question was who was to have it, and from 1600 to 1650 the increasing need of coalowners for it brought an explosion of litigation. Courts were called on to adjudicate between thirsty cattle and thirstier coalmills, as when at Easter 1638 Wortley Goodall, an associate of the Beaumonts of Coleorton, was called before the Warwick Quarter Sessions for interfering with watercourses near Atherstone; his ditch, cut across the flank of a hill to intercept the entire run-off, his millpond and pits are extant but unstudied.[6] A generation earlier Durham Quarter Sessions had tried 20 yeomen who "with 28 others unknown assembled riotously by night in warlike fashion on 27 Aug. 1614 ... at the order of Thomas Liddell of Ravensworth, gen." and dug up 80 yards of Gateshead's public water supply. Liddell owned the lower part of Chow Dane, a typical water-gathering cleft in the side of Low Fell; his riot tells us that the townsmen's thirst had stopped an otherwise unrecorded coalmill and was drowning his coal.[7]

In 1617 a consortium of four considerable partnerships obtained from Newcastle town council the largest available concession on Tyneside, the Whickham Grand Lease. Thomas Surtees, greatest of the early "viewers", as colliery engineers and managers were called, dewatered for them a great area east of the village, the southern part by means of an adit into the Black Burn at Watergate, the northern by a coalmill at Allerdeans. To run his engine he brought water from Dunston Hill to the west. The result was a colliery of unprecedented output, eventually of at least 180,000 tons annually.[8] It raised a storm, the Whickham villagers complaining of wells dried up, of industrial pollution, of children killed on the roads, and in protest picketing the colliery's wains.[9]

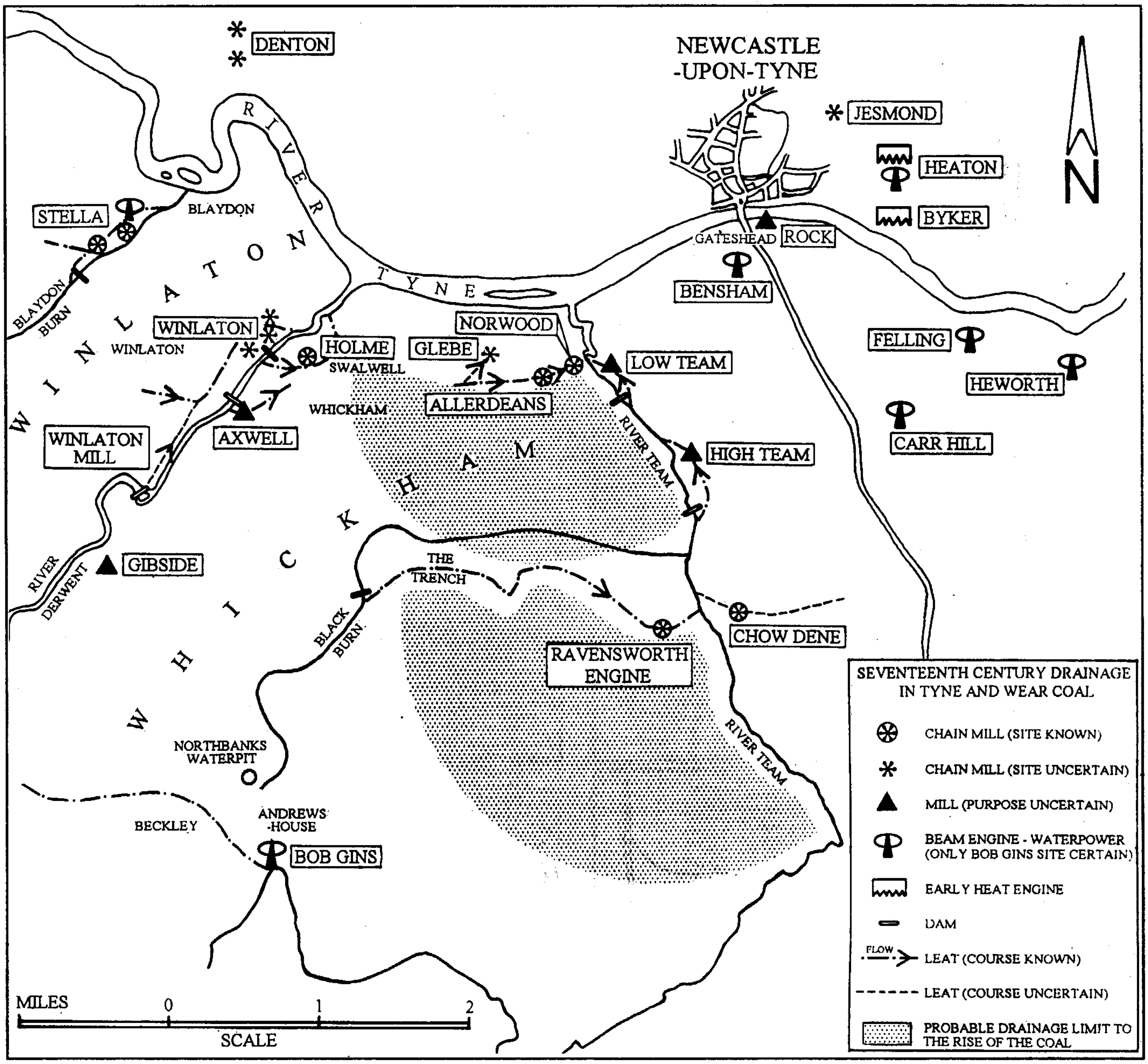
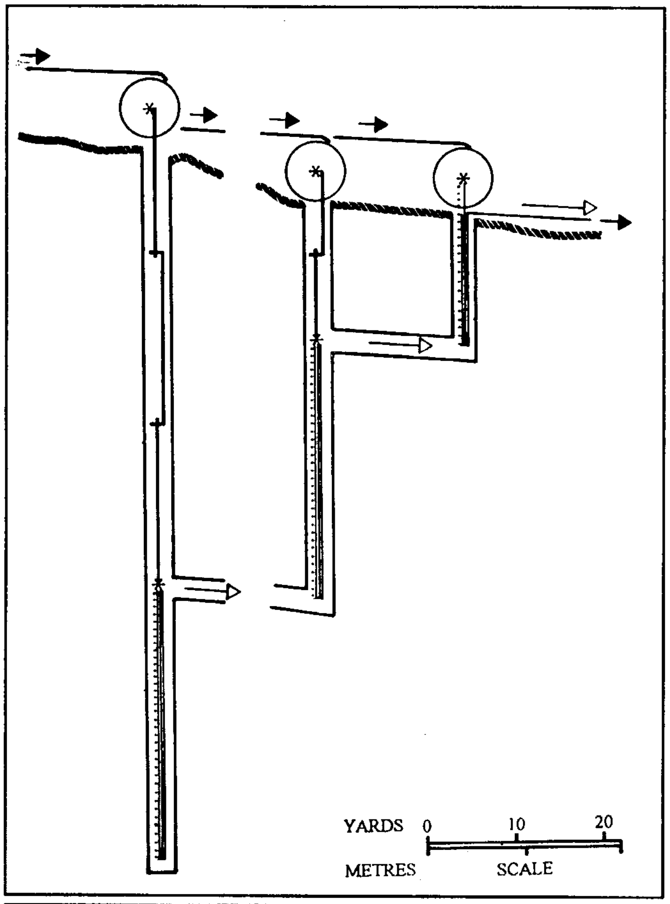


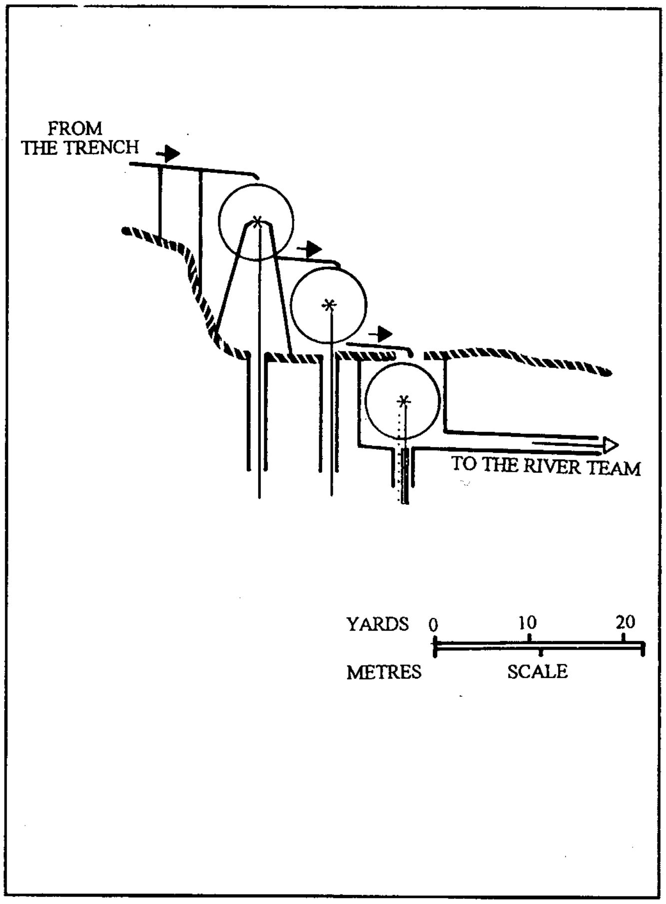
Fig. 1. The exploitation of Tyneside water resources for colliery drainage.

The hardest-fought disputes however, since they were the best-funded, were between rival coalowners. Farnacres colliery lay between the Allerdeans engine and the River Team, and was succumbing to a general flooding of the Tyne peneplain. The waste water of Surtees' scheme was therefore a godsend for a Farnacres coalmill at Norwood. Inevitably, this water was one day diverted, and, despite an injection of £2500, much of Farnacres was drowned; seeking a quick decision on 1623 its owner appealed to the Privy Council.[10] In 1646 the Allerdeans engine itself, after 30 years still draining most of the eastern Whickham coal, had its water supply stopped by a new Whickham Glebe Colliery, lying between it and Dunston Hill. To save nearby pits and threatened workings to the south the Grand Lessee, James Clavering, had recourse to Chancery. It is likely that another unrecorded coalmill had been installed to drain the Glebe coal, and water diverted from the eastern to the northern face of Dunston Hill to feed it.[11]

There was more to such cases than adjusting shares in a common resource. The water supply of a machine-drained colliery was its lifeline, and a stranglehold on it by a rival threatened the enterprise's existence. For their attack on the last sector of Winlaton Hill in the mid 1630s, its lower slopes, the owners of Winlaton Colliery, second only to Whickham Grand Lease in size, provided water for a coalmill by intercepting the run-off from the hill by means of a trench cut just below the crop of the Brockwell seam. This proved insufficient, and by 1639 the colliery had flooded, so Sir William Selby, the principal partner, used the ancient weir of Winlaton's manorial cornmill to divert the River Derwent into the trench for power for more coalmills.

The Grand Lessee, John Clavering, father of James, held most of the opposite bank of the Derwent; he sued Selby because this stopped his own cornmill. A court *status quo* injunction would have the effect of flooding his rival's colliery. The Civil War intervened; the Selbys were Catholic-leaning royalists, Clavering was a Puritan, and the fortunes of war gave hope to both in turn. The outcome was that in 1656 James Clavering got from the Selbys keel-berths and wharfage sufficient to handle over 30,000 tons of coal a year, along with an earlier Swalwell ironmill, Holme Mill; its use to drain the Brockwell seam for a new Swalwell Colliery is likely to have begun that year.[12] These Derwent mills remind us that a watermill was an adaptable industrial motor; any such in an early coalfield is worth looking into, for many uncontested coalmills must have escaped the record.





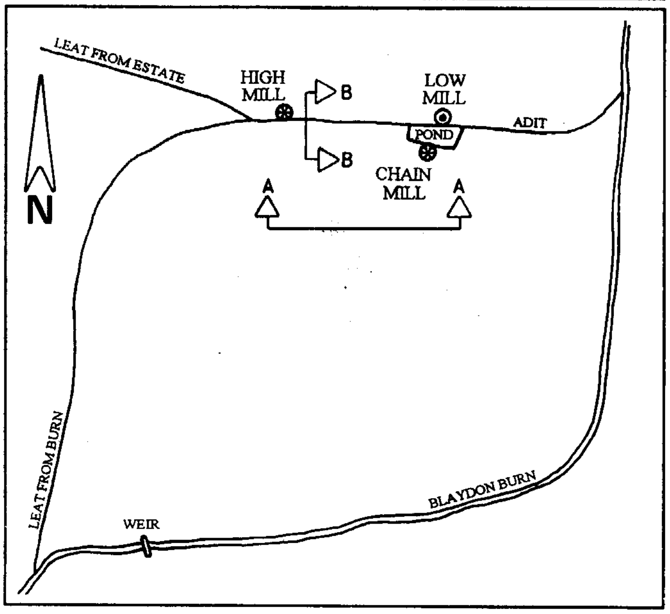


Fig. 2. (top left) The Durham treble-mill system as described by George Sinclair.

Fig. 3. (above) Sir Thomas Liddel's Ravensworth Engine of 1670, after Sinclair.

Fig. 4. (left) The lay-out of a treble-mill colliery: James Weatherley's plan (redrawn) of Steela Freehold Colliery in 1719. High Mill to Low Mill is about 360 yards. Sections A-A and B-B of the underground workings will be seen in Figure 5. Source: Gateshead Central Lib. Cotesworth Coll. G/CK/11/4.

THE TREBLE-WHEEL COMPLEX 1650-1690

After 1650 litigation over coalmills abruptly ended. Workings moved farther away from the Tyne into a zone of large well-watered estates, and great owners invested in railed transport to gain access to free-draining reserves not previously viable. Above all the seismic upheavals of the Civil Wars had relieved social stresses by restructuring the ownership of land, as exemplified by the eclipse of the Selbys. Coal became concentrated in the hands of fewer and like-minded men. In 1669 the second Ravensworth baronet, Sir Thomas Liddell, began a large-scale redevelopment of his colliery which called for a powerful engine.[13] He achieved sufficient waterpower by tapping into the Black Burn which bounded the estate and drained the upland of South Whickham. On the burn's left bank the lessees of both Blackburn and Whickham Grand Lease collieries too had rights on it, and before 1650 litigation would certainly have ensued. But men and times had changed; the Blackburn partners were Liddell himself and Sir James Clavering, who was also the principal Grand Lessee, Liddell's fellow Puritan and tied to him by politics and marriage .

Concentration reduced competition for water but simultaneously increased the extent of holdings of coal, and larger areas to be drained called for deeper waterpits requiring more power. Greater estates however brought a rationalisation of the use of waterpower, a system of threefold mills of which we have eye-witness accounts. In earlier smaller collieries seams had been worked from the dip, their lowest point, one after another by a series of *ad hoc* drainage devices. In large estates it was possible, instead, to plan to draw water from a maximum depth of 240 feet, and so clear several seams over very large areas.

This was done using what in the literature is called the rag pump, but was known in the north as "the chain engine"; it drew water up a standing wooden pipe by means of discs mounted on a continuous chain. Weight imposed on the chain engine a maximum lift of perhaps 90 feet. To raise water 240 feet the work was divided between three waterpits, successively at 240 feet, 160 feet, and 80 feet; in each pit an engine with a lift of 80 feet fed to the next. Pit-head waterwheels drove these machines by rotating vertical axles; the full power of the water supply was given to the first and deepest pit where transmission losses were greatest. As soon as sufficient fall could be achieved the water was passed over the other two wheels, usually placed opposite each other and splitting the supply between them according to their depth.

The Scots physicist George Sinclair described the system as it was applied about 1670 in the Ravensworth Engine (Fig. 3), which had to be built on a cramped site at the foot of a bench overlooking the Team - the site is still extant but unexplored and is now threatened by development of the A1(M) road. Three wheels, apparently 24 feet in diameter, all in series, were achieved by setting the first on posts and the third underground, with an adit to the Team for tailrace.[14] A two-mile leat, the Trench, carried the water from the Black Burn across the Ravensworth ridge. The engine may well have produced something of the order of 20 hp, and, while Sinclair's claim for it is certainly exaggerated, it must have cleared the coal for over a mile and a half to the south, for no other engine in that area is known.

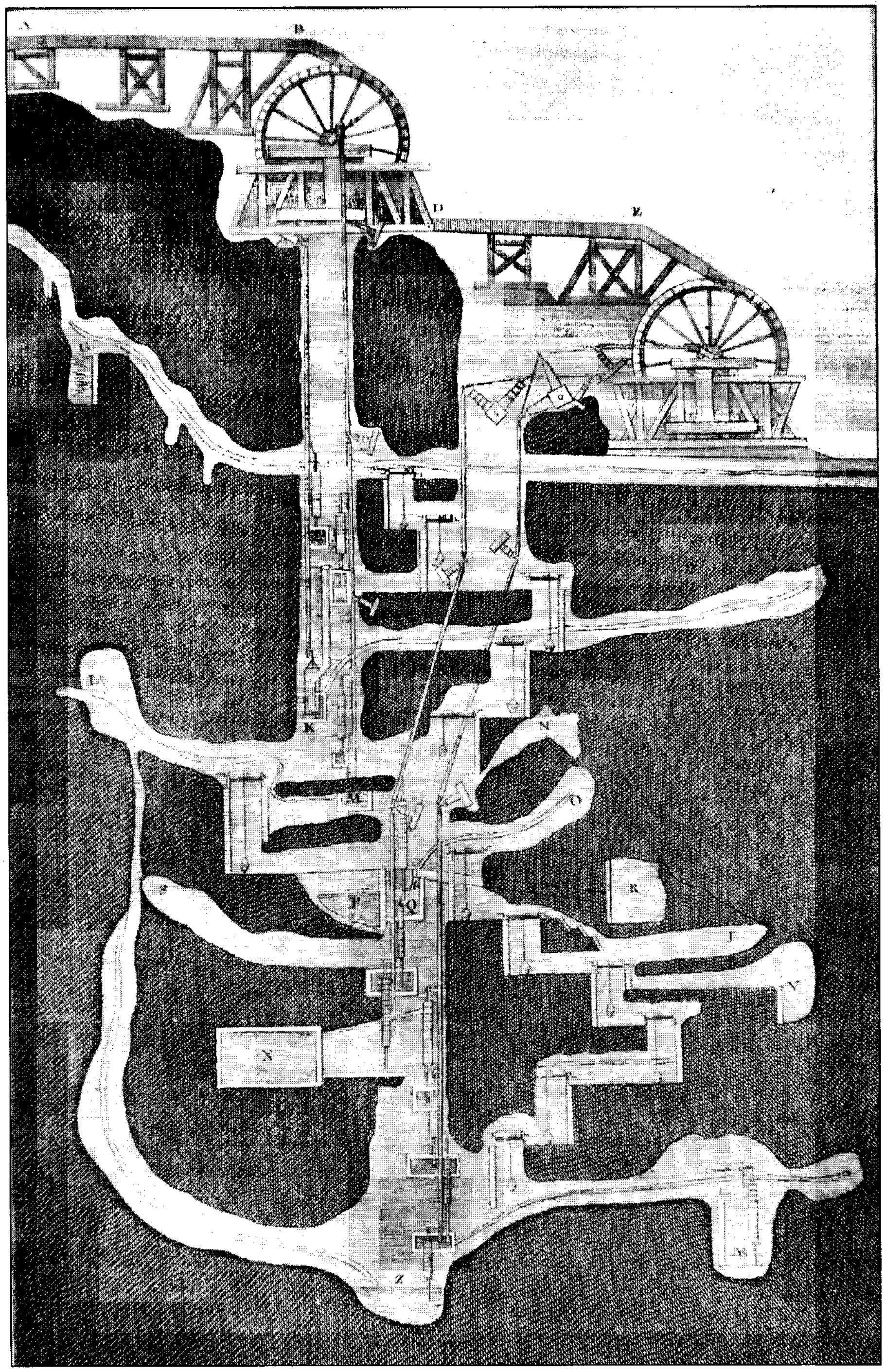
A similar "three-story" engine, accompanied by a "two-story" one, was noted between 1680 and 1684 at Lumley Colliery on the Wear, where one watercourse, it was claimed, drained pits "for 2 or 3 miles together". A plan for this colliery, probably of 1739, shows a three- quarter mile band of disused pits, among them the twin "Chain Engine Pits" North saw, nearly a quarter of a mile downstream from a dam which was later to serve Lumley Forge.[15] These had been augmented later by a water-driven beam engine; there was a "Water Pit" thought to have used another mill to raise a kibble, and the working colliery consisted of 21 pits drained by two "Engine Pits", so that Lumley Colliery had seen no fewer than nine waterwheels. They were the work of two great coalowners, Henry Lambton and Ralph Delaval, to whom the whole of the Lumley coal had been leased for 21 years in 1654.[16]

Finally a straightforward viewer's report of 1719 on Stella Colliery,[17] adjoining Winlaton across Blaydon Burn, allows us to see how the treble-wheel system had arisen in a colliery of moderate size. It had been drained first by adit, and then a second seam had been opened by means of a coalmill; power for a third seam had been obtained by continuing the leat carrying the water for 60 yards, when a sufficient fall was obtained for a second wheel; this proving insufficient, a third was installed opposite it.

THE AGE OF THE BOB GIN, 1690-1740

Towards the end of the 17th century the coalmill entered its last phase when the inefficient rotary drives of the chain engine were replaced by linear motion transmitted through rodding to batteries of reciprocating pumps, worked in a single shaft by a waterpowered beam engine. The northern word for a beam was "bob", and so the new engine was a "bob gin". The reciprocating pump allowed the 240 foot depth barrier to be breached, and around the turn of the century the second Sir William Blackett

Fig. 5. Stages of the three-shaft sytem seen in a mid 18th centuryFrench metalliferous mine. 1 - adit; 2 - shallow shaft; 3 - deeper shaft (on left); 4 - deep staple (centre). Earlier chain engines have been replaced by bob-operated pumps lifting in steps.. Source: Grand Encyclopédie "Mineralogie" reproduced by courtesy of Lancaster University Library.



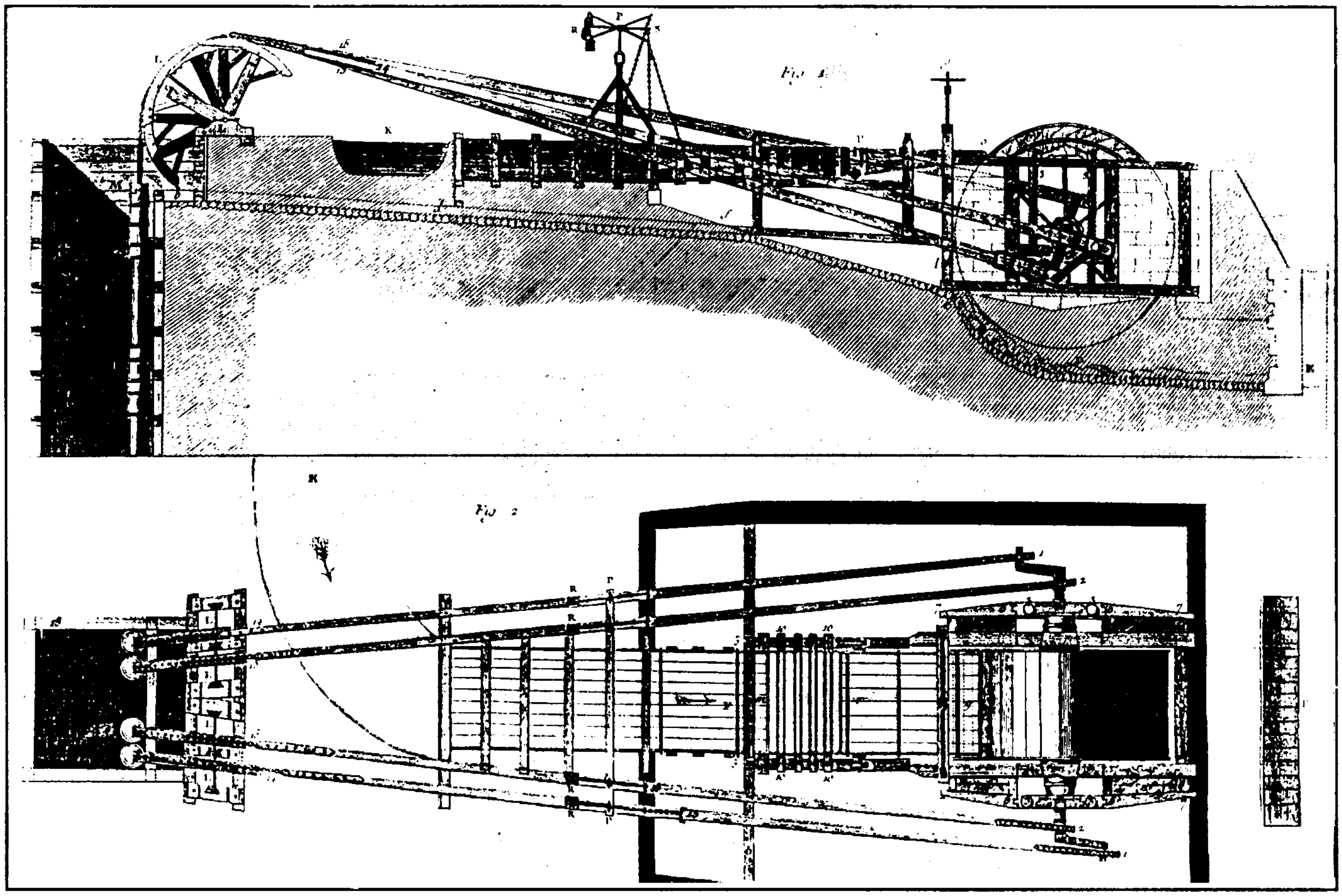


Fig. 6. Coalmill technology forty years after Newcomen; P.J. Laurent's engine of 1755 at the Breton lead and silver mine of Pontpéan, drowned in 1740. Laurent was an engineer from the Mons coalfield. An undershot wheel works twin batteries of pumps, without a beam, by means of sectors and chains. Source: Grand Encyclopédie, vol. VI, reproduced by courtesy of Lancaster University Library.

and his agent John Wilkinson made early application of it in Gateshead, Felling and Heworth. On Carr Hill the top seam, the High Main, was over 300 feet down and could not have been worked by the old treble-mill system; to win it great power was needed, and to provide this Wilkinson seems to have contrived the Swan Pond at 450 feet OD.[18]

Even after the appearance of Newcomen's engine the simplicity and power of the bob-gin allowed it to compete. In 1726 Jane Clavering drained her new Beckley Colliery by a beam engine in her Andrewshouse grounds, powered by a stream which became the Bob Gins Burn. As late as 1767 when Andrewshouse Colliery was redeveloped no heat engine was built. A small 24 yard shaft and apparently a second waterpowered bob-gin sufficed.[19] The replacement of existing coalmills was not an immediate purpose of the Newcomen revolution, for they were cheap and perfectly adequate for what they undertook, and many others must have remained in service in the second half of the 18th century.

For a century after 1620 a good half of the Tyne's output came from collieries largely dependent on waterpower. After 1725 this is no longer certain, but the reason is not that the common engine had replaced the coalmill. Around 1700 entrepreneurs seeking coal faced the choice of going deeper or farther afield, and in the light of the technology and energy demanded the second was the safer option. Extending waggonways to upland areas gave free drainage new life; at Pontop the Western Way was to reach 900 feet. Elsewhere for half a century after Newcomen hydraulic sources may well have continued to provide the greater part of colliery energy, the more so as for the five or six decades before the 1790s when great collieries began steam winding, waterpower was increasingly used for raising the corves.

Of the three phases of the coalmill era, the strife of 1600-1650, the increasing scale of 1660-1690, and the definitive technique of the 18th century, it is the last which is least documented, because the technique had become so commonplace it interested no one other than the viewers who applied it, and this leaves a gap in our understanding of technical development.

THE CHANGING STRATEGIES OF COALMILL BUILDING

We do not know when and how the use of coalmills on Tyneside began. A "great chain" installed in 1492 in an unknown Whickham pit may have been operated by one.[20] By 1580 there was a coalmill at Wollaton on the Trent, but for Durham at this time technical data is sparse. Certainly there were great collieries there in Elizabeth's reign, particularly in Gateshead, which cannot have relied on free drainage. Of these Bensham, perhaps the largest colliery of the 1590s, had within its territory both the High and the Low Team Mills, and Gateshead Grand Lease had a tide-mill at Rock on South Shore, but what these were then used for is not known. The great age of coalmill building running from 1600 to the Civil War was not the result of recent technical advance but of the exhaustion of free drainage.

Growing dependence on a limited natural resource lay behind early 17th century coalmill disputes, but thirst for waterpower often disguised hunger for coal and trade dominance. The old Catholic-leaning Newcastle merchant oligarchy who created the trade had finessed the Grand Lease, square miles of Bishopric coal in Gateshead and Whickham, out of the hands of the Crown and into those of the town council. The father of Sir William Selby of the Winlaton Colliery dispute had

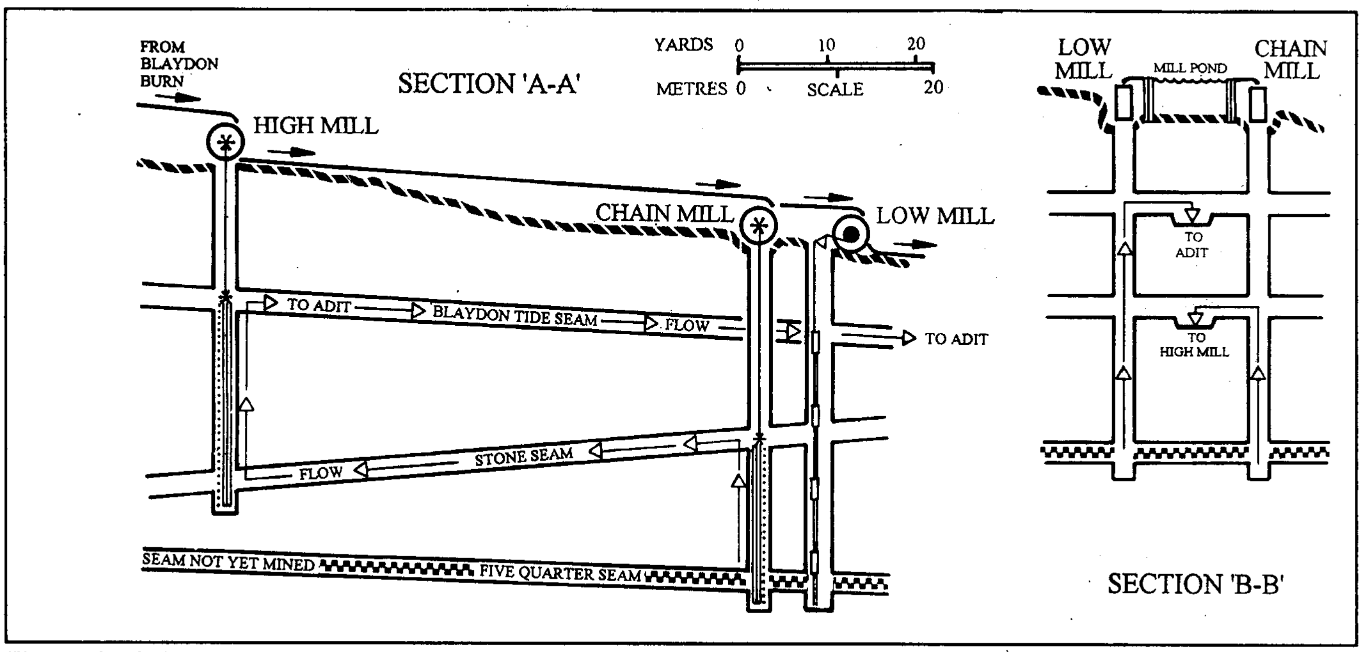


Fig. 7. The drainage system of Stella Freehold Colliery in 1719 as described in James Weatherley's report. (See Fig. 4 for plan). Source: Gateshead Central Library, Cotesworth Coll. G/CK/11/4.

been the principal agent in acquiring the Grand Lease; the father of his opponent John Clavering had been one of a band of new men which had captured the town council and the Grand Lease with it.[21] The one was acquiring a large coal estate and making of Whickham a Puritan stronghold; the Selbys were fighting a losing battle to keep coal and Catholicism. On the Tyne there was positive feedback between coalmill, coal wealth and Newcastle politics which hastened the concentration of the industry in the hands of great owners.

Larger estates brought larger horizons to their owners. Some of the bitterness of the age of disputes came from knowing that an expensive installation was also draining a rival's colliery. The Lambton Engine at South Biddick drained Harraton across the Wear, a matter of concern in 1640 when Harraton had for tenant an aggressive newcomer, a positive advantage in 1696 when the son of the Henry Lambton married the last of the Hedworth owners of Harraton.[22] The increase in the demand for power after the Civil Wars reflected a change in strategy as owners looked farther ahead and farther afield; Sir Thomas Liddell was giving his machines not such water as might be immediately needed, but as much power as he could lay hands on. From the inception of the Ravensworth Engine the Liddell family dominated the Tyne industry; for half a century it allowed them to extract some 40 000 tons a year; as a milestone it ranks with the Winlaton watergate of 1551 or, though on a lesser scale, with Surtees' grand scheme of 1617. It was not replaced for seventy years, until 1750 when the Liddells had already built elsewhere a dozen atmospheric engines. Coalmills of the second period were strategic, intended to allow complex longterm industrial planning, and a concomitant of the concentration of capital.

On Tyneside the introduction of Newcomen's engine owed a great deal to its easier adaptation to such grand and sweeping designs. The first use of it there was for the winning of new collieries. At least initially, when the heat engine was chosen it was not so much in virtue of its power, no greater than that of existing coalmills, and certainly not of its efficiency, in which it rated at best 5% against the overshot wheel's 60%, as of its self- sufficiency. The disadvantage of the waterwheel was neither technical nor topographical, but strategic. Like the waggonway, built on any scale it needed the co-operation of neighbouring landowners, and so was costly in diplomacy, and in wayleaves. Both left the colliery dependent on a lifeline whose protection might become ruinous in litigation and impossible in the long run.

The new heat engine's first intensive development in the North came from a bitter struggle in two adjacent deep collieries, of Richard and Nicholas Ridley in Byker against George Liddell and William Cotesworth at Heaton. Both sides were engaged in the War of the Waggonways over rail access to free-draining coal, which repeated struggles a century earlier over water supply and which cost the industry well over a year's entire profit in legal expenses. As its "tow Engine" shows, first attempts to drain Heaton used coalmills in series; had its owners been unopposed they might quite well have channelled sufficient water for success. As it was, neither partnership could dare rely on waterpower; the supply would have been attacked as brutally as was the Western Waggonway, or cut as neatly as Northbanks' rail link.[23] The fire engine brought security by demanding only a waste product of the mine itself; what Newcomen put out of work was not horses but lawyers.

THE EVOLUTION OF DRAINAGE TECHNOLOGY

The stages of development of the drainage devices operated by the coalmills coincide only in part with the history of the waterwheels.[24] The earliest and simplest was the kibble, a wooden tub wound by whatever means was in use for raising coal. This was the slowest of methods, and only where one of a group of pits could be dedicated as a waterpit could any degree of efficiency be achieved, but it imposed no limit of depth. One such was the Waterpit at Lumley, 300 feet deep, wound by waterwheel, and draining an isolated sector of the colliery until at least 1673.[25] More sophisticated was the continuous chain which dominated the drawing of water for most of the 17th century. At first it was merely a development of the "saqiyah" used since antiquity, an endless belt of open vessels dredging up the water. Stephen Primat, son perhaps of the financier involved in the recovery of Harraton after flooding in 1648, says it was the commonest machine in the north in his time. Its problem was weight, not only of the chain but of the square leather or wooden buckets. The "rag pump" or chain engine reduced this by retaining the chain but replacing the buckets by discs drawn through continuous 6- or 7-inch pipes bored in 12 or 14-inch elm. Ralph Delaval, Henry Lambton's partner at Lumley Colliery, considered them the best device, and they are likely to have been installed there in 1654.[26]

What all three devices had in common was rotary motion, so that they were well adapted to be driven directly by a waterwheel. Chains however were heavy and costly, and the reach of chain engines limited. In consequence in a deep waterpit they had to be driven by a series of immense vertical timber axles, up to 20 yards in length, standing on brass or iron bearings and linked by cog and pinion, through sets of trundle and lantern-wheel gearing. Over 60% of the wheel's energy was lost to friction. At Ravensworth the main drive of this sort was 56 yards long; Lumley was not as deep, but nevertheless needed for its numerous engines "52 gang of Coggs".

At some date unknown but not before the 1680s the coalmill entered its last and definitive phase. The standing pipes were kept, but the axle-breaking chain and energy-wasting gearing abandoned; transmission was through rod and sector. Linear motion from the pithead was made possible by reciprocating pumps, lift pumps dependent on atmospheric pressure, or lift-and-force pumps. These devices were already known in the 16th century when they were widely used for city water supplies, as in London in 1582; they appeared in the mines of Central Europe by the mid-century and those of Liège by its end, and early in the 17th their principle occupied scientific thought. The delay in their introduction to the Northern Coalfield therefore requires explanation; what Graham Hollister-Short stigmatised as "attempting to address the problem of deep mining with the pumping techniques of 1500 or even 1550" would be perverse if the solution lay to hand.[27]

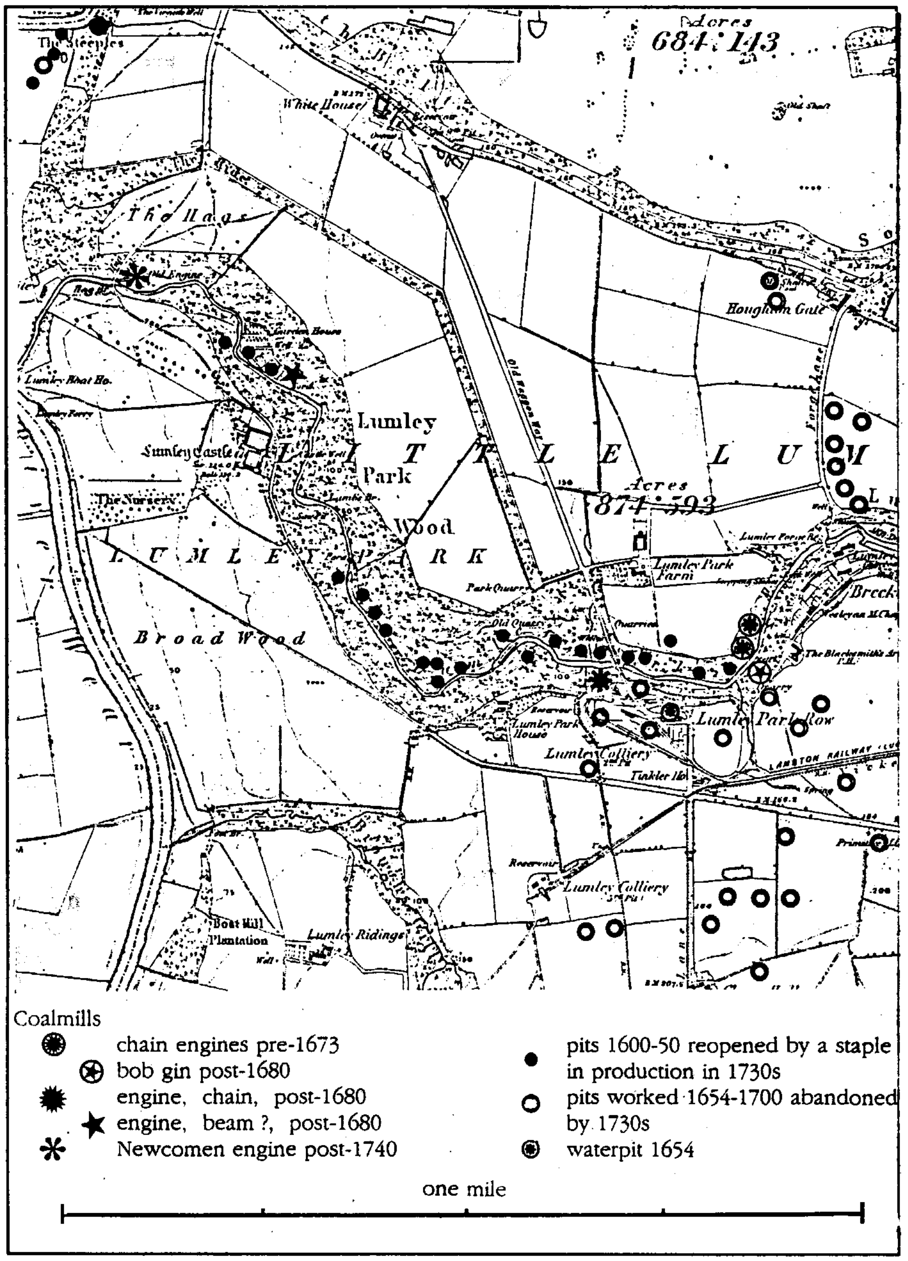


Fig. 8. A great colliery of the 17th and early 18th century drained entirely by multiple coalmills. Lumley Colliery on the Wear: the survey of around 1739 plotted on the first Ordnance Survey map of 1856. Source: Durham County Record Office D/X/P41.

Ignorance cannot be the reason. Around 1670 the Sir Thomas Liddell of the Ravensworth Engine was well placed to have made the change but clearly did not do so. Yet he frequented the Royal Society and had recently been in France where rod-pump hydraulic engines were well advanced, such as that of 1608 at the Samaritaine and its replacement then building at the Notre Dame bridge, as well as a famous prestige project, the *machine d'eau de Marly*, which was to use 14 millwheels set in the Seine and a mile-long transmission to raise water 450 feet to the Sun King's Château. The Black Burn, of course, was not the Seine, the output of both Samaritaine and Marly engines was of the order of 100 gallons a minute, insufficient for a great colliery, and the useful 300 gallons a minute at Pont Notre Dame was not raised 240 feet. Much more important, the French had recourse to Liège for essential metalwork. A decade and a half later, when, on the eve of the general adoption of the rod pump, the ironmaster Ambrose Crowley attempted to install skilled Liégeois on the Wear he caused an anti-papist riot; Liddell was an earnest Puritan.[28]

Moreover, great as were the energy losses in the treble-mill system they cannot have equalled those of the rod-operated Marly Engine, which produced 700 hp but delivered only 150, an efficiency of 21.5%. What in the mid-18th century the authoritative Encyclopédie saw as a technological revolution was not the specialised and demanding "English fire engine" but the bob-gin, the perfecting and generalisation of systems of reciprocating pumps operated by a hydraulic engine of great efficiency in transmission. Diderot rightly saw this as "prodigious progress", and in 1754 remarked of the Marly Engine that a replacement would be a great deal simpler and its capital cost little higher than the maintenance of Louis XIV's prestigious machine.[29] He saw this progress as driven by "thinking in mechanics", but clearly an undocumented spread of engineering skill had also taken place.

In the new machines the waterwheel operated connecting rods by means of cranks. Angled timber rocker beams were also "bobs"; there were T-bobs, L-bobs and V-bobs, often in fact triangular, and this horizontal motion was converted into the vertical by some form of bob to raise sets of pump rods. All such timber connecting bars were called "spears", in origin single lance-like timbers up to 40 feet long, but eventually iron-bound compound rods of enormous length.[30] The plates of the Encyclopédie show the interconnected mine shafts of an earlier metalliferous mining technology with reciprocating pumps operated through bobs by a "two storey engine", raising water from cistern to cistern. In England this last phase of the coalmill introduced an era in mining lasting well over a century; by eliminating the dedicated waterpits of the treble-mill system altogether, bringing great savings on sinkings, it allowed ever deeper single coaling pits with twin batteries of pumps raised alternately by the Beam Engine placed across the pithead. The first half of the 18th century is the age of the bob-gin, and it merges seamlessly into the age of the common engine.

The evolution of drainage systems can be followed in the 1719 description of Stella Colliery, but the stages unfortunately cannot be dated. A mill called Rennison's existed on this site in 1633, but its function is not known; the working of the top seam, done typically by free drainage through an adit to the deep-cut Blaydon Burn, must have been earlier than this. To extract the next seam, water was raised to this adit by what was later known as the High Mill. It is likely to have originally operated a bucket chain, but later updating to a chain engine is probable. 14 yards below this second seam was another, the thick Five Quarters coal. Its winning is likely to have been done by the second Sir Thomas Tempest in the 1670s, for which he used a second mill, the Low Mill, probably merely to raise the water to the seam above for the High Mill to deal with. As at Lumley, for this purpose the Low Mill was twinned with a Chain Engine. The Low Mill's conversion, from driving a chain engine by rotatory motion transmitted underground as at Ravensworth to working a double set of twin reciprocating pumps by rodding is undated. It now raised water from the Five Quarter to the seam above by a double set of spears 24 yards in length, and from there brought the water to the free drainage level by 10 yard spears. The old High chain mill had clearly proved unable to cope with water from the lower seam, and advantage had been taken of the reciprocating pump's extended lift to supplement it. The whole system in 1719 was said to be decrepit; this would certainly be true of 50-year old chain mills, but a normal colliery life was at least 21 years, so that it is hard to believe that the bob gin had been built any later than the early 1690s, but if so no others of this date are known.[31]

Much more complex drainage development can be seen at Lumley, a far larger colliery than Stella with an output at least three times as high. Intensive exploitation had begun soon after 1600 in the Top Main seam in the cliffs above the River Wear at the limit of keel navigation and where the seam drained naturally into the river. At the renewal of the leases in 1624 violence broke out through the granting of one seam to an old entrepreneur and another to an incomer, and it may be at this time that staples, small shafts sunk from the upper seam to a lower which made this possible, gave the area its name: The Steeples. Extraction soon reached the mouth of the Castle dene to the south, and water from a group of pits sunk directly opposite Lumley Castle found its way through these earlier workings to the river. For an extension of the colliery up the Lumley Park Burn an underground watercourse 66 feet down was driven into these, perhaps in the 1630s.[32]

Henry Lambton's new colliery of 1654 represented a fourth step; nearly a mile from the river it demanded machine drainage. Unlike earlier lessees Lambton was in a position to undertake long-term planning, whose first fruit was the more serious Chain Engines which attracted North. These worked in shafts 162 feet deep, their task to raise water 96 feet to the watercourse for its long journey to the Wear. To widen the area of exploitation, as at Stella chain engines were later aided by a Bob Engine powered by the same dam. It is later than North's visit, but to judge by their names the most distant pits to the north are as early as 1689, and just possibly offer a first date for a beam engine. The Bob Engine's shaft allowed the extraction of the Maudlin seam, and by the early 18th century the 300 feet deep pits to the south had wrought out all higher seams. Recourse was then had to staples sunk from the earlier pits along the Lumley Burn. The coal they worked was drained by two "engines" lower down the burn. The first was described as "a Chain"; it may or may not be of a date with the Bob Engine.

The purpose of the lowest coalmill opposite the Castle was to lift all this water into the worked-out waste through which it ran into the main watercourse. Although in this key position it can be of no later date than the higher engine, the volume of water it was required to handle makes the persistence of the chain-pump unlikely here; the fact that we are not told its nature suggests it was what at its innovation would have been called a "bob gin" but was now merely an "engine", as opposed to the new "fire engine". At some date after the View which gives us all this information it was eventually replaced by a Newcomen engine further down the burn.

At the time of the View the working colliery consisted entirely of staples, in three groups, the largest around the engine denominated "Chain", the second around the lower mill, and the third by the river in The Steeples. The most likely date for this inspection is the death of the lessor, the second Earl of Scarbrough, in 1739. We have thus a large mid-18th century colliery still entirely worked by waterpower, as it had been for nearly a century, having seen only a half-century of free drainage.[33]

The efficiency and flexibility of the bob gin pumping technique ensured its persistence throughout the era of the atmospheric engine and beyond. The *Grande Encyclopédie*, reflecting the technology of the 1750s, shows that watermills still remained the commonest engine for draining all kinds of mines; in the articles *Mines and Pompes*, and their illustrative plates though walkmills, windmills and the atmospheric "machine à feu des anglois", are described it is the watermill which has pride of place.[34] As late as 1852, T. J. Taylor affirmed that pumping by watermill "continues to this day to be the simplest, and one of the cheapest modes of draining mines, where sufficient water power can be obtained."[35] Because the common engine could be simply applied by connecting the piston to one end of the beam, the term "beam engine" came to imply atmospheric or steam power, and the coalmill it had been designed for was forgotten.[36]

Seen in perspective the technology of colliery drainage shows a fine and satisfying logic. Inheriting a system of mill, rotating chain, and buckets it first replaced buckets by a pipe, keeping chain and rotation; next chain and ragwheel gave way to spears and beam, but the column of pipes was retained; then the rotary mill was ousted by the reciprocating atmospheric engine driving the existing beam and spears. In this evolution Newcomen's inversion of the atmospheric lift pump to create a new prime mover more heat-hungry than ever the mill had been water-thirsty can lay no unique claim to revolutionary status; before the bob-gin it would have been unworkable. Our constant search for *termini a quo* is suspect; each phase of the coalmill can be seen as revolutionary.

More important, the coalmill reminds us that technological history is not the logic of engineers alone. It is highly dependent on the changing social relationships which bind the entrepreneurs. These can be studied in the archives. What can rarely be found there, except where there has been conflict, is the outcome of the interplay between engineer and entrepreneur, the actual installation of new technology and its date. For this we depend on archaeology; for the early coal industry this is, as yet, very nearly non-existent.

NOTES

1 For output figures see both Hatcher (infra n. 3) 497-8 and F. W. Dendy *Extracts from the Records of the Company of Hostmen*, Publications of the Surtees Society (SS) 105 43-5, 51-4, 65-6, 69, 73-4. Exports rose steadily from about 100 000 tons in 1591 to nearly 280 000 in 1607, then faltered, but peaked at close on 400 000 tons in 1621

2 If we assume the output of a single wheel as about 5 hp known and suspected mills could produce over 350 000kwh per annum

3 Relevant histories are *The Rise of the British Coal Industry* 2 vol, J. U. Nef 1932, reprint 1966 (Nef); *The History of the British Coal industry vol 2 1700-1830* Michael W. Flinn 1984 (Flinn); *The History of the British Coal Industry vol 1 Before 1700*, John Hatcher 1993 (Hatcher); *The Making of an Industrial Society : Whickham 1560-1765*, D. Levine and K. Wrightson 1991

4 If the 33 Tyne keels known to have existed in 1367 had been fully occupied until 1492 they must by then have carried four million tons of coal. *The Archaeology of the Coal Trade*, T. John Taylor 1852/58, 61-63; *Archaeologia Aeliana* (4) xxiii 8 et seq; SS 105 as in n. 1 supra passim; PRO C2/Chas1 C35/27 (n. 11 infra)

5 Nef i 298, 337, 355, 372, 377; Flinn 112, Hatcher 230

6 Warwickshire County Records Proceedings in Quarter Sessions, VI 43

7 C. F. Fraser, Durham Quarter Session Rolls 1471-1625 SS 199 232, 236-7, 239

8 *A Fighting Trade: Rail Transport in Tyne Coal 1600-1800* G. Bennet, E. Clavering and A. Rounding, 2 vol, Gateshead Borough Libraries 1990 (AFT), 37-43; GCL G/Cotesworth C 15/1

9 PRO DURH 7/19; an abstract Gateshead Central Library (GCL) G/Cotesworth C 15/1

10 Nef i 337; C22 501/38

11 PRO C3 482/7; SS 184 106, 137. The major Chancery cases in the Public Record Office, Chancery Lane, London (PRO) involving coalowner conflict over waterwheels are: Maddison, Tempest, Shafto & Hall v Arnold & Hindmers et al, Whickham 1619 DURH 7/19; an abstract Gateshead Central Library (GCL) G/Cotesworth C 15/1 Sherwood v Maddison et al (Grand Allies), Farnacres, STAC 8/245/6; Hodgson v Liddell Farnacres 1640, C2 Chas 1 H19/35; Clavering v Selby & Hodgson, Winlaton Mill 1639, bill C2 Chas1 C35/27; Selby response 1643 C8 55/178; Clavering 1643 C2 Chas1 C126/53; Hodgson response 1640 C21 Chas1 9/35 Clavering v Wood, Anderson & Cole, Allerdeans 1645, C3 482/7; Garter Rolt v Lambton, Delaval et al Lumley 1674, bill C6 214/36; Blackett v Blakiston Denton 1688, C22 501/38

12 PRO C2 Chas1 C35/27; C8 55/178, C2 Chas1 C126/53; DRO D/CG/19/23, 26. I am grateful to Mr David Cranstone, who has made a study of Winlaton Mill and was able to show that Selby's use of the water from it created the present Axwell Park Lake

13 M. J. T. Lewis, *Early Wooden Railways*, 1970 120; AFT 67-9

14 in *The Hydrostaticks* of 1672, edition of 1683 298-9.15; PRO C8 55/178, Nef ii 415

15 Life of the late Lord Keeper Guilford, R. North, edition of 1754, 135.16

16 PRO C8 215/38

17 GCL G/Cotesworth CK 11/4

18 AFT 72-75

19 AFT 163, 155; Northumberland County R. O. NEIMME Watson, Unthank I 1c

20 R.L. Galloway, *Annals of Coal Mining and the Coal Trade 1898* 66-67; Rh. Jenkins "R. D'acres 1660", *Transactions of the Newcomen Society* X 28, considered a coalmill must have been involved

21 For the Grand Lease Nef i 151-4, AST 18-21; for the role of Tyneside Catholics E. Clavering "Catholics in Tyne Coal" *Durham County Local History Society Bulletin* 51, December 1993

22 Birch, *A History of the Royal Society*, iii 439; Nef i 334

23 AFT 110-1 and Chapter Six

24 For the economic historians' account of drainage see Nef ii 444 (and i 255) and Hatcher 212-233. G. Hollister-Short presents the engineer's critique in "The Sector and the Chain", *History of Technology* 4 1979, and challenges the economists' view in "Leads and Lags in English Technology" *History of Technology* I 1976

25 Greenwell 23, 51; PRO C6 215/36

26 The 1673 accounts include "85 bends of pumps lengths £55.19s", the greatest single item, PRO C6 215/36; Nef ii 450; Greenwell 65; DRO D/X/P41

27 *History of Technology* 1 1976, 164. The British backwardness described by Hollister- Short seems a crux in technological history requiring investigation. However ignorance cannot be its cause. The travels of Liddell apart, a number of Catholics in coal had been educated at Saint Omer and Douai in the Anzin coal country, and had sisters in religious houses within reach of Liège. Hollister-Short suggests that Daniel Höchstetter's failure on Cumbria brought lack of interest in German techniques. But he clearly had close connections with Tyne coalowners; no fewer than six Höckstetter descendants found apprenticeships with Newcastle merchants (SS 101 passim), among them two who had watched Huntingdon Beaumont go bankrupt and then, as Grand Lessees, made a triumphant success of the invention which had ruined him. What, then, did they find lacking in Central European technology?

28 *Grande Encyclopédie des Arts et des Métiers* Paris 1754 onwards (GEAM), Plates V Machine de Marli; Forest de Belidor, *Architecture hydraulique*, 1737

29 GEAM XIII 8

30 Greenwell 65, 79; Wright *English Dialect Dictionary*

31 GCL G CK 11/4; AFT 47. I am grateful to Dr Alan Rounding for information on Stella and Blaydon Burn mills. Watermills are long-lived: by 1760 the Chain Mill was grinding corn, and flint in the next century

32 PRO C6 215/36; SS 199 106/1, 110/20; DRO D/X/P41

33 No fire engine appears in the view; unless this was made earlier than the evidence suggests, J. S. Allen in "The Newcomen Engine 1710-33", *Transactions of the Newcomen Society* 42A, is mistaken in according the date 1737 to the Lumley Engine, though it is certain that the Lambton Engine had been converted by this date

34 GEAM Mines X 521-2, GEAM Plates V, VI; T. John Taylor *The Archaeology of the Coal Trade* 1858 facsimile 1971, 42

35 AFT 14, 108-9; PRO C22 501/38; GCL G/Ellison C15/61

36 For Heaton Low Engine see Northumberland County Record Office NEIMME, Amos Barnes' View book 1733. Hollister-Smith, *History of Technology* 4 1979, 181-2, saw that Newcomen engines had taken over from bob gins in just this way.

Eric Clavering