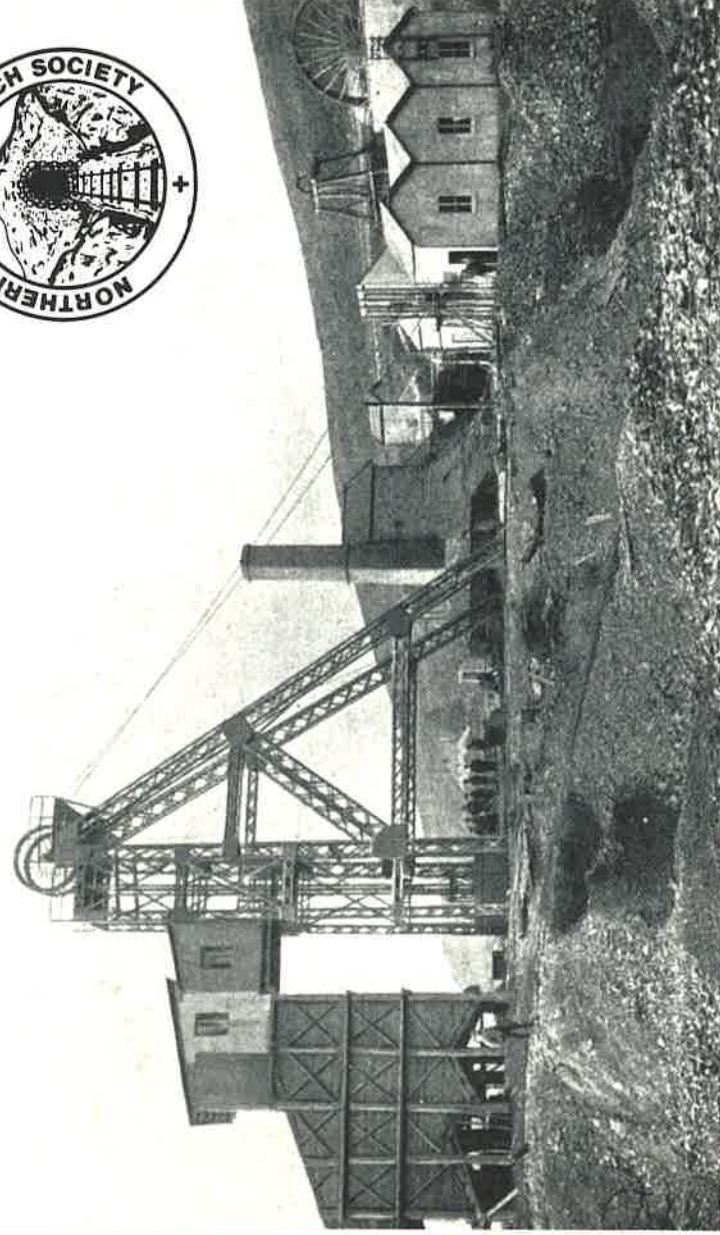


British Mining No 30

FRONGOCH LEAD & ZINC MINE

DAVID BICK



57
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by

David Bick
with contributions by A.J. Parkinson
and Dr.C.S. Briggs.

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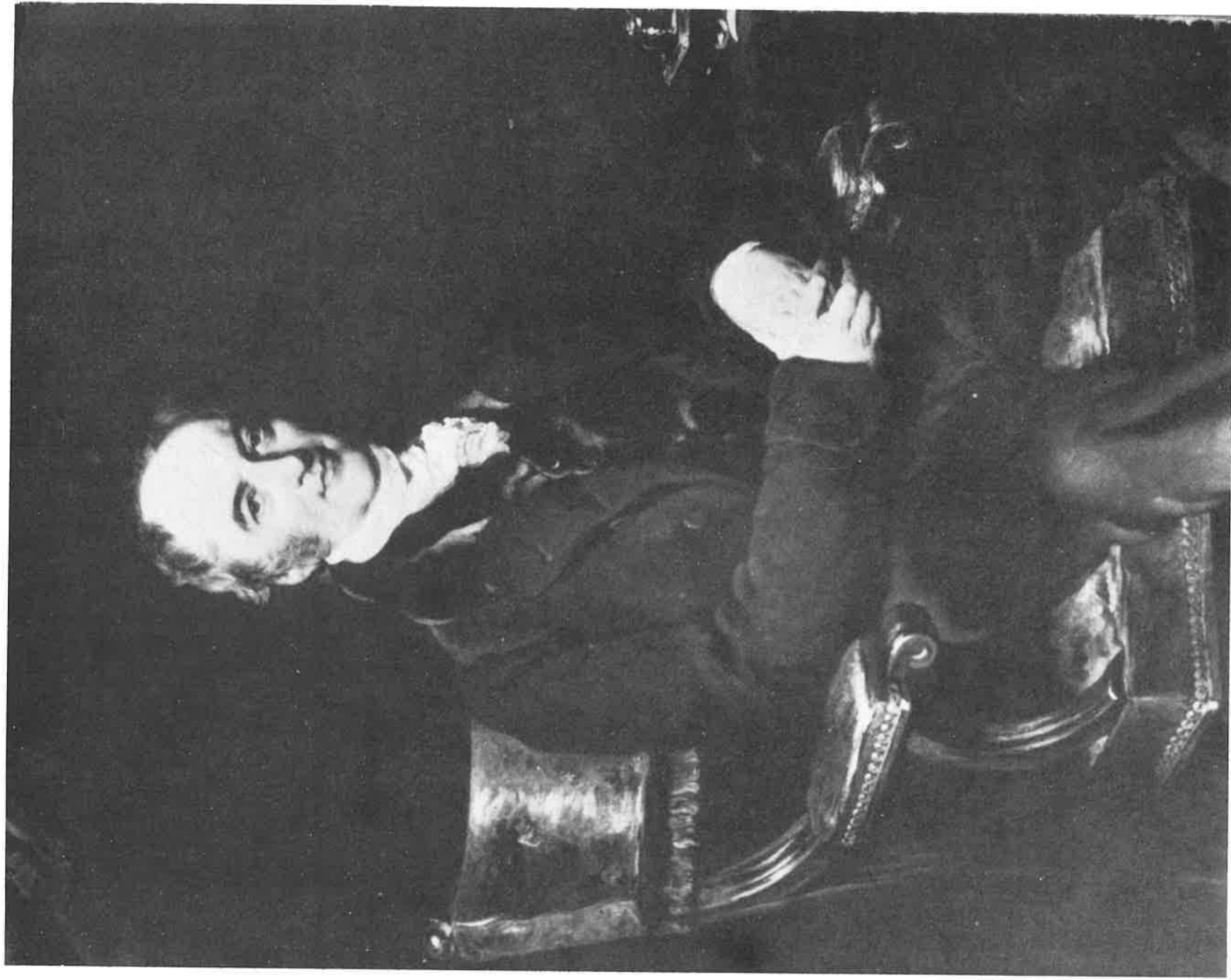
A
Monograph of the Northern Mine
Research Society 1986
in collaboration with the
Royal Commission on Ancient Monuments
for Wales.

BRITISH MINING No.30

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FRONT COVER: Frongoch about 1900, showing the towering headframe at Vaughan's New Shaft. (G.J. Williams)



FRONTISPIECE: John Taylor in 1825, from a portrait by Sir Thomas Lawrence for The Athenaeum Club.

PREFACE

This monograph had its origins in 1982, when the Welsh Mines Society drew the attention of the Royal Commission on Ancient and Historical Monuments in Wales to the three Cornish Engine houses and other structures at Frongoch.

The Commission responded with a detailed survey of this unique group of 19th century mine-buildings, and has also generously contributed towards the cost of publication.

Having known Frongoch for almost forty years, I have derived no little pleasure in compiling an historical account. An Appendix by Dr Stephen Briggs (Trefenter) has also been included, based on Moissenet's visit in 1860.

Though nature and man has dealt harshly with the remaining structures, enough still stands to form a basis for a first-class interpretative centre for the history of lead mining in the Principality, as well as a valuable area of general amenity. It is hoped that something can be done in this direction before decay renders the task insuperable.

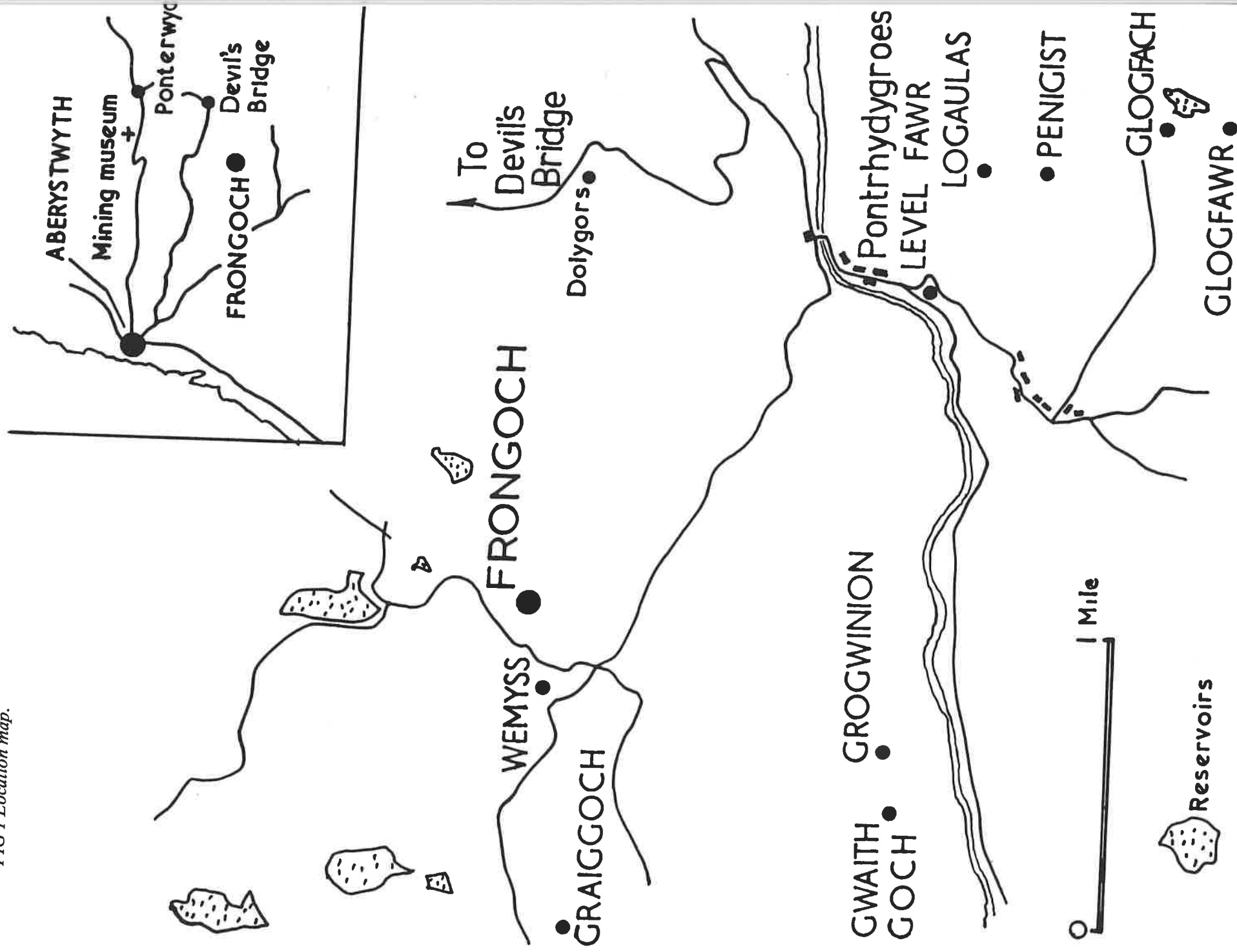
I should like to take this opportunity to express grateful thanks to Professor D.G. Tucker and Mr Peter Smith, without whose interest in the furtherance of studies relating to Industrial Archaeology, this publication would not have come to pass.

My old friend George Hall has again assisted with references in the *Mining Journal*, and I have to thank him for introducing me to Pontrhydygroes-home of the Lisburne Mines-in 1947. I am also indebted for help in various ways to Douglas Hague, Richard Bird, Simon Timberlake, Jeremy Wilkinson, R. Alan Williams, Simon Hughes, A.J. Parkinson, Dr.C.S. Briggs and the staff of the British Geological Survey and the National Library of Wales.

David Bick, FSA.

Pound House, Newent, Glos,
May 1986

FIG 1 Location map.



the Ystwyth valley is a legacy of Taylors' investment to improve communications. The Manchester and Milford Railway, projected in 1860 on a route that would have taken it past the doorstep of the Lisburne Mines, unfortunately never came to fruition.

Waterwheels were the traditional source of power for the industry, but Frongoch was poorly situated in this respect, with more than usual interruptions from frost and drought. As we shall see, steam was tried, but only served to underline the indispensibility of the older method. Steam, which had done so much for Cornwall, influenced the destiny of mining in mid-Wales hardly at all.

By the late 1870s Frongoch was past its best, and with lead prices falling, Taylors pulled out. A new company under John Kitto of Llanidloes continued in hopes of better days but the market never recovered. That the mine was able to continue for over 20 years was mainly due to huge reserves of blende which Taylors had left standing in the workings. In 1881 Frongoch gave employment to over 300 men, women and children – a number only slightly exceeded in the whole of mid-Wales by Van mine near Llanidloes.

However, the high running costs of an old mine over 900ft deep did not deter a Belgian company from making a very large investment in 1898 by installing modern hydro-electric and steam generating plant for all-electric operation. The reasons for this foreign interest are unclear, but within a year or two the evidence of a disastrous commercial blunder was plain. In 1904 the almost new equipment was auctioned at a fraction of its cost. With little or no prospect of work in the neighbourhood, many miners emigrated or went into coal mining – a job which although less unhealthy, was always considered as practically beneath contempt.

Since then mining at Frongoch has ceased, notwithstanding various proposals for a revival. The huge dumps were largely removed for treatment in the 1920s. The site is now in great measure a waste-land, with the shells of huge Cornish engine-houses and other buildings standing in mute testimony, not only to a great mine, but to a Welsh industry that endured on and off for two thousand years.

The western boundary of Frongoch coincided with a small stream running due south about 300yds west of Engine Shaft. Beyond, the lode passed through a different mineral ownership as far as the road down Cwm Newyddion, and worked as the Wemyss Mine, generally in conjunction with Frongoch.

On the continuation of the lode trials were made at Brook Shaft south of Cwm Newyddion Uchaf, and these workings were known as West Frongoch. The latter appellation was sometimes applied to Wemyss, but in this account the above distinction will be observed.

The furthestmost workings on the Frongoch lode were at Graiggoch or Red Rock Mine, on the southern slopes of Cwm Newyddion, about a mile from Frongoch.

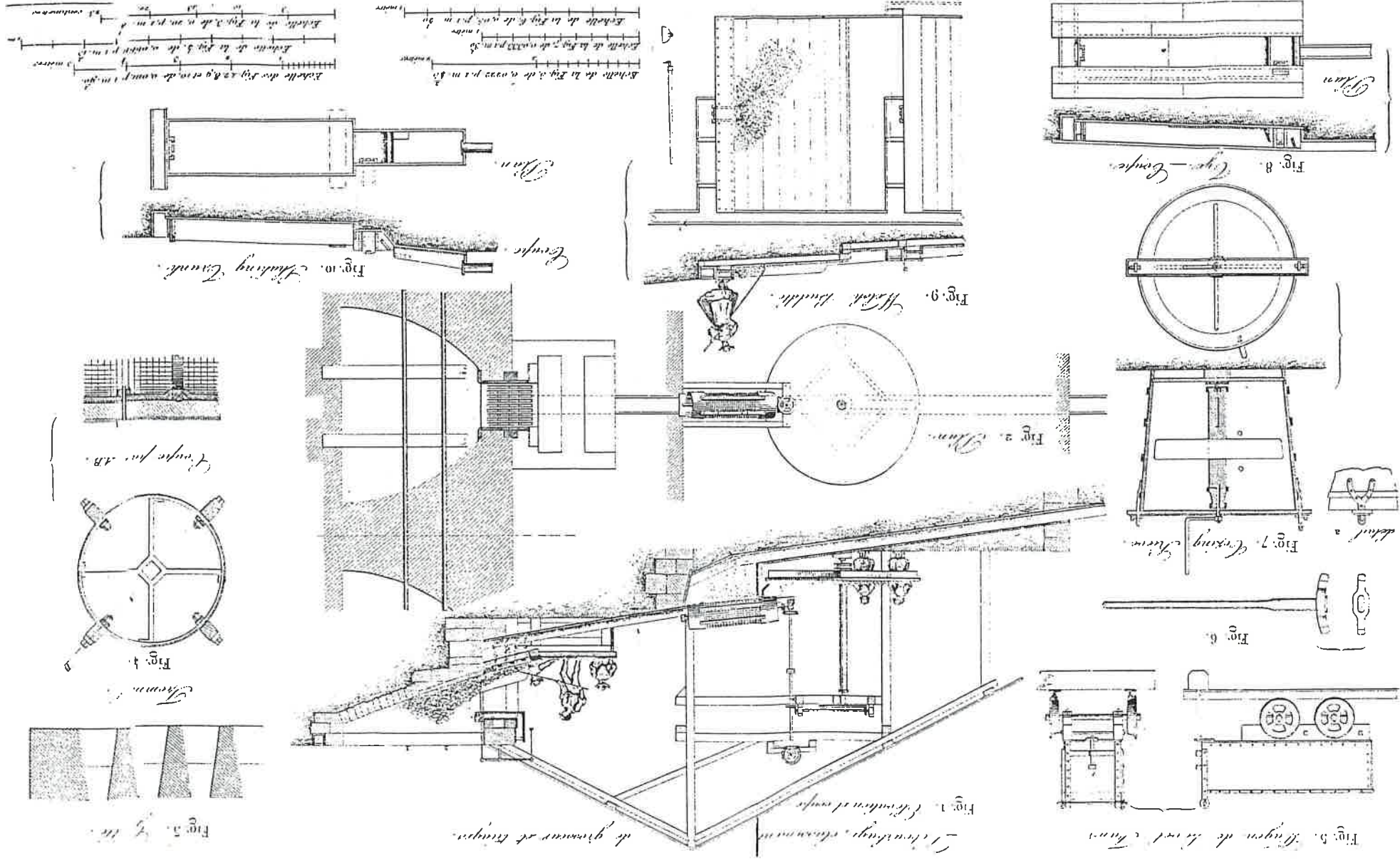
Before proceeding to the history in more detail something must be said of the geology and ore-deposits. The mining region of Cardiganshire consists of Silurian strata, which at Frongoch comprises grey or greenish-grey shales, flags and mudstones. The lodes in which the ores occur are nearly vertical faults or fractures which have become charged with deposits from mineral-bearing solutions probably created by igneous activity at great depth in post-Carboniferous times. The exact mechanism whereby nature assembled ores in so convenient a manner is not thoroughly understood, and none who have seen a vein of shining galena sandwiched between walls of barren rock can fail to wonder at the process.

The Frongoch lode varied in width up to 30ft, of which the galena-bearing part was not more than 24ft and generally much less. As a rule, the ore occurred in two more or less distinct branches, referred to as the north and south part of the lode, with the blende mainly to one side of the galena. Quartz was the other constituent, and this very hard mineral rendered the lode difficult to work by hand-drilling methods. Unfortunately the productive parts became restricted laterally in depth, so that ground which paid to extract for 250 fathoms in the upper workings decreased to about 100 fathoms in the 105 and only 70 fathoms at the 130 fathom level. This, combined with increasing hardness in depth sealed the fate of the mine.

Mineral lodes often split up and divide, and enrichment commonly takes place at junctions of this kind, again for reasons that are not clear. At Frongoch the original workings centred on an intersection at the eastern end. Frequently the galena occurred not as solid ribs, but intermingled with blende, quartz and fragments of rock, so that the whole mass required crushing and dressing in order to separate the valuable constituents.

The treatment of ores was a highly specialised process, relying largely on gravity methods of separation, and under John Taylor & Sons rose almost to the state of an art. Due to its great density, galena was much easier to separate than blende, which could rarely be 'got up' to the same degree of purity. The very low prices sometimes obtained for second-quality blende concentrates reflected this problem. The French engineer Louis Moissenet visited the Lisburne Mines in 1860 and wrote a detailed description of the methods employed. This valuable paper is the subject of a separate chapter.

FIG. 21 Section from Moissenet's work.



From the above the rudimentary nature of the operations is apparent, though provision of a shed for the washers (ore-dressers) is interesting – in mid-Wales this basic protection from the worst of the weather was something of a luxury and rarely encountered.

Work at Llwynnwnwch had begun by August 1794, for in that month a bargain was made to raise ore in the new work at £3.15.0. per ton of lead ore and £1.7.6. for Black Jack.⁵ John Lowe, son of James, was then manager, and was frequently informing Robert Wilding, John Probert's agent, as to progress.⁶

At this time the Napoleonic Wars were depressing prices and morale alike. In June 1795, Lowe wrote:

"I have every reason to believe Llwynnwnwch will make a capital concern provided it is carried on with some degree of spirit, but it cannot be done with any propriety while this ruinous War continues, and hope to God it will be brought to some conclusion before the end of the year or I don't know what will become of us except we turn Soldiers"

A week later Lowe reported that Frongoch looked promising with a good rib of ore 6 inches wide intermixed with Black Jack. He went on:

"I should be glad to know whether you wish to have the Llwynnwnwch Ore carried down or not. The Sun impairs the colour very much, it has almost the appearance of Black Jack..." The observation regarding the galena is curious, and suggests it was intended for a purpose other than smelting.

Further details as to the running of the mines are that carriage of coal from Aberystwyth for the smithy cost 8/- per ton. Timber was being hauled from as far afield as Radnorshire and gunpowder came from Shrewsbury. Unforeseen expenses also occurred, such as the cost of washing ore in the storehouse at Aberystwyth which had become mixed with sand thrown up by the tide. Lead ore was only fetching £8. or £9. per ton but nevertheless in that year Frongoch and Llwynnwnwch raised about 250 tons, as far as can be judged from the records.⁸

About 1796 John Lowe and his widowed mother left Dol-y-gors and moved to Nannerth, near Rhayader, and reading between the lines of a long letter to Wilding dated 29 November 1797, he was being edged out of his job⁹ –

"I hope Mr. Probert through the assistance of his good friends will be as kind as to recommend me to some place or other for which I shall ever acknowledge his goodness..."

Frongoch was struggling on, with some men able to earn 10/- per week, but "poor hands, who could not cut the ground as others do" had to survive on half that reward. Much of Lowe's news was simply gossip or family matters, from which we learn that

"Old Captain Lewis of Aberystwyth has run away with his Servant maid to Ireland." More serious was his concern that "my Aunt Mrs. Gaylor married again about 3 months ago to a young Man and has conferred all her property on him, which was £300 a year. She is upwards of 65 years of Age. I was in hopes she would have given or left the greatest part on her Decease to our family, but that is now all over..." Life was ever thus.

Job Sheldon took over Lowe's role about the turn of the century, and during the next decade lead reached record prices. Both Frongoch and Llwynnwnwch continued at work, and it appears that the latter was also spelt Llwynnunnough, Llwynunnog and perhaps Llwynunno. Various references to these names occur.

FIG 4 Lisburne Mines cost sheet for eight months to the end of 1834.

COSTS AND RETURNS OF THE LISBURN MINE
For Eight Months, to the end of December, 1834.

Task.	Lead Ores.	Amount.	Leads Price.	Leads Dues.	Costs.	Leads.
1834.		£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
33 Weeks to end July.						
August and September	125 3	1233 17 1	186 1 10	1565 15 3	2106 5 2	
5 Months to end Dec.	120 3 2	1233 17 1	188 1 10	1565 15 3	4077 4 3	2311 9 0

Particulars of the Lisburne Mines Costs and Returns for Eight Months, to the end of December, 1834.

	£ s. d.	Lead Ores	Amount	Leads Price	Leads Dues	Costs	Leads
Agnes's Salaries	288 1 4	Lead Ores	150 9 2				
Thomas's Salaries	288 1 4	Deduct Leads Dues	188 1 10				
Burgess's Salaries	288 1 4						
Burgess's Salaries	288 1 4						
Carpenters, Masons, Smiths, &c.	207 6 7						
Carriage and Whim Hire	325 12 3						
Mason's	727 10 2						
Expenses on Ores	303 0 2						
Tithes Subsid and Balances	733 17 10						
Sundry Payments	300 8 9						
	£4,077 4 3						

Dr.	THE LISBURN MINE.	Cr.
1834.	£ s. d.	£ s. d.
Aug. 4.	To paid First Instal.	
	purchase on account of	
	Mine	1,230 0 0
	(1 of 5,000 l.)	2,500 0 0
Nov. 4.	To ditto Second ditto	2,500 0 0
	To Loss on Mine, 8	211 9 0
	months, to end of	
	December	2,711 9 0
	£5,211 9 0	£5,211 9 0

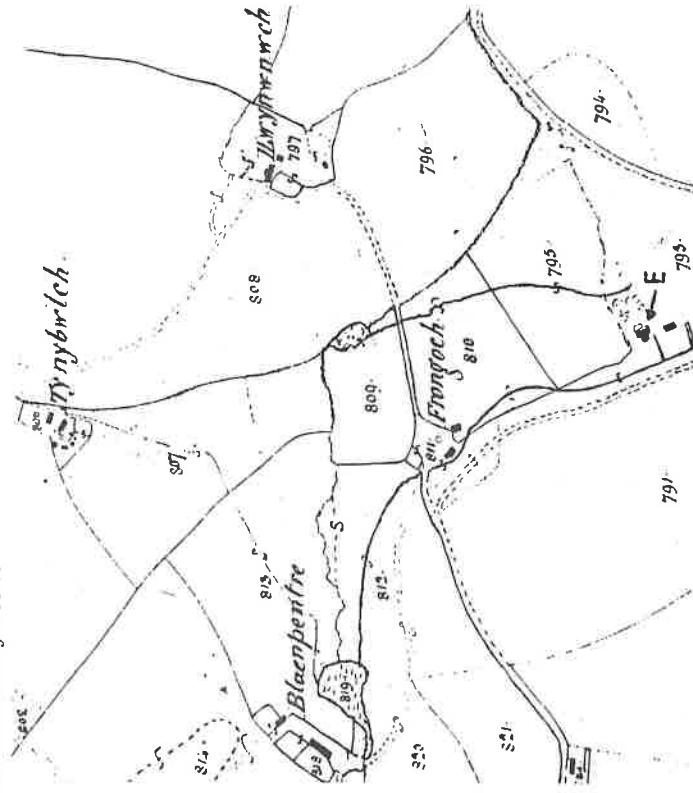


FIG 5 The Tithe Map of 1847, showing ponds near Frongoch farmhouse and leads to the mine. 'E' marks the 1841 pumping engine. (N.L.W.)

In a letter of 1810 to Probert, Sheldon wrote:

"I intend shipping 20 or 30 ton of Llwynunnog Black Jack by way of a trial to Harfords and Bristol Brass Co..."¹⁰ The cargo fetched £36.15.0. but no more was wanted, being of too hard a quality.¹¹ Bristol was then a centre of the brass industry, Black Jack being used in its manufacture. The city also imported considerable quantities of galena, and cargos from Frongoch went to Philip George, a smelter, who also owned the Patent Shot Company for making lead shot.¹²

Frongoch was still at work in 1811 but by 1816 prices had fallen heavily and two years later the mines were practically at a stand.¹³ To compute their output between 1791 and 1818 is scarcely possible due to the fragmentary records remaining. However, it may be estimated that the two mines together raised about 3,000 tons of lead ore, and a similar quantity of blende.

Following an improvement in trade the next upturn came in 1824 when Lord Lisburne's mines were leased to a company consisting largely of the Cornish family of Williams. Those worked were Frongoch, Logaulas, Glogfach, Glogfawr, Gwaith Goch, Graiggoch or Red Rock, Penigist and Rhos Llwyd. The site of the latter is uncertain. Mines on the Gogerthan Estate were also worked, and included Cwmsymlog and Darren.¹⁴

Unfortunately, few details survive of the Williams' activities. One fact worthy of recording is that in 1830 the Cornishman Robert Fox conducted pioneer experiments in Frongoch and Logaulas on electric currents generated in mineral lodes.¹⁵ In respect of the Lisburne mines, the output figures from 1825 to 1834 clearly testify to the relative fortunes of the Williams, and their successors and rivals, John Taylor & Sons.

THE LISBURN MINES. Lead Ores Raised.

YEAR.	WILLIAMS OF SCORRIER HOUSE.						
	Frongoch.	Logaulas.	Glogfach.	Glogfawr.	Gwaith Goch.	Graiggoch.	Rhos Llwyd.
1825.	4.	3.	644.	27.	2.	20.	3.
1826.	24.	14.	542.	26.		43.	10.
1827.	2.	40.	479.	44.			5.
1828.	1.	157.	517.	13.	6.	22.	
1829.	64.	59.	352.	46.	1.	6.	
1830.	216.	191.	359.	20.			
1831.	158.	174.	20.	95.			
1832.	283.	136.	1.	32.			
1833.	387.	122.	5.	17.			
1834.	258.	63.		14.			
TOTAL	1,397.	959.	2,929.	334.	9.	91.	18.
							3.
							5,730 Tons.

JOHN TAYLOR & SONS.

YEAR.	West			
	Frongoch.	Logaulas.	Glogfach.	Glogfawr.
1834.	199.	15.	211.	29.
1835.	149.		80.	73.
1836.	892.	420.	19.	52.
1837.	671.	605.	129.	20.
1838.	447.	819.	17.	3.
1839.	78.	505.	388.	178.
TOTAL	3,094.	2,513.	245.	388.
				3.
				6,421 Tons.

It will be noted that after an excellent start Williams' best mine, Glogfach, gradually went from bad to worse. Logaulas declined after 1830 and only Frongoch, after a poor beginning, was going well when the company succumbed in 1834. Whilst very high royalties of one-seventh or one-eighth and falling prices hastened the end, luck, that essential ingredient in metal-mining, was against them.

The changing fortune of Logaulas is a perfect illustration. In 1785 John Probert began a long drainage adit which became known as Level Fawr or Great Level, commencing above the River Ystwyth at Pontrhydygroes. The task took many years, and its sequel was chronicled by W.W. Smyth as follows.

The rock was hard and the progress slow, but for upwards of 30 years did the miners persevere, till at length, after piercing about 360 fathoms, a lode was cut; but so miserable was the aspect it presented, that after driving right and left upon it for a few feet, the disappointed speculator gave up all his cherished hopes and abandoned the undertaking. After a short interval some Cornish adventurers (Williams) were led to believe that something yet remained to be done, and having set a party of men to push forward the same level, in the course of a few feet cut the true lode, in the midst of a vast deposit of ore which yielded rich returns for several years. This company, however, in their turn, fell into a similar error, and losing the true lode, mistook for it a small vein on the south, dispirited with whose poverty they surrendered the mine. The present holders, (Taylor), after making an accurate survey, were satisfied that they must be too far southward, drove a "cross-cut" towards the north, and very shortly discovered not only the lode, but a rich "bunch" of ore, parallel to which their predecessors had been toiling for many a fathom through barren rock at the distance of only a few feet. The mine has ever since been yielding several thousands of pounds profit per annum.

According to Matthew Francis the driving of Level Fawr cost £14,000 and in his opinion it was a high price to pay for something that could have been accomplished quicker and cheaper by waterwheels for pumping.¹⁷ At all events, the level was eventually extended to Glogfach and Glogfawr, and at its mouth were extensive dressing-floors and the headquarters of the Lisburne Mines throughout the 19th century.¹⁸

4: ECONOMIC ASPECTS.

The Lisburne Mines were held as 400 shares of capital, each of £18.15s, with a total invested capital of £7,500. By November 1864, the mines were worth £40,000, having produced a dividend of £403,500, with a capital value of only £90,000, the equivalent of 2,815% on original investment. About £½ million worth of ore had been sold. Total production figures for the Lisburne Mines group were given for the years 1857, 8 and 9 showing net annual profits:

Ore sold (tonne of 1000kg)	1857	1858	1859	total
galena	2,318,531	2,444,044	2,453,921	7,246,544
blende	278,706	153,033	541,285	541,285
market value (£s)	34,523.6s	32,985.16s	34,489.18s	101,207
less royalties	3,324.10s	3,168.19s	3,282.17s	97,242.16s
value to company	31,196.8s	29,824.19s	31,167.1s	92,118.8s
total expenditure	23,531.15s	22,439.11s	22,129.16s	68,101.2s
total net profit	8,467.	7,385.8s	9,039.6s	24,889.15s

The exploitation of galena and blende were intimately connected. From each average ton of galena at £13.18s per ton, about £3.7s or 24.11% was profit. Wages accounted for 9.66% and overheads 65.93% of the total returns. These compared well with the figures given by Phillips and Darlington in their *Records of Mining and Metallurgy*, p. 255. Interestingly, once it had arrived at the port of Aberystwyth, the purchaser of the ore paid its carriage. The cost varied from 4 to 7 shillings per tonne, depending on its destination.

The ore was sold by the ton of 21 hundredweight (*quintaine*) of dry dressed mineral (*mineral sec*) amounting to 2,352 lbs. But weighing out at the mine was of 20 hundredweights of 119 lbs, grossing 2,380 lbs per ton. 2,380 – 2,352 lbs left an excess of 28 lbs, intended to cover any loss incurred in transport. The ore was carried in heavy-duty sacks by road to Aberystwyth, where it was assayed for humidity before embarkation. Hygroscopic readings of at least 2.45% by weight were to be expected. Freight charges were estimated by wet weight, though marine tonnage was calculated upon dry. Aberystwyth Harbour Authority levied 1.s per ton carried ((p. 124)).

A table follows, giving detailed monthly out-goings at both Level Fawr and Frongoch together with average prices and wages.

For Frongoch these run as follows:

SALES 1847: mineral extracted by tonnage: galena 21.243; sold, 1.356, 3cwt 3 q.(yield 6.38%), price £15.8s 3¼d. per 21 cwt ton; blende 264 tons 7 cwt lq. sold at £3.8s, 3¼d, per ton.

PRODUCTION COSTS:- galena Crop: 11s, 2¼d; slimes: £21.3s, 8¼d, and blende, crop:10s.

SALES 1858: min, extr, galena 16.193; sold, 1,078 tons 20cwt (yield 6.53%). price, £14.2s, 9¼d, per ton; blende 143 tons 11cwt sold at £3.14s, 8d, per ton.

PRODUCTION COSTS:- galena crop: 9s, 3d.; slimes: £3.6s, 1¼d.; blende crop. £10.

SALES 1859: min, extr, galena 18, 908; 1,033 tons 5 cwt (yield 5.46%) sold at £14.12s, 5d, ton; blende 105 tons 10cwt sold at £214.0s per ton.

PRODUCTION COSTS:- galena crop: 14s 0¼d.; slimes: £3.8s, 7½d.

It is difficult to analyse the monthly averages provided on the same table, since these include complex factors relating to the other mines (Glogfach and Logaulas) which processed at Level Fawr. Moissenet offered several useful observations upon this collected data. Between 1857 and '59, production at Level Fawr rose while that at Frongoch fell. Up until 1857 Frongoch had upheld the production of the group as a whole. Then, after tribute payments had been introduced at Logaulas in 1857, their roles had virtually reversed. The relative profits per ton (21 cwts) for these years were:

	1857	1858	1859
Level Fawr	14s.2d	£3.2s, 2d,	£4.18s, 3d,
Frongoch	£5.9s,	£2.12s, 10d,	£2.11s, 3d,

Profits at Level Fawr had risen from 4.43% to 14.26%. Percentage yields at Frongoch declined slightly from 6.58 and 6.55, to 5.46%, but these differences were to be put down to the extreme difficulty with which ore-washing was undertaken, owing largely to the presence of blende. The production of both crop and slimes thus rose appreciably over the three-year period ((p. 129)). But whilst the cost of raising a ton of ore at Frongoch was cheaper than at Level Fawr, it came to only 5½d at the former and 1s. 6½d. at the latter and processing inflated these figures to respectively 12s and 16s.

A detailed discussion follows, of relative production costs of crops, slimes and halvans from the mines in the Lisburne group.

Moissenet had been anxious to establish the exact yield of metal from the ore, but in this he had not succeeded. Although somewhat affected by the blende within the ore, lead crop from Frongoch, like that from Level Fawr, was probably up to 78% and around 55% from the fines.

He discussed at length the way in which losses of mineral were part of the manufacturing process (p.134-5)), and offered the theoretical mean of 9% loss at Frongoch (p. 136)).

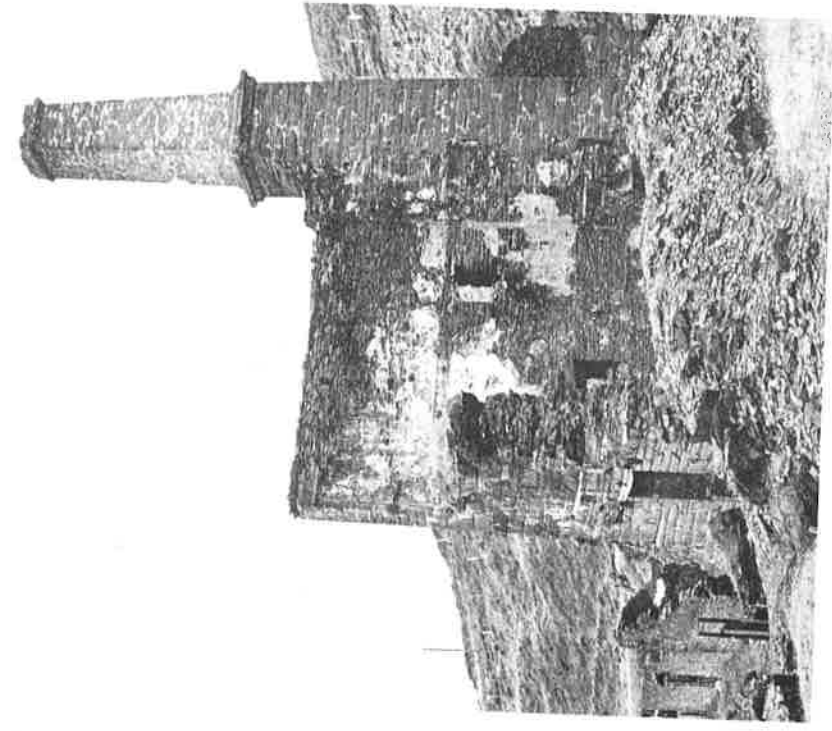
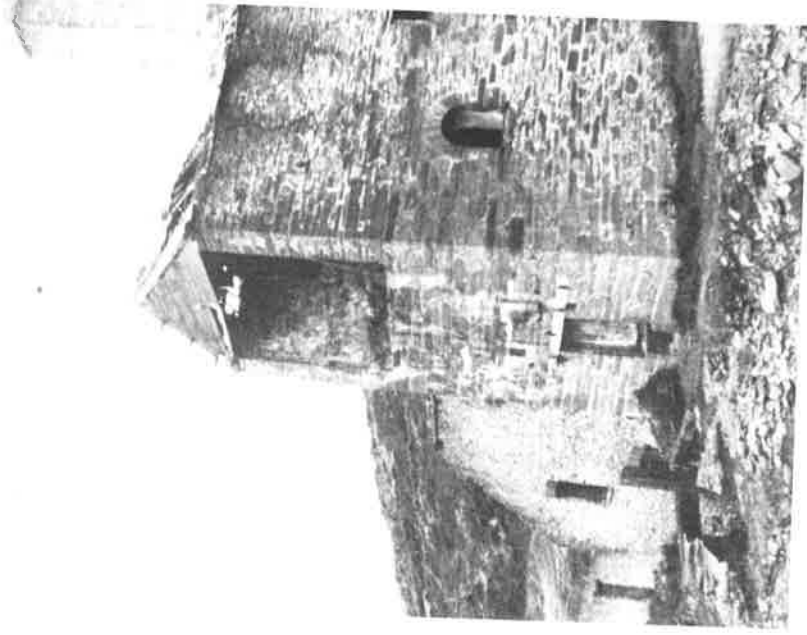
In a critical summary of his work at the Lisburne Mines, Moissenet regretted that hand cobbing by hammer had disappeared. Frongoch was all but a model workshop, though sizing griddles should be introduced, and these would complement the virtues of the Lisburne buddle. 'Thus complete, it seems to me that ore processing at Frongoch, already close to a working perfection, would in future rank among those classic establishments which served as milestones to progress in the art of mining ((p. 137)).

ACKNOWLEDGEMENT

The compiler of these notes wishes to thank Mme Marie-Noëlle Maisonneuve, librarian and archivist to the École de Mines, Paris, for her generous assistance in his search for information about Moissenet.

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PLATES II & III. The 60 inch Engine House, as it was in 1932 (left) and (right) 1978. (D. Dixon & R.H. Bird)

Matters now improved, partly by acquiring the neighbouring Wemyss mine to the west which was under separate ownership. The lode ran through both properties and the Wemyss adit by extending eastwards was made to serve both workings. The best ore occurred at the junction of two lodes, which were very productive and 30ft. wide for a length of 40 fathoms where they ran together. To the east, the main lode became impoverished and a level driven 200 fathoms proved nothing worth working. Trials west on the north lode yielded much ore, but not profitably.⁵

By 1846 Frongoch was down to the 56 fathom level with the 24 fathom level driven west as far as Boundary Shaft, beyond the road. In or about 1848 the Wemyss adit finally holed through to the 24 fathom level which then became the deep adit, the old shallow adit being only 5 fathoms below surface. Its site is now lost. In the Wemyss property the adit began on the main lode near the road, but after about 150 fathoms turned north-east for about 25 fathoms before continuing eastwards on a north lode which outcrops on surface about 20 fathoms north of Boundary Shaft. A crosscut driven at this point brought the adit into the Frongoch workings.⁶ Eventually the adit or 24 fathom level with all its twists and turns, cross-cuts and exploratory drivages on parallel lodes was extremely long. As far as can be judged from a plan c.1870, it then totalled about 3 miles.

In 1850 annual output reached nearly 2,000 tons of galena, but the year was marred by a bad accident when seven miners were killed by three barrels of gunpowder exploding, caused by the proximity of a lighted tobacco pipe.⁷

By 1851, calls on the original 100 shares had risen from an initial £25 per share to a total of £75, making a capital of £7,500. Thus far, the Lisburne mines had yielded £620 total dividends on each £75 share.⁸ They were run on the Tribute system where every month miners contracted to work the lode for an agreed fraction of the value of ore raised.⁹ If it turned out richer than expected the men stood to gain, but generally the dice were loaded against them. Taylor considered the method led to mining at the lowest possible cost, but it complicated the day-to-day operations since very tributer's pile of ore needed separate handling from the stopes right through the dressing floors – an aspect that has scarcely been studied by historians and industrial archaeologists. This somewhat barbaric system of sweated labour endured almost universally to the end of the industry in Wales.

The French engineer Louis Moissenet came to Britain to study its ore-dressing techniques and a report of his visit to the Lisburne mines in 1860 was published in great detail. It is extensively quoted in an Appendix and provides valuable information about Frongoch at its middle period. The mine was then down to the 78 fathom level with workings extending over $\frac{3}{4}$ mile, including the Wemyss property.

Another important source is a Government enquiry into the working conditions in mines other than collieries, under the chairmanship of Lord Kinnaird.¹⁰ In July 1863 the Commission examined Henry Thomas, general manager of John Taylor's mines in Cardiganshire, and from his evidence we learn that the mine was 103 fathoms deep, and again interrupted due to lack of water. The question of ventilation was raised, its virtues being expressed unashamedly in terms of cash.



PLATE IV. In the Frongoch Adit 1986: timbering in soft ground. (S. Timberlake)



PLATE V Standing above flooded stopes with the ladder to the original level of the catwalk over the stope. (S. Timberlake)



PLATE VI The pit for the 56ft. waterwheel at Wemyss, used for pumping Frongoch via flat rods. (R.H. Bird)

IN RELIEVING THE LISBURNE MINES CO. OF ITS BURDEN, LORD LISBURNE ALSO AGREED TO purchase the machinery for £5,000.¹ Having acquired the mine as a going concern he forthwith handed over the lease on 31 July 1878 at 1/20th royalty to Henry Davey and Alexander Kerby, both of London, and John Kitto of Llanidloes.²

The driving force behind the venture was Kitto, born in Perranzabuloe, Cornwall, in 1830. He had come to Wales from the Isle of Man in 1864 to manage the Brynpostig lead mine near Llanidloes³, and many mid-Wales mines were given a new lease of life under the direction of himself and his son. Few however, achieved much success – a reflection more of exhaustion of orebodies and falling prices than Kitto's competence as a mining engineer. And if in promoting a company his public trumpetings exceeded his better judgement, it was a characteristic endemic to his contemporaries and the industry as a whole. At a time when metal mining had come to be viewed as a high-risk gamble, like football pools, to err on the cautious side was simply to attract no capital at all. How the industry gradually succumbed to this fatal disease, akin to drug addiction, whether it might have been prevented or even cured, and to what degree its life might thus have been prolonged, are subjects of great interest which have to some extent received attention elsewhere.⁴ But we must return to matters in hand.

Having obtained the lease, Kitto passed it on to the Lisburne Syndicate Ltd., registered at 80 Cornhill, London, with a capital of £14,000 in £10 shares.⁵ Of these he held one hundred, George Ross & Co. acting as managers. The directors were Henry Davey, Thomas Kent of Southampton and William Bowman of Middleton in Derbyshire.

On 24 October 1878 a further company, Frongoch Ltd., became incorporated to acquire the lease, plant and machinery from the Syndicate. Whatever the need for this further development John Kitto now firmly held command, with more shares than any other subscriber. The nominal capital was £25,000 and George Ross acted as chairman. The directors were Ross, Bowman, Kent and William Brookes of Hinckley, and the venture was launched with the usual gusto.

According to the literature 'without any doubt this is one of the most perfect investments of its kind that has been offered to the investing public since the Van Mine was brought under their notice'. The declining state of the lead market due to continuing imports from abroad was not mentioned, neither that the best management in the country had given up the property as beyond redemption. Nevertheless money was quickly subscribed and work began.

At this juncture a good idea of the underground state of the mine may be gleaned from Kitto's report, dated 1 July 1878.⁶

'There are three principal, or main shafts for pumping and drawing, besides two or three others of less importance for ventilation, and ladder roads, the deepest of the three (which is known by the name of "VAUGHAN'S") has been sunk about 6 fathoms below the bottom, or 142-fathom level. At that depth a cross-cut has been driven through the lode from South to North, and on the latter side has intersected to be rapidly extending itself Eastwards in going down. A stope is being worked underhand here on a good course of Ore, which I value at 3 tons to the fathom.

The 142-fathom level has been driven East of Vaughan's shaft about 31 fathoms, and west 22 fathoms, principally on the South part of the lode, and near the end of the latter level there is another bunch of Ore, quite separate and distinct from the one referred to above; a stope is being worked in the back of this level upon this bunch from 6 to 8 fathoms in length, and is worth about 20cwt. of Lead Ore to the fathom. The stope in the winze at bottom of Vaughan's shaft is on the North part of the lode, but this is on the South part, and I am strongly of opinion that the North side has not been seen at, or even near this point, and that a cross-cut should be driven in that direction. The same remark applies to the level East of shaft.

The 130-fathom level has been driven from same shaft 32 fathoms East, and 45 fathoms West, and about 15 fathoms from the latter end there is a bunch of Ore on which a stope is being worked about 9 fathoms in length, and which is worth from 25 to 30cwt. of Lead Ore to the fathom. This is in whole Ground below, as the 142-fathom level has not been driven up to this point by 4 or 5 fathoms.

There are several other stopes in the various levels, but the whole of them, together with those to which I have referred, are being worked on "Tribute" at prices varying from £3 to £5 per ton of Ore, and there are many other places that could be worked at a profit with Ore selling at a fair average price. I may here remark that the stopes, to which I have referred, have yielded for some time past an average of 90 tons per month, and that this has been done without an inch of new ground being opened out, but if the deeper levels were extended, and the mine properly developed, I have no doubt that this quantity could be considerably increased. In order to secure this result, I would recommend that "Vaughan's" new perpendicular shaft should be completed and communicated with the old underlie shaft (of the same name) at the 90-fathom level, that this shaft be sunk for a new 154-fathom level as quickly as possible and simultaneously with the completing of the new part'.

To conserve water in periods of drought the usual practice allowed the bottoms temporarily to drown whilst continuing the upper workings. This at least maintained some output, albeit at the eventual time-consuming task of raising ore and waste accumulated in the meantime.

Large stopes tended to become dangerous if not supported, and at Frongoch waste the size of coarse sand from the dressing operations was channelled down through the workings in square pipes to fill the voids. This led to the death of John Lewis aged 27 on 24 November 1879 by suffocation from a sudden run in the 117 fathom level. Another accident, on 27 February

1880, due to a fall of ground after blasting, injured the back of David Jones aged 45. The poor man already suffered from curvature of the spine, 'the result of disease', and had not returned to work nearly a year later.⁷

In the summer of 1880 lack of water for pumping delayed exploration of the 154 fathom level until mid-August.⁸ A crosscut had proved the lode fully 60ft. wide, but reading between the lines it was better in the promise than the substance.⁹ A 10% dividend was shortly declared, with a good improvement worth 2 tons of lead ore per fathom in the north part of the lode at the 154 east of Vaughan's Shaft. Other levels in work included the 142 and 130 west of Vaughan's, (where the ground could scarcely be worked at a profit due to its hardness) the 56, 44, 34 and 24.¹⁰ Much blende was being raised, but at poor prices; in October 100 tons fetched only £3 7.9. per ton and 50 tons of poorer grade, £2 15.0. After deductions for mining, dressing, cartage and royalties little enough remained for profit.¹¹

The ordinary general meeting early in 1881 tried to disguise the truth with a further 10% dividend which could be ill afforded, whilst also issuing 1500 shares at £2 to raise some floating capital. Much was made of what profits might have been, had not prices continued to fall.¹² References to potential in depth had now ceased, the 154 having failed to meet predictions. However, it later improved and by the end of the year plans were afoot to go deeper. Practically every level in the mine was now at work with much ore revealed by further driveage and stripping down immense reserves of blende left by the Taylors.

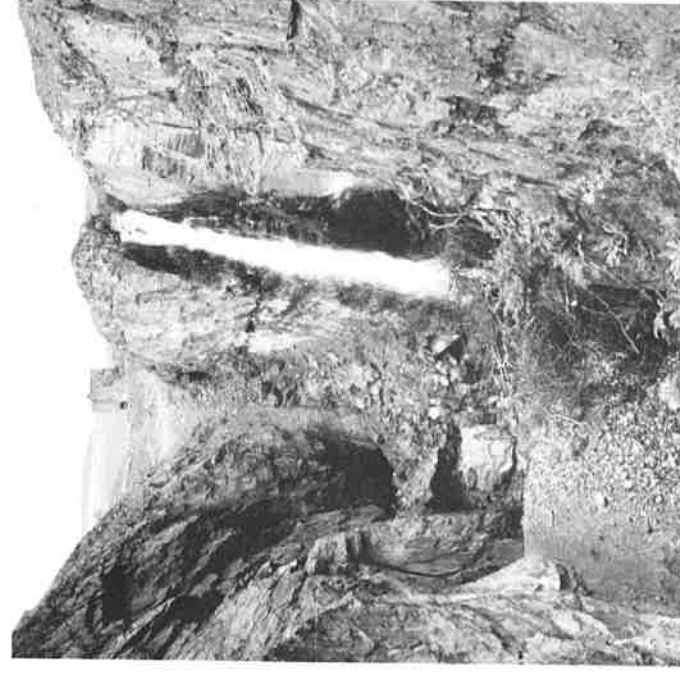
This was an exceptionally busy time for Kitto and his son Frederick, who were also managing many other mines in mid-Wales, and with nothing faster than a horse for transport. The family lived in some style with two servants at Vaeor Park, Llanidloes, and afterwards at Glandwr (now St. Idloes Church Hall).¹³

Unfortunately the hardness of the lode in depth, still worked by laborious hand-drilling, proved fatal. Prospects became bleak and further demands for cash faced shareholders at the 1883 general meeting. By 1885 things were no better, although good lead ore was reported in the 10 and 20 fathom levels east, and a new shaft was sinking from surface to the 24.¹⁴ But a few months later shortage of ready cash was so serious as to prevent development of new reserves. Some idea of the parlous state of the market was revealed from the current rates of blende – 100 tons at £2 17.9. per ton and 50 tons of lower grade at £1 12.6. Such prices could barely pay for stoping, far less all the other costs involved.

Towards the end of 1885 it appears the lease passed to John Kitto himself;¹⁵ regular reports to the mining press ceased, and with them much of our sources of information. But such were the resources of this renowned old mine that for a further decade ore returns hardly declined at all. Indeed, aided by a brief improvement in prices, 1888-91 yielded the highest values in the whole Kitto reign, 2850 tons of blende being sold in 1883. Judging from the tramways marked on the 1st edition 25 inch Ordnance map, much of the ore came from workings at the east end, where vast opencuts to this day revealing mineral bear testimony to the material removed. (See Plates VIII & IX)

By 1898 Kitto was approaching 70 years old, and after a hard life was no doubt ready for retirement. To what extent he gained financially from his 20 year stint is not recorded, but from the year 1879 to 1897 inclusive, sales of ore (less royalty) totalled £180,483. Wages and other expenses amounted to £157,091 leaving a profit of £23,392. The average price gained for blende was £3 6.0d. and galena £7 10.10d. Royalties (which were reduced to 1/30 in 1894) came to £8,170.¹⁷

Thus the blende years had not proved entirely unsuccessful. But for Kitto it was time to go, and time for a younger generation with new technology to show what it could do.



PLATES VIII & IX Two views of the opencut on the site, together with its spectacular waterfall. Through a hole near the bottom can be seen an inclined skip road in a blocked shaft and numerous stulls are in evidence. (R.H. Bird)

CHAPTER 4

FOREIGN ENTERPRISE

IT WAS SYMPTOMATIC OF THE INDUSTRY THAT AS LONG AS MONEY COULD BE FOUND, old mines were never allowed to die. Instead, they were kept alive or even resurrected by a series of financial injections, as though by some miracle the laws of economics might be reversed. Indeed, aided by the gullibility of investors, such promotions are not unknown in this country today.

Such were the circumstances behind the last great working of Frongoch. The company initially involved was a Belgian firm of lead smelters from Liege, the Société Anonyme Minière, and it leased Frongoch and Red Rock (Graiggoch) from 18 November 1898 for a period of 42 years. The annual rent was £230, together with a complicated royalty based on a sliding scale of market prices, which, with lead at £14 per ton, came to about 1/40 of the value of the ore.¹ In spite of a huge investment in modern machinery the venture proved a failure, and its course was recalled by the ex-manager, George Trefois, shortly after work ceased.

'The Plant (inherited from Kitto) was antiquated and worked only at a high cost. The Société Minière being satisfied from the reports of excellent experts that the property could yield very large quantities of a very good Zinc and Lead Ore, immediately started erecting a modern Plant to obtain a high output and reduce the working costs.

The principal Shafts were repaired and re-timbered, also the levels and footways. The previous Companies worked principally the east part of the Mine between Edwards' and Pryce's Shafts. They found there a very rich chute (sic) in which they sank down to 154 fathoms. This part of the Mine was considered as practically exhausted down to the 90 fathom level which was the deepest worked by the Société Minière. Therefore the first trials were made on the Eastern continuation of the lode : 400 fathoms of virgin ground remain before the boundary of the lease is reached. These trials led by a local Captain were made without the necessary push and perseverance. Efforts were spread on many points instead of concentrating on one, and it is true to say that this exploration Eastwards remains entirely to be done.

The price of metal at that time, 1896 – 1899, being very satisfactory, the Socété's immediate aim was to obtain a sufficient output to take advantage. This could be got best from the Western part; the old levels and passes gave a basis to open Blende stopes in a district where Lead only had been worked to some extent. The Western part between Vaughan Shaft and Boundary Shaft was immediately prepared, and stopes gradually started.



PLATE X The barracks at Frongoch, c 1900. The building was afterwards moved to Cwmystwyth. (S.J.S. Hughes)



PLATE XI A view down the incline to the new mill showing the bridge under the road. (R.H. Bird)

In the meantime there arose a good opportunity to purchase the neighbouring Mine, West Frongoch (Wemyss). The capital of the Société Minière being fully invested in other ventures – Rosas, Lakamody, Gra-Roubon, etc., the Frongoch Mine and Plant were sold (in 1899) to the Société Anonyme des Mines de Frongoch with a profit of £8,000. This latter Company purchased West Frongoch and continued working the West part of Frongoch. Till recently it can be said that practically all the crude Ore wound to the surface came from this district, about 35,000 tons. The working costs were low but the yield in concentrates was not high enough – slightly over ten per cent – and with the prices of metals which ruled then (1901 and 1902) it did not pay.

It was then resolved to try the pillars left in the North-East chute, and to open up the continuation of this chute between the 78 fathoms and 90 fathom levels. The yield was found to be very good: twenty to twenty-five percent of concentrates; but the working costs were high on account of the hardness of the ground. Three Gradner Electric Drills were tried, but did not give all the expected results. The installation of Air Drills was no doubt advisable, but the Société hesitated spending the necessary capital for this new Plant, and all work in the Mines was stopped in December 1902.

However, the Dressing Mill was kept going day and night with the dumps from the old Mine and this left a satisfactory margin of profit. A few men were kept prospecting in the 90 fathoms E. and the 66 fathoms W. and their discoveries altered favourably the prospects of the venture. But the Shareholders had definitely decided not to finance the undertaking any more, and put the Société in liquidation on the 15th June 1903. The Mill worked the dumps up to the 10th August. The Machinery and Plant were sold to Messrs. R.A. King & Company on the 20th November 1903.¹

Reading between the lines it was the old story bringing its inevitable conclusion, but nevertheless one which with better management and foresight might have been postponed.

The most remarkable feature concerned a wholesale replacement of plant and machinery by the latest electrically driven equipment, as is described in a later chapter. However, to what extent this investment actually reduced working costs, but at a time when compressed-air drills were being rapidly introduced elsewhere, such developments were strangely ignored.

Metal prices improved in 1898, but they held only for a year or two. Unfortunately production did not get into its stride until 1902, with 426 tons of lead ore and 2726 tons of blende, much of which, it appears, came from the old dumps.² Even so, Kitto had equalled or beaten these figures on several occasions, antiquated machinery notwithstanding. Indeed, in 1888 his output of 310 tons of lead ore and 2850 tons of blende had been achieved with a total labour force of only 147, including women³ – some 88 less than employed in 1902, as noticed below. Kitto himself died in 1903, and it was perhaps appropriate that the mine which he had struggled for 20 years to turn into profit, did not survive him.

In some respects the management seems to have gone out of its way to jeopardise the chances of success. The problems were much compounded by the cosmopolitan nature of the venture, involving Belgian capital, British, French and German machinery, and a Welsh and Italian labour force. The latter inevitably invited clashes of race and creed, to say nothing of language and communication difficulties. To the Italian miner, rural Cardiganshire at the turn of the century must have seemed as remote as the moon, and hardly more hospitable.

According to the late R.R. Nancarrow of Pontrhydgroes, the immigrants' arrival led to a 9 months strike, and on 24th November 1900 the *Mining Journal* reported: 'For the past week disturbances have taken place at the Frongoch lead mine, Aberystwyth, which is worked by a Belgian company. At these mines 250 Welshmen are employed with 200 Italians, and since the foreigners were imported there has been trouble. The disputes which have arisen during the past 10 days have been of a serious character, necessitating the presence of county police day and night, the tact of Chief-constable Evans alone keeping the Welsh miners in check. The managers were readily disposed to argue the question out, but the police were, nevertheless, compelled to guard the Italians to and from the mines.'⁴

In addition, on several Italians becoming unwell, alarm arose lest they should have unwittingly introduced ankylostomiasis, or miner's anaemia to the area.⁵ The Government Inspector, Dr. C.Le Neve Foster, submitted samples for bacteriological examination but the fears proved groundless. In the same report he commended the Belgian company for providing accommodation 'far ahead of that which prevails in some parts of Wales' – an allusion to men sleeping two in a bunk with straw for a mattress.

Other factors contributing to the mine's collapse were the erection of a 20 ton per hour mill without sufficient equipment underground to feed it, and inadequate sliming plant so that half the values were lost.⁶

Shortly before closure Thomas Garland of Laxey made a thorough inspection of the workings above the 90 fathom level, from which it was abundantly clear that precious little ore remained in sight. In his opinion the best prospects lay in trying the lode beyond disturbed ground east of the mine, but the advice was never carried out.⁷

However, the fundamental problem was the weakness of the market, and we can guess the response to this pathetic little advertisement that appeared in the *Mining Journal* for August 1903: 'Blende mine for sale in Wales, four miles from Station in steady working. Mineral of excellent quality. Well equipped with Ore Dressing machinery of latest type, all motivated by Waterpower.'

The period may be summarised as follows:⁸

Year	Numbers employed		Total	Ore Returns (tons)		Manager
	Surface	U/ground		Lead	Zinc	
1898	70	88	158	201	1649	Max Stegemann
1899	133	95	228	43	549	B. Nogara
1900	125	145	270	42	663	G.H. Trefois
1901	90	69	159	333	1739	"
1902	120	115	235	426	2726	"
1903	?	?	?	202	1453	"
				1,247	8,479	



PLATE XII The new mill at Wemyss Mine. (R.H. Bird)

CHAPTER 5

SCRAPING THE BARREL

THE FINAL CHAPTER HARDLY CONCERNS MINING AS SUCH. IT IS IN GREAT MEASURE THE story of how the enormous waste-dumps were removed and treated for lead and zinc which hitherto had been deemed scarcely worth the cost of recovery. Although this development did not begin until the demand for metals rose during the First World War, the company involved was the Lisburne Development Syndicate, formed in 1907.

The Syndicate began operations at Glogfawr, where a practically virgin north lode was profitably exploited.¹ The manager was R.R. Nancarrow, who at the age of 24 supervised construction of the Davey Shaft by simultaneously rising from the 90 fathom level (Level Fawr) and sinking from surface.² Such a project called for the utmost precision in surveying under difficult conditions, and its successful outcome confounded the sceptics, who numbered the great majority.

By 1917 the Glogfawr north lode was almost worked out, and the company turned to Gwaithgoch in the Ystwyth valley south of Frongoch.³ Blende and galena were fetching excellent prices, and good ore was reported in winzes sunk below No.3 level, to be worked by a projected deep adit. The Frongoch dumps also attracted attention, and the Lisburne Development Syndicate proposed an aerial ropeway from thence to the Gwaithgoch Mill, to which a long timber bridge over the River Ystwyth would give access. Nancarrow planned the whole operation, including a new leat to convey the waters of the river to a turbine at the mill. In September 1919 William Thomas, late head of the mining department of the Camborne School of Mines, reported as follows:⁴

A scheme for working GWAITH-GOCH MINE had been prepared before the national necessity arose for the increase of home production of zinc and lead ores to meet war requirements. That necessity, together with your acquisition of FRONGOCH DUMPS made it desirable to amend the original GWAITH-GOCH scheme. This has been done.

The FRONGOCH DUMPS contain about 150,000 tons of lodestuff, which will pay handsomely for treatment at present prices for zinc and lead, the average dump contents having been ascertained to run 5% blende with One ton of galena per 10 tons of blende. These dumps accumulated in the earlier part of the last century, when FRONGOCH was a rich lead mine and blende was thrown aside as waste.

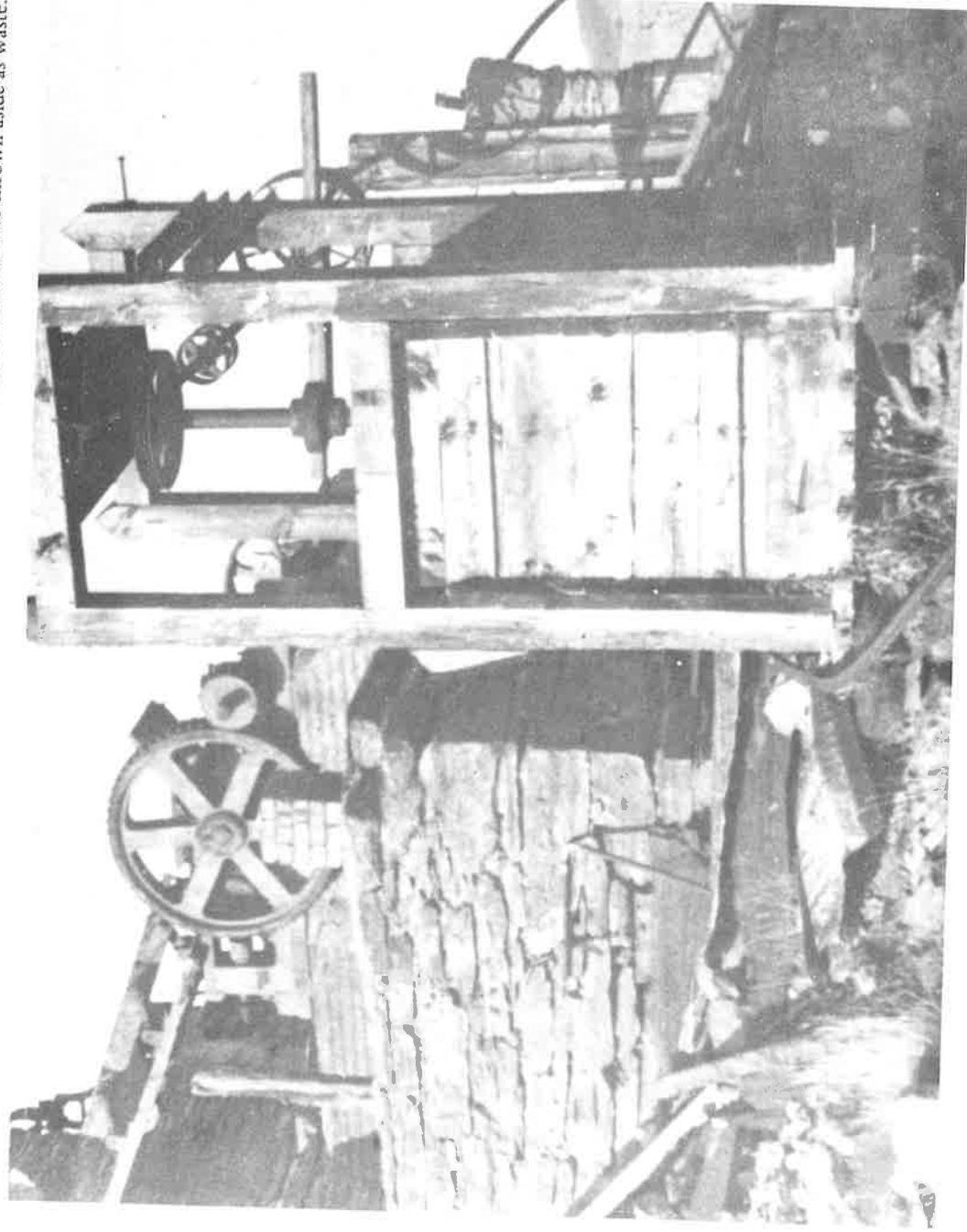


PLATE XIII Flotation cells near Vaughan's New Shaft C 1958 (S.J.S. Hughes)

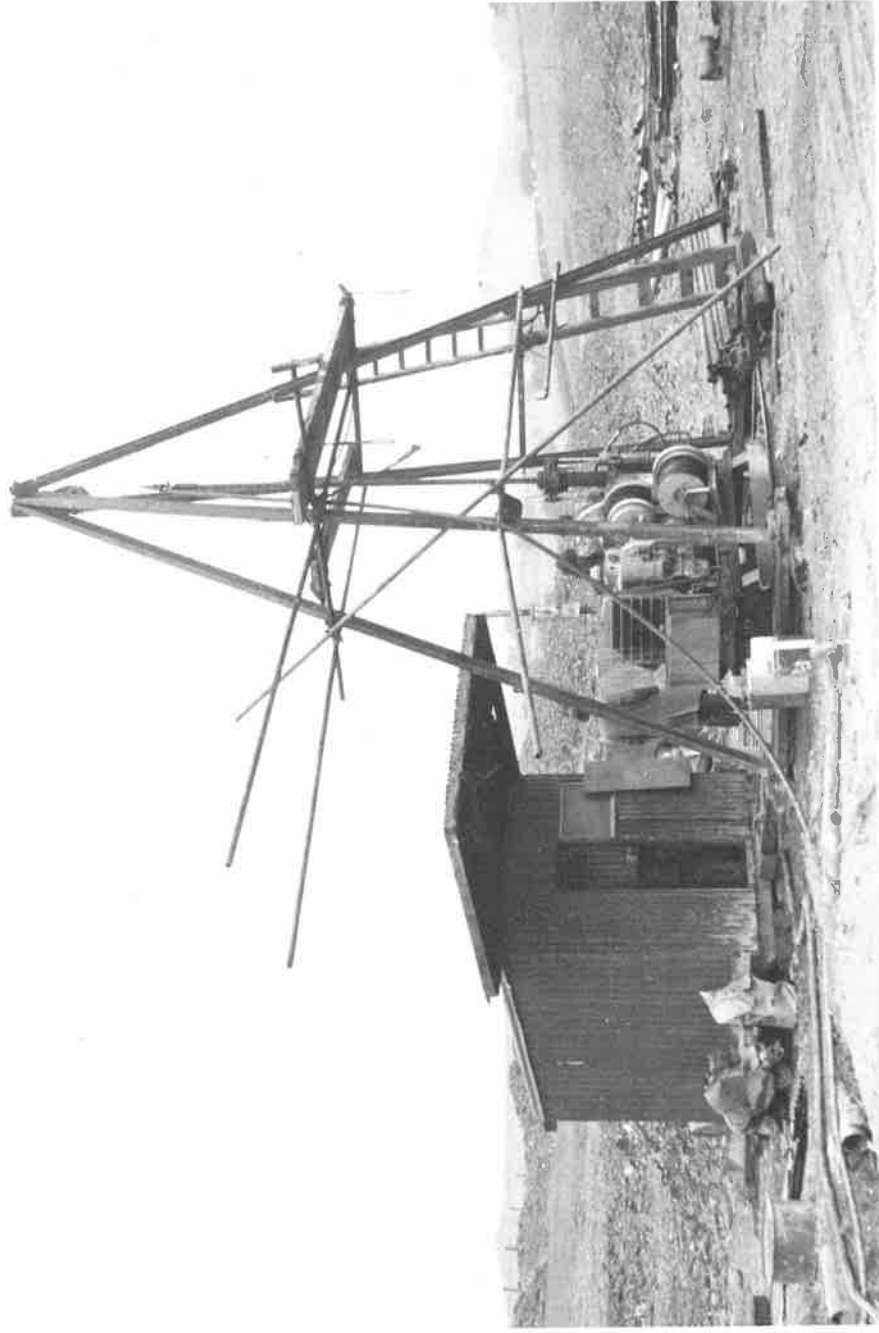


PLATE XIV August, 1971. A borehole put down to a depth of over 800ft. proved little mineralization. (David Bick)

An aerial Ropeway has been constructed from FRONGOCH to GWAITH-GOCH mill-site, a distance of 3,050 yards. The mill house has been erected and concrete foundations practically completed for a well designed crushing and dressing plant which is ready for immediate delivery.

At the present time about £12 per ton is obtainable for blende concentrates of 50% zinc. At this price and with a recovery of 85%, ensured by the inclusion in the dressing plant of an efficient floatation unit as proposed, the dumps will yield a profit of between £40,000 and £50,000 under existing conditions and calculating for current rate of labour and prices of materials.

A Dam 28 feet high by 120 feet in length at the top has been built across the YSTWYTH RIVER and a water-course 2,400 yards in length, is under construction. This will convey a sufficient volume of water from the Dam to provide 200 b.h.p. by means of a turbine near the mill site. In addition to providing the necessary power for crushing and dressing, the turbine will also suffice for pumping, hoisting and indeed for all power demands at GWAITH-GOCH MINE. I have carefully examined all the details of the scheme and am satisfied that it meets all the requirements of the case.

In the winter of 1919/20 control passed to a new company, the Welsh Mines Corporation Ltd., with the Earl of Lisburne as chairman and Nancarrow as general manager. It acquired mineral rights over 2,500 acres including Gwaithgoch and the Frongoch dumps, and a year later a correspondent of the mining press described the operations.⁵

'At Frongoch two reservoir pools are a source of power for the Pelton wheel which drives the mechanical haulage and the machinery at the sorting station. The lode-stuff from the dumps is raised into a portable bin by a 'Priestman' steam crane grab, from whence it is conveyed by a mechanical haulage to the elevated sorting station, which is equipped with storage bins having a total capacity of 240 tons. At this sorting station a large portion of the debris is discarded and the mineral conveyed by means of a ropeway (of Messrs. Ropeways, London) to the mill. The ropeway has a maximum capacity of 15 tons per hour and extends across valleys and down mountain-sides, constituting a most interesting and picturesque sight. Of the buckets that pass along this ropeway, at the time of our correspondent's visit, 66 were operating, each holding about 3 cwt. On arrival at the mill, the ore is dumped into storage bins. The mill itself is of modern construction and is capable of treating about 7½ tons per hour. It is contained in a building where everything has been arranged for the utmost economy in treating the produce. The ore, passing down through various stages of sizing, crushing, classifying, separation and concentrating, is untouched by hand from the moment it enters the stonebreaker until the dressed mineral is weighed.'⁶

Unfortunately the plant was not ready for production before metal prices fell upon release of government stock-piles after the war. Blende became virtually unsaleable and it was therefore decided to produce metallic zinc on the spot by means of electrolysis. The process had been developed within the past few years, and was not without its teething troubles. Attempts to obtain a loan under the Trade Facilities Act met with a very guarded response from a consultant, and it does not appear the idea came to fruition.⁷

In 1923 the Lisburne Development Syndicate and the Welsh Mines Corporation amalgamated under the control of the Cambrian Electrolytic Zinc Co. and Nancarrow continued as manager. Treatment of the dumps began but prices had not recovered sufficiently, and the Debenture Holders put the new company into the hands of the Receiver. The assets were sold to the Western Mining Co. and production continued until low prices forced a final suspension. According to Nancarrow from 1924 to 1930 over 51,000 tons of low grade lead/zinc ores from Frongoch dumps were treated by flotation, yielding some 6,000 tons of blende and 600 tons of galena concentrates.⁸

In 1929 Nancarrow re-examined Frongoch above adit level.⁹ Some twenty years afterwards, the late Mr. Dandrick of Cwm Rheidol acquired the Lisburne mineral rights and set up a small dressing plant near the New Vaughan Shaft for blende concentration. He commenced a level from the shaft about 60 feet down towards the lode, but it does not appear that these endeavours led to any production. Since then, depressed prices and other factors discouraged further attempts, although a deep borehole was drilled in 1971.

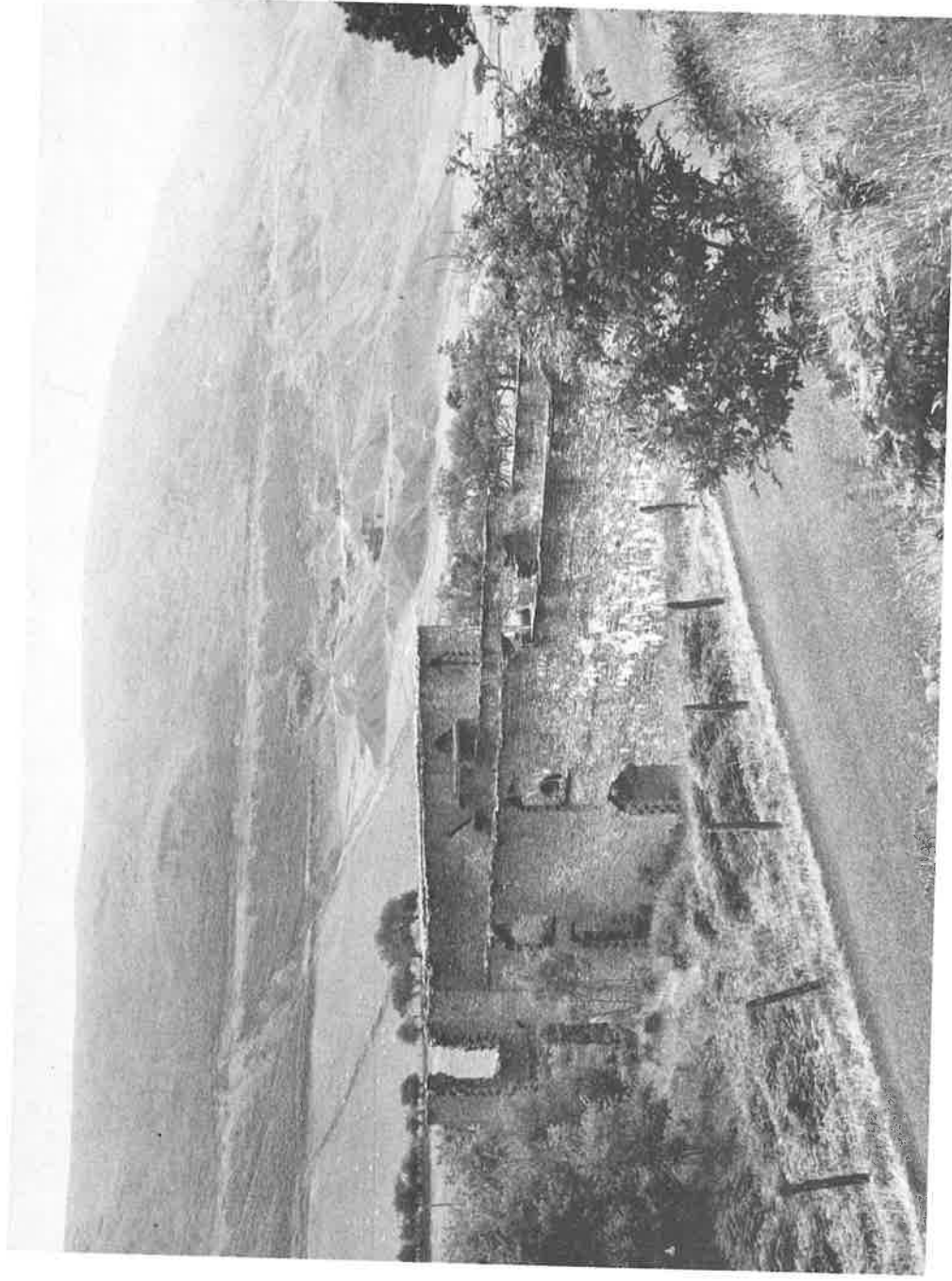


PLATE XV The Generating Station, with Red Rock Mine and the leat from Wemyss in the background. (R.H. Bird)

PLANT AND MACHINERY

*Tramlines, slag heaps and pieces of machinery,
That was, and still is, my ideal scenery.*

W.H. Auden

MORE THAN A CENTURY OF ALMOST CONTINUOUS ACTIVITY WITNESSED COUNTLESS changes and modifications to the machinery, to say nothing of numerous developments of an experimental nature. From rudimentary beginnings almost every phase of mining technology was passed through, culminating in the latest state of electrical power engineering at the close of the 19th century.

Pumping burdens nearly every mine, but unfortunately those in the clay-slate rocks of Wales were not generally very wet. Provided surface water was excluded as far as possible, small workings could reach considerable depths by manual pumping alone, or by raising water in a barrel with the ubiquitous horse-whim. Nevertheless, such was only achieved by relentless and often exhausting labour, which may be better appreciated by the realization that a flow of no more than a kitchen tap amounts to 15 or 20 tons in weight every 24 hours.

At Frongoch it appears these primitive methods sufficed until the Williams era, 1825-34, for no mention has been found of an engine-shaft or any form of mechanical pumping before that time.

But however detrimental water proved below ground, its presence above was indispensable. Waterwheels were common in nearly every Welsh mining district, and fed by long leats from storage ponds were the equivalent of the modern electric motor and grid system.

Unfortunately, being placed on a plateau, Frongoch was poorly situated. The small catchment area set a definite limit on the power attainable no matter how many storage ponds might be constructed, and proved a major restriction on the rate of output. Theoretically at least, the ample headwaters of the Mynach east of Devil's Bridge could have been brought to the mine, and in view of Taylors' long leats elsewhere, one wonders why it was never done.

An early reference to waterpower occurred in June 1795, when John Lowe wrote: "The Stamps are quite at a stand owing to the scarcity of water occasioned by the present Drought. Most of the Springs are quite dry...."¹ It was a cry endlessly repeated. When John Taylor & Sons took over in 1834, the mine was drained by a 40ft. waterwheel and it was prophesied that a new reservoir would render an adequate supply for all seasons. Hitherto, with regard to crushing the ore, there is little doubt that stamps had provided the only mechanized means. But although more effective than manual methods, stamps tend to produce an excessive amount of fines. Taylor had introduced crushing-rolls to his lead mines elsewhere, being better adapted for the primary treatment of such ores.² Rolls were soon at work at Frongoch, for Absalom Francis wrote from Halkyn to his nephew Matthew on 31st January 1838: "I have noticed your sketch for decreasing the speed of the Frongoch rollers and will order the necessary things to be sent with the next vessel direct from this place to Aberystwyth."³

Within a year or two water shortage was again apparent. Steam seemed the only solution, and from his experience in Cornwall Taylor determined to introduce it here. In April 1841 he wrote informing his manager Matthew Francis of the appointment of James Morcom as engineer to his Cardiganshire mines. "Your uncle (Absalom Francis of Flintshire) has recommended him strongly...I suppose his principle attention will be directed to the erection of the Frongoch Engine..." The machinery came by coaster from Taylor's Rhydymwyn foundry in Flintshire.

In the Lisburne Mines report for June 1841, shareholders were informed of the new development and must have learned with some surprise that the engine was to pump water from adit-level for re-circulation over the waterwheels – an application reverting a century to the days of Thomas Newcomen.⁴ But although inefficient it could be simply applied, and short of drastically re-designing the plant, nothing else was feasible.

The total fall over the wheels amounted to 16 fathoms or nearly one hundred feet. They comprised two for pumping, 44 and 20ft. diameter, and one for a crusher and jiggling machine, 18ft. diameter. A special shaft, the exact site of which is now uncertain, was sunk from surface to adit to accommodate a lift of 24 inch diameter pumps for the purpose.

In April 1842 it was admitted that the cost of the engine and its erection had involved an overall loss of £3,246 on the year's working. Great benefits were needed to justify such an outlay, but were not forthcoming. After only a few years of occasional use the experiment was abandoned with the 40in. x 9ft. stroke engine advertised in February 1847 for £650, with boilers extra at £12 per ton.

Within a few months Frongoch was once more inundated, and the deserted enginehouse prompted an embarrassing correspondence in the *Mining Journal*. One contributor volunteered the information that an hydraulic engine was shortly to be applied, and since it is known that a double-cylinder Darlington water-pressure machine was installed at one of the Lisburne mines, we may suspect its site was Frongoch.⁵ In confirmation the deep adit communicated with the 24 fathom level about this time, rendering the fall from surface quite sufficient to work such a machine.

At all events, interruptions continued. After a visit in 1860 the French engineer Louis Moissenet wrote: "The motive power of the Lisburne mines is entirely hydraulic, an almost vital condition in a locality where coal costs 25 shillings per ton...At Frongoch to guard against want of water, recourse has been had to vast reservoirs; the principle wheel is used for pumping; it is not less than 55ft. diameter

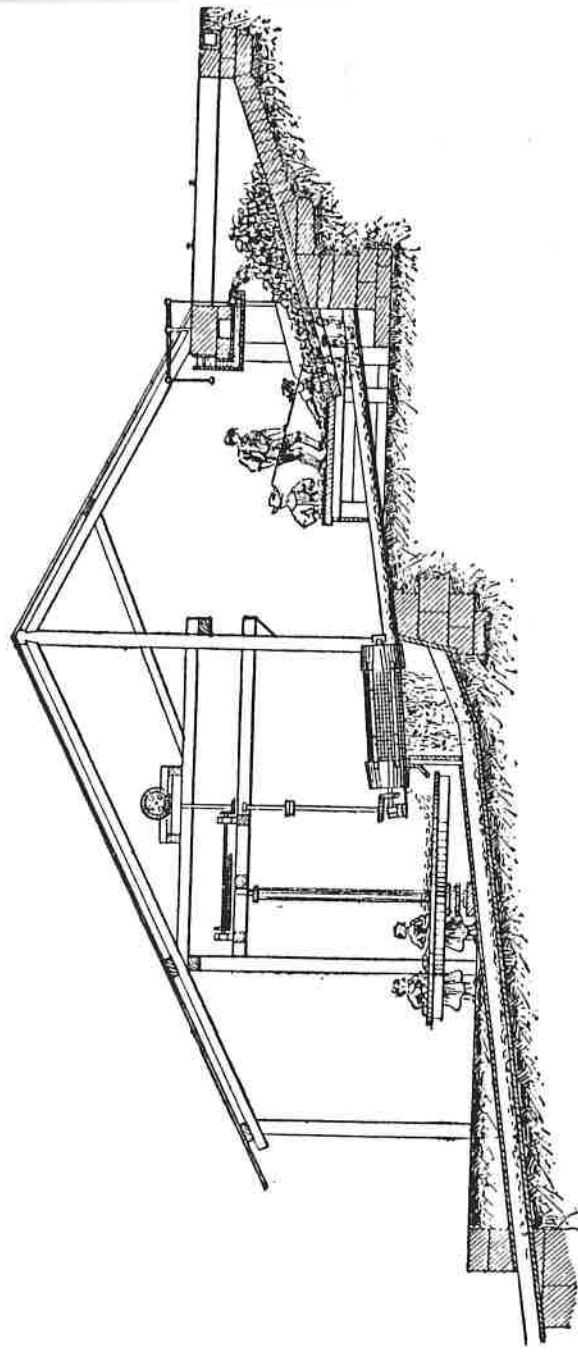
and 4ft. 6 inches wide, and estimated at 60 horse power..." The reservoirs included the old ones in the valley above Frongoch, and two big ponds hidden away in the hills to the north-west, Rhos-rhydd and Glan-Dwgan.

When the Kinnaird Commission took evidence in July 1863 Frongoch was again idle, with the desperate remedy of steam once more in contemplation. In the summer of 1867 the railway station opened at Crosswood, only 4 miles from the mine. The prospect of cheaper coal may well have swung the balance, for two engines were erected, one being a 60 inch x 11ft. stroke for pumping at Engine Shaft, the other a 25 inch rotative for drawing (winding) and crushing at Taylor's Shaft.⁶ The 60 inch engine came from Sandicroft Foundry and the large heap of grass-grown cinders, still extant, testifies to its labours over the years.

In this decade we have Moissenet's detailed description of the dressing floors and there is no doubt that this complex plant represented the best technology of the time.

When new management took over Frongoch in 1878 extensive changes followed; the plant and equipment it inherited is given in detail by an inventory accompanying the new lease.⁷ Although somewhat garbled it is reproduced in full, and incidentally gives a good impression of the scale of operations.

FIG 7 On the dressing floors, C 1880. A wash-kiln, sizing trommel and hand-sorting or picking table. (R. Hunt)



SCHEDULE

One 30' x 3' 6" waterwheel, one 56' x 5' waterwheel with crank and balance-bob. One 26' x 7' waterwheel, drawing-machine to ditto. One 20' x 3' waterwheel, crusher to ditto. One 20' x 2' waterwheel, rock-breaker and gearing to ditto. One 12' x 2' waterwheel (undershot) driving three riddles and round tables and including shafts and gearing. Two waterwheels for driving collieries jiggers and coal rake. One 30' x 3' old waterwheel, drawing-machine attached. Six small waterwheels on the flooring and at Smith's shop. One 14' x 14" waterwheel, 3 collars (collieries?) jiggers with gearing, one coal rake ditto, two Zennor buddles ditto, 9 round buddles ditto, six hand-jiggers. Crushing-mill connected to steam engine, drawing-machine ditto. Sheds throughout the mine, three shaft tackles, five pulleys, timber etc.

One shears at the pumping-engine, two balance-bobs, 220 fathoms 9/16 chain 18lbs per fathom 2 tons, 150 fathoms 1 1/8" wire rope 9lbs per fathom 11cwt, 100 fathoms estimated of another piece 12 cwt. 252 fathoms 3 inch round iron rods 143lbs per fathom 16 tons, 120 fathoms 2 inch rod, 63lbs per fathom 3 1/2 tons. Pulleys and stands under rods say 60 in number, pulleys 1 1/4 each 75 lbs, woodwork £20. Pulley stands under chain and wire rope say 120 fathoms, lines 20 stands pulleys 12 cwt woodwork £10. Pulley-stands, weighbridge, smith's shop, two bellows, anvils, tools say 10 cwt. Rails at surface including pond 810 fathoms double 16lbs per yard 23 tons. Rails underground 1,850 fathoms single, 3630 double at 16lbs per yard 50 tons, old scrap and cast-iron, worn out pit-work, old chains, iron in balance-boxes etc say 45 tons, a number of tram wagons at surface and underground.

In shafts — Vaughan's (Taylor's)

One 8" bucket lift 12 fathoms long say 3 tons, one 10" plunger lift 23 fathoms long say 9 tons, one spare 9" bucket lift 12 fathoms long, 23 fathoms or 138 foot run of 8" square rods say 60 feet cube, strapping plates and connections to ditto 10 cwt iron, other things, round iron rods to surface 1 1/2" to 2 1/2" say 2 1/2 tons, balance and angle-bobs, skip-road 6 inches and 5 inches, from bottom of Vaughans shaft to surface 160 fathoms say 420 feet cube.

Engine Shaft

From the 56 fathom level to the 24 fathom level 16" plunger lift 32 fathoms long 21 pipes each 9ft long 336 cwts, plunger case 16 cwts add 'H' piece and say 20 tons. From the 90 fathom level to the 56 fathom level 15" plunger lift 31 fathoms long, 21 pipes at 15cwts each and other parts say 18 tons. From the 117 fathom level to the 90 fathom level 12" plunger lift 28 fathoms long, 19 pipes at 12 cwts each with plunger case say 13 tons.

52 fathoms or 312ft 14" square rods	424 cu.ft.
31 fathoms or 186ft 12" square rods	186 cu.ft.
52 fathoms other rods to surface	312 cu.ft.
28 fathoms or 168ft 10" square rods	116 cu.ft.
	1,038 cu.ft.

Strapping plates, bobs etc say 6 tons, balance bob at 44 fathom level, fend-off bobs etc, skip-road from 90 fathom level to surface say 120 fathoms or 720 feet, 300 fathoms (computed) of ladders. At surface, pipes about sufficient to make up 2 lifts at 15 fathoms each.

Steam Engines

One 60" cylinder pumping engine with 2 boilers, one 25" cylinder drawing and crushing engine and 1 boiler, sundries reservoirs sluices, leats etc.

The inventory gives rise to queries such as the purpose of 'collieries jiggers and coal rake' but also throws light on the pumping arrangements and machinery. It appears that 8 and 10 inch pumps in Vaughan's (Taylor's) Shaft raised water from the bottoms only about 35 fathoms, from whence the larger steam pumps at Engine Shaft brought it to the adit or 24 fathom level, together with water from the upper parts of the mine. Thus even with steam, in times of drought the workings could only be kept dry down to the 105.

Of the waterwheels the 26ft. example working a drawing machine (winding drum) calls for comment, being of no less than 7ft. breast. Such a width implies an unusually large flow of water, which in turn suggests re-circulation by some means or another, akin to the experiments with steam in 1841. The 56ft. wheel was at Wemyss, west of the road, to which a long and circuitous leat conveyed water from the dressing floors. It presumably replaced the 55ft. wheel recorded by Moissenet, and the impressive wheelpit still survives. (See Plate VI)

One of John Kitto's first moves was to fix a line of rods from the Wemyss wheel to Vaughan's New Shaft. By June 1879, he had applied 24 inch pumps to recirculate water over the wheel, apparently as a kind of perpetual motion device, but one which nevertheless was reported to work exceedingly well.⁸

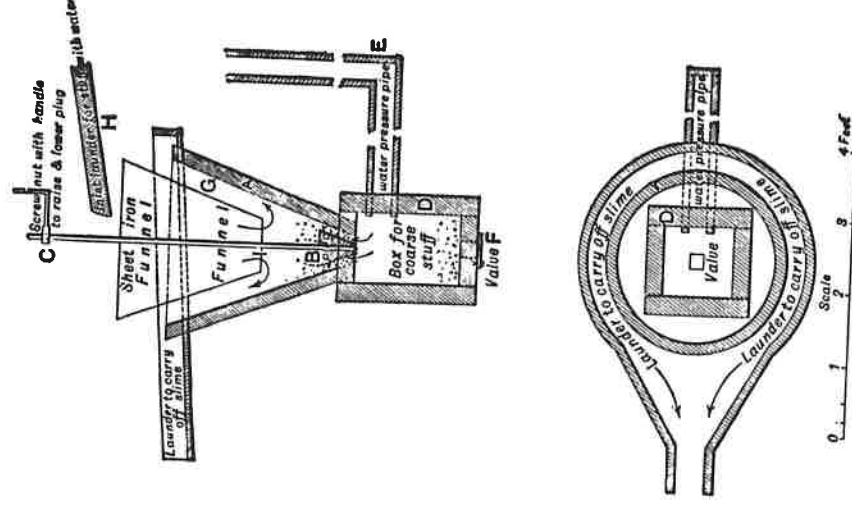
Winding arrangements at Frongoch had advanced a long way from the horse-whim and kibble, but via Richard Trevithick one of Kitto's improvements is directly traceable to that time-honoured machine. Robert Hunt relates an amusing tale from the early years of the 19th Century when Trevithick constructed a much larger kibble for the new steam whims. The winding wheels were raised so that the kibble might go higher, whereupon the landing-man exclaimed, 'I wonder who is going to land them big kibbles, I shan't land them.' Captain Trevithick replied 'Can't you wait a bit?' When it was all complete the kibble did not need landing. It turned upside down, and the stuff fell directly into the wagon.⁹ The system was not however, entirely automatic.

Vaughan's New Shaft was completed to the 154 fathom level by the summer of 1879, the last 64 fathoms extending the old shaft which followed the dip of the lode. It was fitted with a double skip, this being a box-like vessel running on wooden guide-rails. To develop Trevithick's ideas further, the rope was not fixed to the top of the skip but to the bottom, which together with an ingenious geometry of the guide-rails in the head-frame, enabled the skip automatically to invert itself, and discharge. According to Le Neve Foster, this simple and elegant device was due to Captains Kitto, Paul and Nancarrow.

To make the best returns from blende which Messrs Taylor had in great measure ignored, revision of ore-dressing practice was essential,¹² and we are fortunate in having detailed descriptions of some of new plant. The run-of-mine ore was sized as previously by means of gratings and trommels, and girls using revolving picking-tables separated the material by hand into three sorts – 1. Pure blende and galena. 2. A mixture of blende, galena and rock. 3. Waste rock. An illustration of the building and plant is appended.¹³ (See Fig 7)

The fine material went straight to the jiggers, – the larger sizes being put through crushing-rolls and further graded by another ingenious device called a Separator.¹⁴ In the diagram, (Fig 8) water under pressure flowed up from the box D into the conical chamber A, into which the launder H conveyed the product from the crusher. The upward current carried the light and fine material away, the coarse and heavy constituents sinking and being removed through the valve F. The jigger for separating galena, blende and waste rock comprised an oblong box in which a wooden board acting as a piston moved on a horizontal axis between two compartments.¹⁵ The motion came from a crank driven by a waterwheel, and the device worked in somewhat similar principle to the separator. Whether Kitto and his colleagues also devised these appliances is an interesting question, and probably with an affirmative answer.

FIG 8 A separating table C 1890 (C Le Neve Foster)



But the limitations of waterpower were still very much apparent, both engines again being reported in steam at the 1881 AGM.¹⁶ In a further attempt at salvation Kitto erected another big wheel for winding, if not for pumping also. It was located alongside a big disused crusher-house and above Orebreaker Shaft and worked a drawing-machine with a 5ft. diameter drum via spur gears and belts. From the 1904 sale catalogue Orebreaker Shaft had a wooden headframe with 7ft. diameter sheave, apparently worked from the above drum, which however was by no means aligned on it. (See Front Cover). Presumably the ropes passed round pulleys in a horizontal plane to change their direction nearly 90° – an unusual arrangement. The new wheel called for a greater head of water and the leat system was altered to provide it.¹⁰

The next major change in the plant and machinery was as imaginative as it proved misguided. On taking over Frongoch in 1898 the Soci   Anonyme Mini  re determined to grasp the nettle with a strong, not to say fatal, dose of modern technology. Under a young Italian electrical engineer named Nogara,¹⁷ the old waterworks were ruthlessly supplanted by electric motors energised from a cathedral-like power-station a mile to the west. It contained a 2300 volt A.E.G. alternator driven by a 400 h.p. Escher-Wyss Pelton Wheel operating under a 400ft. head and supplied by three existing reservoirs. One of these was the old Frongoch Pool, and 3 miles of leat were dug to convey its waters to the small header pond high above the power-station. But in the event of drought the expedient of a 360 h.p. Willans & Robinson 6 cylinder compound steam engine complete with Babcock & Wilcox boilers was also provided.¹⁸ The more things changed, the more they stayed the same.

New dressing-floors were built at Wemyss mine, and fed from Vaughan's New Shaft by half-a-mile of chain-operated tramway which passed under the road in a cutting. In essentials, the mill comprised two stone-breakers, crushing rolls 30 x 16 inch by Green of Aberystwyth and 21 x 12 inches by Krom. There were also numerous trommels and elevators, 16 jigs by Green and sundry vanners and other plant too numerous to itemize. Various electric motors had marble switch-boards and liquid starting resistances,¹⁹ some of the smaller machines being run on 220 volts via a transformer.

Similar extravagance applied at the mine, where at Vaughan's New Shaft Fraser & Chalmers erected a 60ft. high lattice-girder headframe with 8ft. diameter sheaves. A corrugated-iron shed housed a 125 h.p. motor by Pinette of Chalons-sur-Saone with gear reductions to the winding drum. It is not without a certain dry amusement to record that in the midst of all the latest technology, one spur-wheel had cogs of apple-wood, with ample spares provided, in the best tradition of the medieval mill-wright. There were also 80 h.p. and 75 h.p. motors by A.E.G. and a 30 h.p. for winding at Edwards' Shaft. The mine never worked below the 90 fathom level, from which depth an underground electrically driven pump operated. However, according to a report by John Mitchell, towards the end it was relieved of its duty by an old-fashioned waterwheel.²⁰ Truly the wheel of destiny had turned full circle.

FIG 9 Frongoch electrical circuit, 1901 (E.H. Davies)

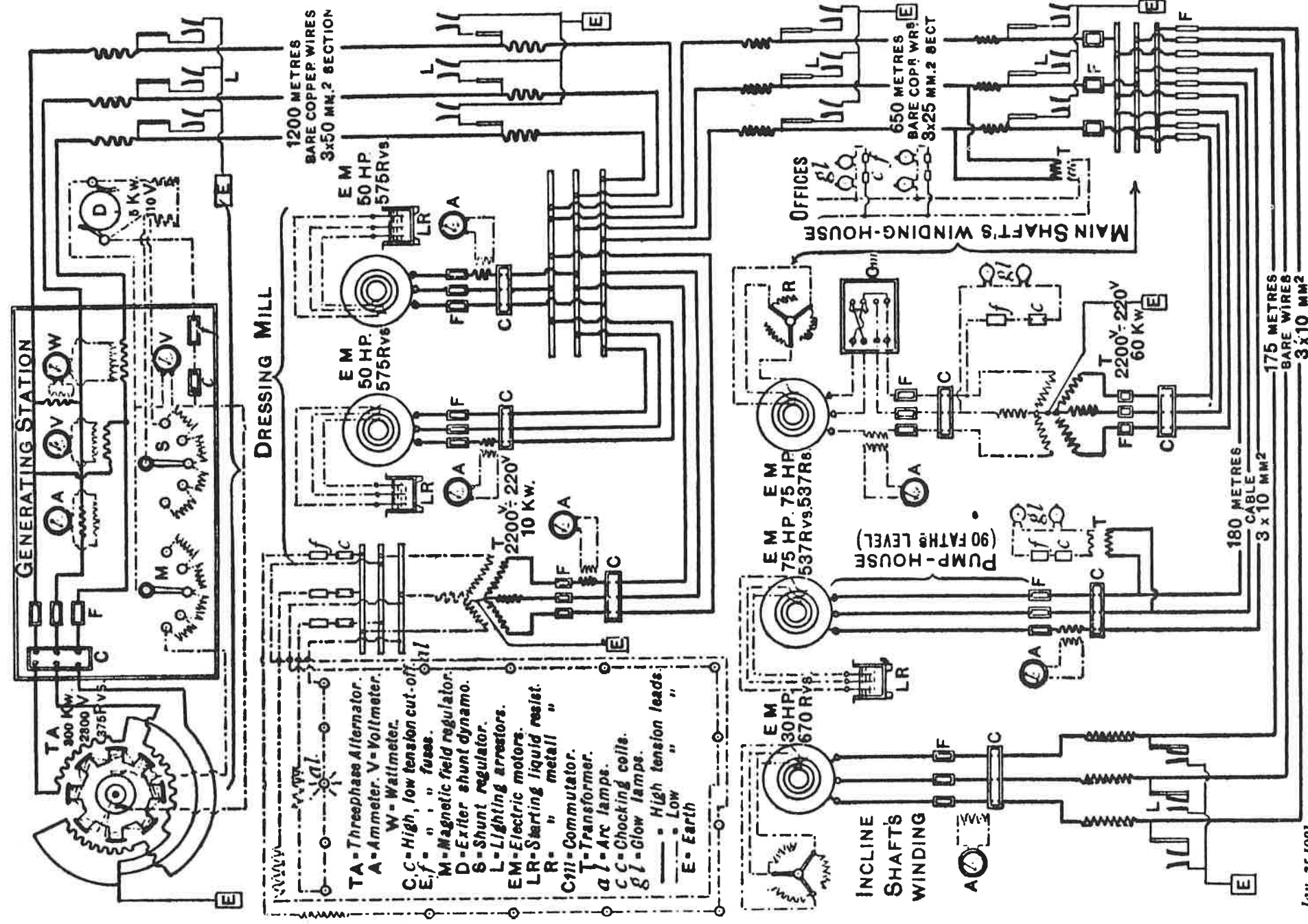




PLATE XVI Inside the Generating Station (R.H. Bird)

As to the total cost of the plant and machinery there are conflicting accounts. E.H. Davies, a well-known mining engineer and a friend of Nogara, put the figure at £10,000.²¹ Mitchell quoted £45,000 – a much more probable sum, though even this may not have included labour. At all events, the five-day sale in 1904 recouped but a tiny fraction of the capital invested.

In view of the electrification the waterwheels at Frongoch must in general have been redundant for years, and from the 51 page catalogue the list appended below makes an illuminating comparison with that of 1878.

1878	1904
56 x 5ft. Pumping	50 x 4ft. Drawing
30 x 3ft. 6in.	29 x 3ft. 6in.
30 x 3ft. Drawing	26 x 6ft. Drawing
26 x 7ft. Drawing	12 x 1 Blacksmith's Shop
20 x 3ft. Crushing	2 unspecified
20 x 2ft. Rockbreaker	
14 x 14ins.	
12 x 2ft. undershot	
8 unspecified	

It appears that apart from the 26 x 6ft. example which may equate with the 26 x 7ft. of 1878, not a single wheel from the earlier period had survived. Furthermore, the altered range of diameters suggests not so much a replacement of old by new, but a thorough re-design of layout and surface arrangements during the Kitto period. This is confirmed by the layout of the mine-buildings.

Also sold was a brand-new pitchpine headframe at Ball's Shaft, 'cut, jointed and partly framed, but never erected.' At the offices could be bought an 8 day clock in a mahogany case, and a miner's dial. Altogether a pathetic end to a brave but misguided venture.

PART 2

INDUSTRIAL ARCHAEOLOGY

GENERAL DESCRIPTION

The continuous development of the site, culminating in the wholesale removal of much of the waste for re-processing, has meant that there is a very complicated palimpsest of remains. Most of the standing buildings are along the higher ground to the north-west of the dressing-floors; but from beneath the tipped rubble emerge walls and other structures, most of which can be identified.

Very little can now be recognised of the mine before the Taylors acquired it. There was an 'old engine shaft', which presumably retained its name thereafter, and a pumping wheel (the location of which is uncertain) powered by water from at least two reservoirs.

The fifty years of working by the Taylors enlarged the workings very considerably, and most of the visible remains date from their period. Individual structures can be dated by reference to maps, to the known history, and occasionally by internal phasing within a building.

The earliest depiction appears to be the Tithe Award map of 1847. This shows the engine-house of 1841, a building to the south-west (perhaps next to Engine Shaft), the office with two smaller structures to the north-west, and another building further to the south-west in a plot described as 'Cae Gwaith Mwyn and Buildings'; it was listed as being under pasture. Above the buildings was a long leat, terminating in a possible water-wheel close to the location of Engine Shaft, and with a second branch ending just south-west of the engine-house.

Moissenet described the workings in great detail in 1860, and his plans are of considerable accuracy (see fig. 17). He stated that two shafts were sunk below the 143m (78 fathom) level: on his plan only Pryse's Shaft and Taylor's Shaft are indicated, both evidently productive since tramways ran from them to the dressing mills. The mills took advantage of the slope of the ground so that the spillway of one water-wheel either fed the next wheel in the sequence or provided water for the various buddles and separators.

By 1878 there had been considerable change again: the scale of this is apparent from the list of machinery in the inventory of that year (see p. 26) and from the OS 25" map of 1885 which shows the enlarged dressing mills. However it is equally clear that many of the new buildings must have been insubstantial (like so many contemporary mine-buildings elsewhere), since by 1904 they had been removed and almost no trace now remains.

60 inch PUMPING ENGINE HOUSE

The most spectacular building remaining on the site, the engine house was built c.1870 to house a Cornish beam-engine with a 60" cylinder and 11ft. stroke built by the Sandycroft Foundry (Flintshire). The date of purchase is unknown, but it is probably soon after the opening of the railway to Trawscroed since without the railway neither cheap coal nor cheap bricks would have been readily available so far inland. The engine was probably dismantled after the sale of 1904: in the catalogue it was described as having a double cast-iron beam and a 36ft. spear-rod. The eastern half of the engine house has collapsed, but the remainder (including the stone and brick chimney stack) survives to its full height. Adjacent is the boiler house for the two 36ft. by 7ft. Lancashire boilers, and a coal store. The pump-rod remains in the shaft: to either side is a balance-bob pit. That to the west is the original one: when the shaft was deepened and the weight of the pump-rods increased a second pit was devised, angled so as to clear the existing outlet culvert and to avoid weakening the foundations of the building.

Structurally the engine house is in several phases, although clearly it was designed as a single unit. The chimney is constructed of large blocks of rubble, and although the quoins are only dressed above roof-level it is obvious that the rest of the building was added to it. Presumably the free-standing chimney was built first, then the rest of the engine house constructed around the engine itself. The south-east facade (the bob-wall) is faced with large rubble blocks more or less well dressed, clearly for effect. The top of the chimney is built in yellow brick. Beam-slots and the scar of a stair-way indicate the basic internal arrangements.

The boiler house was added, using altogether smaller rubble for the walls. The scar of its very peculiar hipped roof is still visible. Added again is the wall of the coal store, in the same sort of masonry as the boiler house.

25 inch STEAM WINDER & CRUSHER (south-east of the dressing mills)

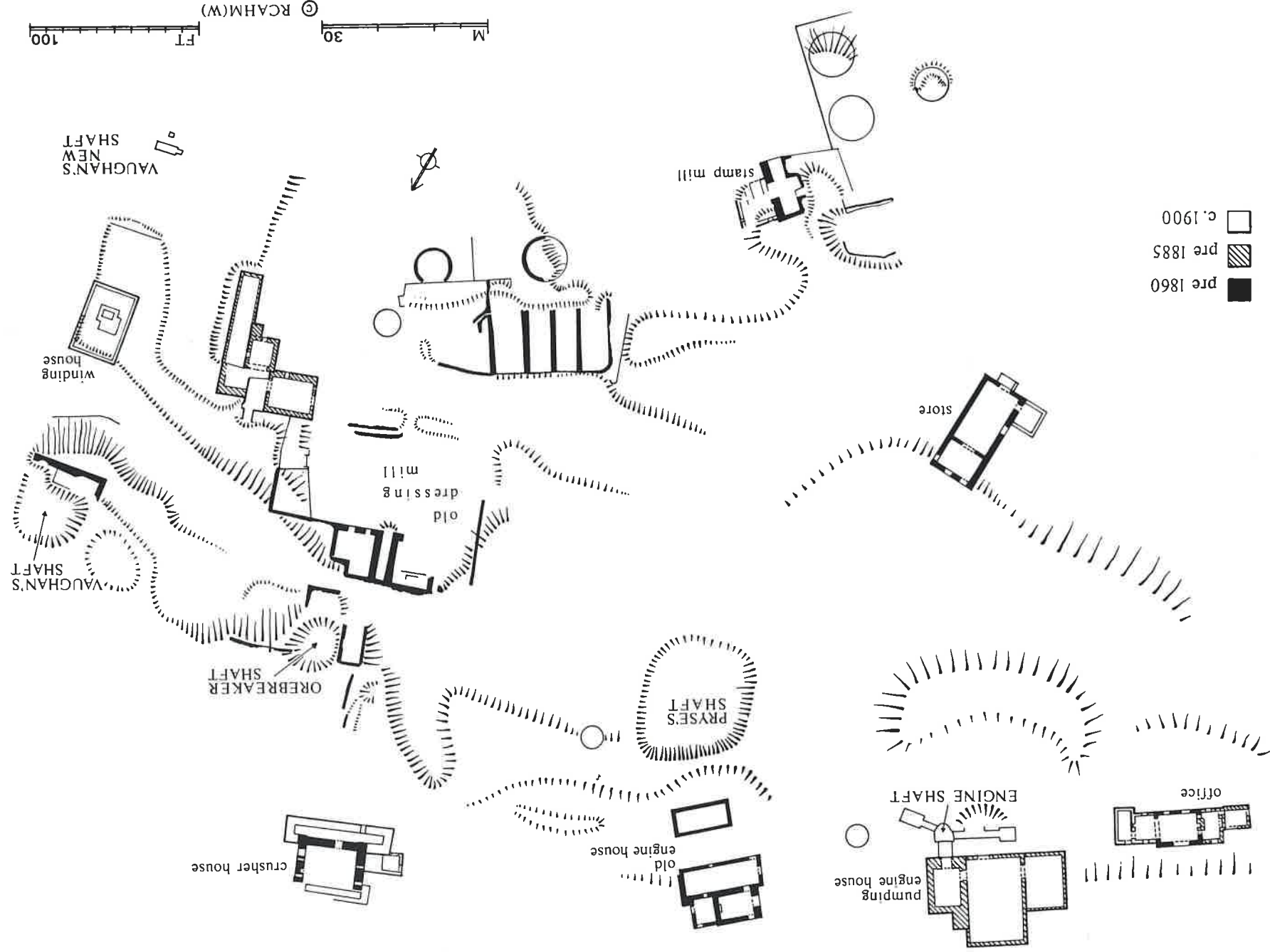
The only group of buildings surviving from the dressing-mill complex shown on the 1885 OS 25" map are the winding-engine house of c.1870, the crusher house, and various attached buildings. The earliest part is the engine house, which is very similar in its details to the pumping-engine house: the bob-wall is built of long rubble blocks, the chimney is structurally free-standing, and the top of the chimney was of brick. It contained the 25" rotative engine: what is not clear is how the winding-gear operated, since no known shaft is in direct line with the engine, although it is roughly aligned with Vaughan's Shaft.

Nor is it known how long the engine continued in use. It had been removed before the sale of 1904, but there are concrete blocks and hold-fast bolts in the fly-wheel pit suggesting that something was still operating there until at least the end of the century.

This is a detailed topographic map of the Iron-ore mine area. The map shows various features including:

- Water Bodies:** Llyn-y-nuch (4.635), Llyn-y-synod (5.804), and several smaller ponds and streams.
- Buildings and Structures:** Barracks (demolished), Engine house, Pump house, Dressing mill, and various smaller buildings and sheds.
- Shafts and Tunnels:** Numerous shafts are marked, including Edward's Shaft, Llyn-y-nuch Shaft, Llyn-y-synod Shaft, and others.
- Topography:** Contour lines and spot heights (e.g., 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000) are shown throughout the map.
- Infrastructure:** Roads, paths, and a railway line are depicted.
- Orientation and Scale:** A north arrow and a scale bar (0 to 1000 feet) are included.

FIG 11 General plan of the north east area. (R.C.A.H.M.(W))



Attached to the engine house are two ruined buildings, one at the north-west now totally ruined but built of massive rubble blocks, the other very long but with slighter walls. Originally both were under a deep sloping roof. One of them must have been the boiler house, probably the long building.

To the south-west of the fly-wheel pit is the crusher house, built of rough rubble with large roughly squared quoins. It was originally gabled, and the north wall was partially rebuilt. The crusher rolls were supported on six massive cross-beams set deep into the walls. Subsequently a chute for crushed rock was contrived in the south wall, whence led a wooden channel of which the wooden and concrete supports survive.

40 inch PUMPING ENGINE HOUSE for recirculating water

In 1841 Taylor brought in a steam-engine with a 40" diameter cylinder: the water which it pumped from an unspecified shaft was recirculated over the water-wheels. This building, which is shown on the 1847 Tithe Award map, must have been its engine house. It is considerably ruined, but the massive bob-wall remains, faced with long blocks of rubble: in the north-east wall are the stumps of heavy beams. A secondary building attached to the south-east is probably the boiler-house, with perhaps a coal yard further to the south.

It is not certain whether the engine was rotative, pumping by flat rods from the present Engine Shaft, or whether it pumped directly from a now lost shaft immediately outside the engine house. However, no sign of such a shaft survives, either on the ground or on the plan of c.1870: moreover a rotative engine would have been the more useful since it could have been used for other purposes such as crushing or winding as well. But conversely there is no sign of the supports for the flywheel of a rotative engine or of the necessary angle-bob for the flat rods (since the engine house does not align with Engine Shaft): the diameter of the cylinder is uncommonly large for a rotative engine; and in the advertisement of 1847 the engine is not described as rotative. Finally there is no reason why this isolated engine house (almost the only building on the site in 1841) should not have been aligned with Engine Shaft if flat rods were to have been used: and the Tithe Award map clearly shows a short watercourse, presumably for the pumped water, between the engine-house and the main leat.

The engine was sold in 1847: a flue and fireplace were inserted into the north-east wall of the engine house later on, but there is no clue to the new function of the building. It is not mentioned by Moissenet, which suggests that it did not contain machinery at the time of his visit.

CRUSHER/WINDER

To the north-west of Orebreaker Shaft is a puzzling building of several phases, consisting of a much-altered crusher house extant in 1885 with a second wheel-pit added. The crusher house has only three walls, with a contemporary wheel-pit across the open fourth side. The walls are built of massive blocks of squared rubble, with shallow 'pilasters' at the corners. The original form of the roof is uncertain, since the tops of the walls have been lowered. Two sets of slots indicate the position of massive beams, and blocked openings in the south-east wall suggest that a basement storey has been totally filled. It is possible that this was the location of the crusher driven by a 20ft. x 3ft. water-wheel in 1878: Moissenet does not mention it, so it may be later than 1860. It has not proved possible to reconstruct it satisfactorily: however, there is a similar crusher house at Glogfawr Mine.

By 1904 the building had been totally altered. A huge wheel-pit had been added against the south-east wall, the crusher had been replaced by shafing and gearing for a belt-driven engine winding from Orebreaker Shaft driven off the 50ft. water-wheel visible on the photograph of c.1900. The new machinery is listed in detail in the sale catalogue. The roof had been altered: a small fireplace was inserted into the north-east wall and a chimney of small rubble masonry with a brick cap was added. At the same time a small structure was attached to the south-west end of the building, containing the concrete base for an unidentified machine.

DRESSING MILLS

The location of the dressing mills in use before 1860 is uncertain. There was a water-powered crusher and jigger in 1841, possibly in the stamp mill building (q.v.); but nothing identifiable as a mill is shown on the Tithe Award map of 1847. Moissenet's plan shows that by 1860, however, there was an elaborate complex on three main levels, much of which can Moissenet's plan shows that by 1860, however, there was an elaborate complex on three main levels, much of which can still be traced in outline. The inventory of 1878 suggests that by then many of the water-wheels had been replaced, and by 1885 the mills had been almost totally rebuilt.

Moissenet's mills were divided into three main levels. The Upper Mill was just below a tramway between Pryse's Shaft and Taylor's Shaft; ore-bins by the tramway fed rock-breakers, classifiers and jiggers which were driven by a water-wheel close to the later Orebreaker Shaft. The walls of what may be this wheel-pit can be seen, with traces of the leat above it. The sorted rock passed to the crushing rolls in the Middle Mill, which were powered by a water-wheel of 29ft. 6inch. diameter: in the same building were two banks of jiggers and the Lisburne buddles. The upper revetment wall of the mill and the walls of the wheel-pit can be seen, although the sites of individual machines cannot be identified.

FIG 12 The 60 inch pumping engine house, C 1870.
The engine came from Sandycroft foundry. (R.C.A.H.M.(W))

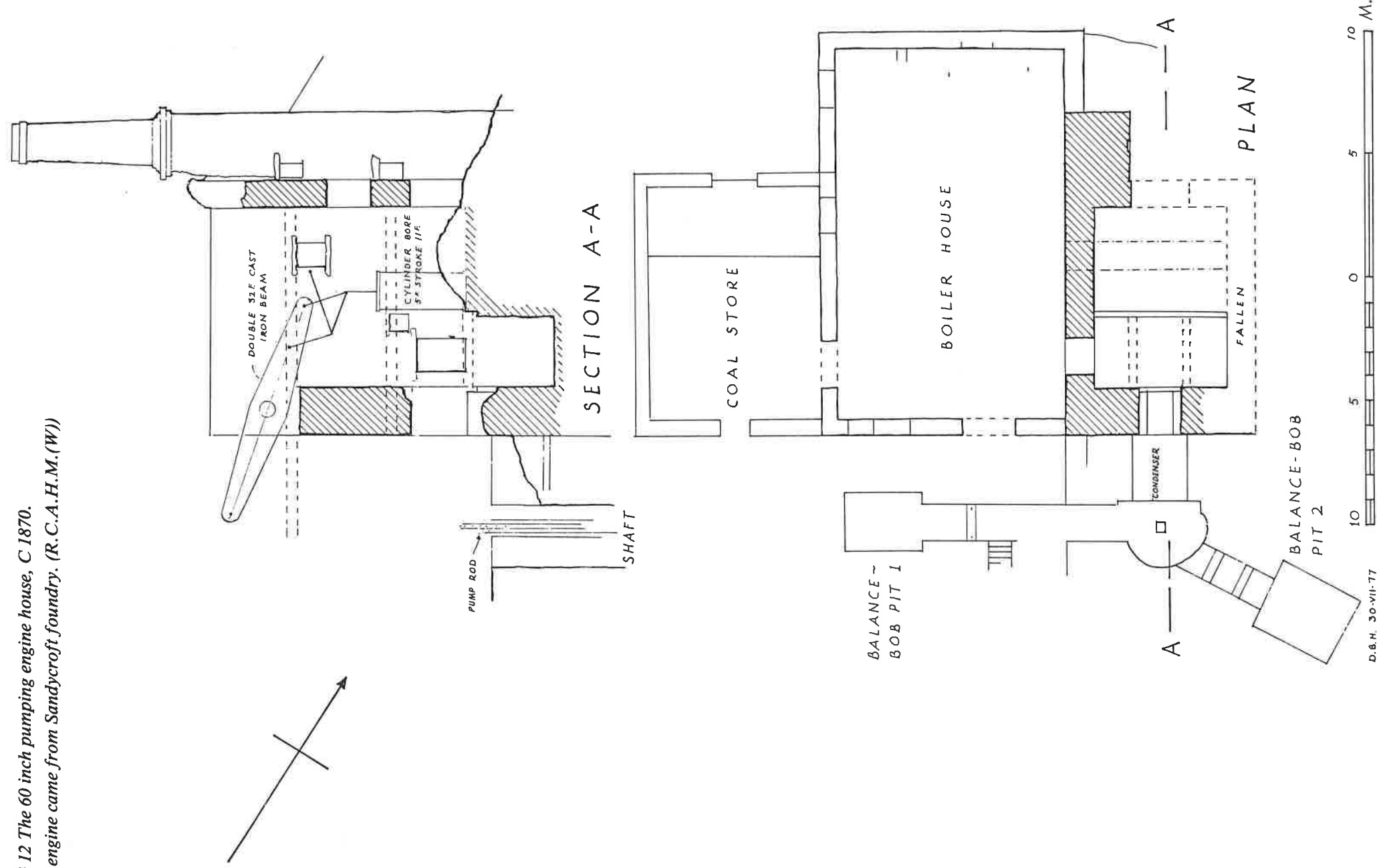


FIG 13 The steam winder and crusher, C 1870 (R.C.A.H.M.(W))

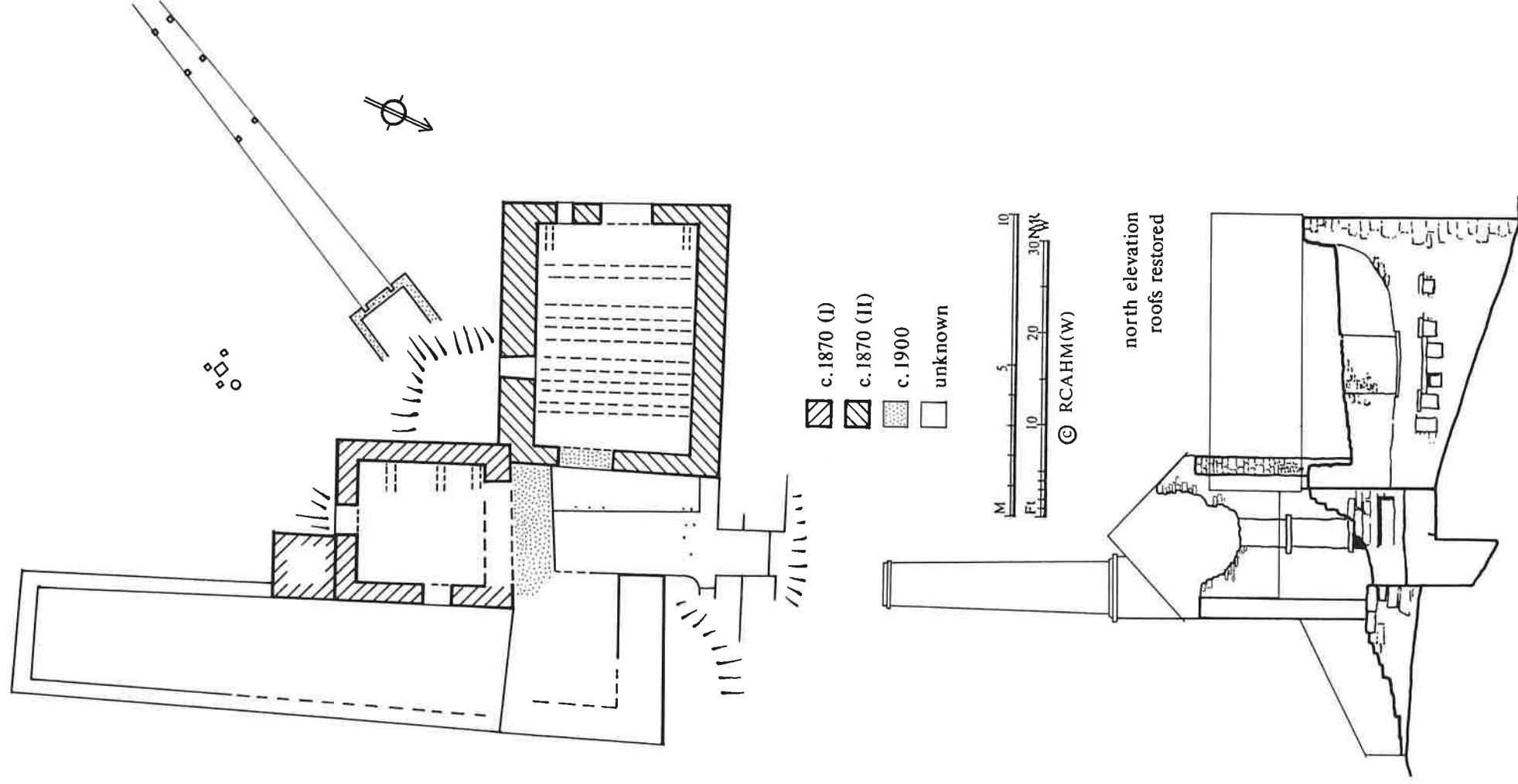


FIG 14 Stamp Mill, Crusher/Winder and Engine House for re-circulating water. (R.C.A.H.M.(W))

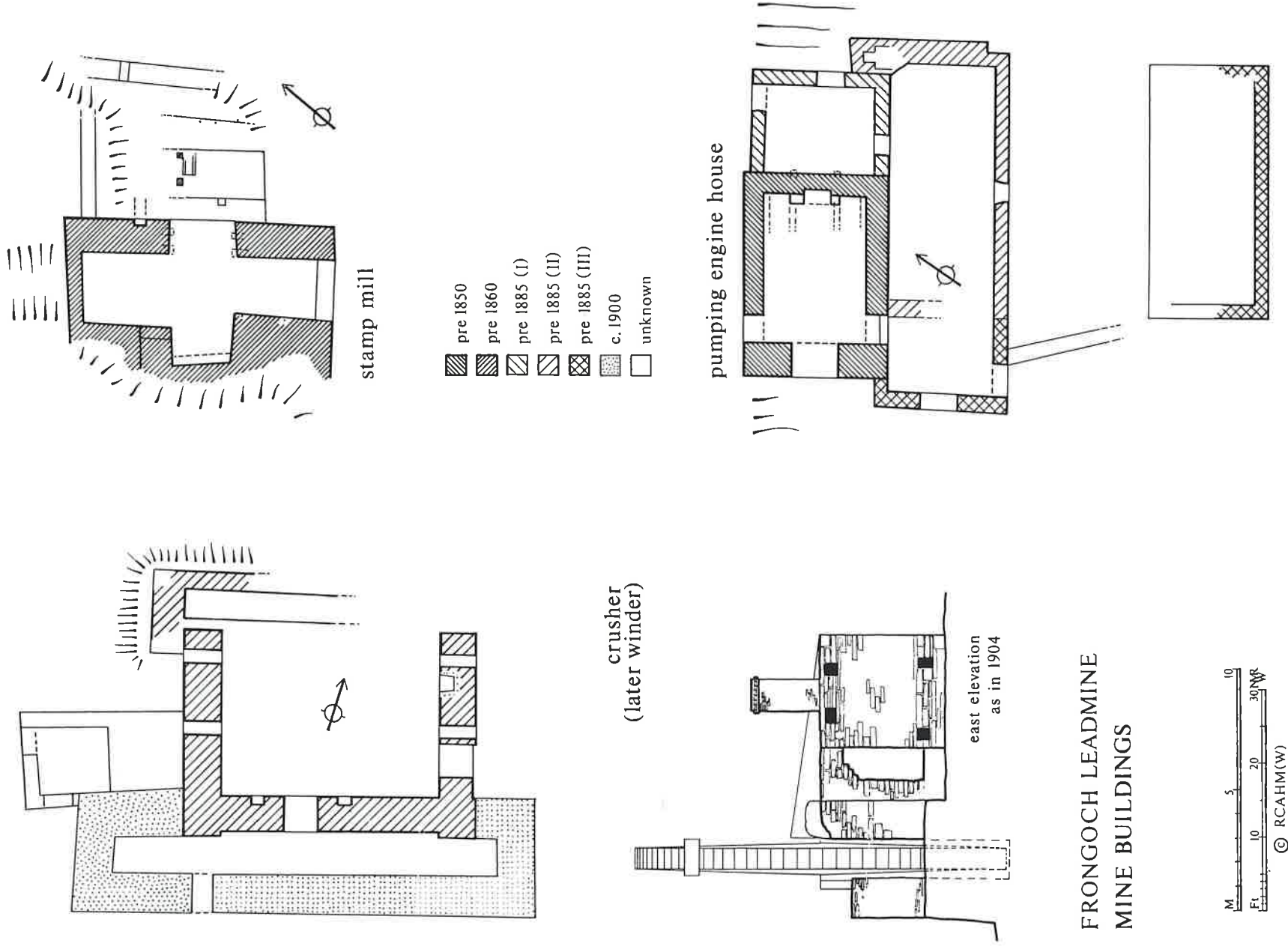


FIG. 15 Ancillary buildings

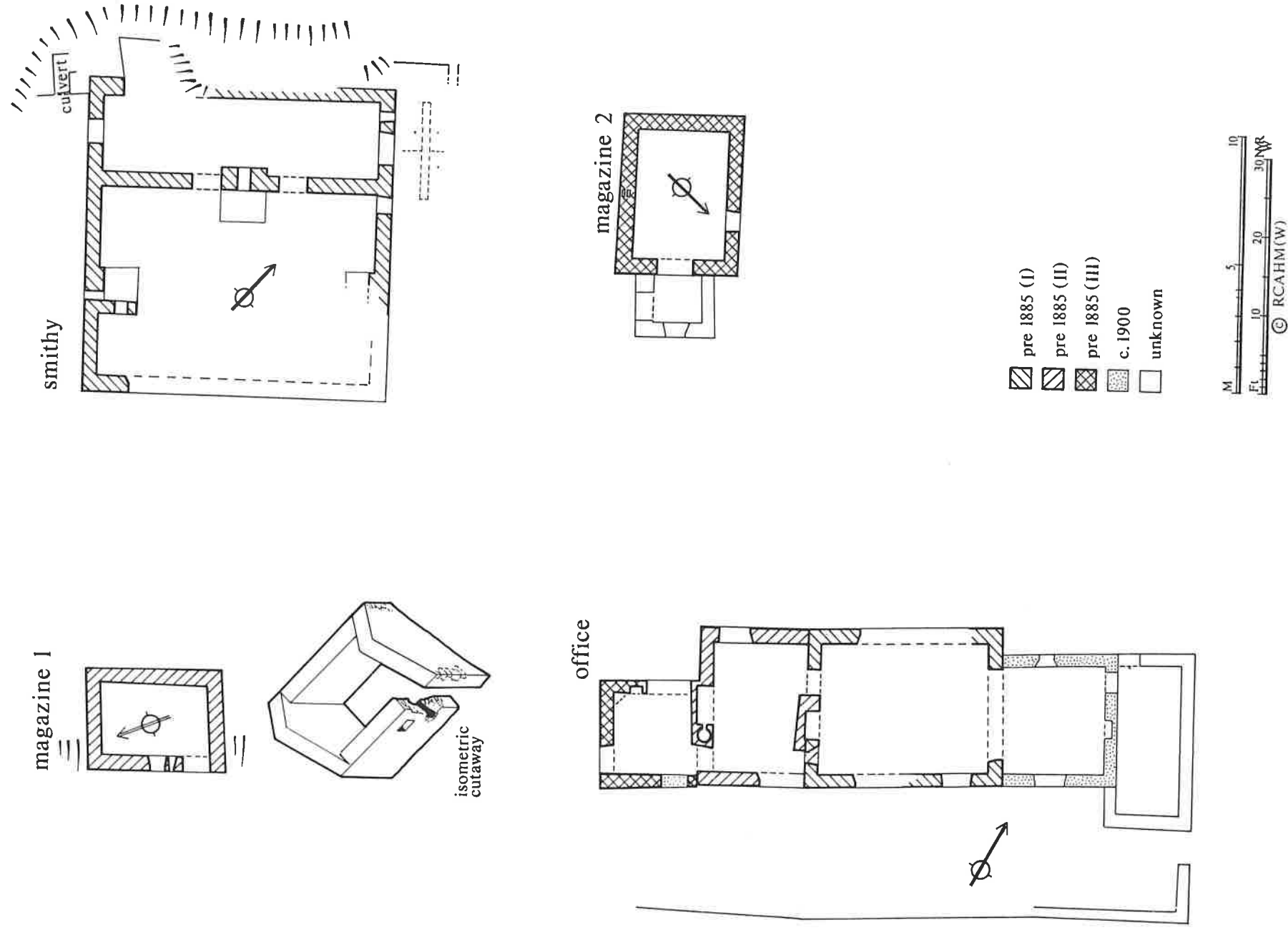


FIG 16 Dressing Mills area, 1984 (R.C.A.H.M.(W))

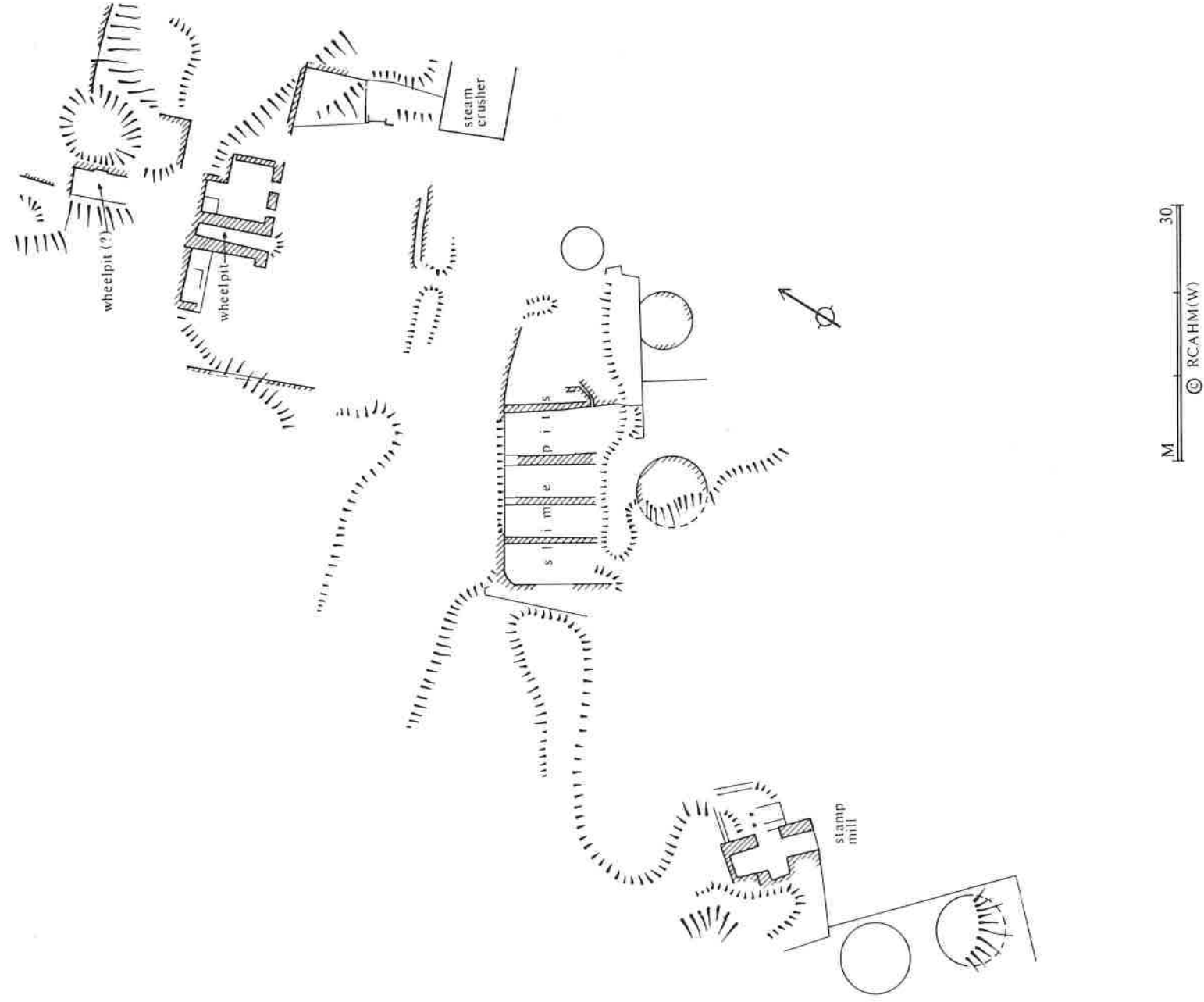
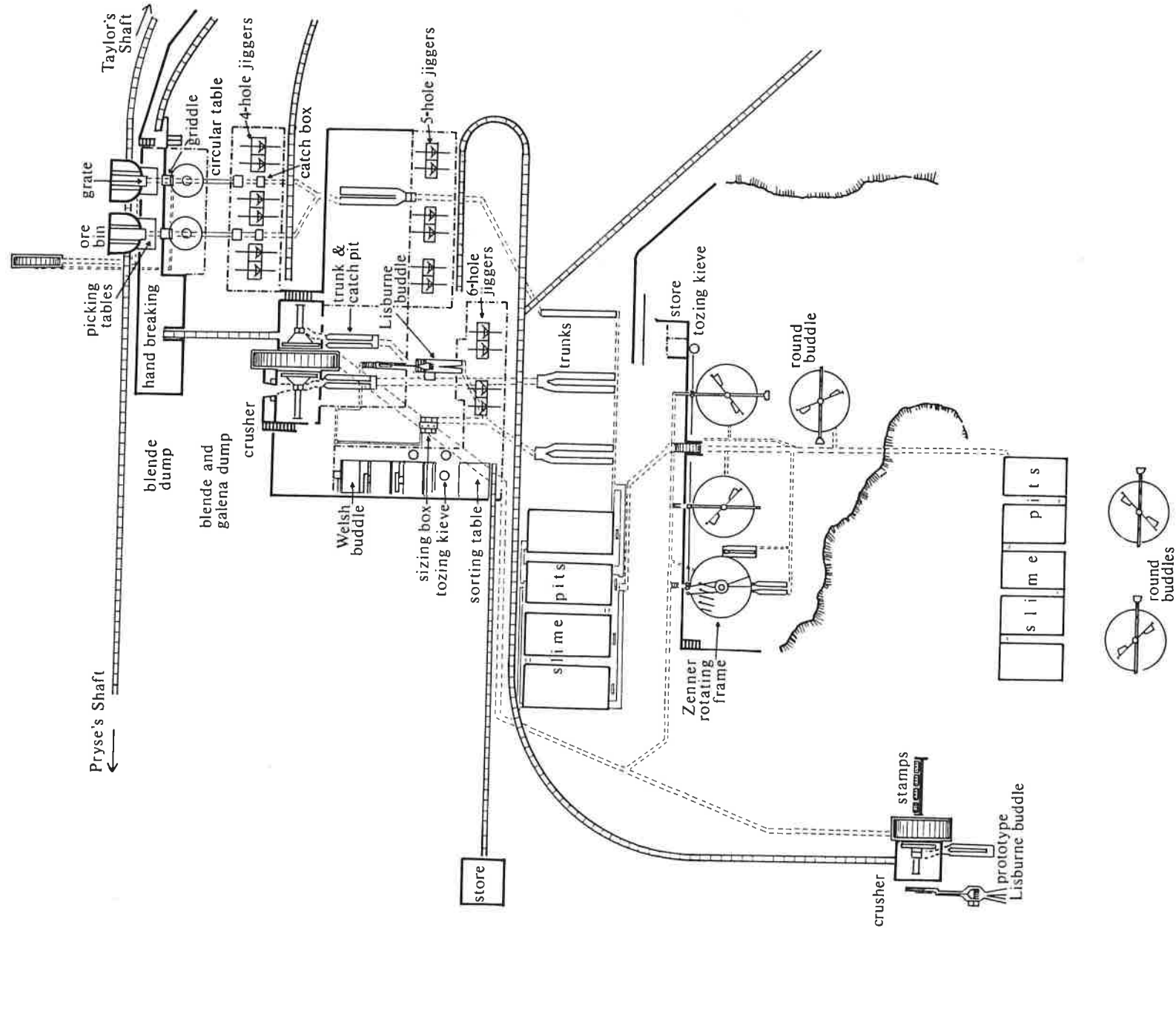


FIG 17 Dressing Mills, 1860 (after Moissenet) (R.C.A.H.M.(W))



Below the Middle Mill was another tramway system, to the store, the stamp mill and the dumps: a possible fragmentary section of this can be seen west of the later steam-powered crusher house. Further to the south was the Lower Mill, where the enriched sands were allowed to settle in a series of slime pits and were then finally sorted in the round buddles. The four slime pits can be seen, and the outlines of two round buddles: one has been overlaid by the walls of a later structure, and there is another smaller one, presumably later, to the north east. A further series of slime pits and buddle shown to the south on Moissenet's plan have been destroyed.

The inventory of 1878 hints at expansion, listing 'six small waterwheels on the flooring', together with 'Collieries Jiggers and Coal Rake'. This strange machine could possibly be the Lisburne buddle, unknown outside the area and therefore not understood by the agent preparing the inventory. The steam-powered crusher was in use soon afterwards, if not already then.

By 1885 the mills had been considerably enlarged, but the principles of operation were the same. The Upper Mill remained, with its isolated water-wheel and the tramway. The Middle Mill was substantially the same, perhaps no longer with water-powered crushers since the wheel-pit appears to be empty. However the Lower Mill had been enlarged. To the north-east of the slime pits a long structure reaches as far as the crusher house; it was probably open-sided, since two buddles on the south east are partly covered. A further four buddles of various sizes (one an old one) stood further to the south east. The stamp-mill building survived but possibly without a water-wheel: south of it were three buddles, two of which are still visible. Further to the south east Moissenet's five slime pits and two buddles were increased to two sets of slime pits and three buddles.

By 1904 this had changed dramatically: all dressing was now undertaken at the new mill at Wemyss, although some of the buddles and slime pits remained, and a wheel in the Middle Mill (shown on the 1904 OS 25" map) suggests that the crusher here was still operational. The Wemyss mill (built in 1898), like the older mills, was built on a steep slope so that each successive machine was fed by gravity. A series of revetment walls and platforms supported the machinery: the plans of the contemporary mill at Cwmystwyth (see E.H. Davies, *Machinery for Metalliferous Mines* (1902) figs. 302-308) gives an idea of the scale of such an integrated plant.

A final stage may be identified. A plan showing the lead and zinc dumps (undated but post-1904) indicates the line of the aerial ropeway to Gwaith-goch. This began at the side of the steam-powered crusher, to which ran a pipeline from the north. There was also an incline to the dumps south of Vaughan's New Shaft. It would appear that the eastern end of the tramway to Wemyss had already been destroyed, although the western end, running under the road, is still in existence.

ANCILLARY BUILDINGS

1. *The Office*: of four constructional phases, all but one shown on the 1885 OS 25" map, it stands on a revetted platform. The earliest part was in use by 1847: the single large two-storey unit has walls of thin split slatey rubble masonry plastered inside and out. To this was added a two-storey room to the south west, which had fireplaces in the gable (the ground-floor fireplace including a brick oven). Beyond this was another addition, single storeyed and having two small fireplaces in the west end. The final alteration, an addition at the north-east end, was built before 1904; it was also of a single storey, with segmental arches of yellow brick over the windows.

2. *The Smithy*: a large building with an undivided main room and a contemporary lean-to-rear section, already in use by 1878. The facade (now mostly demolished) was faced with long blocks of dressed rubble, and the rest of the walls were of smaller rougher masonry. There were three hearths: the holes for the bellows can still be seen in two of them. The rear section probably contained shafting from the water-wheel which drove the bellows, and the general location of the wheel is indicated by holdfast bolts outside the building: water-wheels for the smithy are listed both in the 1878 inventory and the 1904 sale catalogue. By the western corner of the building is a low vaulted culvert.

3. *Magazines*: two buildings are so named on the OS 25" maps. On structural grounds they seem to be of two different dates. Magazine 1 has walls of rubble masonry in lime mortar, and probably a slate floor. It had one very small window and between it and the doorway was a narrow splayed chute through the wall. It is fairly close to a small trial level. Magazine 2 is slightly larger, and had an additional unit built after 1885 in the form of a large porch. It had a suspended wooden floor, and in the thickness of the wall are possible ventilation slots. It seems that it may have been a store for high explosive with a separate storage area for detonators.

4. *Store* (see general plan): a long ruined building with walls of rubble masonry above a plinth of coursed masonry. At the south end is a loading platform: footings at the south-west corner indicate the position of a small secondary building. The form of the roof is uncertain: it may have been in two parts, gabled at the southern end and taller and hipped to the north. Moissenet's plan indicates a store in the right general location, but it was either much smaller (about 4m. square) or conventionalised: the present building was in use by 1885.

THE SHAFTS

- A. The remains of six shafts can be seen: the locations of others can be pinpointed on maps, but no trace now remains.
1. *Vaughan's Shaft (or Taylor's Shaft)*, shown on the 1885 OS 25" map. The southern wall of the shaft-head survives with a recess for the balance bob of a pumping engine: a ladderway used to be visible.
 2. *Vaughan's New Shaft*, replacing Vaughan's Shaft about 1880. It is blocked below a concrete lip: the bolts for the head-frame and the foundations of the engine house (both of which are shown on the photograph of c.1904) are still visible from the proximity of the stone breakers in the dressing mill.
 3. *Orebreaker Shaft*, blocked and with ruins of three sides of the shaft-head walling only. The name presumably derives from the proximity of the stone breakers in the dressing mill.
 4. *Engine Shaft*, blocked but evidently still subsiding. The walls of the shaft and its associated balance-bob pits are built of good-quality rubble masonry.
 5. *Pryse's Shaft*, although concealed by 1904, its location is probably a deep hollow in the spoil-tips south of the 184 engine house.
 6. *Boundary Shaft*, (west of the modern road), now full of dumped rubbish. A fine horse-whim circle is visible nearby.

At the Wemyss Mine, Ball's and Glanville's shafts can also be identified.

★★★★★

FIG 19 Production and employment.

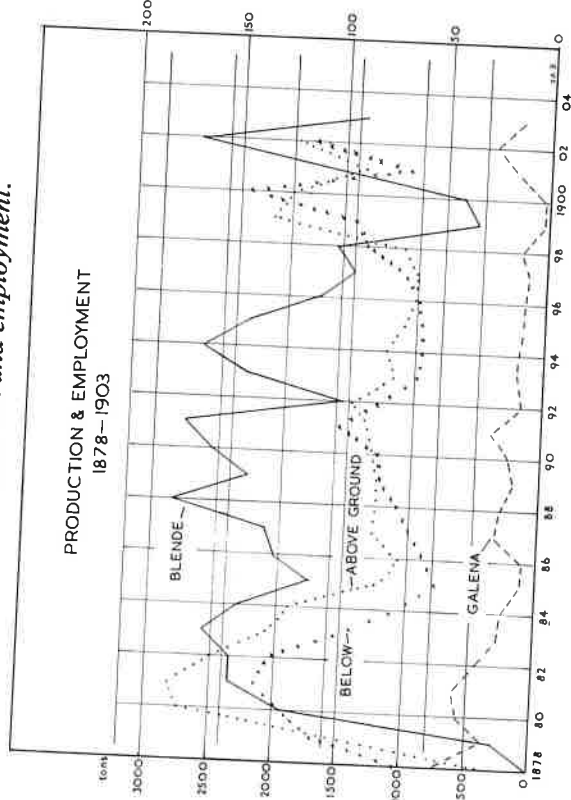
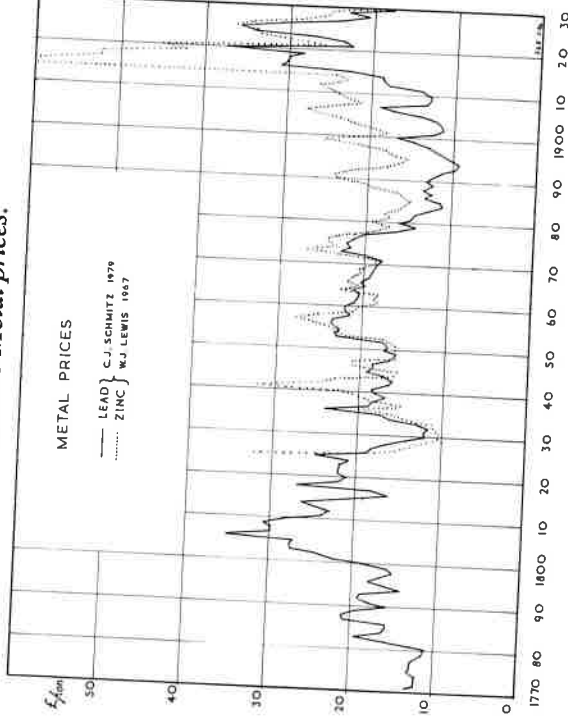


FIG 20 Metal prices.



NOTES AND REFERENCES.

Recurring references are indicated as follows:

- B G S British Geological Survey, Aberystwyth.
 Bick David E. Bick. *The Old Metal Mines of Mid-Wales*, parts 1-5, 1974-8
 Crosswood Crosswood Deeds & Documents, National Library of Wales.
 Jones O.T. Jones *Lead & Zinc* 1922 H M S O Special Reports. (Reprinted 1986)
 Jones Mss. W.J. Lewis *Lead Mining in Wales* 1967
 M J *Mining Journal*
 M W *Mining World*
 N L W National Library of Wales, Aberystwyth
 P R O Public Record Office, Kew.

INTRODUCTION

- 1 For a general introduction, see Lewis and Bick.
- 2 R.A. Williams, *The Old Mines of the Llangynog District*, 1985. British Mining No26 N M R S.
- 3 Lewis, 110
- 4 Lewis, 115
- 5 Lewis, 171

CHAPTER 1

- 1 Unless qualified, the word ore means lead-ore (galena)
- 2 N L W, Crosswood
- 3 N L W, Powys 1618. Meyrick in his *History of Cardiganshire* 1810, states that Frongoch consisted of 1/6 lead ore, 1/8 black jack and the rest quartz.
- 4 Black Jack is the old name for zinc sulphide or blende, the ore of zinc.
- 5 N L W, Powys 21939
- 6 N L W, Powys 1627
- 7 N L W, Powys 1626
- 8 N L W, Powys 1653
- 9 N L W, Powys 1733
- 10 N L W, Powys 3734. Harfords and the Bristol Brass Company lasted well into the present century. For further details, see Joan Day *Bristol Brass* 1973.
- 11 N L W, Powys 4179
- 12 N L W, Powys 4203, 4156
- 13 N L W, Powys 4175
- 14 Lewis, 174. According to George Hall tradition has it that Glogfawr was discovered by miners on their daily walk from Pontrhydygroes to Esgairmwyn.
- 15 Robert Hunt, *British Mining* 188, 320
- 16 W.W. Smyth *Memoirs of the Geological Survey* Vol 2. Part 2 1848, 671. When I explored Level Fawr some years ago Smyths' story came vividly to mind, though it was not altogether borne out by evidence underground.
- 17 N L W, Druid Inn papers
- 18 For a section of the workings on Level Fawr see Bick, Part 1, 31.

CHAPTER 2

- 1 N L W, Druid Inn Papers, Lisburne Mines Report, 8 July 1835.
- 2 For a biography, see Roger Burt, *John Taylor* 1977
- 3 For biographical details of the Francis family see Bick, Part 1.
- 4 Jones Mss, 37
- 5 M J, 1845, 477
- 6 Jones, 109
- 7 M J, 1850, 540
- 8 M J, 1851, 174
- 9 According to Simon Hughes *The Cwmystwyth Mines* 1981, British Mining No17 the system was in use in Cardiganshire as early as 1760.
- 10 H M S O, Kinnaird Commission Report 1864, 504-506
- 11 Jones Mss, 37
- 12 Jones Mss, 37

CHAPTER 3

- 1 Crosswood 11, 1408
- 2 Crosswood 11, 1407, 1454. I suspect that Davey and Henry Davey (later of Hawthorn, Davey) inventor of the Davey Differential Steam Pump, were one and the same.
- 3 Bick, Part 4, 50
- 4 Roger Burt, *The British Lead Mining Industry* 1984
- 5 P R O, BT 31/2450/12464
- 6 *Money* 6 Nov 1878.
- 7 H M Inspectors of Mines Reports, 1879/80
- 8 M W, 14 Aug 1880
- 9 M W, 17 July 1880
- 10 M W, 11 Sept 1880
- 11 M W, 16 Oct 1880
- 12 M J, 29 Jan 1881
- 13 1881 Census Returns
- 14 M J, 1885, 780. This may have been Orebreaker Shaft, which according to a report by Thomas Garland dated 6 June 1903 'was made chiefly through old workings to the 66 fathom level.' Its purpose is not clear.
- 15 *Mineral Statistics*
- 16 In 1896 Kitto was living at Blodwen House, Aberystwyth, where he died in 1903.
- 17 B G S. Report on Frongoch, West Frongoch (Wemyss) and Red Rock mines.

CHAPTER 4

- 1 N L W. The Crosswood Estate (Thesis) J.M. Howells 1956, 398
- 2 B G S. J. Trefors, *Report on the Frongoch Mines*
- 3 H M Inspectors of Mines Reports.
- 4 For details of this disease at British mines see Boycott & Haldane, *Ankylostomiasis Journal of Hygiene* Jan 1904.
- 5 The total of 450 employees is suspect. The *Mineral Statistics* records only 270 for 1900 and less for other years.
- 6 B G S, R.R. Nancarrow, *Report to Capt. J.M. Carey, H M Inspector of Mines* 20 Sept 1939.
- 7 Report held by B G S.
- 8 H M Inspectors of Mines Reports and *Mineral Statistics*.

CHAPTER 5

- 1 Manager's Report, 10 Aug 1908. (In possession of G.W. Hall)
- 2 Information from G.W. Hall.
- 3 M W, 29 Sept 1917.
- 4 Report to Directors, 1 Sept 1919 (In possession of G.W. Hall).
- 5 M W, 8 Jan 1921.
- 6 The ropeway ran almost dead-straight, its course being shown on contemporary One-inch Ordnance maps.
- 7 B G S, F.W. Harbord, *'Report on the Recovery of Zinc... by Electrolysis'* 1922
- 8 R.R. Nancarrow, *'Synopsis of Mining Career'* 20 March 1945. It must be observed that the yield seems suspiciously high (In possession of G.W. Hall).
- 9 Hall recalls that Nancarrow told him that as a leg-pull he had suggested to O.T. Jones extending the Level Fawr at Grogwinion (north of Gwaithgoch) a mile or more to Frongoch to provide a deeper adit. The professor not only approved, but put the idea forward in print (Jones, 107).

CHAPTER 6

- 1 N L W, Powys 1626.
- 2 For further details of 19th century ore-dressing, see R. Burt *British Ore Preparation Techniques* 1982.
- 3 N L W, Druid Inn papers.
- 4 In the 1740s a Newcomen engine powered ten waterwheels at Coalbrookdale in this manner. See John Farey *A Treatise on the Steam Engine* 1827, 296.
- 5 Philips & Darlington, *Records of Mining and Metallurgy* 1857. Water pressure machines used high-pressure water as the source of energy, being similar in operating principle to steam engines. For further details with a list of Welsh applications, see Bick, Part 1, 40-47.
- 6 In my Part 1, 14-17 mistakes occur, Engine Shaft being described as Vaughan's, and Boundary Shaft as Ball's Shaft. Also the '25 inch whim enginehouse' is the 40 inch enginehouse of 1841, for recirculating water over the wheels.
- 7 P R O. BT31/2462/12579.
- 8 M J, 1879, 510, 623.
- 9 R. Hunt, *British Mining* 1887, 627.

- 10 As result of many accidents manriding was generally forbidden, but in 1958 I tasted this harrowing mode of conveyance to
the bottom of Bearhaven Copper Mines, Co. Cork. At lease it was quicker than ladders.
- 11 C. Le Neve Foster, *Ore and Stone Mining* 1897, 416-7.
- 12 For a general introduction, see R. Burt *British Ore Preparation Techniques* 1982.
- 13 M J, 19 Nov, 1870.
- 14 C. Le Neve Foster *Ore and Stone Mining* 1897, 576-7.
- 15 C. Le Neve Foster *Ore and Stone Mining* 573-4.
- 16 M J, 1881, 131.
- 17 Nogara wrote a paper published in Sardinia on his Frongoch experiences, 'Descrizione della Miniera di Frongoch, *Resoconti
delle riunioni dell' Associazione Mineraria Sardo Anno VI No 3, 1901*. I have been unable to trace a copy in this country.
- 18 E.H. Davies *Machinery for Metalliferous Mines*, 2nd edn. 1902, 496/7.
- 19 Liquid starting resistances consisted of a large tank of electrolyte, (often salt-water which gave off chlorine gas) in which
the distance between two poles could be varied by a lever. I witnessed such a contraption working at a Ffestiniog slate mine in 1962.
- 20 B G S. Report by John Mitchell, August 1903.
- 21 E.H. Davies, *Machinery for Metalliferous Mines* 1902, 498.

APPENDIX I

Principal Shafts on the Frongoch Lodes* (From East to West)

Mine	Name of Shaft	Vertical/Inclined	Depth(Fathoms)
FRONGOCH	Miller's	V	24
	Edwards	I	78
	Llwynwnnuch	I	24
	Taylor's(Vaughan's)	I	154
	Vaughan's New	V	90/154
	Orebreaker	I	66
	Pryse's	I	105
	Engine	V	117
	Williams	V	66
	Boundary	V	56
	Glanville's	I	16
	Ball's	I	76
	Road	V	18
	Brook	I	30
	Red Rock	I	23
	New	I	73
WEMYSS			
WEST FRONGOCH			
GRAIGGOCH			

* Based on George Trefois, 'Notes on the Frongoch Mines', 1903(BGS) with additions.

APPENDIX II

Frongoch Production Figures, to nearest ton.

Pre	Date	Lead Ore	Blende(Zinc Ore) 3000*1881	Date	Lead Ore	Blende(Zinc Ore)
1825	1825	3000*		1881	600	2350
	6	4		2	460	2350
	7	24		3	285	2558
	8	2		4	260	2304
	9	1		5	125	1750
	30	64		6	104	2050
	1	216		7	330	2110
	2	158		8	310	2850
	3	283		9	220	2260
	4	387		90	250	2550
	5	457		1	390	2762
	6	807		2	155	1560
	7	892		3	210	2321
	8	671		4	205	2645
	9	447		5	185	2305
	40	78		6	165	1769
	1		5426, ref O.T. Jones.	7	147	1509
	2			8	201	1649
	3			9	43	549
	4			1900	42	663
	5	900*		1	333	1739
	6	876 +		2	426	2762
	7	79 +		3	202	1453
Notes:						
					58,295	49,701 tons

Silver returned in the years 1859,60,62,63,75-81,
1896, 1901, 03. Total, 24,414 oz.

Post 1845, the above figures are extracted from
Mineral Statistics, except in those years where
Frongoch output was aggregated with other Lisburne
mines.

For further details, see Roger Burt, *The Mines of Cardiganshire*, 1985(NMRS). The blende figures in particular are incomplete, the *Min. Stats.* not listing this mineral pre-1854.

* = *estimate* + = *money*, 6 Nov 1878.
1824-39, NLW Crosswod II, 1045, 1174.

Ores extracted from the dumps post-1903 are additional.

4	1232 +	
5	1062 +	
6	1442 +	
7	1355 +	
8	1037 +	
9	1033	153
60	1110	52
1	1422	52
2	1946	
3	1498	194
4	1455	107
5	1540	
6	1560	
7	1586	
8	1170	
9	1500	
70	1248	
1	1314	60
2	1145	
3	1040	
4	850	
5	1162	
6	990 +	
7	1070 +	
8	749	
9	370	300
80	570	1965

APPENDIX III

Frongoch Ownership & Management (1860-1903)

(Abstracted from Roger Burt, *The Mines of Cardiganshire*, 1985.)

OWNERSHIP

- 1860-67 John Taylor & Sons
- 1868-77 Lisburne Mining Co Ltd
- 1878-82 Frongoch Lead Mine Co Ltd
- 1883-85 Frongoch Mining Co Ltd
- 1886-89 John Kitto & Sons
- 1890-97 John Kitto
- 1898 Société Anonyme Minière
- 1899-1903 Société Anonyme Des Mines De Frongoch

MANAGEMENT

- 1862-3 Henry Thomas
- 1864-7 Thomas Ball
- 1868-77 John Taylor & Sons
- 1879-88 John Kitto & Son
- 1889-94 Abel Paull
- 1895-97 John Owen
- 1898 Max C Stegemann
- 1899 B. Nogare
- 1900-03 G.H. Trefois

SECRETARY

- 1872-4 Henry Taylor
- 1877 H.H. Oakes
- 1879-81 H.R. Moore

Other names included D. Simmons, R. Glanville, P. Garland and H. Clernes

LEON MOISSENET'S VISIT TO FRONGOCH IN 1860

by
Stephen Briggs

Leon-Vivant Moissenet, (1831 – 1906) was a remarkable French engineer, whose working life was spent almost entirely in the service of the Ecole de Mines in Paris. Although there had existed strong traditions of industrial espionage in Britain by Frenchmen in the seventeenth and eighteenth centuries, these were terminated by the Revolutionary and Napoleonic Wars. After that time, Frenchmen looked to the historic mines of Middle and Northern Europe, for geographical convenience, and because German mining technology and metallurgy was considered well advanced. Moissenet broke away from this, preferring instead to study the developing mines of the British Isles. He was the first French teacher and scholar of note to have done so.

Taking advantage of generous government bursaries, between 1855 and 1865 he took at least six summer tours, variously in England, Ireland, Scotland, and Wales. During these tours he suffered two accidents, one involving a vehicle outside Caernarvon in 1860, the other five years later, which almost cost him his life, at the man engine of Devon Great Consols Mine.

In later life, he became consulting engineer to the Montebbras tin mine, Creuse, where he was to put to use his observations made abroad, which included the employment of the Lisburne Buddle.

Moissenet enjoyed a correspondence and friendship with several noted mining engineers, and his interest and advice was recognised to the advantage of local mining captains in Britain, though most particularly in Cornwall (Micaud 1909). However, the greatest testimony to his endeavours rests upon a series of papers published in the *Annales de Mines*, during and soon after his travels in Britain. These include accounts of lead mining in Flintshire (1857), copper metallurgy in Shropshire (1862) and aspects of mining in Cornwall and Devon (1858, 1862). The paper which concerns us, however is his treatise on lead mining in Cardiganshire (1866).

THE 1866 MEMOIR ON THE LISBURN MINE*

In summarising, and to a lesser degree, in editing this work, references to the original text are within double brackets thus: (()).

Entitled 'Préparation Mécanique du Minerai de Plomb aux Mines de Lisburne, Cardiganshire, Pays de Galles' (on the mechanical preparation of lead ores at the Lisburne Mines, Cardiganshire, Wales), Moissenet's paper appeared in the *Annales de Mines*, sér. 6, Tome ix, 1866, pp. 1 – 137, after he had for the years 1862-5 given lectures at the school of Mines on the mechanical preparation of ores in Britain. The paper was accompanied by three plates of line drawings which conveyed his message in a clearer manner than it was possible to do verbally. Their contents were:

Plate I. Fig.1, plan of Level Fawr, Pontrhydgroes, 1860, Fig.2, plan of Frongoch, 1860;

Fig.3, Accessories of the Round Buddle; Fig.4, Plan of same; Fig.5-11 sections and elevations of same.

Plate II. ((concerns washing and grading of ores)), Fig.1, section of process house; Fig.2, plan of same; Fig.3, section of cast grate; Fig.4, trommel; Fig.5, Waggon at Level Fawr; Fig.6. (?); Fig.7, toizing Kieve; Fig.8, Tye, section of; Fig.9, plan and section of Welsh Buddle; Fig.10, plan and section of shaking trunk.

Plate III. devoted entirely to 18 Figs. of plans and sections of the Lisburne Buddle.

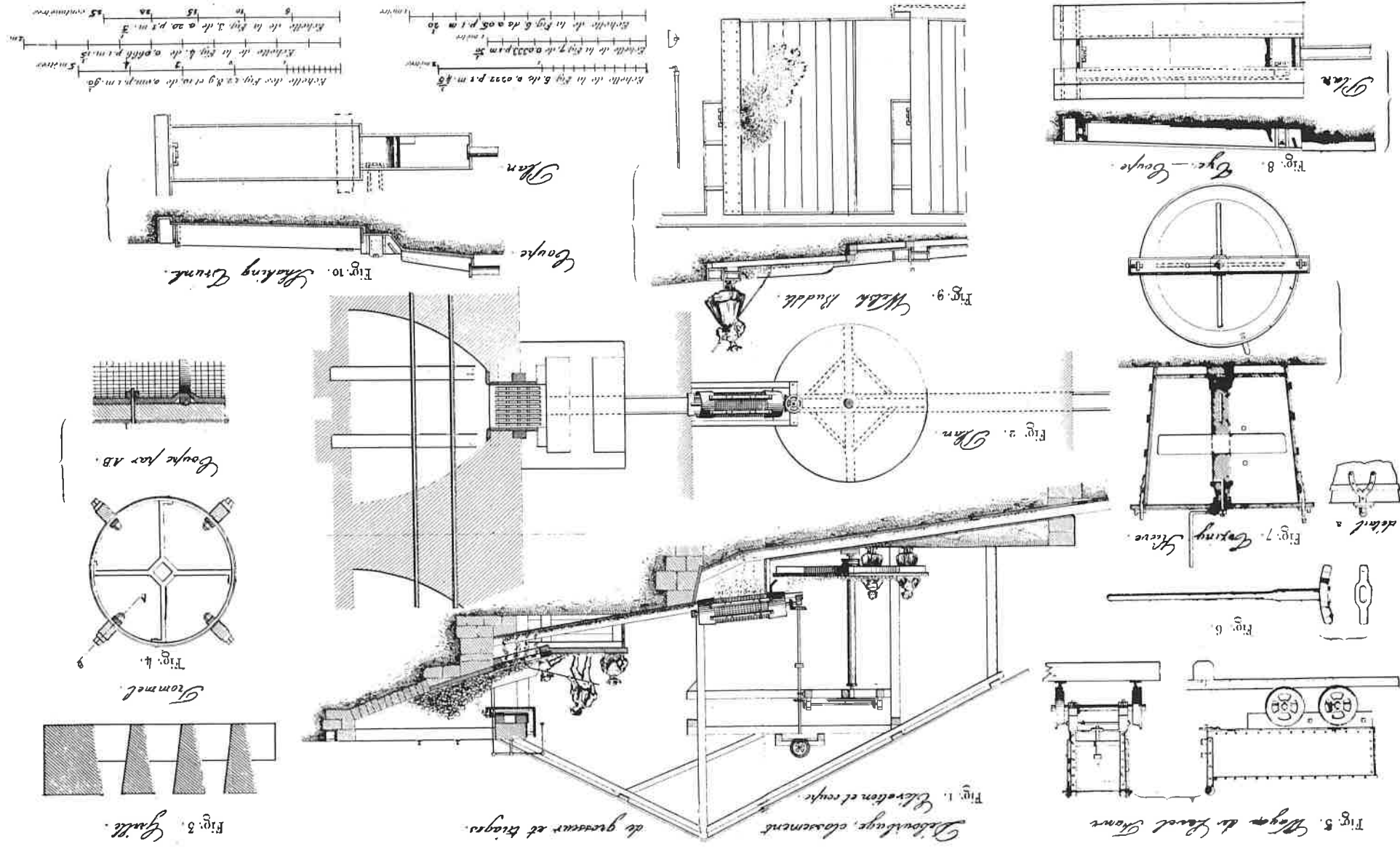
Plate I, Fig. 2 has been re-drawn by A.J. Parkinson, and is printed above. (Fig 17) It should be used in conjunction with headings 2 and 3 below. Plate III is omitted, since it is of specialist interest, and could only be successfully reproduced if there were a near-full translation of its accompanying text. However, Plate II is reproduced, and should be consulted in conjunction with the descriptive text. (Fig 21)

The memoir shows that Moissenet was not only familiar with Frongoch and Level Fawr, but had also visited and studied Logaulas (Logylas), Glogfach, Esgair Mwyn and Grogwynion.

In collecting the most detailed information he seems to have had a four-fold objective; first ((chapter 1, pp. 1-15)), to relate the mines to local geology and mineralogy, making general observations upon how they were staffed, how many adits had been driven, and how the workshops could be related to the mines; secondly ((chapter 2)), to explain the methods employed in ore preparation, first at Level Fawr (pp. 15-50)), then at Frongoch (pp. 51-77)); then ((chapter 3, pp. 78-120)) to provide a most detailed description of the construction of the machinery contemporarily employed in ore processing at the Lisburne mines, offering a critical evaluation of their relative operative efficiencies; and finally ((chapter 4, pp. 115-137)) to examine the financial basis of the Lisburne Mines Company.

Several problems are encountered in summarising this work. Moissenet must have had access to the accounts books of the Mining Company. These were no doubt kept in £.s.d. He converted this currency to contemporary French francs at (15s. = 18 frs 75 centimes) or 25 frs to the £ sterling, and throughout, naturally enough, he gives unit costs in francs. A similar difficulty is to be met with in his spatial measurements; here, feet and inches are liberally interdigitated; throughout the paper the English fathom of 6 feet seems to equate with the old French *toise* of 6½ feet without the necessary adjustment. Equally, it is rarely clear when the English ton is being converted directly to the metric tonne of 1.0161 tons. He also refers throughout to 'Angleterre' when it is clear that Britain is intended.

FIG. 21 Section from Moissenet's work.



It is clear that contemporary and later writers on British mining were well acquainted with Moissenet's work, and although a proper evaluation of his contribution to mining and metallurgical studies must await more detailed future study, it is worth noting that Hunt's *British Mining* of 1887 actually used the illustration of the Frongoch ore preparation shed presented here (Moissenet 1866, pl.2; R. Hunt, 1887, *per* Burt 1982, Fig.1, 15).

In the summary which follows, some effort is made to restrict discussion to Frongoch. But as Frongoch and Level Fawr both belonged to the Lisburne Mines, and as, particularly for economic considerations, Moissenet on occasion treats both together, it has not always been found possible to exclude other mines from the summary.

1: DESCRIPTION OF LOCALITIES AND OUTCROPS

In his opening remarks, Moissenet draws attention to the potential ascendancy of Frongoch over Level Fawr on account of the recent introduction of the Lisburne Buddle, setting the general tenor of an argument about buddles and buddle efficiency which underlines the entire paper.

The main working at Frongoch was 1200m long with veins from 30-50 fms in length from 10 to 30 ft thick, dipping to the south. These were orientated 0 12° E of true north. There were two varieties of ore; one laminated, the other fine-grained, with, more rarely, metallic lead. They yielded 5 ounces of silver per ton, and about one-eighth of the mineral extracted was of blende ((p. 10)).

Little wood was employed, since the country rock was very solid ((p. 11)). Running costs for driving the adits were about £3. 10s. per metre through vein-ore, and about £3 per metre for galleries and stopes. These costs were a little higher than those of Logylas, but considerably greater than those at Glogfach, where vein driving came to well under £2 per metre.

In 1859 there were 324 underground workers in the Lisburne Mines. They were paid a total of £11,933, 1s. 8d ((298, 328 frs)) per annum, which represented 53.92% of total overheads, (giving each worker an average £36.16s. per annum). For both contract groups, the mining company provided powder, rope, candles and tools at a heavy subsidy, which in 1859 amounted to 7.55% of overheads. However, the greater 'perks' went to the 'tribute' workers ((p. 13)).

Frongoch and Level Fawr dressing floors each employed 70-80; few were men, some were boys and girls, but most were older women. Men were paid monthly and according to their ability; the youngsters, by the day, between 4 and 11d., their average being 7d. The combined total cost of surface workers' pay at both mines in 1859 was £1,669, 18s. In that year 26,550 tonnes (metric) of ore left the mines for sale, and this included 2, 454 of galena and 112 of blende ((p. 14)).

In the main, Moissenet felt that working conditions at Frongoch were almost ideal. The company was fortunate to have waterpower, a content workforce and fair wages. But he expressed surprise that the owners of the mineral rights extracted such huge royalties, amounting here to a tenth the value of that which lay at the mine ((pp. 14-15)).

2: THE SURFACE WORKINGS; ORE PREPARATION

Moissenet begins this section by explaining that the processes dealt with an ore poor in lead, strongly mixed with blende in an extremely hard quartzose gangue. Its yield was less than 6 percent of the extracted rock. As has been shown, (above pp. 34,41 and FIG. 7), the crushing mill was at four levels, set into a gentle slope; an upper, middle, lower, still in use. The fourth, lower still, was inactive at the time of the visit.

On the upper level ore sorting was organised like that at Level Fawr though the ore here passed through a grille with 1½ inches between the iron bars and a one-inch square mesh on the griddle ((*trommel*)). At Level Fawr the mesh was smaller. The sorting operation was overseen by a lad with a long iron pick ((*crochet* pp. 17, 51)). There were three groups of jiggers ((*cribles*)): 6 four-holed, 6 five-holed and 4 six-holed and two types of hand-jigger; one set with 7 perforations per inch. These were the only ones made of wire-mesh. Then there were copper sieves or *copper bottom* with a 1 mm mesh, used to finish washing the fine ore grains. Different types of griddle were used, having varied sizes and numbers of holes.

At the time of the visit, the Welsh buddles were inactive. There was no shaking trunk. Instead, their place was taken by the Lisburne buddle and the sizing box.

The Lisburne buddle had first been built in 1855. Its introduction profoundly changed operations at the mine. It was essentially an inclined table, irrigated from the upper end by water, through which the ore was pushed diagonally by a heavy rake((*rateau*)) having 21 teeth reverberating at 20 oscillations per minute. The resultant sorted ore was then shovelled into the topmost of four boxes, the smaller material falling into the other three, mud alone arriving in the lowest box.

This sizing box (*classeur à jet d'eau*) consisted of three graded boxes through which water jets were directed from below (p. 54)). The larger grains were resisted by the current, and fell into the first box; the finer grains fell more slowly into a second box, mud escaping elsewhere. The machine was not working as efficiently as it might have been, due, Moissenet felt, partly to the way in which this particular model had been constructed, and partly to its being forced to take a larger, more unsuitable grain size.

On the lower floors were three round buddles, a kieve with a mechanical agitator, and a rotating table. The latter, of German origin, was known as a Zenner rotating frame, and was employed alongside the round buddles. Moissenet observed that its use here was nothing less than characteristic (p. 53)).

Moissenet then went on to explain in great detail the layout of the works, as illustrated upon his sketch plan, ((Plate 1)) (see FIG. 17 above), providing detailed measurements of each individual installation (pp. 53-56)). The slime and finings issued at the lower end of the workings, after having passed through a grinder, the first Lisburne buddle, a crusher, five large slime pits and two round buddles. It cost £5 to wash each ton of ore.

Some attention was paid to the several qualities of mineral debris which issued from each particular piece of plant, together with an account of its passage to the next machine (pp. 58-63)). There follows a much more detailed description of the Lisburne buddle, in which Moissenet enters into a closely reasoned account of its theoretical aims, its performance, and its products, and the nature and function of its attendant plant. Its analyst concludes that, even used judiciously, this type of buddle is not to be recommended for use with a good number of ore-types (pp. 64-72)).

Tables follow, summarising the passage of ore around the workshops and the degree to which metal-enriched material was eventually deposited to be collected for despatch (pp. 74-77)).

3: DESCRIPTION OF THE MACHINERY

See Plate II (here FIG. 21)

Moissenet next details the dimensions, functions and products of the other machines; the slide (*trémie*), the grate (*grille en fonte*), and griddle (*trommel*). Here (p. 80)) he adds the interesting detail, in a footnote, that the steel-gridded mesh sheets which comprised the casing upon the griddle cylinders, were to be bought in Aberystwyth for 1/6d per square foot. Those at Level Fawr only lasted 2 months. In perforated sheet steel, rather than of steel wire, the cylinders lasted 6 months. He goes on to provide unusual detail about the staff employed in the sorting tables of the grading shed: one strong small boy by the grille; 4 strong girls as sorters, 2 each standing on either side of the table, holding stretchers in their arms; 4 more small girls, standing around the lower rotating table (p. 82)). The big girls and the boy were each paid 9d, the younger girls, 5d per day. They dealt with 80 tonnes of ore per working day of 10 hours; the mine produced an average of 65 tonnes per day.

Again, but only in a footnote, we are furnished with great detail of the underground tram waggons; they ran on 2'6" iron rails 36 lbs weight per yard, and the trams weighed 8 cwts unladen and at Logaulas would carry up to 0.9 tonne of mineral. The enterprise cost 5d per waggon load (p. 83)).

The dimensions of the driving rollers in the crushers are given (pp. 84-85)), also details of the passage of water through the crushing gear and thence to the several canals (launders?) (pp. 86-8)). The largest waterwheel turned 8 to 9 revolutions per minute. Its crusher processed 30-35 tonnes per day of 10 hours (p. 85)).

The jiggers are similarly treated by Moissenet, with statistics on the price of copper sheet, plain and unperforated, since 1844. Interestingly, for 1 1/8th" gauge it rose from 3/2d to 6/2d per square foot during the observed 15 year period. There is an account of the way in which the finings are dealt with by girl workers, who, for 9 pence per 10 hour day processed 6 tonnes of it (pp. 90-91)).

The shaking trunk, the tye, Welsh buddle and Lisburne buddle are again explained (p. 91-94)). According to Moissenet, the Lisburne buddle was invented and first built at Frongoch by Captain Vigus late in 1855. Attention is drawn to the account of the buddle given by Phillips and Darlington in their *Mining Records*, p 127. Moissenet goes to town on its construction and dimensions, working, hydraulic needs, motive force and unit costs. Here we find that its operation required 67 gallons of water per minute, and once more required 4 strong girls. It could process between 15 and 40 tonnes a day, and averaged 25. Up to 70% lead could be recovered from the first box on the buddle, 40% from the second, 25% from the third and 4% from the fourth (pp. 95-106)). Moissenet next enters into a lengthy and complicated theoretical essay into the trajectories of mineral grains and their behaviour in the buddle (pp. 107-114)). This, in turn is followed by a similar analysis of the sizing box (pp. 114-5)).

After mentioning the then almost obsolete crushing plant at Level Fawr, round buddles are next described; they had been known for over 20 years, but had more recently fallen into disrepute on the continent. As they worked perfectly at the Lisburne Mines a clear explanation seemed to be demanded of how they could be used to best advantage. Basically, he explained that it had required modification for success (pp. 116-20)).

Finally, of the processing apparatus, he explained the tozing kieve, by that time redundant at Frongoch, but still in use at Level Fawr.

4: ECONOMIC ASPECTS.

The Lisburne Mines were held as 400 shares of capital, each of £18.15s, with a total invested capital of £7,500.

By November 1864, the mines were worth £40,000, having produced a dividend of £403,500, with a capital value of only £90,000, the equivalent of 2,815% on original investment. About £½ million worth of ore had been sold.

Total production figures for the Lisburne Mines group were given for the years 1857,8 and 9 showing net annual profits:

Ore sold (tonne of 1000kg)	1857	1858	1859	total
galena	2,318,531	2,444,044	2,453,921	7,246,544
blende	278,706	153,033	541,285	541,285
market value (£s)	34,523.6s	32,985.16s	34,489.18s	101,207
less royalties	3,324.10s	3,168.19s	3,282.17s	97,242.16s
value to company	31,196.8s	29,824.19s	31,167.1s	92,118.8s
total expenditure	23,531.15s	22,439.11s	22,129.16s	68,101.2s
total net profit	8,467.	7,385.8s	9,039.6s	24,889.15s

The exploitation of galena and blende were intimately connected. From each average ton of galena at £13.18s per ton, about £3.7s or 24.11% was profit. Wages accounted for 9.66% and overheads 65.93% of the total returns. These compared well with the figures given by Phillips and Darlington in their *Records of Mining and Metallurgy*, p. 255.

Interestingly, once it had arrived at the port of Aberystwyth, the purchaser of the ore paid its carriage. The cost varied from 4 to 7 shillings per tonne, depending on its destination.

The ore was sold by the ton of 21 hundredweight (*quintaine*) of dry dressed mineral (*mineral sec*) amounting to 2,352 lbs. But weighing out at the mine was of 20 hundredweights of 119 lbs, grossing 2,380 lbs per ton. 2,380 – 2,352 lbs left an excess of 28 lbs, intended to cover any loss incurred in transport. The ore was carried in heavy-duty sacks by road to Aberystwyth, where it was assayed for humidity before embarkation. Hygrosopic readings of at least 2.45% by weight were to be expected. Freight charges were estimated by wet weight, though marine tonnage was calculated upon dry. Aberystwyth Harbour Authority levied 1.s per ton carried (p. 124)).

A table follows, giving detailed monthly out-goings at both Level Fawr and Frongoch together with average prices and wages.

For Frongoch these run as follows:

SALES 1847: mineral extracted by tonnage: galena 21,243; sold, 1,356, 3cwt 3 q.(yield 6.38%). price £15.8s 3¼d. per 21 cwt ton; blende 264 tons 7 cwt lq. sold at £3.8s, 3¼d, per ton.

PRODUCTION COSTS:- galena Crop: 11s, 2¼d; slimes: £21.3s, 8¼d, and blende, crop:10s.

SALES 1858: min, extr, galena 16,193; sold, 1,078 tons 20cwt (yield 6.53%). price, £14.2s, 9¼d, per ton; blende 143 tons 11cwt sold at £3.14s, 8d, per ton.

PRODUCTION COSTS:- galena crop: 9s, 3d.; slimes: £3.6s, 1¼d.; blende crop, £10.

SALES 1859: min, extr, galena 18, 908; 1,033 tons 5 cwt (yield 5.46%) sold at £14.12s, 5d, ton; blende 105 tons 10cwt sold at £214.0s per ton.

PRODUCTION COSTS:- galena crop: 14s 0¼d.; slimes: £3.8s, 7¼d.

It is difficult to analyse the monthly averages provided on the same table, since these include complex factors relating to the other mines (Glogfach and Logaulas) which processed at Level Fawr. Moissenet offered several useful observations upon this collected data. Between 1857 and '59, production at Level Fawr rose while that at Frongoch fell. Up until 1857 Frongoch had upheld the production of the group as a whole. Then, after tribute payments had been introduced at Logaulas in 1857, their roles had virtually reversed. The relative profits per ton (21 cwts) for these years were:

	1857	1858	1859
Level Fawr	14s.2d	£3.2s, 2d,	£4.18s, 3d,
Frongoch	£5.9s,	£2.12s, 10d,	£2.11s. 3d,

Profits at Level Fawr had risen from 4.43% to 14.26%. Percentage yields at Frongoch declined slightly from 6.58 and 6.55, to 5.46%, but these differences were to be put down to the extreme difficulty with which ore-washing was undertaken, owing largely to the presence of blende. The production of both crop and slimes thus rose appreciably over the three-year period (p. 129)). But whilst the cost of raising a ton of ore at Frongoch was cheaper than at Level Fawr, it came to only 5½d at the former and 1s. 6½d. at the latter and processing inflated these figures to respectively 12s and 16s.

A detailed discussion follows, of relative production costs of crops, slimes and halvans from the mines in the Lisburne group.

Moissenet had been anxious to establish the exact yield of metal from the ore, but in this he had not succeeded. Although somewhat affected by the blende within the ore, lead crop from Frongoch, like that from Level Fawr, was probably up to 78% and around 55% from the fines.

He discussed at length the way in which losses of mineral were part of the manufacturing process (p.134-5)), and offered the theoretical mean of 9% loss at Frongoch (p. 136)).

In a critical summary of his work at the Lisburne Mines, Moissenet regretted that hand cobbling by hammer had disappeared. Frongoch was all but a model workshop, though sizing griddles should be introduced, and these would complement the virtues of the Lisburne buddle. 'Thus complete, it seems to me that ore processing at Frongoch, already close to a working perfection, would in future rank among those classic establishments which served as milestones to progress in the art of mining ((p. 137)).

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FIG 18 Frongoch. Plan of levels, C 1870. (R.C.A.H.M.(W))

