The Mechanical Preparation of Ores in England

Galena, and Mixed Galena and Blende at the Lisburne Mines, Cardiganshire.

7 Lessons given in 1865 at the School of Mines.

by
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* By direction of the Minister of Public Works I gave at the School of Mines in 1864 and 1865 some lessons on the methods adopted in England for the mechanical preparation of Ores; The present memoir is the development of the subject treated in the lessons of 1865.

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Introduction

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Galena is worked in England in two very distinct positions; in the Carboniferous Limestone on the one hand, and on the other in the ancient schists of the Silurian and Devonian formations.

During the decennial period 1848-1859 the United Kingdom produced

Lead Ores. 923,145 tons. (@ 21 cwt.)
Metallic Lead. 652,926 tons.

More than half this produce was yielded by the mines opened in the Carboniferous Limestone of the North of England and the North east counties of Wales. But while abounding in Lead this formation yields silver sparingly; the mean yield of the different districts varies from 6 to 12½ ozs Troy Silver in a ton avoirdupois of Lead.

The ancient schists on the contrary contain the two varieties; lean ores, and

argentiferous ores. Thus in Cardiganshire the mean yield of silver reaches 14½ ozs; in the Isle of Man 19½ ozs; in Cornwall 34 ozs; and in Devonshire 39 ozs.

Some mines yield parcels of lead ores which are very rich in silver, but this is a purely accidental occurrence; so that for the precious metal no deposit actually worked in England is comparable to the French mines which maintain a regular production of lead yielding 114 ozs, 163 ozs and upwards.

A ~~true~~ complete study of the preparation of English lead ores should include three examples, chosen with a view to shew the modifications which result, (beyond local usages) on the one hand from the nature of the gangue; and on the other from the yield of silver.

It would thus be necessary to examine the treatment of;—

(1) Poor galena from the carboniferous limestone of the North of England.
(2) Poor galena from the Silurian schists of Wales.
(3) Argentiferous galena from the Devonian schists of Cornwall and Devonshire.

It is the second type alone which I propose to study in the present work in

* On the Mining district of Cardiganshire and Montgomeryshire, Memoirs of the Geological Survey. Vol 2. part 2. pp. 655–684

† Records of Mining and Metallurgy. 1854.

chaux carbonatée

describing the dressing works floors of the Lisburne Mines in Cardiganshire.

Some notices on the preparation of lead ores in Wales have already appeared; Professor Warington Smyth,* has described the method adopted at Goginan where the average yield of silver reaches 29 ozs; Phillips and Darlington† have briefly described the method and the appliances used in Cardiganshire.

Under the term Lisburne Mines are included several works, the principal of which are, Frongoch, East Logylas, and Glogfach. These mines supply two dressing floors.

The Frongoch dressing floor is reserved for the mine of that name; that of Level Fawr situate at the entrance to the great Logylas drainage and drawing level, receives also the Glogfach ores. Notwithstanding numerous points in common, these two floors present well marked differences, which besides corresponds to the varieties of the ores and the conditions of the work.

At Level Fawr the gangue is shale and carbonate of lime ~~calc spar~~; the yield of galena is 20 or 22 per cent of the material brought out of the mine; ~~the mine is~~ numerous tributors are employed

* Conwythwith situate ~~West~~ east of Loggylas, belongs to a company distinct from the Lisburne Mines but is placed under the same management.

which compels the lots extracted, to be prepared seperately; and lastly, the ground on which the floors are formed is hilly and from the head to the tail there is a great difference of level.

At Frongoch the gangue is quartz; the galena ~~is not~~ scarcely reaches 6 per cent of the stuff extracted; there are no tributers; the works extend on a gentle sloping ground; and lastly and above all, the ore is notably Blendy.

The method at Level Fawr may be consi=dered as ~~the~~ typical in Cardiganshire; it is applied to the important mine of Cwm-ystwith*; it has been followed at Frongoch; but the recent introduction of a very ingenious apparatus, the Lisburne Buddle, has just brought about, at Frongoch a notable modification in the course of operations.

Not only does the Lisburne Buddle facilitate the delicate operation of separating the Blend from the Galena, but it singularly simplifies the labour of concentrating the two ores. Its part can only be properly understood by considering the two systems of management, that is, that preserved at Level Fawr and that judiciously modified at Frongoch. So to avoid repetition I think it useful to describe, side by side, the

two works.

This Memoir comprises the following divisions;

Chap 1. Description of the localities. Bearings.

Chap 2. Methods of preparation. Systems of treatment.

Chap 3. Description and working of the apparatus.

Chap 4. Economical results.

I express here my thanks to the skilful managers of the Lisburne Mines, Messrs Taylor and their Agents; especially to Captain Vigus the superintendent of the dressing floors.

Chap 1.

Description of the Localities. Bearings.

Topographic sketch. — The port of Aberystwith serves for exporting the minerals, and importing stores & provisions for great part of the neighbouring mines. ~~The~~ Its situation in the centre ~~midst~~ of the Cardigan Bay, and its picturesque shores, have made it the favourite ~~place of~~ resort tourists in the West and the retreat of such sea bathers as seek a certain retirement.

The town stands near the confluence of the rivers Rheidol and Ystwith; the first comes from the East, the second from the Southeast.

The argentiferous mines of Goginan, Darren & others lie to the North, on the right bank of the Rheidol at about 10 miles from its mouth; those with which we are concerned are near the Ystwith.

From the port to Logyfas is 14 miles; the route first follows the spur which divides the two valleys, then skirts the Ystwith and passes on the left bank to Pont Llanafon; thence, by an occupation road 3 miles long, leads to the works at Level Fawr established on the flank of the mountain and bounded by the escarpment of the river bank. Glogfach lies a mile to the Southeast of Logyfas, in an elevated region; Frongoch, 2 miles to the Northwest of the same point (14 miles from Aberystwith by the direct road); lastly, at 4 miles eastward, on the right bank of the river.

In this region the Silurian shales are intersected by deep valleys; some are nearly straight with a length of several miles, and a considerable width; the bottom is occupied by watercourses, ~~sinuous~~ meandering in ordinary times, but large when swollen by rains; drift with pebbles of shale occurs on the sides, witnessing a former superior level.

Other valleys are steep, narrow and generally tortuous; they open upon the preceding

* I will instance two quarries, one near Llogfach Mine; the other on the bank of the Ystwith half a mile east of Pont Llanafon

and interrupt the line of their sides.

Surrounding Rocks. The shale is usually foliated passing into slate; its colour is a bluish grey more or less dark; in certain places, the cleavage is less defined, and the more compact rock may be quarried for building purposes. Even in this case the blocks obtained are very irregular from the number of oblique joints.

From Aberystwith to Llanglas, the general strike of the measures is Southwest and Northeast (magnetic) that is sensibly of the Longmynd system; near the town the beds dip to the Southeast, but after several plications, they are seen clearly to be inclined towards the North west in the district of the mines. Here the shale is more compact; its colour being a somewhat clear blue grey.

Directions. Most of the lead veins of Cardiganshire have a bearing of East - West, to Northeast — Southwest; but notwithstanding this general resemblance, as happens in most cases, there are many exceptions.

We shall be able to judge without going beyond the restricted space which we are now considering. Here are some mean bearings taken from a small scale plan, and which

are somewhat rude approximations; besides the metallic veins they comprise powerful quartz-ose veins whose position has been ascertained.

Going from the Southsoutheast to the Northnorthwest there occur in succession.

Name of Veins	Direction reduced to True North	Made towards,	Length of Base to a fathom of height
Lead Veins of Esgair-y-Mwyn	E 44° N	North	2ft 6"
" " " Glogfach	E 23° N	Do	1ft 6"
" " " East Logyfas	E 31° N	South	2ft 6".
" " " Old Logyfas.	E 40° N	Do	"
Quartz Vein	E 40° N	Do	3ft
Lead Vein of Grogwquion	E 10° N	Do	"
Its prolongation to Pont-rhyd-y-groes	E 5° N	Do	"
Quartz Vein	E 40° N	Do	"
" "	E 35° N	Do	"
Lead Veins of Frongoch	E 12° N E 9° N	Do	2ft 6"

The ancient systems of upheaval are as is well known strongly impressed on the contour of Wales; almost everywhere it is easy to recognise the characteristic influence of several ~~some~~ of them.

If we examine on the Maps of the Geological Survey the triangular space having

Aberystwith at its Northern, Llanrhystyd at its Southern and Logylas at its Eastern angle, we may remark that notwithstanding numerous protuberances, the ground is far from being so hilly as in the neighbouring regions. Parallel to the Coast for a length of 2 miles the slopes are easterly following the Longmynd system; from Aberystwith to Logylas the mean direction of the River Ystwith is that of the system Morbihan, interrupted near Llanllar by that of the Longmynd, then near Lauralt, by the Westmoreland System, Lastly the South side of the triangle is traced nearly in a straight line at first by the river ~~Ceryn~~ Cwm-wyras, for 8 miles, between Llanrhystyd and Pen-y-carran, towards the North foot of the chain of Mynydd Bach; then, after having crossed a defile, by the course of the Ystwith from Pont Llanafon to Logylas, The sinuous prolongation of the same line would extend to the Cwm-ystwith Mines; the line thus marked out being not less than 12 miles long, and following the system of the Land's end.

On the South, East, and North of Logylas, the most obvious directions are those of the Systems Longmynd, Morbihan, and Westmoreland. This latter system often appears deviated by the anterior influence of the System Finisterre and

probably also of the Longmynd.

There is sufficient ~~xxx~~ to warrant the supposition that the period of the filling of the veins by lean galena, here as in Flintshire, may have extended to the epoch of the system Ballons; that is, has been posterior to the deposit of the carboniferous limestone.

The direction proper to the system Ballons is met with more rarely in the fissures, inasmuch as the earth had been so extensively fractured by the previous upheavals. Even if we consider only one epoch as the time of formation of the lean galena in Cardiganshire, it is easy to understand how the contents of the veins might be variable. In fact the tolerably constant direction of the strike of the beds, (Longmynd) forms very different angles with the ancient systems, such as the Finisterre, Westmoreland, and Land's End; ultimately from the further disturbances produced under the influence of the system Ballons, new angular differences have been brought into play; lastly in each locality the nature of the shale has been more or less favourable to the formation of clefts.

In the before mentioned mines we find as ruling directions; the system ——

* The declination at the Lisburne mines in 1860 was estimated at 22½°; the magnetic bearings E 18° N and E 15° N reduced to true north become E 40½° N and E 37½° N; now the system Westmoreland represented by the great circle of the corresponding pentagon, has a bearing:-

At Holywell, Flintshire E 38° 16′ N;

At the point in Cornwall E 40° 24′ N.

Westmoreland at Esgair-y-mwyn; the Westmoreland modified in sundry degrees at Glogfach and Logyfas; lastly the system Lands end and even Ballons, at Frongoch and Grogwynion.

Deposits. The Esgair-y-Mwyn lode is a true fracture; its general direction is E 44° N, and it attains 30 feet in width; the mass of the lode consists simply of broken shale, traversed by cross veins, some of which contain galena almost free from gangue. Gossan is here found to a considerable depth.

At Logyfas and Glogfach, the lodes are less powerful but more regular; the branches are richer than the main lode, and it is chiefly at the points where it meets the branches that the main lode becomes productive.

In the ancient open works on the outcrop of the lode at Logyfas, the trenches still open and evidently made on the rich parts, bear E 18° N magnetic. In the mine the profitable parts bear E 15° N; whilst in the direction E 10° N the lode has been followed entirely barren and even scarcely discernable.

At Glogfach E 18° N is also the useful direction; it is precisely that of the system Westmoreland *

At Logyfas as almost everywhere, ground country

* Since 1860 the yield of silver appears to have notably increased at Glogfach; Mr Robert Hunt's statistics for 1862 show a production of

Ores 7715 tons yielding { Lead 612 tons. Silver 9,800 ozs.

Being about 12·65 ozs of silver to the ton of merchantable ores.

of middling hardness is favorable to the richness of the deposits.

The lode is principally filled with broken shale, the fragments of which seem to have a bearing; the vein shale is generally hard and quartzy; in places, it contains ore and gangue in the form of small veins. Whence it happens that mineral of a somewhat high mean yield is extracted but not in large masses.

Accompanying the lode are of a very quartzose shale or capel which sometimes contains much disseminated galena.

Logglas and Glogfach present a very similar assemblage of minerals. There occur, cleavable galena, brown blende, carbonate of lime, sometimes crystallized and hyaline, but generally cleavable, opaque and of a slightly rose tinted white; this gangue in moderate quantity is considered a good indication. The quartz is there crystallised but is not abundant, iron pyrites is rare.

At Logglas, the galena yields 3 ozs of silver to the ton of washed ore; at Glogfach the yield reaches 6½ ozs. (in 1860).*

Frongoch mine is opened on a powerful

quartz lode, containing galena and blende. The workings has extended a length of over 1300 yards; the width of the vein varies from 10 to 30 feet. Flats Courses of ~~ore~~ paying ore have been met with 30 to 50 fathoms long; these ~~deposits~~ flats dip to the West, as do the shales of the surrounding enclosing ground.

The great quartz vein bears 8° to 12° North of true East, ~~that is~~, corresponding with the system Land's End; whilst galena is also met with in the branches from the main lode and which bear 2½° to 7½° North of West. (Ballous.) This is notably the case in the 56 fathom level east of Taylor's shaft.

The favourable shale is of a clear grey, and traversed by veins of quartz.

Besides quartz, which always predominates and is sometimes well crystallised the lode contains quartz of shale or imperfect Capel.

There are two varieties of galena; the one laminated and cleavable, the other fine grained, called "steel lead" and which is less plentiful. In each variety the yield of silver is 3ozs to the ton.

The blende is brown; it is found according to the part whence obtained more or less mingled with the galena; the two often forming what might be termed,

; in some places they are in veins and large patches in the quartz; still the mixture is not completely intimate.

In the extracted minerals, the proportion of blende to galena is about one eighth.

To the East of the mine, the explorations made on the back of the lode, have yielded a large quantity of blende mixed with oxide of iron; a sort of blendy gossan. At the 24 fathom level the vein stuff has abruptly changed and galena takes the place of some of the blende. Still it has been observed that in depth the blende without being abundant extends over greater lengths in the levels, whilst the ~~patches~~ masses of galena seem to become more contracted.

Principle facts in the Working. To these notes on the mode of occurrence of the deposits of ore, I will add a few more on the state of the works executed at the Lisburne Mines, and on the resources available for working them.

Logyas Mine certainly owes its present prosperity to the great adit, which having been driven 364 fathoms has just cut the lode at 60 fathoms deep. There are nine levels; at 20 30, 44, 60 (the adit), 70, 90, 105, 120 and 130 fathoms. The last is 130 fathoms below the

(Does lemon exactly at 60 f

surface of the ground and only 120 fathoms below the adit level. In 1860 the most active explorations were in the 105 and 120.

Glogfach, mine much more recent, but rapidly being opened, has only four levels as yet; those at 48, 58, 73, and 88 fathoms.

At Frongoch, although the works are very extensive in a horizontal direction, they have not yet attained great depth; two shafts are being sunk below the 178 fathom level; the adit only drains down to the 214 fathom; below this are the 34, 44, 56, 66, and 178 fathom levels.

The drivings in these various explorings both in the lode and in the adjoining measures require ~~a large quantity of~~ little timbering; everywhere the ground is solid, although at Glogfach it is not so hard as at Frongoch; as appears from the following figures:—

Name of Mine.	Average price paid in 1859 per lineal fathom	
	In the lode	Across country
Glogfach	£3. 6. 0 / £3. 4. 6	£4. 16. 9 / £4. 13. 3
Logylas	£5. 2. 4 / £5. 0. 0	£5. 5. 7 / £5. 3. 9
Frongoch	£6. 7. 2 / £6. 5. 0	£5. 10. 4 / £5. 8. 0

The resistance of the rock may be

* at 25 frames to the pound in red. 25.57 to a pound in black.

* They consume 100 to 120 tons yearly of Coal bought from Ruabow.

compared with that of other mines by bringing together the price per fathom and the wages and mean &c. costs of the miner hereafter given.

Water is not abundant in the workes; but there is a sufficient surface supply for the dressing of the ores, and numerous falls have been made and utilised by bucket wheels. (overshot). The motive power is entirely hydraulic, an almost vital condition in a locality where coal costs 25 shillings per ton. *

A long conduit, ending above the outcrop of the lode at Logylas serves two waterwheels, one 36 ft. diameter and 4 feet wide for pumping and the other 40 ft diameter and 4 feet wide for winding the stuff. These have merely to lift the water and stuff to the adit level. After leaving these wheels the water rushes down the hill side and at about 110 yards vertical lower arrives at the Level Fair dressing floors.

At Frongoch to guard against want of water recourse has been had to vast reservoirs; the principal wheel is used for pumping; it is not less than 55 feet diameter and 4 ft. 6 ins wide and is estimated at 60 horse-power.

Persons employed. The Agents or Captains are Cornishmen; this is enough

distributed ;-

	Number of Miners.	Wages earned in 1859.
Sutwork	222	£144 . 5 . 7
Tribute	102	£486 . 16 . 9
Totals.	324.	£1934 . 2 . 4

The following are the ~~me~~ average monthly earnings of the workmen according to the wage books and the cost of materials debited to them,

	Average per month per man	
at Sutwork ,	Earnings £2 . 12 . 3.	Materials . 15 . 8.
At Tribute ,	" £3 . 3 . 4.	" £1 . 3 . 4.

The difference between the earnings of the sutworkman and the tributor is not abnormal, since the tributor is likely to display more thought and intelligence; the costs of materials however require some explanation.

The costs are more than the real expense; in fact the company furnishes the workmen with powder, fuze, candles, tools, &c, at a known tariff, but fictitious as to the real value of these materials, and high enough to form a strong incentive to economy on the part of the workmen. Besides this at Copiapo the tributor pays the cost of drawing the stuff from the mouth of the adit level to the dressing floor

and the costs of dressing which are fixed at 15s. 0d per ton of merchantable ore placed to his credit.

The dressing floors of Frongoch and Level Fawr each employ 70 to 80 hands: there are few men, a certain number of lad and young girls, and a large proportion of young women. The men are paid by the month according to their strength as surface labourers; the lads and females by the day.

The days wage varies from 4d to 11d and averages 7d. If we assume 26 working days per month these prices give as limits 8s 8d. to £1. 3s. 10d. and as an average 15s 2d per month.

In 1859 the cost of labour on the two floors was £1,669. 18. 4, or say about 7.55 per cent of the total expenses of working. There were 26,125 tons of stuff received at the floors and they delivered for sale, 2414 tons of galena and 110 tons of blende.

These figures suffice to shew the importance of the dressing arrangement at the Lisburne Mines.

On the whole the company command excellent aids to successful working, waterpower, and good workmen who are content with

moderate pay; on the other hand the landlord imposes a heavy charge, for the Royalty amounts to one-tenth of the merchantable value of the ore at the mine.

Chapter 2.

Methods of preparation. Systems of Treatment.

1. Level Faur Dressingfloors.

This second chapter will be purely descriptive. We shall study successively the dressingfloors at Level Faur and Frongoch, and for each we shall give;

A summary sketch of the various steps of the operations, and of the purposes of the apparatus employed.

A description of the establishment in the form of ~~an~~ detailed explanation of the sketches figs 1 and 2. Plate 1;

A detailed examination of the operations;

Tables of the methods of treatment.

Sketch of the Operations. At Level Faur the circumstances favourable to the work are the already high richness of the stuff as drawn, (20 to 22 per cent), the somewhat muddy slightly

* The somewhat hard shale in the Loggas lode gives little mud; the quartzy shale and quartz of Trongoch produces still less. In this respect the ~~ores~~ stuff drawn at Loggas is analogous to that of Wheal Trelawny a silver-lead mine in Cornwall; as opposite types I may cite Cargoll, a rather wet mine in clay shale in the district of Newlyn in the same county, and in France the softer parts of the lodes at Pontpéan near Rennes.

nature of the gangue*, a plentiful supply of water, and a considerable and well regulated slope of the ground on which the floors are situated. We might add the procinity of the River Ystwith which receives and carries away the refuse.

As special difficulties may be noticed the dissemination of the galena in the gangue, the necessity of preparing the ore for sale of as great richness as possible, and the introduction of the tributing system, which compels the separate preparation of the lots sent out by the several gangs of men.

The floor is divided into two unequal parts by the road leading to Aberystwith; the higher contains the crushing rollers and jiggers, and yields alone nearly 8⁄ per cent of the saleable ores; the lower one receives only the finer substances and treats notably the stamped stuff; ~~and crushed products~~, all the washed ore which issues from it belongs to the company without royalty to the tributors. A third floor, called the halvan-floor treats the slimes from the preceding. The preparation is here done by a special staff of tributors who receive a fixed price of £3.15.0 per ton of ore enriched to about 55 per cent of lead.

The sketch does not extend to this

floor which lies to the west between the road and the river: besides the produce is not more than 1 per cent of the whole ores sold.

The whole process comprises three divisions;-

1st. Operations before crushing; comprising; the cleaning of the ~~ores~~ stuff, the classification according to size, which separates the small ore from the blocks and ~~lumps~~ fragments, then the ~~bucking~~ spalling and sorting of the blocks, and handpicking cobbing + the fragments, whence results refuse and good crushing stuff, and lastly the preparation of the small ore.

2nd. Treatment of the crushed ores: there are two pairs of rollers; the large rollers crush the sorted stuff rather coarse; the small rollers crush it finer, and receive the secondary products of preparation, whether small ore, or coarsely crushed stuff, or lastly the stuff requiring to be finely crushed.

3rd. Treatment of the ~~finely crushed~~ stamps stuff and the slimes from the whole floors; the stamps are fed with the small and poor secondary ~~matters~~ products from the work, the small ore, and the crushings; they yields sands and slimes; the sand is washed separately whilst the slimes flow into settling tanks with

all those from above: the settlings are treated in the lower dressing floor.

Notes on the Apparatus.