Bulletin of the Peak District Mines Historical Society Vol. 12, No. 3, Summer 1994.
Historical Metallurgy Society Special Publication: Mining Before Powder.
Papers presented at Ambleside 25-27th of March 1994
to celebrate the 500th anniversary of the birth of Georgius Agricola

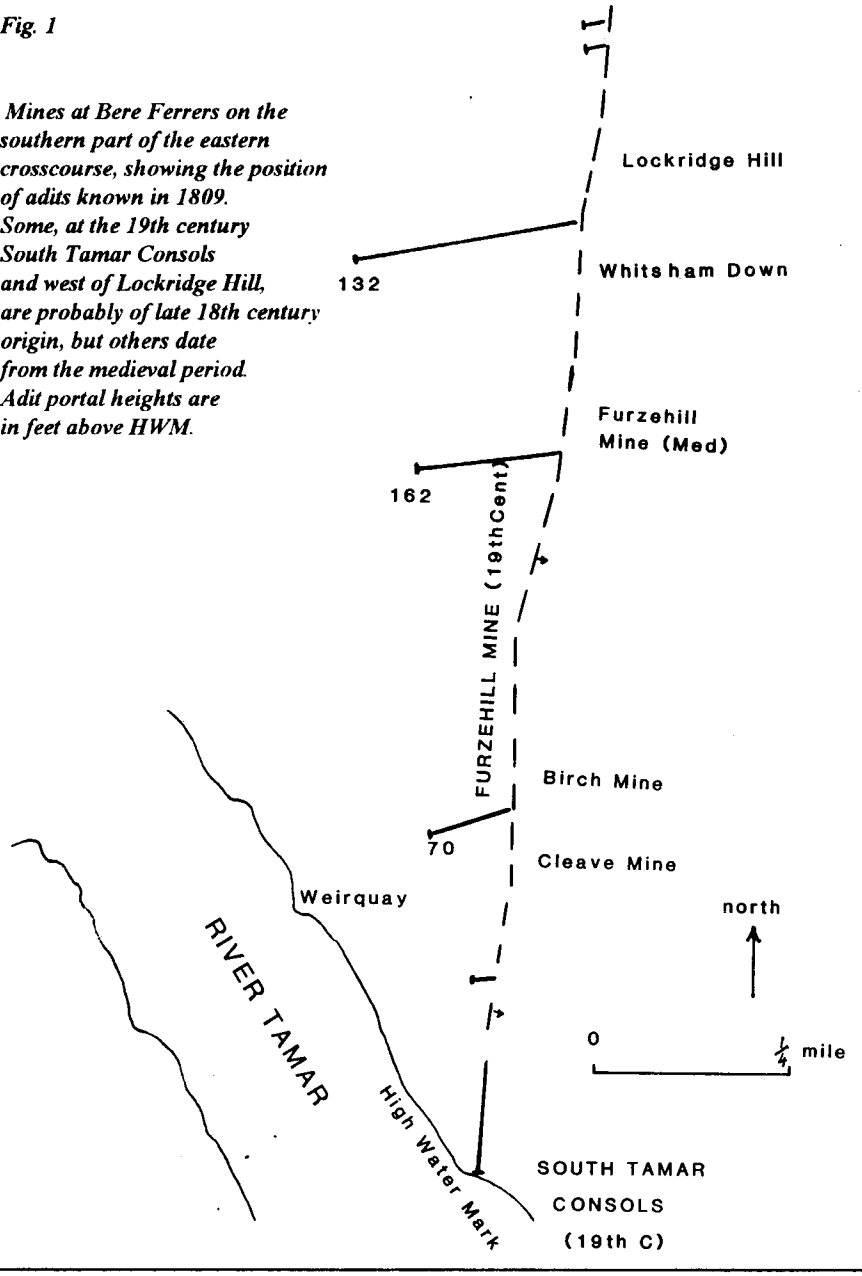
SILVER-LEAD - A RESTRICTED RESOURCE: TECHNOLOGICAL CHOICE IN THE DEVON MINES

Peter Claughton

Abstract: The silver-lead industry, confined to a limited resource base, was at the forefront of technology in the medieval and early modern period, but the choice of technologies was influenced by the availability of labour. A declining population stimulated the introduction of mechanisation in the 15th century, and it was not until the 17th century after the opening-up of new sources, that population recovery allowed the reintroduction of some labour intensive methods.

Fig. 1

Mines at Bere Ferrers on the southern part of the eastern crosscourse, showing the position of adits known in 1809. Some, at the 19th century South Tamar Consols and west of Lockridge Hill, are probably of late 18th century origin, but others date from the medieval period. Adit portal heights are in feet above HWM.



INTRODUCTION

Native silver is found in only a few locations in England and Wales and then in only small amounts. By far the largest proportion of silver is combined with the lead ores galena (lead sulphide) and cerussite (lead carbonate) and to a lesser extent copper ores and the complex tetrahedrite ores found in conjunction with some lead deposits. Whilst lead ores are found over much of upland Britain, in only a few areas do they contain sufficient) silver to justify refining and only a small number of these were known to the medieval miner.

Particularly rich deposits were exploited in the Carlisle mines, in the area of the Northern Pennines now known as Alston Moor and to the east around Blanchland, production there peaking in the mid 12th century.[1] With their demise in the early part of the 13th century there was no reliable home source of silver until the Devon mines were opened up in the 1290s. For over 250 years the Devon mines were to remain the only reliable source, a restricted resource under Crown control exploited to the full, to the limits of available technology. There was to be no other substantial production centre until the mines in Cardiganshire, in Mid Wales, were opened up during the second half of the 16th century.

This paper examines the technologies employed in the late medieval and early modern periods; primarily in the field of mine drainage, but touching on smelting and refining which are addressed in detail elsewhere.[2] The choice of technologies is viewed against a background of the restricted nature of the silver-bearing deposits, the continuing demand for silver and, in particular, a declining population level in the second half of the 14th century and through the 15th century. Finally reviewing those carried forward into Wales as the centre of production shifted away from the South West of England.

MINING PRIOR TO THE BLACK DEATH

When the mines in Devon, at Bere Ferrers, Birland and Combe Martin, were opened up in the late 13th century the population of England was probably at a peak not to be surpassed for five centuries. Labour was cheap and large numbers of skilled miners and smelters were available to volunteer or be pressed into Crown service. These brought with them techniques developed in the established lead mining areas. In ore extraction and drainage those were to serve them well during the early decades of the new operations; but in smelting

they were found wanting and only after a period of experimentation were processes suited to the more complex silver-lead ores developed.

At least six different processes, including a form of liquation[3] were tried before the bole / furnace complex was found best suited to the ores. The blackwork furnace was eventually adopted in the lead industry by the 15th century. The turnbole (bolas turnellas or bolas versatilis) was one adaptation of the bole which did prove successful but remained peculiar to the Devon mines. Unlike later Derbyshire practice, silver-lead smelting was virtually a year-round activity, ensuring a steady flow of fertile lead to the refinery. This left the bolers to cope with the vagaries of the wind, employing multiple bole sites without the advantage of prominent high ground sites available to their contemporaries in the Pennines. By at least 1296 a bole structure had been mounted on a platform capable of being turned to face the wind.[4] These turnboles became a permanent feature of the Devon mines. As smelting activities were moved around the Bere Ferrers area, and across to Calstock, in response to the availability of wood for fuel, the substantial timber base was uprooted for transfer to the new site. The development in Europe of the post mill provided an ideal model on which to base its construction, although confirmation of this must await the identification and archaeological investigation of specific sites.

At Buckland Monachorum in 1302 it took seven men a whole day in 'removing the post and timber of the said bole from the ground'[5] for which they were paid 4d each, over twice the normal rate for such labour - heavy work indeed.

Whilst high wages could be paid for such work those for routine unskilled tasks were very low, perhaps 1d per day. Such low rates and the ready availability of local labour had a definite influence on the level of technology used. When the first refining furnaces were erected at Maristow in 1292 they were equipped with bellows powered by waterwheel (et molend empt' pro magnis folliis vel sufflett ftis pro affinations),[6] a technique probably known for centuries. However when the centre of operations was moved to Calstock in about 1302 it was evidently cheaper to employ bellows blowers at 1d per day, three to each refining furnace - than to incur the cost of not only erecting a new wheel but also bringing in an adequate water supply.

Manual labour was similarily employed at the smelting furnaces. Only in the crushing of blackwork[7] was animal power resorted to, supplementing the use of bucking hammers.

It was also deemed adequate in the early days to rely on teams of water winders equipped with leather buckets, ropes and windlass to drain the lower parts of the workings. At Bere Ferrers in the five weeks to 13th August 1306, 87 new water bags were made, at 1d each, and 31 old bags were repaired, at ½d each; a total of 12 cow hides were then purchased at a cost of 42s 1d to make and repair further bags. This gives some idea of the numbers involved and the capital costs of manual drainage, a task which was, prior to 1309, the responsibility of the miners themselves. In that year the Crown paid wages to 13 of the water winders for five months whilst an adit was brought up to drain the active workings and subsequently appears to have met the bulk of labour costs incurred in manual drainage in addition to the capital costs.

Adits were a major capital cost at Bere Ferrers from their inception. They allowed free drainage from the upper parts of the working, reducing the labour of the water winders and extending the working season into the winter months.[8]

In the early period they appear to have been driven along the veins in soft ground requiring timbers for support and launders to channel water through active and abandoned workings. Such edits would be liable to collapse quite quickly and appear to have done so judging by the amounts regularly spent on their upkeep. During the Friscobaldi's tenure they were evidently not maintained and in the half-year to Michaelmas 29 Ed. I (1301) £56 0s 9d was expended in new drivage and repairs, rising to £343 18s 5½d and £307 18s 10d in following years. By 1308 costs were lower; £4 4s 0d on clearing out adits, £10 13s 4d on new work. Costs fell to 32s for repairs in 1309-10, with new work confined to the boring of a rock or blockage of rock from the 'head of the adit of the mine of Furshill lying through the middle vein, in length 60 fathoms to the south (iacent' per mediam venam in longitudine - 60 teys versus austr') . . . so that water could have its course to the adit' at a cost of £20.[9]

It was not until the year 1 Ed. III (1327) that there is any suggestion of crosscuts to increase the depth at which an adit would drain old workings. An adit of 50 fathoms in length was proposed at Furshill to get under the old workings in an area where, as stated above, there was already a long adit along the vein. The cost estimates for that new adit were correspondingly higher, £1 per fathom as against 6s 8d per fathom for the extensions along the vein in 1309 and earlier, reflecting a slower drivage rate in hard rock. It would have taken at least one and a half years to complete.[10]

The tools employed were principally iron picks; the techniques used varied with the type of rock encountered. In a partially completed adit recently examined at Combe Martin, in soft Lester Slates and Sandstone, the face was advanced uniformly by clean sweeps of the pick without resorting to undercutting or working outwards from a central 'slot' as in the harder rock encountered in Derbyshire and parts of Cornwall.[11]

Despite being labour intensive the expenditure on adit driving was a capital cost, adding to the fabric of the mine. However the ore shoots at Bere Berrers, and particularly at Combe Martin, are of limited lateral extent, controlled by the junctions of mineralised horizons with

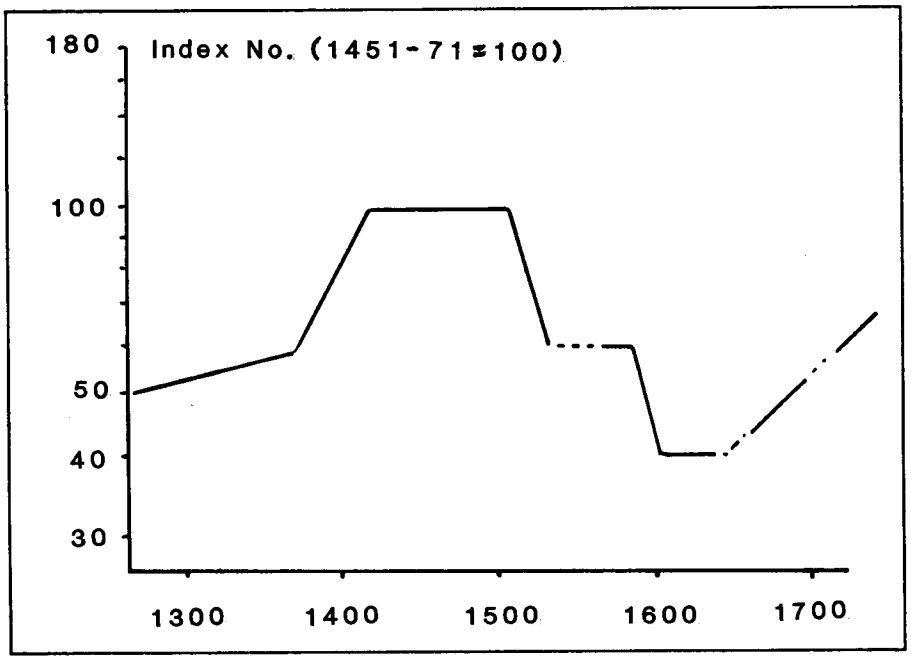


Fig. 2. Changes in purchasing power of wages (real wages) [13].

north-south crosscourses. They had to be followed deeper to maintain production. This entailed further adits at lower levels to effect drainage at a greater cost in labour.

THE LABOUR CRISIS

We have seen how manual labour was a major component in the technology chosen in the early part of the 14th century, influenced by the availability of ample, cheap, manpower. However there is some evidence for a slow decline in population around that time, with poor harvests in the second decade of the century, although the South West, and Cornwall in particular, fared better than the rest of the country.

The dramatic fall came in 1348-50 with the outbreak of Plague, the Black Death. Its effects across the country were variable but some mining areas evidently suffered badly. In Derbyshire for example in the Earl of Kent's manor of Ashford there was 'a lead mine formerly worth £20 yearly, but now stopped for want of workers.' That was in 1354, eight years later it had still not recovered its former profitability being worth only 100s (£5).[12] Bromfield and Yal, in North Wales, were also badly affected; the mines there were moribund for over thirty years.[13] But it has been suggested that, at first, the overall effect was to bring the population down to a sustainable level. Agricultural rents remained high, and, after an initial reaction and countering legislation, general wage rates continued at pre-plague levels. It was not until the 1360s and 70s that repeated outbreaks of disease on both a national and local level, becoming endemic in many areas, had weakened the population such that a labour shortage became apparent as wage rates began to rise.[14]

Although the available evidence is patchy, the situation in the Devon mines appears to have followed the national trend. Activity at Bere Ferrers, confined to reworking of blackwork and earlier residues, ceased at Michaelmas 1349 and although a new keeper was quickly appointed, there is no evidence that he made any returns to the Exchequer.[15]

The keepers of the Combe Martin mines in 1360-64 and 1370-71 could not expect to draw on a large body of skilled workers in the established lead mining areas as in the past, requesting only a handful of miners and smelters from Derbyshire and Yorkshire, and some of those impressed openly resisted the move.[16]

That mining continued at all reflects the perpetual demand in precious metals for coinage. In a situation where the lead producers of Derbyshire would be content to migrate to new shallow deposits, the restricted nature of the known silver-bearing deposits meant their continued exploitation at deeper and deeper levels.

Drainage by adit now had the double burden of increased length and increased drivage costs. The time-cost penalties at Bere Ferrers, where few deep valleys cut the mineral deposits, would be excessive, leading to an increased dependency on manual water winding. By the mid 15th century wage rates in the mines had in some cases more than doubled. (See Table 1).

But cash wage figures do not provide a complete picture of the problem. Blanchard[17] has already shown how variations in the cost of living influenced the labour intensity of the miner on Mendip in the 15th century. There not only the price of food but that of the lead ore he produced entered into the equation. However, the Crown silver-lead miner engaged in drainage received a daily wage-rate which was not tied to metal prices, but he still controlled the number of days he worked.

A miner or skilled worker at Bere Ferrers in the mid 15th century could earn over £4 per annum: over twice that of a 'professional' miner on Mendip, but the potential for having any excess was limited. As the quantity of consumables he could buy with his 4d per day, real wages, rose, and remained high through the century, the number of days he needed to work to maintain his required standard of living fell. With far fewer potential miners available in a competitive market, and with the demands of increased tin production on nearby Dartmoor also drawing on human resources, there ensued a crisis in such labour intensive activities as drainage.

THE INTRODUCTION OF LABOUR SAVING TECHNOLOGY

There had been a low level of production at Bere Perrers through the early part of the 15th century to 1448, followed by a steep rise apparently associated with the working of a small group of six shafts on the north side of Lockridge Hill (Fig 3). This was maintained after the impeachment and death of the sub-lessee, William, Duke of Suffolk, by reopening old workings along the veins to the north

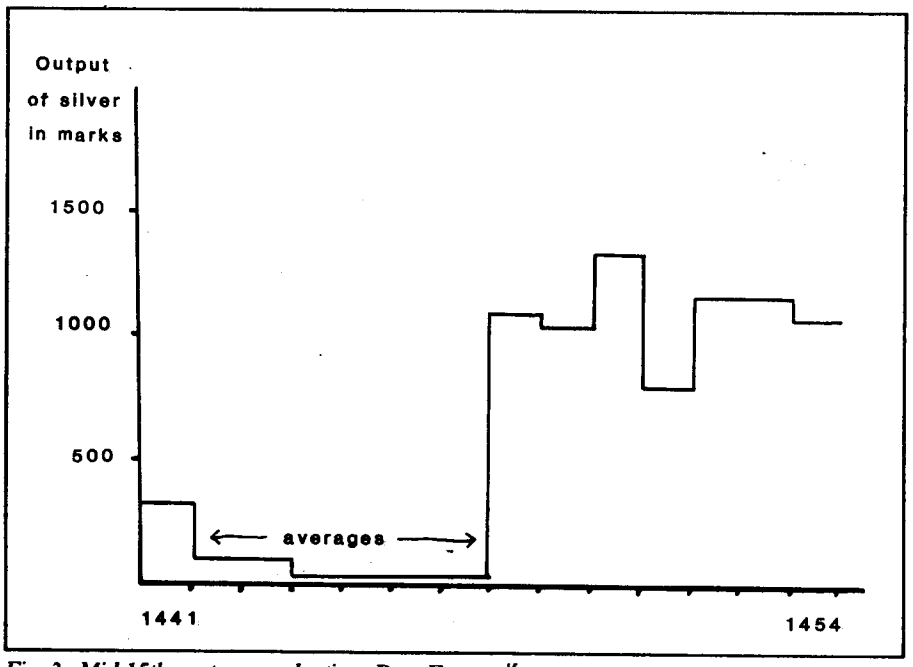


Fig. 3. Mid 15th century production, Bere Ferrers.[15]

Table 1. Wage rates in the Bere Berrers Mine.

	1300-10[1]	1348-49[2]	1380-81[3]
Miners	9d/week		4d/day
Water winders	10d/week[4]		4d/day
Boler	15d/week	4d/day	4d/day
Furnaceman	10d to 12d /week	2d/day	4d/day
Refiner	18d/week	6d/hearth	5d/day
Bellows blowers	6d/week	1d/day	none employed
Carpenters	1½ to 3d /day		4d to5d /day

1) Claughton 1993 The Medieval Silver-Lead Miner. *Bull. PDMHS* Vol. 12, No. 2.
2) PRO E 101/263/11; reworking of blackwork only. No mining accounted for, the refiner was underemployed.
3) PRO E101/266/25.
4). PRO E101/261/12 - 1309-10 only.

Fig. 4. Boring Pump Trees - Agricola (1856) De Re Metallica.

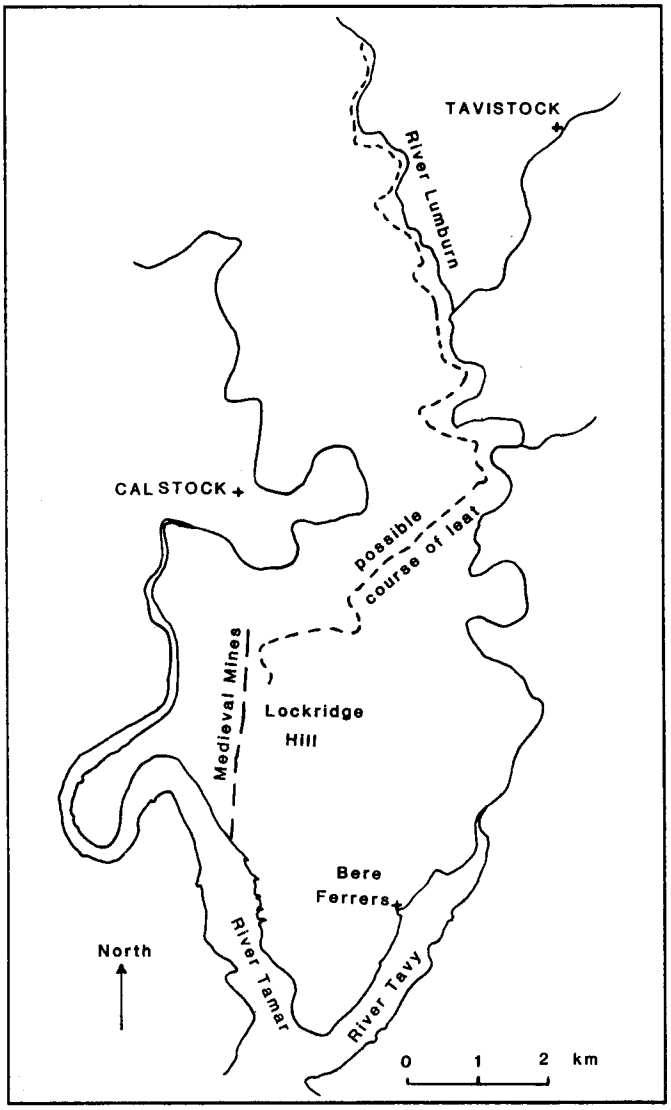


Fig. 5. Medieval leat in relation to the mines at Bere Ferrers.

and south; these were for the first time leased individually to small adventurers (See Table 2). For at least one of those involved this proved a disastrous investment: John Falron was allowed, and appears to have spent, £250 in drainage costs at Lockridge Hill and Whitsam Down without producing one ounce of silver although his sett was bisected by the deepest valley in the area.

This division of the Bere Ferrers lasted at the most fourteen years and appears to have been of only short term benefit to the Crown. It was not repeated. The desire to maintain a tight control over silver mining activity in the early years meant a centralised management structure had been imposed on the industry.[18] With the capital demands of deep working this resulted in a scale of operation very different from that in the lead mining areas. No body of customary law was allowed to develop and the mines were worked as large units.

It was under these conditions that the various factors, scarcity of silver-bearing ores, increased working depths, scarcity and increased cost of labour, combined to stimulate the mechanisation of drainage. Whilst primitive pumps had been known in antiquity and may have been used at Bere Ferrers, as suggested by the Sump Shaft north of Lockridge Hill (See Table 2), the introduction of piston pumps powered by waterwheel in 1480 would appear to be truly innovative.

Sir John Fogge had been appointed keeper of the mines in 1471 but mechanisation took nine years to plan and execute.A large proportion of that time being taken in bringing in a leat to the wheel installed over a specially prepared shaft. The pumps (plumpas) comprised 20-fathoms of bored tree trunks in nine lengths (Fig. 4) brought up from Plympton Wood. A leather hide providing the packing and valves for 'les sowkers' was attached to the piston rods.[19]

Providing an adequate supply of water was a problem. The medieval mines at Bere Ferrers are situated on a ridge of high ground between the rivers Tamar and Tavy. No streams with an adequate flow were available close to the workings and to take water from the Tamar was impractical.

Booker[20] makes reference to a medieval leat in Shillamill Wood, on the steep west bank of the Tavy some six kilometres north north east of the Bere Ferrers mines. Just below the 400 foot (120 metre) contour. That leat would have taken water from the River Lumburn, near Millhill west of Tavistock, and was well placed to supply, not mines on the Tavy side of the ridge as suggested by Booker (they were not active at that period) but those in the area of Lockridge Hill and Whitsam Down. This could be achieved by crossing the shallow saddle in the ridge in the area of Higher Gawton and bringing the leat west and then south around the high ground occupied by the village of Bere Alston. Documentary confirmation for Lockridge Hill being the site of the pumping shaft is not available, but, given the likely route of the leat, and the area's prominence in the 1440s, further field investigation should support that site.

We have no total figure for the cost of pumps, wheel (les ordenance) and leat used in 1480 but it was probably not cheap; squaring and boring of the pump trees alone cost 12d per fathom. However, it was not just substitution of capital for labour, for what labour was employed in its construction although divorced from mining activity was on site. Once the pumps were installed they required only one man to supervise their operation day and night and another to watch over the leat. Labour used in their construction was then available for redeployment on tasks directly connected with ore extraction. The requirement for water winders was reduced to seven men working only 21 to 59 days each in the year.

Where did Fogge acquire the technology employed at Bere Ferrers? Was it adopted from indigenous sources and modified for use in the mine, or had it diffused to this country from the continent where piston pumps were in use for urban water supply in the late 15th century? At the time he was working in Devon adventurers of German origin were active in the Northern Pennines, at Fletcheras and Sheldon, and in the Keswick area. At least one metallurgical expert, again a German, was employed there by the Crown. Fogge, as treasurer to the royal household, would probably have had knowledge of, if not direct contact with, these activities, and although his lease predated the reopening of the northern mines, he could have developed his plans to accommodate continental technology. However, there is no evidence for similar technology being used at Fletcheras or the other mines although there appears to have been interest, if not activity, there for at least a decade.

Similar mechanisation had already occurred in smelting and refining. The 'fynyngmyll' was again water-powered, no bellows blowers being employed in the smelting process. This trend was not confined to the silver-lead industry, with water-blown blackwork furnaces being used in Weardale in 1423 -25.[25]

Pumps continued to be employed in the silver-lead mines despite an expanding population and a down-turn in real wages after 1530. By that date the accessible deposits in Devon were virtually worked out, only 235 marks worth of silver having been produced in 1480-81, and a wider search was on for new sources of silver.

NORTH		
	The high North Shaft	Acreman and Glover 1 December 1452
	The Sumpte Shaft	
	"the vj shaftes which be called the Kinges shaftes"	Reserved to the Crown
LOCKRYGE HILL		
	Two shafts together on the highest part	Falron 20 March 1453
	old shafts	
	Water "coming from Dammewell and going down to the sea" (Tamar)	Falron 3 June 1452
	old shafts	
WITTESHAM DOWN		
	Hill called Pechis Medows	
	old shafts	
	Babewell	
	Old shafts on hill called Styffe Down	Ram 1 November 1451
	Tonnewell	
	Two northernmost shafts adjoining the adit of tonnewell	Ram 30 May 1452*
	Two shafts called "the new shaftis" on the southermost hill of the mine	
THE SEA (TAMAR)		

* At least 30 shafts to be worked in this section.

Table 2. Bere Ferrers: sections of the mine farmed out in 1451-53.

WALES: THE NEW PRODUCTION CENTRE

Two factors were to affect the industry dramatically in the 16th century, opening the way to a brighter future. Improved regional stability in Wales, allied to the legal changes in the so-called Act of Union, made available rich shallow deposits in Mid Wales at Cwmsymlog, Cwmerfin and other Cardiganshire mines. At the same time new smelting technology, born of resource depletion in the lead industry on Mendip, allowed the working of these and other new deposits at Combe Martin and in Cornwall.

Bevis Bulmer is credited with the introduction of improved pumps at Treworthy, in Cornwall.[22] These were no doubt in use earlier at Combe Martin, where Bulmer appears to have been instrumental in the use of the new ore hearth smelting process. There, working had reached a depth of 32 fathoms (57.6 metres) by 1590-91. Probably in an area where a 'drawing and forcing pump' manually operated by a brake staff 12 to 14 feet (circa 4 metres) long was recovered in the 1830s.[24] Such pumps were to be commonplace in Mid Wales in the 17th and 18th centuries.

At Cwmsymlog in the 1620s Myddleton utilized the fast flowing streams of the area to feed two water engines to power his pumps. But the 17th century was to see a return to the deep adit as an aid to drainage. Long crosscut drives were commenced at Cwmsymlog, Daren and other mines by Thomas Bushell, with similar activity in the Derbyshire lead mines.

If we look again at the fall in real wages, to a low point in the 1630s, and a rising population, the conditions were there for a return to such labour intensive projects. That at Cwmsymlog required an unproductive drive of about 350 metres and, probably the most ambitious of all, one of well over half a kilometre was commenced at Combe Martin.

Once reintroduced, deep drainage adits were to remain a common feature of both lead and silver-lead mining. More than thirty soughs were driven in Derbyshire by 1700, where they were sometimes developed independently of the producers, the small customary mines. The deep adits of the silver-lead mines were a key component in a co-ordinated approach to mining. In Wales they were to contribute to the opening up of rich deposits, the envy of local land-owners, leading in 1692-93 to the removal of the Mines Royal monopoly. The trend however was set: silver-lead working continued as it had since the medieval period, a large scale activity, centred on deep mining with attendant capital investment in drainage techniques, although it was increasingly dependent on the price of lead to stimulate that investment.

In Devon, at Bere Ferrers and Combe Martin, it was not found possible to drain the mines below the old medieval - early modern workings until the 19th century and the installation of powerful steam pumping engines, by which time silver-lead was a mere adjunct to the lead industry.

ACKNOWLEDGEMENTS

Thanks are due to Calstock Parish Archive, for allowing access to the text of documents translated under a Manpower Services Commission scheme, and their translator, Peter Mayer, for work on other documents on my behalf. Also to Mick Warburton, Roger Burton and Mike Gussin for access to workings at Combe Martin; to Linda Drury for information on Weardale; to Allen Buckley, for correspondence and sight of his thesis on adits (although I cannot agree with his theory that the adits at Bere Ferrers predate the late 13th century activity, it has stimulated my thoughts on the subject); and to Dr Roger Burt, for commenting on a draft or this paper and suggesting avenues for further investigations.

REFERENCES AND NOTES

1) Blanchard, Ian. 1992 Technical implications of the transition from silver to lead smelting in twelfth century England. IN L. Willies and D. Cranstone (Eds), *Boles and Smeltmills*, Historical Metallurgy Society, pp. 9-11.
2) Claughton, Peter. 1992 Medieval silver-lead smelting in Devon, IN *Boles and Smeltmills op cit* pp.12-15.
3) Liquation, a key feature in the saiger process for extracting silver from copper ores, normally attributed to Johannsen Funken,1451; Gill, M.C. *1993 Lead Mining in the Pennines*, unpublished M.Phil. thesis, Exeter.
4) Public Record Office (PRO) E372/145.
5) PRO E101/260/22.
6) PRO E101/260/4 f3.
7) Blackwork - opus nigrum - the residues from the intial smelting, be it by bole or furnace.
8) Salzman, L.F. 1923 *English Industries of the Middle Ages*, p. 53; PRO Ancient Correspondence Vol. 48, Item 81.
9. PRO E101/262/12.
10) PRO E101/262/13; based on drivage rates in the 16th century quoted in Buckley, J A. 1992 *Economic significance and role of adits in Cornish mine drainage (1700 - 1900).* Unpublished M.Phil. thesis, Camborne School of Mines, p.27.
11) Buckley, *op cit*, p.17.
12) PRO *Calendar of Inquisitions Post Mortem*, Vol. 8, items 46 and 657.
13 Pratt, D. 1976 Minera: Township of the Mines, *Trans. Denbighshire Hist. Soc.*, Vol. 25, pp.114 - 154.
14) Hatcher, John 1977 *Plague, population and the English Economy, 1348-1530.* Economic History Society.
15) Based on figures contained in Blanchard, Ian. 1984 The British Silver-Lead Industry and its Relations with the Continent 1470-1570. IN *Montanwirtschaft Mitteleuropas vom 12 bis 17 jahrhundert.* Ed. Kroker and Westerman, Bochum. (My thanks to Dr Tom Greeves for bringing this article to my attention.
16) PRO Cal.Pat.R. Ed. Ill, Vol. XIV p.476; Cal.Close R. Ed. Ill Vol. XI p.37; See also Claughton, P. 1993 The Medieval Silver-Lead Miner: a preliminary study. in *PDMHS. Bulletin* Vol.12, No.2, pp.28-30.
17) Blanchard, Ian 1978 Labour Productivity and Work Psychology in the English Mining Industry 1400 - 1600, *Economic History Review*, 2nd series, Vol.XXXI, No.1, pp.1 - 24.
18) Claughton, 1993 *Medieval Silver-Lead Miner*; op cit.
19) PRO E101/266/25; *Oxford English Dictionary*, Sowk - obsolete form of suck, Sucker - embolus, piston or rising valve of a pump (1611).
20) Booker, Frank 1967 *Industrial Archaeology of the Tamar Valley.* David and Charles, Newton Abbott.
21) Drury, Linda. 1987 *Leadworks in Weardale.* Durham County Local History Society, p.38.
22) Hammersley, G. 1973 Technique or Economy. *Business History*,Vol. X, No. 1, p.8.
23) A simplified graph based on information in Brown and Hoskin. 1956 Seven Centuries of the Price of Consumables Compared with Builders' Wage Rates. *Economica*, Vol. 23.
24) Claughton, P.F. IN *Industrial Archaeology of Exmoor.* Ed. M. Atkinson. In preparation.

Peter F. Claughton.