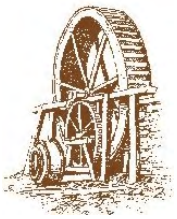
WELSH MINES PRESERVATION TRUST

Yr Ymddiriedolaeth Cadwraeth Mwynfeydd Cymru



NEWSLETTER

Number 32 May 2013

SPECIAL EDITION

TO MARK THE HOLDING OF THE NAMHO CONFERENCE 2013 IN ABERYSTWYTH

CONTENTS

Graham Levins

SECRETARY'S NOTES

Welcome to the latest edition of the WMPT Newsletter. I am afraid that, due to pressure of work, this is the first one for a while. Unfortunately we are a victim of our own success: over the last few years we have become involved in so many projects that the workload in addition to my full-time employment is more than I can cope with at times. Since the last edition there have been some interesting developments and projects carried out.

We have continued with our excavations at Cwmbyr: see Nigel Chapman's article.

Early in 2012 the Environment Agency (EA) announced their intentions to carry out Water Quality Remediation works at Frongoch: this involves constructing a settling lagoon and concrete-lined drainage culverts across the lower part of the site. We were concerned about the archaeology that could be buried inches below the surface and would be vulnerable to damage by their works and movement of heavy machinery around the site. We approached the EA and the landowner John Bray, who gave their permission for us to carry out a survey and excavations. We planned to hold one weekend there, but so much was found (see my report) that we spent three weekends there and still did not complete our work. We hope to return to Frongoch at some point when the EA works have been completed to carry on with our investigations.

The Trust has also played a part in the rescue and future preservation of the George Green Boiler from Tan Yr Allt Mine, near Talybont: see Simon Timberlake's article. Later in the year we will be carrying out work on preserving the boiler and members will be invited to assist. If you would be interested in helping please get in touch with Simon at simon.timberlake@btinternet.com (01223 292090). At present the boiler is in a safe location in Aberystwyth while its future location is discussed.

In this time of financial restraint we would find it difficult to obtain funding for preservation projects; but what we can do is to investigate sites and record what is still there, before it is lost for ever. If you think that a particular site is worthy of investigation, please do not hesitate to get in touch.

We include in this issue articles by Nigel Chapman on Cwmbyr, Simon Hughes on Buddles, Simon Timberlake on the Tanyrallt boiler, Robert Ireland on the electrical plant at Pont Ceunant, and myself on our explorations at Frongoch. We also welcome a new contributor, Ioan Rhys Lord from Cwm Rheidol, who has been exploring the mines in the Rheidol Valley for several years. Ioan has written an overview of these mines, and will in future editions be providing more in-depth discussions of the various sites.

I hope that these articles will add a greater variety to the content of the newsletter. Anyone who wishes to contribute an article to the next issue should please contact me. The article can be about any aspect of the Trust's work. If you are working on a site, a project, or a piece of source-research of your own, we would love to hear from you.

DATES FOR YOUR DIARY

NAMHO CONFERENCE

This year's NAMHO Conference will be held in Aberystwyth over the weekend **28/29/30 June**. Nigel Chapman and I will be giving a talk on the work of the Trust, and on Sunday 30th we will be holding an open day at Frongoch so that delegates can see our work there.

WORKING WEEKENDS

We will be holding working weekends on the following dates:

27/ 28 July: Cwmbyr Mine, Aberhosan: meet 10.30 a.m. each day.

31 August / 1 September, **5 / 6 October**: I am not able to confirm locations yet as this depends on progress of the EA works at Frongoch.

If you are interested in attending, please contact me (as above), and I will advise the locations closer to the date. Details of Trust events when confirmed will appear in the WMPT section of the Welsh Mines Society website, www.welshmines.org/wmpt/

SUBSCRIPTIONS

Membership fees have been held at £8.00 per year: a form to pay this year's subscription is included with this newsletter.

My thanks to all the contributors and to Robert Ireland for compiling this newsletter.

Nigel Chapman

A SITE VISIT TO CWMBYR MINE IN 2012

Cwmbyr lead mine is near Aberhosan, Montgomeryshire, at SN 786947.

THE PUMPING WHEEL. To the north of the mine and to the west of the gate in a hollow are the shale slab built walls of a water wheel pit. Said to have been constructed for a 41 feet by 6 feet water wheel that was erected to pump from the main shaft. By means of a long run of flat rods terminating at a wooden quadrant placed on the edge of the shaft the mine was pumped dry. This alignment would have required the flat rods to pass over the roofs of several of the mine buildings. The pit is now filled with rubbish and quite overgrown with the sides collapsing inwards. The condition of these remains is very poor.

THE SHAFT TOP AREA. Raised about 10 metres above the mine site on a bank of mine waste are placed the three structures of the shaft top buildings. To the east is the shale slab built pit for a pumping quadrant complete with the pivot and base of the quadrant still in place. Two large iron mountings bolted to timberwork are placed between two parallel slab built walls on the edge of the shaft. A large solid iron casting pivots on the mountings and carries two large timber beams, both now reduced to short stumps. These beams were positioned to form an L creating the turning point from horizontal to vertical for the flat rod system to drive the pump in the shaft. Still in the shaft against the west side is the pump rod disappearing into the rubbish tipped by the local farmer. Rough cut in the rock, the shaft has a secondary excavation to the east, this was probably to extract a pocket of lead ore. Open and dangerous, the shaft has been used for dumping farm waste.

West of the pumping quadrant pit and below the level of the pit top are three shale built walls probable the site of a stone breaker for reducing the ore to a uniform size for the crushing mill. To the west is an ore slide with the west edge destroyed by the Forestry road building activities. Further west is a steel built rectangular body of a tub, much battered it still retains the axle mountings. It should be either recovered to a better home or at least drawn. South west of the shaft is the levelled site of a horse gin with a trackway leading down to the west.

In the stream bed to the north west of the shaft area and buried under the tip is a slab built drift, probably the outfall from the shaft pumps.

SHAFT TOP BUILDINGS. As I understand the shaft top area, the ore was brought to grass in trams in a single cage operated by a turbine winder. So the trams would have been landed on the shaft top area and taken to be tipped into one of the two ore slides built into the west side of the pit bank. Lumps of ore would have been taken through a doorway on to tables to be washed and broken small enough for the crushing mill. By our period in the 1860s the Blake's jaw crusher would have been the standard breaker machine and one must have been used here. The area on the 1880s map has a large roof over the front of the slides and area north of them. The breaker could have

been accommodated in the small room to the north of the ore slides with power taken off the pumping rods. Once reduced to about 4 inches cube, the ore would have then been barrowed down a track to the hopper placed above the feed point of the crushing mill, where a raised area of shale marks the site of the hopper.

With a set of pumps in the shaft, the shaft top area must have had space for a horse gin to raise and lower the pump rods, a wooden head frame over the shaft and probably a building for the shaft top crew.

WINDING. To the north, at a slightly lower level to the shaft top was a building housing a Girard's turbine, to drive the winding ore from the shaft. It is quite possible that with this machine at the mine, a cage could have been used in the shaft instead of the usual kibble. The use of a turbine, appears to have been an attempt to speed up the wind in the shaft and therefore improve the output from the mine. Water to drive the turbine was lead down the mountain side in 18 inch diameter pipes to supply the necessary pressure to operate the machinery.

THE DRESSING FLOORS. Further to the west and above the Nant Cwm Byr are several projecting timbers. One is part of a wooden water wheel, probably of about 8 feet diameter and supplied power to operate two round buddles further to the south. Some timberwork and bolts mark the site of the wheel pit which is filled with mine waste. It is suggested based on the remains of the wheel that about one third of this wooden water wheel could exist buried in this pit. It would make a suitable subject for excavation.

Further to the south with a several projecting timber posts is the site of two round shale built buddles. Placed in a hollow, both buddles can be noted being about 4 metres in diameter. Along the edge of the dressing floor above the Nant Cwm Byr are

several posts probably part of the drive mechanism from the water wheel. When excavated during 2010 the north buddle was found to have the foundation ring and three pieces of the original flooring of wood still in place. The south buddle retained a complete circular wooden floor with a central hole and the detached metal pivot for the sweep arms. As the buddle operated it had caused a slight movement of the inner edge of the floor giving an indication of the direction of travel.

Pieces of wood, some in situ and some scattered about the floors remain, also some pieces of iron. Two small parts of a gear wheel were found including a couple of teeth. A large piece of one of the crushing rolls from the mill lies in the grass.

Much of the eastern side of the floors has been ripped up by the Forestry Commission to permit the planting of trees, destroying much of the area. However in the process they have broken into the wooden lined channel taking water from the Crushing Mill wheel to feed the pumping wheel down the valley.

THE CRUSHING MILL. The southern end of the dressing floors is occupied by a large shale slab and block built crushing mill. The building is aligned north to south with a wheel pit in the middle. A water wheel of 27 feet by 3 feet wide is said to have operated here and some pieces of a wooden wheel can still be found. To the west are two massive block and slab built walls to carry the rolls of the crushing mill. Two large timbers of the first floor remain with holding down bolts in two instances still with timber beams in place. The building was once roofed with slates but appears to have either been open to the west or had a wall of weatherboarding.

To the south of the mill a retaining wall abuts the mill probably built to prevent the encroaching tip from reaching the dressing floors. To the east of the wheel pit is a long narrow single storey room complete with a fireplace at the northern end of the east wall. Also in the eastern wall is a doorway. It is suggested that this was a winding house for the shaft being very similar to the house at Graig Goch before its destruction.

Excavation within the house during 2011 revealed the existence in the right position of a pit 2.2 metres long by 1.3 metres wide for the winding drum. On this mine we appear to have a high speed turbine winding system to wind from the shaft and a slower winding system operated from the water wheel. Which superseded which or were they both working at the same time?

Slightly north of this building is a plinth of slabs with a projecting iron rod. This appears to be part of a flat rod system to pump from the shaft. The remains suggest that the water wheel was driving a crushing mill, winding from the shaft and pumping water also from the shaft. At a later date it is suggested that the wheel was also powering the jigger. An alternative for this plinth is that it was used to provide power to operate the stone breaker. With the 43 feet wheel now believed to be the pumping plant until closure of the mine, then the other requirement for power was to drive the stone breaker.

Under the rolls of the crushing mill, to take the crushed ore from the mill was a cylindrical drum mounted at a slight angle and rotated by gearing from the water wheel. The sides of the drum were perforated with sections of holes, each section having larger holes than the last. As the drum was turned the crushed rock moved gradually down the drum, while the smaller particles fell through the holes, to be sent to the jigger. Any rock reaching the end of the drum would have been returned to the

crushing mill for a second pass. Known as a Trommel or Spiral Classifier, this was the first stage of a mechanical process of ore separation.

By this means a continuous run of crushing mill, spiral classifier to jigger was possible, followed by the slimes overflowing into the hutches along side. The slimes could then continue from the hutches to the settling boxes on the dressing floors. In theory it should be possible for the slimes then to flow onto the buddles, so that apart from two or three people to operate and watch the process the dressing floors could operate a continuous process. With the various hutches and settling boxes filled, the man and wheel barrow would have been necessary to move slimes or concentrated lead to the next part of the process.

While discussing the crushing mill, south of the building, at a higher level on the tips is a rectangular shale foundation forming the base of the bridge for the ore to be loaded into the hopper above the crushing mill.

To the west of the crushing mill, aligned on the axle of the water wheel, stands a two-compartment timber-built ore jigger. Probably added to the mine later in its life, this jigger took crushed ore directly from the mill to be jigged and separated from the waste rock. Power was taken from the water wheel by cogs and shafts through the crushing mill. The jigger by a series of plungers driven by eccentrics on a shaft aggravated the ore in water, so that the light waste went over a timber wall and out to the north into a square wooden trough. The lead ore went to the bottom of the jigger, into wooden square cones and though an opening in the base of each cone into further wooden troughs along the north side of the box. A similar arrangement of troughs is suggested for the south side, but little evidence was seen. Water from the jigger went out a closable opening in the base of the west wall of the jigger. A wooden

channel appears to have taken the water away to the Nant through a second doorway in the channel. It is suggested that the water could have been directed north across the dressing floors by means of the second door.

The jigger was constructed in two compartments, the first with a wooden ridge from east to west had three small square cones along each side. The ridge in this area was at a very steep angle. The second compartment consisted of central ridge aligned east to west but at a lower level set at a much shallower angle, again each side was divided into three square cones, each with a square flat base and a small outlet to a wooden square box outside the jigger. Excavation during 2011 proved that each side of the jigger were four wooden boxes roughly square in size. Ore from the jigger was released via ports in the sides of the machine to fill the four hutches. The overflow from theses hutches went via cut outs in the top edges of the hutches to flow along a series of wooden lined channels to the western or front of the jiggers. Each jigger side had four hutches to feed into the channels, the southern channel feeding across the front of the jigger, while the northern series could feed either to a north heading wooden channel to large settling box above the buddles or west to the settling boxes directly above the Nant Cwmbyr. Small wooden blocks could be inserted into the wooden channels to stop the flow and send it off in other directions. So after a settling box had become full it could be cut off from the system for emptying while allowing the slimes to flow to other boxes. It is now suggested following some research that the jigger is of the Argall's type as illustrated in R. Hunt, *British Mining* (1887). One major detail noted on the Argall jigger is the lever operated doors at the base of the machine, similar to the Cwmbyr example.

Unfortunately the upper parts of the jigger have gone, leaving the two compartments rotting. Where the jigger was buried into the ground much of the woodwork survives in very good condition.

THE OFFICES. To the east and across the existing road from the dressing floors stands a long single storey row of 40 metres long by 6.5 metres wide. Originally a single block, the building has been extended north and south on at least two occasions, probably more. A room to the south has parts of a large fireplace against the north wall suggesting this was the blacksmith's shop. Adjacent to the Blacksmith's shop was a pile of waste pieces of iron of every description from wheel rims to horse shoes and brackets. Many were different lengths and thicknesses of rod. Excavation during August 2011 showed that the office had plastered walls with a wooden floor.

The structure is now in poor condition, with door and window openings projecting from the rubble.

THE CULVERT. With a mine site placed in a steep sided valley the only way to develop a levelled area for the dressing floors was to build a culvert over the Nant Cwmbyr and infill with waste shale from the mine. At this point a track leads across the next field and away in the direction of Forge about six miles away. Here the concentrated lead would have been loaded on to carts and the stores for the mine brought in. The ore would eventually be delivered to Derwenlas harbour for shipment to South Wales.

LEATS. About two miles of leats supplied water to the mine from the mountains to the east. The major leat terminates about 100 feet above the shaft area and could have operated the turbine winding plant. Looking at the Nant Cwm Byr, this could have been harnessed below the waterfall and by a leat system taken to drive the wheels at the crushing mill and then the other two wheels on the mine. Any visible remains of such a system have been destroyed by the forestry road building.

It is suggested that the water of the Nant Cwm Byr was collected in a pool below the mountain and released into a leat to feed the crushing mill wheel. When not in operation the water would have been permitted to pass under the wheel to a covered culvert and to head north along the side of the dressing floors. At the north end of the mill building a stone-arched culvert took water under the dressing floors and out to the Nant. At present we therefore have two outlets for the water supply. While the known arched leat went to the Nant and away the other system heading north has only been found in two holes created by the forestry operations. Some form of water delivery along this leat must have existed to feed the buddle waterwheel.

CONCLUSIONS. One thing that stands out from the activities we have undertaken on the site is the extensive alterations done in the nineteenth century to this valley. What with the culverting of the Nant Cwmbyr and the construction of heavy machinery in a remote area of Mid Wales we can only assume that a large part of someone's or several fortunes were sunk into this mine. From studying what little written evidence we have for the mine it would suggest that somewhere about 1860 the major part of the existing structures were erected in this remote Welsh valley.

OWNERS. The veins at this mine cross the Nant Cwmbyr, so could have been located in the dim and distant past, but all traces have been destroyed by the

nineteenth century activities. These appear to have commenced in about 1860 with Robert William Hand, who was soon joined by William Spooner and James Vaughan who worked the mine until 1879. They probably had the best ore out of the mine, being reported as having made profits from the sale of the concentrated lead. They were followed in 1880 by Messrs Hughes, Jones and Griffiths, who lasted until 1884, while the mine stood until 1887. After that the machinery and timber was gradually removed until somewhere in the 1930s a sale of what was left took place. Even then quite substantial remains of wooden water wheels and timber and ironwork remained on site.

OUTPUT. The mine is credited with having produced 476.8 tons of lead concentrates, 816.7 tons of zinc ore and 218 ounces of silver during its working life.

The Trust is grateful to the landowner, Huw Denman, for allowing us to carry out our work at Cwmbyr, and to Emyr Williams, Felin Dulas, for his help.

Graham Levins

FRONGOCH EXCAVATIONS 2012

At the Ceredigion Mines Forum (CMF) Meeting in 2012 the Environment Agency (EA) announced their plans to carry out water quality works at Frongoch Mine. This would involve the creation of a settling lagoon, the construction of concrete-lined drainage channels and covering a large area of fines dumps with topsoil. The area affected by this work was the Lower Dressing Floor Area and southeast to the Frongoch Stream.

I was concerned about the possible amount of previously unrecorded archaeology that could lie just beneath the surface that would be damaged by the work and the movement of heavy machinery around the site. At the CMF Meeting I gave a report and showed photographs of the excavations that the Trust had carried out at Cwmbyr, where various artefacts had been discovered literally a matter of inches below the surface. I asked the EA for their permission for us to go to Frongoch to investigate if there were any remains that could be vulnerable. With permission of the EA and the landowner John Bray we organized a weekend in July to see what remained there. So much was found that we returned for two further weekends in September and October and we still did not complete our investigations. In July the Dyfed Archaeological Trust (DAT) were commissioned by the EA to undertake a survey of the site, mostly in areas not covered by our survey. They dug a series of trenches to see what features remained at depth. They have published a report of their excavations.([1])

Armed with a copy of Moissenet's plan of 1860 and the Royal Commission for Ancient and Historic Monuments of Wales (RCAHMW) survey of 1984 — which were both published in David Bick's Monograph on Frongoch([2]) — we walked the Lower Dressing Floor area to identify any features visible on the surface. The Upper Dressing Floor area, below the remains of the buildings, was not affected by the EA's planned works; unfortunately this area is covered with a mass of wood chippings from the Saw Mill operation at the mine in recent years and could not be surveyed.

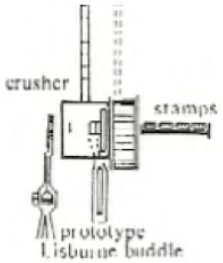
Several features on the Lower Dressing Floors were identified; the site of the Stamp Mill, several buddles, slime pits, walls, wooden launders and sawn-off wooden posts set in concrete. We divided this part of the site into four areas (see plan), then began excavations to see what remained below the surface.

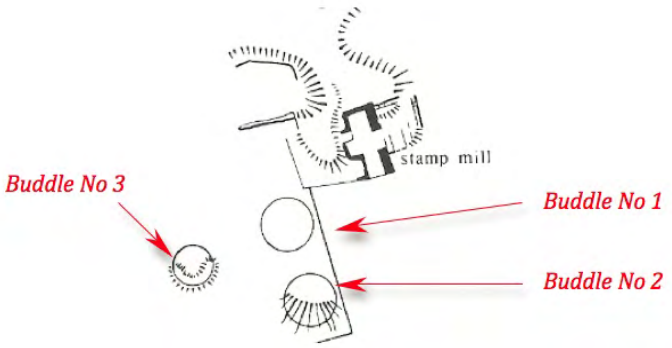
---

(1) Frongoch Metal Mine Remediation Project: Archaeological Assessment, Report Number 2012/11, Frances Murphy, Dyfed Archaeological Trust 2012.

(2) The Frongoch Lead and Zinc Mine, David Bick, published 1986 by the Northern Mine Research Society, revised edition published 1996.

Area 1



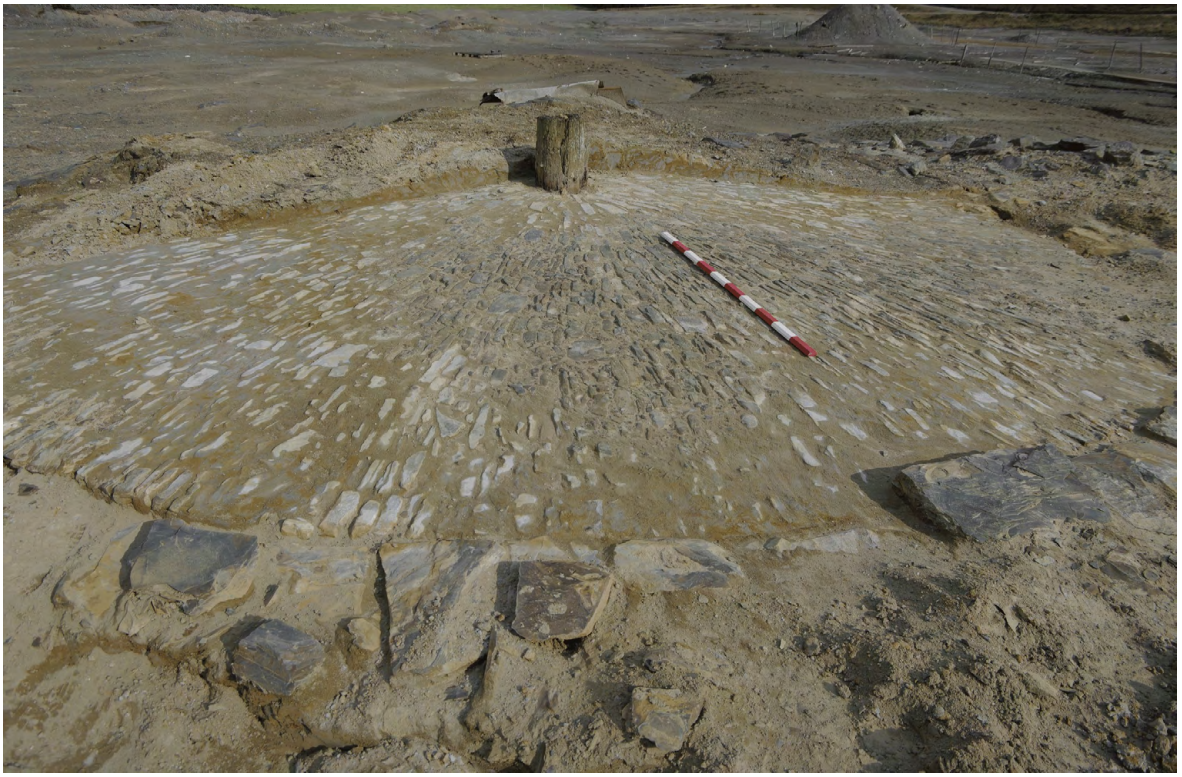


Moissenet's Plan 1860 *RCAHM (W) Plan 1984*

Area 1. In addition to the standing remains of the Stamp Mill [below, to N]

we discovered the remains of three buddles:

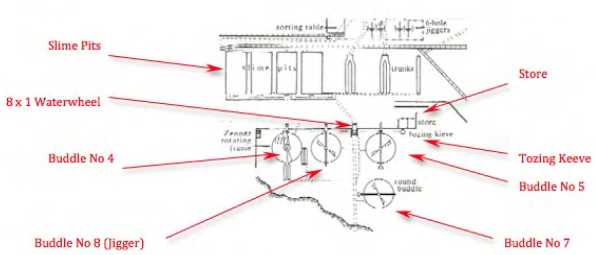
No. 1 [above, to N]: complete stone outer wall, no remains of wooden deck.
No. 2 [below]: only a small part of the outer wall at the northern end remained.



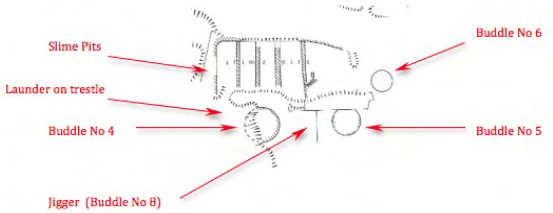
No. 3 [above, to W: below, detail]. This was the star find. When we began there was a rough circular shape visible on the surface and a small amount of cobbled floor. As we exca-vated we discovered it had a complete cobbled floor. No timber remains were found. It is open to debate if it had a timber floor or the cobbled floor we discovered.

The other feature we hoped to find was a remaining feature of the prototype Lisburne Buddle shown on Moissenet's 1860 plan. After many hours it suddenly dawned upon us that we had been looking at it all the time without realizing it. Just to the east of buddles 1 and 2 was the outline of a low wall showing at the surface. When excavated [below, to W] the wall extended for a considerable distance and several pieces of wooden launder were found. Buried alongside the wall were a rectangle of screen material and a large adjustable spanner, probably dumped there after the Lisburne Buddle was taken out of use and Buddles Nos 1 and 2 were built on top of its base.

Area 2



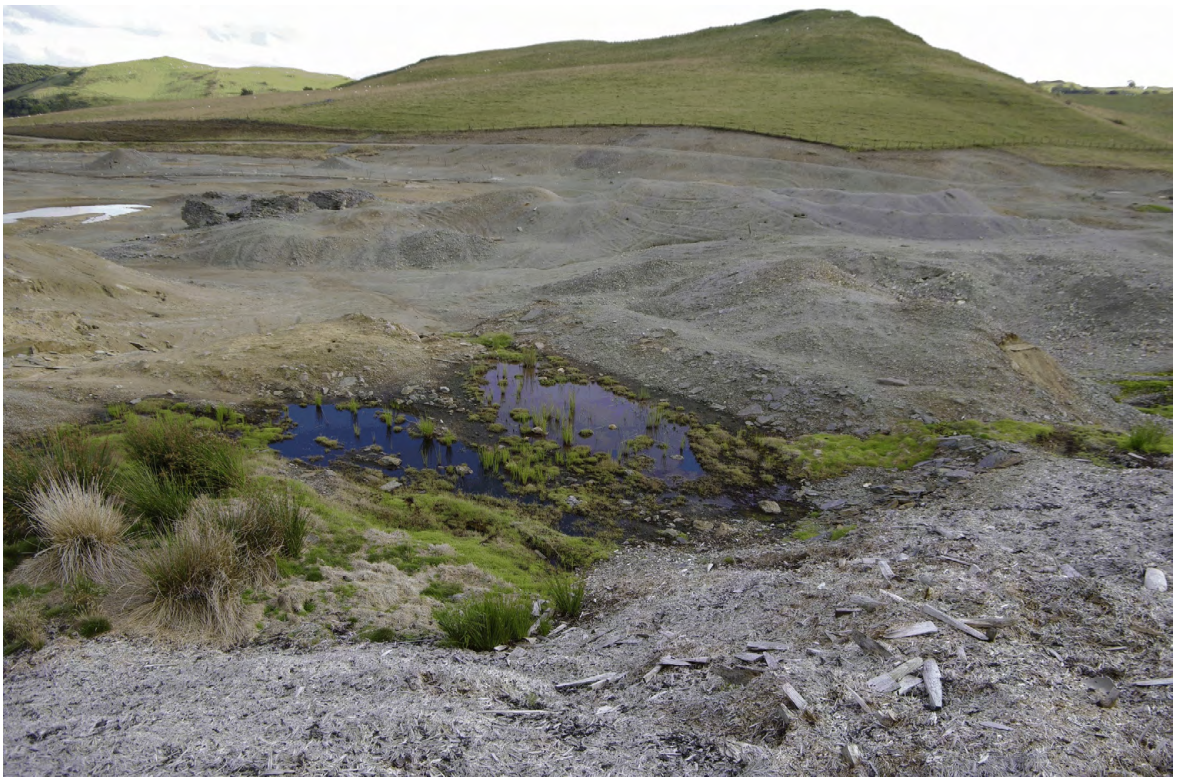
Moissenet Plan 1860



RCAHM (W) Plan 1984

Area 2 is located to the northeast of Area 1: the initial survey revealed the remains of the upper slime pits and the outline of two buddles, two sections of wooden launders and a portion of wall. Once excavations began we were amazed to find five buddles, one of which was not recorded on either Moissenet's or the RCAHMW plans, and that one buddle had been replaced by a jigger (or jiggers) since Moissenet's survey in 1860.

Upper Slime Pits, to S. The four compartments were still discernible but we did not excavate.



Buddles:

No. 4 [above, to S: below, detail]. Shown on Moissenet's plan as a Zenner Rotating Buddle. Only the eastern outer wall remains: the rest has been lost.

At depth, two wooden launders pass beneath it. It is possible that the Zenner was replaced by a conventional buddle at some point.

No. 5 [above, with upper slime pits behind: below, detail to E]: the almost complete outer wall was excavated. An interesting feature we found was that the wall running to the north of the buddle was curved to follow the outer wall of the buddle.

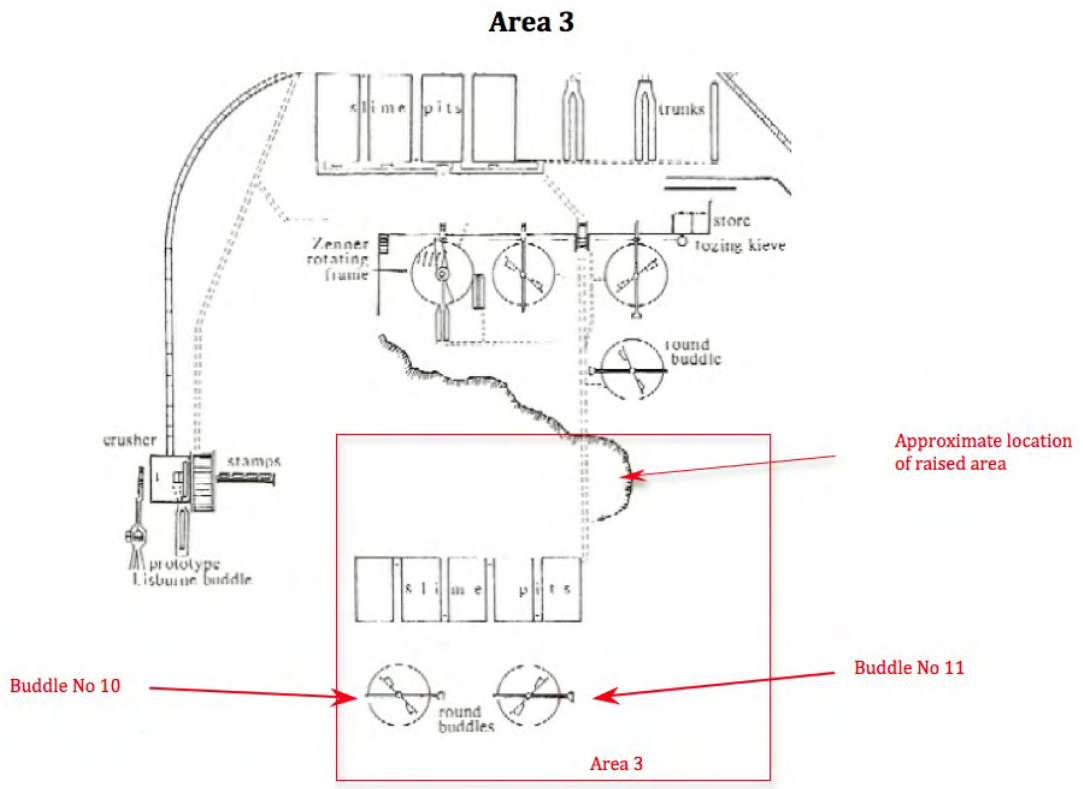
No. 6 [below, to N, and detail to E] was located and excavated, exposing the outer wall, the northwestern portion of which was missing, possibly damaged by the natural extension of the slime pit drainage to the east.

No. 7 was not found: a future excavation may locate it.

No. 8 [above, to N: left, detail to E]. Excavation showed that this buddle had been dismantled and removed sometime after Moissenet's plan was drawn, and had been replaced by jiggers, of which only one remains: this was also excavated.

No. 9. Another buddle, not shown on either plan, was found to the east of buddle No 6. The circular outside wall was excavated.

The site of the 8 foot × 1 foot waterwheel which provided power for the buddles was located and excavated. This revealed that the waterwheel had been taken out of use after 1860 and the pit was used for another piece of equipment. This requires further investigation.



Area 3 is located to the south of area 2. In this area we noted a raised area with two sawn off wooden posts set in concrete and a length of wooden launder protruding. To the south of this area (at the left of the photograph, next page) are the remains of the lower slime pits, now just a puddled area after rain

Below this the DAT during their trenching found the remains of a buddle, which they left exposed for us to investigate further. This area is not shown on Moissenet's plan, but two buddles and the slime pits were surveyed by RCAHMW during their 1984 survey.

The problem with this area and Area 4 further south is that the First World War reprocessing scheme, where a large amount of dump material was taken 1 ¾ miles via the aerial ropeway to the new mill constructed at Gwaith Goch beside the River Ystwyth, has left these areas very disturbed, and many features have either been buried or destroyed.

Buddles

No. 10 [next page, to N, and detail]. This buddle was found by the DAT: we enlarged their trench to expose more of the structure. It had an almost complete wooden deck and partial remains of the centre post. The outer wall was in a poor condition and was not dug.

No. 11. Not found, but future excavations may reveal some remains.

Area 4. This is located to the south of Area 3. It is not shown on either Moissenet's 1860 plan or the RCAHMW Survey of 1984. We found a level floor [below, to E; lower, to N] with a retaining wall to the north and another wall to the south. There were some other masonry remains connected to the retaining wall to the north.

On the raised area above the wall we found several sawn-off wooden posts set in concrete.

So far we have not had the time to carry out any excavations in this area: hopefully we will have the opportunity to investigate fully in the future. We can only speculate on the function of this area: one possibility is that it was the terminating point and loading area for the Aerial Ropeway.

All features discovered have been photographed and surveyed, and are in the process of being drawn.

Once the EA works that commenced in January 2013 are complete we hope to return to Frongoch to finish our survey and excavation work there, following which we would like to continue at Wemyss and West Frongoch.

The Trust would like to express its thanks to the landowner, John Bray, for allowing us access to the mine; *also to Paul Edwards of the Environment Agency for his assistance.*

Bernardino Nogara

THE HYDRO-THERMO-ELECTRIC INSTALLATION AT FRONGOCH MINE

translated by Robert Ireland

In 1899 a 29-year-old Italian engineer, Bernardino Nogara, was employed by the *Société anonyme minière* of Liège to equip their recently-acquired property in Cardiganshire, Frongoch mine, with the very latest in mining machinery: a 'hydro-thermo-electric' plant which, it was hoped, would breathe new life into the dying mine. The electrical installation seems to have caused something of a sensation in the mining world: E. H. Davies devoted three pages of his *Machinery for metalliferous mines* ([2]1902, pp. 496–8) to a description of the system and its devices, together with a copy of the circuit diagram; and the *Iron and Coal Trades Review* for 13 September 1901 carried (pp. 701–3) an article on the mine, illustrated with photographs showing the site, the buildings, and the various items of electrical equipment.

Two years later, all was in ruins. The story of Frongoch during those years has been told elsewhere, and there is no need to repeat it here: it is enough to say that not even the most advanced technology could protect the mine against collapsing ore prices, rising labour costs, and foreign competition. On 15 June 1903 the holding company was liquidated, on 10 August the dressing mill worked for the last time, and on 20 November the plant was transferred to Messrs King & Co., who, between Monday 11 and Friday 15 April 1904, sold off, by auction, every item of the mine's equipment and effects, from the 60-inch pumping engine and its new 36-foot Lancashire boiler ('never been used'), the AEG three-phase alternator, the solid marble switchboard, and the 70-feet-long corrugated-iron two-storey barracks with single-storey wings and two lean-to bathrooms, to four reels of fuse wire, sundry veterinary medicines, an eight-day clock in a mahogany case, and three feather pillows. Nogara returned to Italy, where he continued to take an interest in the application of electrical power to metal mining: in 1926 he undertook the expansion of the hydro-electric installation at Raibl,([1]) where he was assisted from 1932 by his son Giovanni. By now, however, he had become increasingly involved in banking and finance:([2]) as a director of the Banca Commerciale Italiana he had already negotiated the purchase of shares on behalf of

(1) South of Tarvisio (Udine) in the far north of Italy, on the border with Austria and Slovenia.

(2) It will be interesting to see what the *Dizionario biografico degli Italiani* says about Nogara's financial activities — when its article appears: the latest volume to be published (2012) stops annoyingly short of surnames beginning NO–. The provisional sketch above has been compiled from various official and unofficial sources, some of questionable reliability: the Raibl Mine website (in Italian) is of particular interest, and should be consulted (at www.minieradiraibl.it/storia2.htm), if only for its photographs.

Pope Benedict XV in 1914; in 1919 he attended meetings of the Economic Committee at the Versailles peace conference, and in 1929 he was appointed financial director of the Holy See and private adviser to Pope Pius XI: not for nothing was he known as *il banchiere di Dio,* 'God's bank manager'. It is alleged that Mussolini's invasion of Ethiopia in 1935 was partly financed by loans organised by Nogara. He retired from his post in 1954 and died in Rome at the age of 88 in 1958; by which time the far-off power station beside the Newydion brook was an empty and roofless shell, and the nearby dressing plant a broken mass of tiered masonry amidst a waste of fines. Offices, barracks, power lines, headframes, launders, tramways, ropeways — all were gone; the gaping shafts and wheel-pits were choked with rubbish; and the main site lay deserted, a wilderness of spoil-heaps and poisonous pools, of concrete foundations and shattered walls, watched over by the towering ruins of the great engine-houses, silent and forbidding witnesses to the fate of all extractive industries.

It had all looked so different at the beginning of the century: and something of the excitement and optimism which the new technology inspired can be sensed not only in the pages of Davies and the *Iron and Coal Trades Review* but also in an account of the Frongoch electrification written in Italian by Nogara himself and included in the Reports of the Sardinian Mining Association for March 1901. It is not too much to claim that Nogara's *Descrizione dell' impianto idro-termo-elettrico della miniera di Frongoch* and the exhaustively detailed study of the *Préparation mécanique du minerai de plomb aux mines de Lisburne* published in 1866 by the French engineer Léon-Vivant Moissenet are the two most important foreign-language works written on Cardiganshire mining in the nineteenth century, and it is unfortunate that they have so far been accessible to English speakers only in paraphrase: Nogara in the extensive summary of his article presented by his friend E. H. Davies in *Machinery for metalliferous mines,* Moissenet in the inadequate and not wholly correct *précis* printed in *British Mining* 30. To remedy this deficiency I have recently translated both texts, in full, into English; and although the translations still await final revision, the *Descrizione* at least is in a sufficiently advanced state for me to offer the current working version to readers of the present Newsletter, who will be aware of the Trust's close and continuing involvement with the site which Nogara and Moissenet so marvellously describe. I am extremely grateful to Simon Hughes for providing me with the materials for making the translation, for reading through the result, and for improving my understanding of technicalities. The rendering is as close and accurate as I could make it without re-writing it into a wholly modern idiom or imposing English thought-patterns on the structures of the Italian text: here and there I have inserted a word in square brackets to clarify the original expression, and matters of interpretation are dealt with in footnotes. The abrupt paragraphing, faulty spellings, and occasional italics, are those of the 1901 print, whose pagination is indicated {in brace brackets}.

Italian text: in *Resoconti delle riunioni della Associazione Mineraria Sarda* (Iglesias [Cagliari], Italia), Anno VI n° 3 (17 marzo 1901), *Allegato* B, pp. 9–14: B. Nogara, *Descrizione dell' impianto idro-termo-elettrico della miniera di Frongoch* (*Reports of the meetings of the Sardinian Mining Association* [Iglesias (Cagliari), Italy], Sixth year, no. 3 (17 March 1901), *Annex* B, pp. 9–14: B. Nogara, *A description of the hydro-thermo-electric installation at Frongoch mine*)

{p.9}

A DESCRIPTION

of the hydro-thermo-electric installation

AT

FRONGOCH MINE.

Frongoch mine is at present the property of the *Société anonyme des mines de Frongoch* ['Frongoch Mines Public Company'] (a Belgian company) and is situated in the county of Cardigan in Wales.

The mine was discovered about 80 years ago and has been profitably worked since then, first by the extraction of lead ore (galena), subsequently by the extraction of zinc ore (blende). A total of 80,000 tons of merchantable ore have been extracted, of which about 40,000 were galena and 40,000 blende. The mine was worked extensively down to a depth of 280 metres by means of a main shaft; but it was re-opened for the extraction of blende about 25 years ago, and the works for the extraction of blende do not go any deeper than 140 metres.

When the new Company took over the business, the plant consisted of an old system based on water-wheels, each installed in succession below the outflow of the previous one, and, generally speaking, each machine had its own more or less large water-wheel to drive it. In this way, with a flow of 200 litres of water per second, about 120 h.p. was available, applied to the pump, the winding gear and the treatment plant.

To work the mine productively, modern machinery and a considerable power system needed to be introduced, to enable it to treat low-grade ores. The plant required a power of 350–400 h.p., and this power had to be derived from the water of the area, not from coal from the far-off mines in the South. For this reason, a complete overhaul was undertaken, by reorganising the existing water system for the purpose of creating a fall which, with an average quantity of 200 litres of water {p.10} per second, could provide the power necessary for the work of the mine.

It should be noted that the water-courses in this part of Wales run in the bottom of valleys flattened by erosion, and have a small flow. In this region, all of the mines have hydraulic power, but this is derived from the regulated storage of the water produced by the frequent rain-storms over the high ground. When one remembers that the rainfall over the hills of mid-Wales amounts each year to a depth of 1.8 metres, one can understand how, by creating a series of artificial reservoirs, it is possible to have a constant supply of usable water throughout the whole year. It is by profiting from this rainfall that the great cities of Liverpool, Manchester, and many other smaller cities, have provided drinking-water for their huge populations by building vast artificial lakes in the mountains of mid-Wales.

In the same way, Frongoch mine has been provided with special reservoirs, fed by the rainwater collected in very long channels running for many kilometres round the edges of the high ground, then along the eroded valleys.

There are three main reservoirs so formed: Tynbrolch,([3]) Frongoch, Rhos-Rhyd: the fourth, Glandwgan, is of secondary importance, only receiving the water from the spillway of the Rhos-Rhyd reservoir. Each of these reservoirs, with separate leats cut into the ground, carried water to the mine to produce the motive power.

It was necessary to bring all these water-courses together into a single leat, and to carry them to a particular point to make a usable pond there. The lower reservoir of Tynbrolch was taken as a basis, and, starting from this, a new leat was excavated, which collected on its way, as tributaries, the water from the two upper reservoirs. Because the Glandwgan reservoir was too low and of little importance as a feeder, it was omitted from the motive-power system, and maintained to feed the treatment plant with water.

With this new leat a fall of 126 metres became possible, with an average supply of 200 litres of water per second. But with a delivery of only 200 litres it was still not possible to achieve the desired objective, the mine requiring at least 350 effective h.p. at certain times when it was working. The main and secondary shaft winders, running at irregular intervals, needed power only for intermittent periods of operation; the same applies to the electric lighting system and so on.

{p.11} Consequently, a system was required which was capable of producing the maximum power needed, but which could also store power up.

For this purpose it was absolutely necessary to have a new high-capacity reservoir, which could provide, when needed, whatever quantity of power was required for the operation of the machinery without altering its level to any appreciable extent, and which, again, could fully retain it at times when the machinery was operating under a light load. A new reservoir was therefore built with a capacity of about 40,000 cubic metres, achieving the aim of creating an economical store of power and a regulator for controlling the outflow of the various reservoirs sited at considerable distances.

The water is brought from the new reservoir to the site of the machinery (the Central Station) through a system of steel pipes of increasing resistance, 60 cm in diameter and about 450 metres long.([4]) At the end of the run a Pelton wheel with automatic

---

(3) *Sic,* throughout, for *Tyn*(*y*)*bwlch,* and compare *Aberystroyth* for *Aberystwyth* in Nogara's plan of the site, plate I below: an easy misreading (if one does not know the names) of the curious *w*, formed with a high transition to the second stroke (ẘ), found in some 19th-century scripts and typefaces.

(4) The increase in resistance (and hence in water pressure) was achieved by successively reducing the internal diameter of the pipes in stages increasing in length as they approached the end of the line. As is clear from their context, lots 341–3 of the 1904 sale catalogue list the pipework in order from the

governor, developing 400 effective h.p., receives the feed-water; the alternator and the steam engine kept in reserve are of the same power.

The alternator can be driven directly either by the turbine or by the steam engine, by means of two interchangeable flexible couplings.([5]) The Pelton wheel was supplied by the firm Escher Wyss of Zurich, with a guarantee of 75% efficiency and with variations of speed of 2% – 4% – 6% – 8% respectively for variations of power of $^1/_4$ – $^1/_2$ – $^3/_4$ – $^4/_4$. The last conditions were not completely fulfilled. The three-phase alternator, like the entire electrical part of the installation, was supplied by the Allgemeine Elecktricitäts([6]) Gesellschaft of Berlin. The steam engine was supplied by the well-known firm Willans & Robinson of Rugby (England). The boiler, of tubular type, was supplied by the firm of Babcock & Wilcox.

It is not necessary to give details of the installation in this description, because they are all summarised in the diagram below (see plate [II]); on this are marked also all the instruments and all the power-lines, as well as the machines taking power.

The three-phase current is generated at 2300V, and carried to the mine along an overhead line about 2000 metres long from end to end.

The treatment plant, which is capable of handling 15 tons an hour, is situated 1200 metres away. In this are installed two high-tension motors, each of 50 nominal h.p. Motors of this kind {p.12} can be worked hard to develop 75 h.p. almost continuously without overheating. Such results are rarely found in motors supplied by other firms. One motor is used to drive the trommels, the jiggers, the slime tables,([7]) the pumps, and the elevators or transporters. The other motor drives the inclined plane, two stone-breakers, four crushers and the sorting table.([8])

At this point in the main line the current for the electric lighting of the treatment plant is taken off through a 10 kW transformer, which feeds three groups of five arc-lamps in series. A resistance is introduced into each group, because the transformer, reducing the voltage from 2200 to 220V, would require six lamps in each series. The three resistances thus take the place of three spare lamps, and have an efficiency of 75%.

The main shaft, with adjacent pumping and winding equipment, is 650 metres from the treatment plant.

---

power station upwards: reversing the sequence, the steel can be seen to increase in gauge from $^1/_8$" (for 13 25-foot lengths) at the dam, through $^3/_{16}$" (for 16 lengths) down the hill, to $^1/_4$" (for 17 lengths) into the turbine. The external diameter (60cm / 24") remaining constant, the internal diameter decreases.

(5) 'Elastic shifting couplings' Davies.

(6) *Sic* Nogara: 'Electricitate' Davies; correctly 'Elektricitäts'. The sale catalogue (lots 290 &c) writes even worse German ('the Algemaine Electricitats Gesellschaft').

(7) *I classificatori, i crivelli, le tavole per i fini* Nogara: English equivalents from Davies.

(8) ... *due frantoi, quattro macine e la tavola di cernita* Nogara: English equivalents from Davies.

Two take-offs are provided in the winder-house([9]) for two motors, each of 75 h.p.

One motor is at high tension and is placed in the mine at a depth of 160 metres. Current is taken to it by means of a cable. This is where the three-ram([10]) electric pump is installed, with a capacity of 1500 litres of water per minute. The motor is mounted on the bed-plate of the pump and connected to the main pinion-shaft([11]) of the pump through a flexible coupling. A small transformer, sited in the pump chamber, provides current for the lighting of the [pump-]room and the lighting of the main working gallery at the 120-metre level.

The other motor is at low tension and is installed on the surface and fixed to the bed-plate of the two-drum winder. This motor is capable of producing 125 h.p. to drive the winder. A 60 kW transformer is of course introduced between each motor and the line, reducing the voltage from 2200 to 220V; this is to avoid the dangers of high tension in working the winder.

The point of special interest in this electric winder consists in the resistance introduced to govern the speed and in the commutator which reverses the phase of the current,([12]) and hence the direction of rotation of the motor. Phase-reversal is achieved by moving a simple hand-lever. This lever is attached to the band-brake in such a way that the motor cannot be run when the brake is on. {p.13} This protects the electrical system and ensures the safety of the winder when in use.

The lamps for lighting the winding-room, the shaft headgear,([13]) the dump([14]) and the inclined plane([15]) are derived from the same transformer.

---

(9) 'winding-shed' Davies: *la sala della macchina d'estrazione* Nogara.

(10) Davies: *a 3 stantuffi* Nogara.

(11) Davies: *l'albero principale della pompa* Nogara.

(12) *l'invertitore della corrente* Nogara: I take 'commutator' from Davies. In the next sentence, 'phase reversal' represents *l'inversione della corrente*. The translation has been made technically accurate at the expense of Nogara's style. Perhaps he genuinely thought of the device as an 'inverter', or perhaps this was the only term available to him. I am not sufficiently familiar with the relevant 19th-century technical literature in Italian to know what range of meanings *invertitore* and *inversione* might cover, or what other words could have been used; but as Simon Hughes has pointed out to me, a phase-shifter, not an inverter in the strict sense, is employed to reverse the direction of rotation of a three-phase AC motor.

(13) 'the tipping platform of the shaft' Davies: *il castello del pozzo* Nogara.

(14) 'the sorting-shed' Davies: *la discarica* Nogara. It would seem more sensible to light the sorting-shed than the dump, but *discarica* definitely means 'waste, tip, spoil-heap'. Given that the dumps were being recycled, was there a sorting-shed on or near them? The description of the electrical system in the *Iron and Coal Trades Review* of 13 September 1901 mentions lighting for 'the winding house, the tipping place for the ore at the pit-head, and the feeding place for the inclined railway' (p. 702 col. *b*, at foot): *la discarica* might refer to either of the latter.

(15) 'the top end of the endless chain' Davies, who was evidently not paying close attention to what he was writing: *il piano inclinato* Nogara.

A small transformer for the lighting of the offices is placed on the same line leading from the treatment plant to the shaft.

At 175 metres from the main shaft is placed another high-tension motor of 30 h.p. to drive a winder with a single drum, intended to serve an inclined shaft.

The installation described, as carried out, makes ample provision for all the services of the mine, and can also be further extended by adapting them to requirements.

The cost of the installation was considerable, especially for the hydraulic system, as is shown by the figures which follow this short description.

The *costs of the installation* were approximately as follows:

Leats, launders, siphons &c	(sterling)	£1000	
Reservoir with earth embankment		£2000	
Pipes		£1200	
Turbine and fixing		£800	
Steam engine and fixing		£1200	
Steam boiler		£1000	
Central Station buildings		£2000	
Alternator and fixing		£1000	
Exciter, switchboards		£400	
Overhead line		£800	
	Total	£11,400	= Fr. 285,000.([16])

This was the cost of the installation in the Central Station and of the overhead line. The *working costs* are approximately as follows (note that the calculations include the use of steam power for three months):

Interest on capital at 5%	(sterling)	£570	
Amortization of the installation at 10%		£1140	
Coal used		£200	
Personal expenses and repairs &c		£300	
	Total	£2210	= Fr. 55,250.

{p.14} The average power consumption during the first months of operation was 250 kW, and this output was developed for 300 days in the year, each day being of 20 hours. In other words, the annual cost of 1 kW is £8/6/10 (= Fr 22.10) per year of 6000 hours. 1 kW/h is therefore delivered to the terminals of the various motors at a

(16) The francs could be either French or (more probably, given the ownership of the company) Belgian: according to *Whitaker,* both currencies were exchanged, *c.* 1900, at fr. 25.2 / £ sterling. Any modern equivalent is likely to be delusive, but (other things being equal) the prime cost of the plant at today's value of the pound, as against its value in 1901, would be over £1,000,000, and the working expenses (below) at least £200,000.

cost of about $^{35}/_{100}$ of a penny (= Fr 0.036)([17]) — which may be described as a satisfactory result as regards the economy of the installation.

The six months of successful operation which have passed are a guarantee of the technical excellence of the installation.

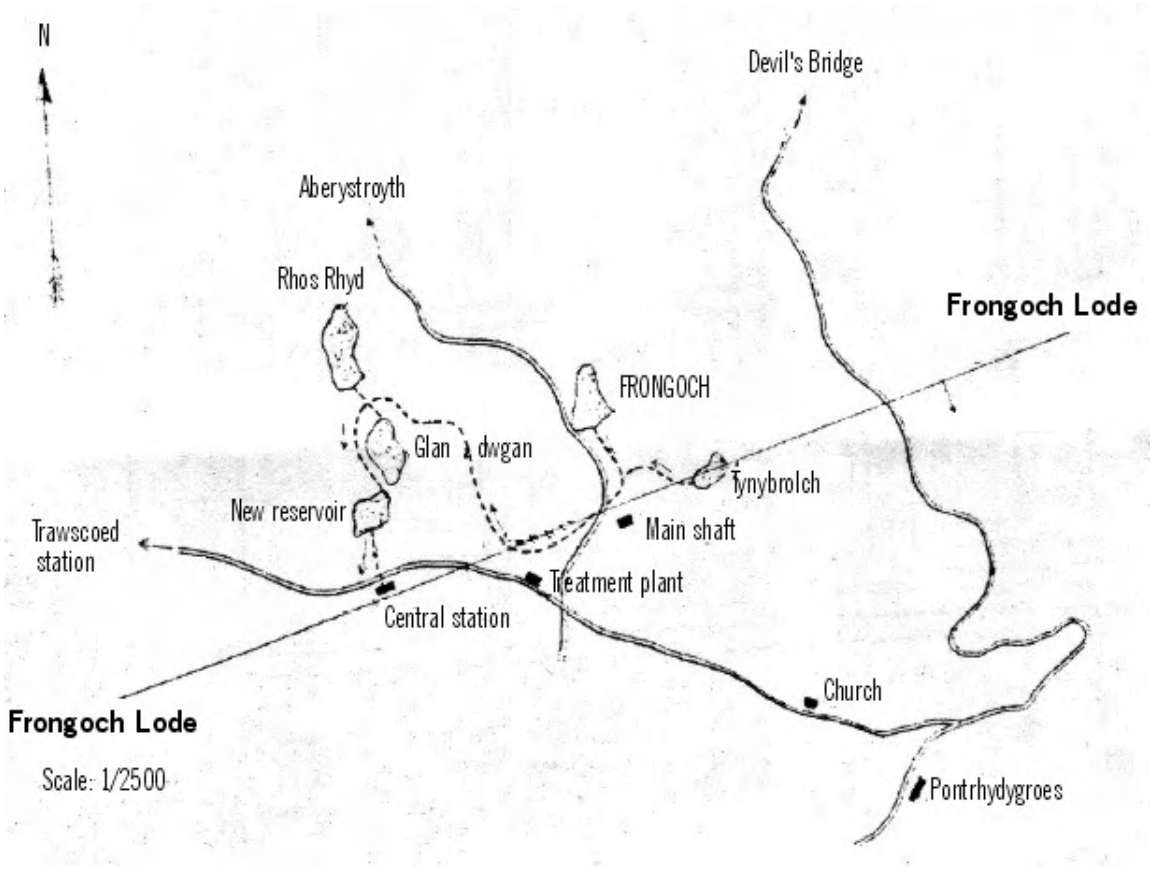
Aberystwyth, 21 *February* 1901.

B. Nogara, Engineer

Member of the Institute of Welsh Engineers (Cardiff)

PLATE I

'Frongoch Mine in Cardiganshire (Wales), England' [!!], adapted from Nogara 1901

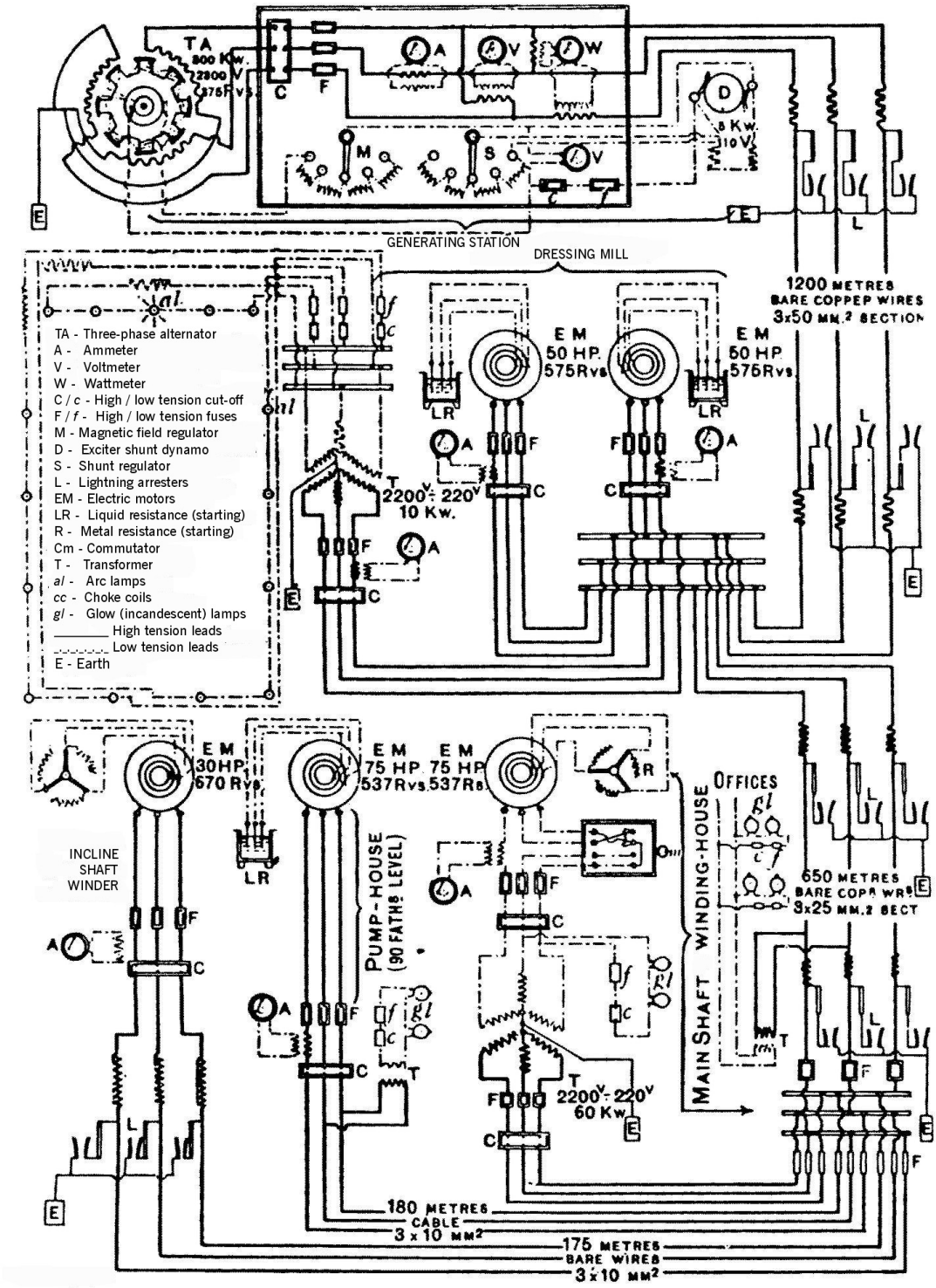


['Aberystroyth', 'Tynybrolch' *sic*: see footnote (3) above)]

(17) Perhaps 35p in modern money.

PLATE II

'Diagram of the Electrical Installation', adapted from Davies 1902



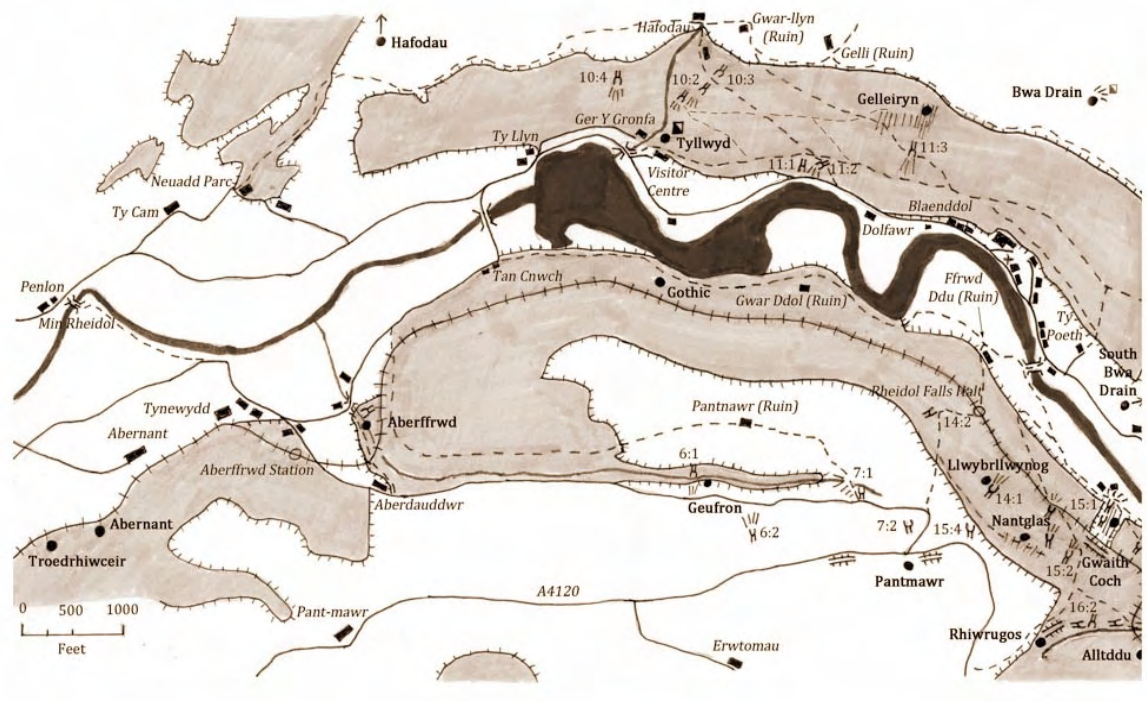
Ioan Rhys Lord

THE MINES OF CWM RHEIDOL

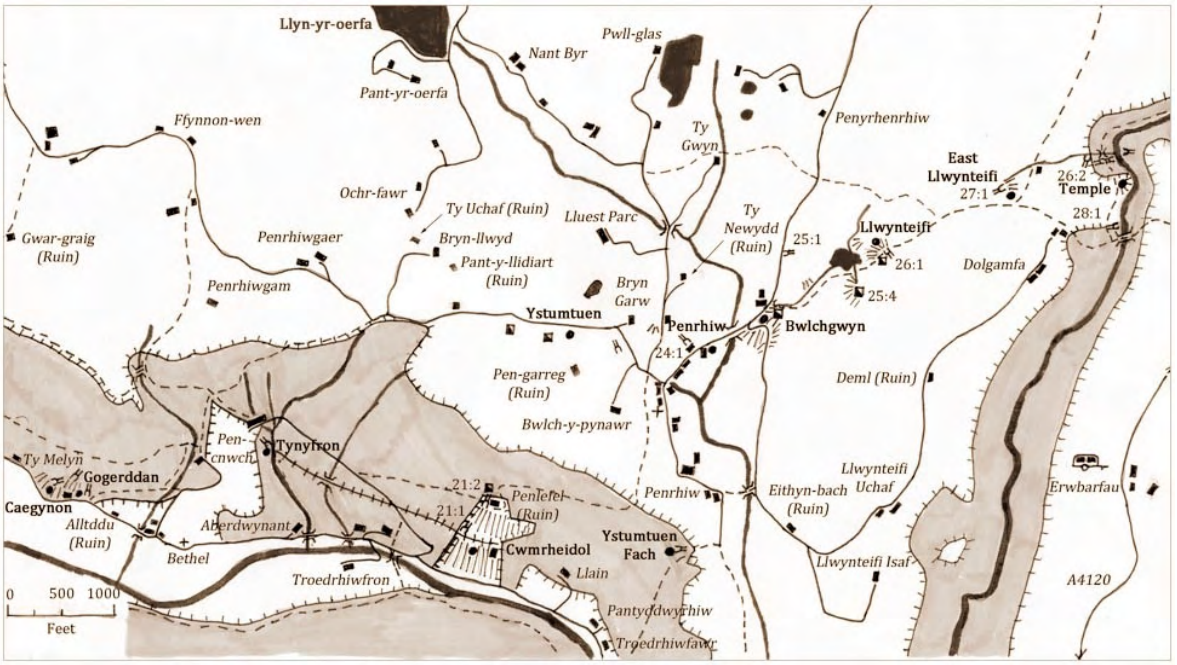
Cwm Rheidol, near Aberystwyth, Mid Wales, is steeped in metal mining history dating back to well before the 1700s. These workings were nothing like the great Dylife, Van or Cwmystwyth Mines but worked on a much smaller scale. Many adits and shafts remain hidden in the woodlands and overgrowth, and several are seldom visited. However, features both underground and above ground remain, just as special as any encountered at Dylife or Cwmystwyth. One working in the valley even has an underground feature rather unique to a Mid-Wales metal mine and one will have the impression of being at a slate mine in North Wales.

MINE	GRID REFERENCE	ADITS	PRESENT-DAY REMAINS (5 stars maximum)
Nantyronnen	SN 667 777	3	*
Cefn Nantyronnen	SN 670 780	2	*
Troedrhiwceir	SN 679 784	1	*
Abernant	SN 680 784	2	**
Aberffrwd	SN 688 787	1	*
Geufron	SN 698 786	3	**
Pantmawr	SN 704 784	2	****
Gothic	SN 699 791	0	*
Hafodau	SN 690 803	2	*
Tyllwyd	SN 699 798	7	**
Gelleiryn	SN 705 796	4	***
Bwa Drain	SN 711 797	0	*
South Bwa Drain	SN 713 787	3	*
Foxpath	SN 707 786	2	****
Nantglas	SN 709 784	6	***
Gwaithcoch	SN 710 785	4	***
Rhiwrugos	SN 711 781	8	*****

Alltddu	SN 713 781	3	**
Caegynon	SN 717 783	3	*****
Gogerddan	SN 718 783	1	*
Tynyfron	SN 723 785	2	*
Cwm Rheidol	SN 729 781	2	*****
Ystumtuen Fach	SN 735 781	2	*
Ystumtuen	SN 732 787	1	*
Penrhiw	SN 736 787	1	**
Bwlchgwyn	SN 738 788	2	***
Llwynteifi	SN 742 790	2	**
East Llwynteifi	SN 745 791	1	*
Temple	SN 748 792	5	*****



△ Cwm Rheidol (West) map. Mines are marked in bold face, houses in italics. The numbers given to workings do not correspond with anything in this article.



△ Cwm Rheidol (East) map. Mines are marked in bold face, houses in italics. The numbers given to workings do not correspond with anything in this article.

Starting from the west, we shall journey east along the valley, visiting each mine briefly and examine the present-day remains. Nantyronnen Mine lies beside the lane from the A4120 to Nantyronnen Station of the VRR, and a small cluster of vegetated tips can be seen below the road. Two run-in adits are found at the top of these small tips, each with a stream of water flowing from the portals. Alongside the lane on the other side, a noticeable cutting leads to a quite backfilled adit portal, almost full to the roof of rubbish bags and agricultural waste. Immediately behind it, a shaft has been sunk and one can see that the adit only leads some 2 feet into the latter.

Slightly further down the lane, just before Nantyronnen Station comes into view below, Cefn Nantyronnen Mine is passed, its Upper Adit commencing just below the lane. However, there is only 20 feet before the forebreast is reached. Further down the small stream, which springs from the latter, the Deep Adit is barely open. It is not easily accessed, and a shallow air shaft has been sunk into the tunnel some 10 feet behind the portal. The shaft is unfenced and situated in woodland just above the railway.

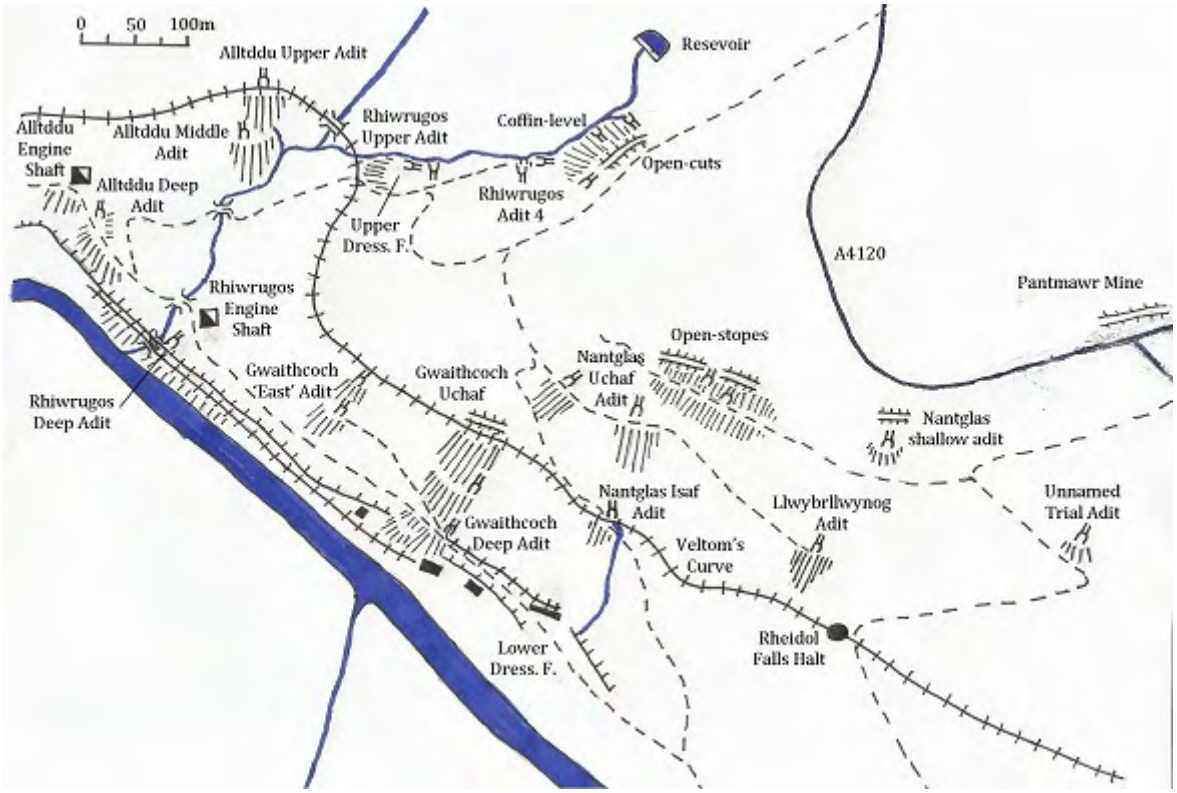
Following the railway some 2000 feet up the line from Nantyronnen Station, the run-in Western Cross-cut of Troedrhiwceir Mine can be seen in the hillside, whilst a considerably-sized tip and a possible wheelpit lie below. No. 2 Cross-cut, part of the Abernant Mine sett, lies a short distance further along the railway. It is also run-in, and indicated by another tip. The No. 3 Cross-cut was blocked whilst constructing the railway around 1900. Above the 3 adits of these two adjacent mine setts, a series of deep open-stopes and Oddy's and Hughes' Shafts can be found, surrounded by secure fencing.

There is little to say about the tiny Aberffrwd Mine adit, which commences from the stream below Cwmdauddwr Embankment of the VRR just outside Aberffrwd Station, as we follow the lane back up towards the A4120. The more interesting and extensive workings are reached this way. Geufron Mine is passed once we are up in the narrow Nant Yr Aber valley, and its main adit can be seen down at the stream, and quite deep in water. A small trial adit has been driven 20 feet along a geological fault above the lane in the field, and while exploring this I came across a wonderful abandoned bird's nest containing three eggs.

Where the lane reaches a tight curve at a yellow sand box, with the A4120 visible above, the Pantmawr sett is reached, where the very interesting Deep Adit has been driven from the stream directly under the road and the sandbox. Just inside the portal is a large alcove, probably the underground stone quarry on the Upper Devil's Bridge formation. Following the adit onwards, a partially submerged wooden tram wagon is found at a fork in the tunnel. Stopes and a maze of extensive drifts follow, and the main cross-cut continues some 400 feet further south. At the end of one drift below the main road, a winze drops down to the Foxpath Deep Drainage adit which emerges below in the valley, over 200 feet below. The Foxpath also worked as a separate mine, being one of the Rheidol United mines. Above the lane where the Pantmawr Deep Adit passes beneath, a small agricultural cutting lies on the right, with a grassy depression above, indicating the run-in Daniel's or Shallow Adit.

Down in the valley, on the southern shore of the reservoir, the once extensive Gothic Mine now barely shows through the trees. Once boasting a fine dressing-floor, two adits and an engine shaft approximately 360 feet deep, the site has been destroyed during the building of the reservoir. A section of the shaft's pumping mechanism, a chain and a tram wagon lie in the overgrowth alongside the footpath.

We next come to the wonderful Rheidol United Mines, where a warren of 23 adits, open stopes and shafts cover the mountain between Rheidol Falls and the Rhiwrugos Ravine. The four main lodes were Alltddu, Rhiwrugos, Gwaithcoch and Nantglas. The five mines working the latter were Alltddu, Rhiwrugos, Gwaithcoch, Nantglas and Foxpath. Foxpath worked the Nantglas lode further West than the mine of that name, and also served as a Deep Drainage Adit for Pantmawr Mine above.

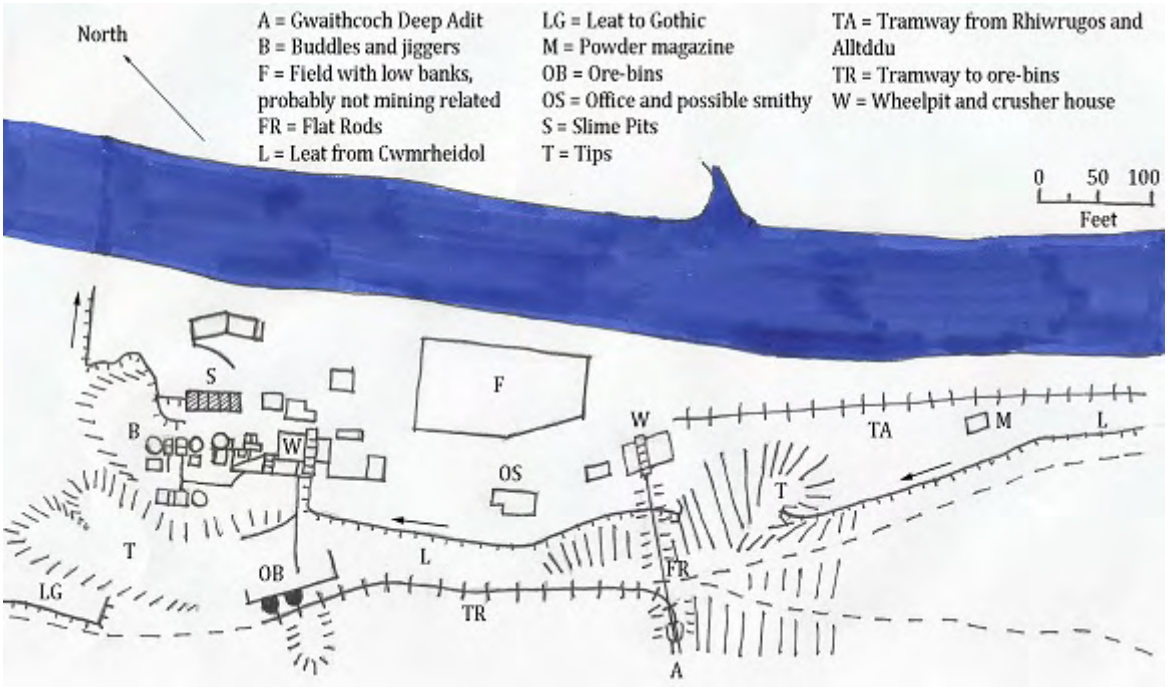


△ Rheidol United surface plan

There is an unnamed trial adit above the footpath a short distance west of the Foxpath, or Llwybrllwynog Adit, which has been driven about 20 feet along a small copper vein with hanging wall and footwall exposures within. The Llwybrllwynog or Foxpath adit itself is very interesting. A few feet deep in water, the adit leads to extensive stopes on the Nantglas lode before continuing as a cross-cut towards Pantmawr. Unfortunately, there is a collapse before reaching the bottom of the winze, which prevents what would be a rather exciting round trip, emerging from the Pantmawr Deep Adit.

Nantglas Mine is rather ancient, and there is an adit driven by Thomas Bonsall near the Upper or Nantglas Uchaf Adit. Bonsall's Adit leads to a collapse from a partially backfilled portal and Nantglas Uchaf also has a very small portal. One has to scramble through the collapse in the portal on his/her stomach until reaching the dry and spacious adit beyond. On the edge of the stopes, a large whim chamber welcomes the explorer but houses only a small iron wheel nowadays. The adit continues on the other side of the stopes until coming to a collapse. Originally the cross-cut continued and cut two smaller lodes. Nantglas Isaf adit lies alongside the VRR trackbed, at a walker's crossing, and is quite deep in water. However, it leads to a collapse quite near the lode.

The lower and main dressing-floors used by Rheidol United were at Gwaithcoch, where the tips have unfortunately been spread, completely covering the buddles and jiggers. However, two fine ore-bins, an office and a surviving wheelpit complex can still be seen.

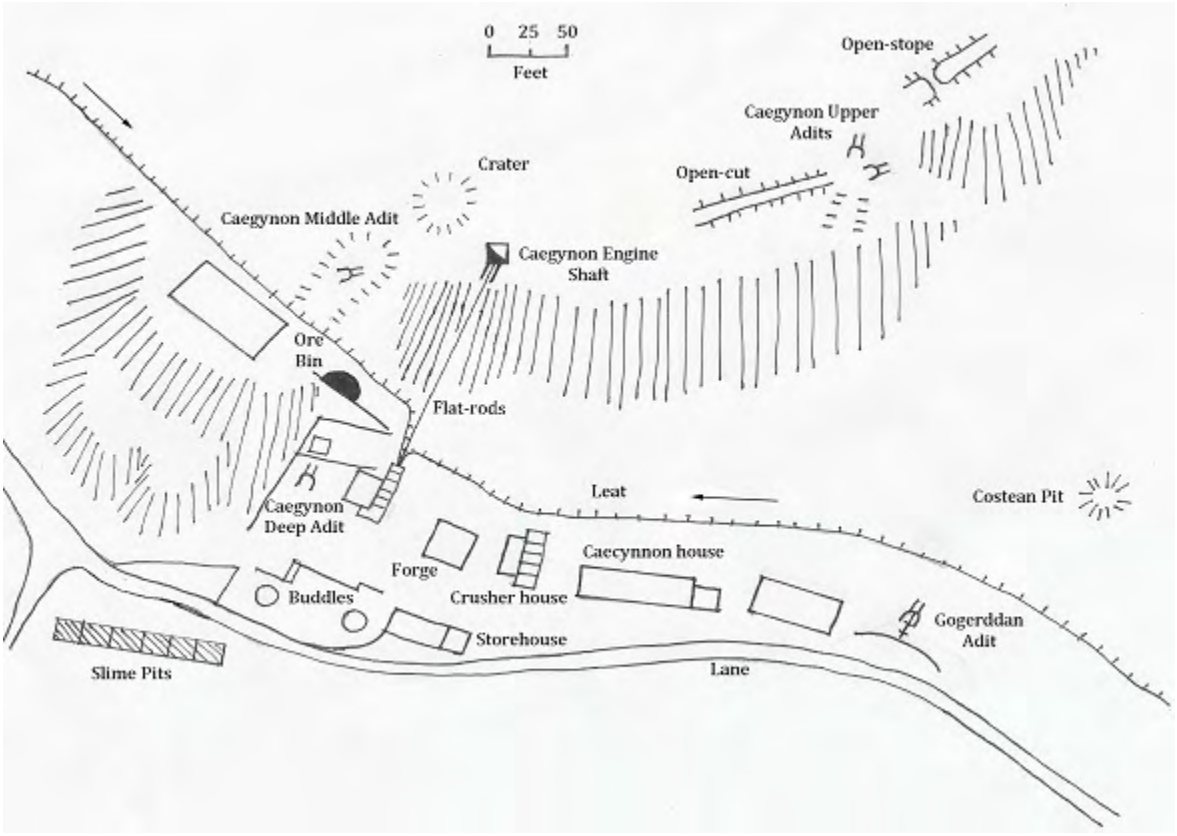


△ Rheidol United main dressing-floors at Gwaithcoch

Rhiwrugos Mine is one of the best in the valley, containing 8 adits, open-stopes and cuts. The Midway, or Upper Adit commences at railway level at the back of a 20th-century dressing mill. It cross-cuts to the Rhiwrugos Lode, where extensive stopes lead east and west. A hole in the false floor when entering the stope indicates the head of the former ladderway. Heading east along the lode, the floor is solid, but tons of stacked deads bend the rotting timbers above. An old wooden ladder is reached where a level branches away from the stope and leads along a footwall. Along the western level from where the adit cuts the lode, the floor is false. However, fine wooden ore-chutes can be reached down here. Continuing along the main cross-cut adit, another lode is reached, where stoping has only been carried out eastwards. A deep winze prevents exploration of this stope. The main adit leads to a dead end beyond a pile of deads some 200 feet further.

Further up the ravine, a small adit cross-cuts to the first lode reached in the Upper Adit, but follows it as a drift for a short distance. There is a winze at the end of the passage. Nearby this adit's portal, another rather ancient adit commences from a small waterfall. Further up again, a fine coffin-level is situated by the stream and leads underneath the extensive open-cuts and stopes above. These are the ancient workings: another adit, which may have been a coffin-level in the past, leads underneath them. This adit has a wall covering three-quarters of the portal, built by the 20th-century miners of the Midway Adit. This made this shallow adit serve as a reservoir for the dressing-floors below. There is another blocked adit which was driven as a drift under the open-cuts. Above the open-cuts, in the field, a small reservoir can be seen, also built in the early twentieth century. This mine was one of the oldest and most recently worked in the county.

All adit portals at Alltddu are blocked today except for the Deep Adit, which is masonry-lined for the first 20 feet and then blocked by the collapsed engine shaft above. The pumping wheelpit for the engine shaft alongside the footpath can just about be seen in the field below, but it is in a very ruinous state due to years of farm stock walking over the walls.



△ Caegynon and Gogerddan Mines

Crossing the valley, we reach Caegynon Mine, where the dressing-floors have unfortunately been flattened. The old forge is now a house, and the Deep Adit completely lost. However, the oldest adit, Middle, is well worth exploring. It is reached by following the old leat south-east from where the footpath reaches the boundary into the Coed Simdde Lwyd Nature Reserve.

The adit is very low and tight, and leads past two junctions and on to the engine shaft, where heavy surviving rails cross it like a tightrope. At the edge of the drop, a wonderful winch from the 1920s still stands in perfect condition. It was used to raise and lower an electric pump installed in the 1930s. The rails still span the shaft like a tightrope and continue along the drift opposite, though getting over there is a difficult task! A large stope is reached by following the two side-passages away from the main adit, where a very deep winze drops hundreds of feet below, and is flooded at Deep adit level.

The Gogerddan Mine remains a bit of a mystery. Opened just east of Caegynon, the cross-cut adit commenced from behind a large corrugated steel workshop, which survives today right above the lane next door to Caecynnon house. The portal was found 'squeezed up' by a heavy overburden and inaccessible when the miners arrived for work one morning in 1938. The modern adit was driven to the lode, then one drift was driven along the Caegynon South Lode's footwall, another along the hanging-wall. The two drifts were connected at regular intervals by levels, dividing up the lode into square blocks. The tools, wagons and artefacts are said to remain entombed within the lost adit into which many people over the years have tried, without success, to enter. In 1990 a local man tried to gain access with a mini-excavator but had nowhere to tip the rubble from the portal. A fine concrete loading bay stands alongside the lane where lorries used to park so that the wagons could tip their contents into it. This accounts for the lack of a tip outside the adit, which was never more than a trial in its short life.

Back west along the valley, above the Visitor Centre, Tyllwyd Mine lies hidden in the woods. Consisting of 7 adits, an engine shaft and a long line of former flat-rods across the valley, little can be seen of the workings today. The dressing-floors were situated in what is now a little tip near Ger Y Llyn house, opposite Gothic Mine. Flat-rods were driven from the syphon-powered waterwheel at the dressing-floors, across the valley on dollies, and up a portion of the hillside to the engine shaft. Today, the trench for the rods can still be seen, and a balance-pit and a ruinous building at the shaft collar. The deep adit and the next adit up can be seen, both run-in, above each other near the stream. Further up the hillside are two obvious tips, the adit at the top of the lower has a foot of its portal still open, and the upper is completely run-in. There is a small shaft next to the lower adit. The fifth adit, further up again and just below the footpath, is an ancient hand-picked level, and only about 4 feet tall! It leads into a small stope with a shallow winze dropping down some 10 feet into the forebreast of another level. This level runs back below the adit and into a shallow shaft, which commences at the hand-picked adit's portal. All of the adits of Tyllwyd were driven into the vein at various depths, but the Deep Adit was the only one that seemed to matter. There is another adit just above the footpath which leads a short distance to a dead end, and another spacious trial adit set away from the main workings in the dense woodland to the west. Hafodau Mine lies up near the top of the

brook above Neuadd Parc farm, but a 20-foot long adit is the only thing that remains here today.

Gelli Mine lies a short distance east of Tyllwyd, and Francis's or Deep Adit commences directly below the footpath which climbs from the lane behind Dolfawr house. Unfortunately, the adit leads to a collapse beyond an air shaft to the surface. Bonsall's Level, a hand-picked adit from the 1700s, lies at the top of a tip higher up the hillside, and has very scenic views up and down the valley. It, also, leads to a collapse at where it might have intersected the lode. However, a winze remains open which drops down into Francis's Adit. 'The Stag', as the tips are locally known above Bonsall's Level, has been attacked by vegetation and no longer looks like an animal. The Upper Adit, run-in today, commenced here and met the lode a very short distance inside. Filled-in open-stopes are seen between the 'antlers' of the 'Stag'.

Tynyfron Mine, beyond Gogerddan Mine and below Tynyfron house further east, has a rather interesting story which occurred in the 1980s. Right by the house, a stream cascades into a deep open-stope which connects with the Deep Adit which, along with the upper adit, was blocked. The force of the stream damming up behind the backfill caused the 'blow-out' to occur. The water exploded out on a Sunday morning, washing a large chunk of the hillside around the portal downstream in a small tidal wave. At the bottom of the stream the Cwmrheidol lane bridges it, and the large amount of earth dammed up behind it until it washed the whole bridge and the lane away into the river. Both parts of the valley were cut-off and the residents, including my father, remember gathering at the edge of the drop, looking down at the tiny stream which had now returned to its normal flow. Whilst crossing the bridge today, the tips can be seen right on the riverbank where it was washed down 30 years ago. The adit is the most unstable in the valley and going in would be complete idiocy. The soil around the portal collapses weekly, but the adit remains open for a short distance until the point where it has collapsed completely. There was a smaller blow-out between 2007 and 2012 which enlarged the portal of the Deep Adit incredibly, as seen in the pictures below.

◁ Tynyfron deep adit, 2007

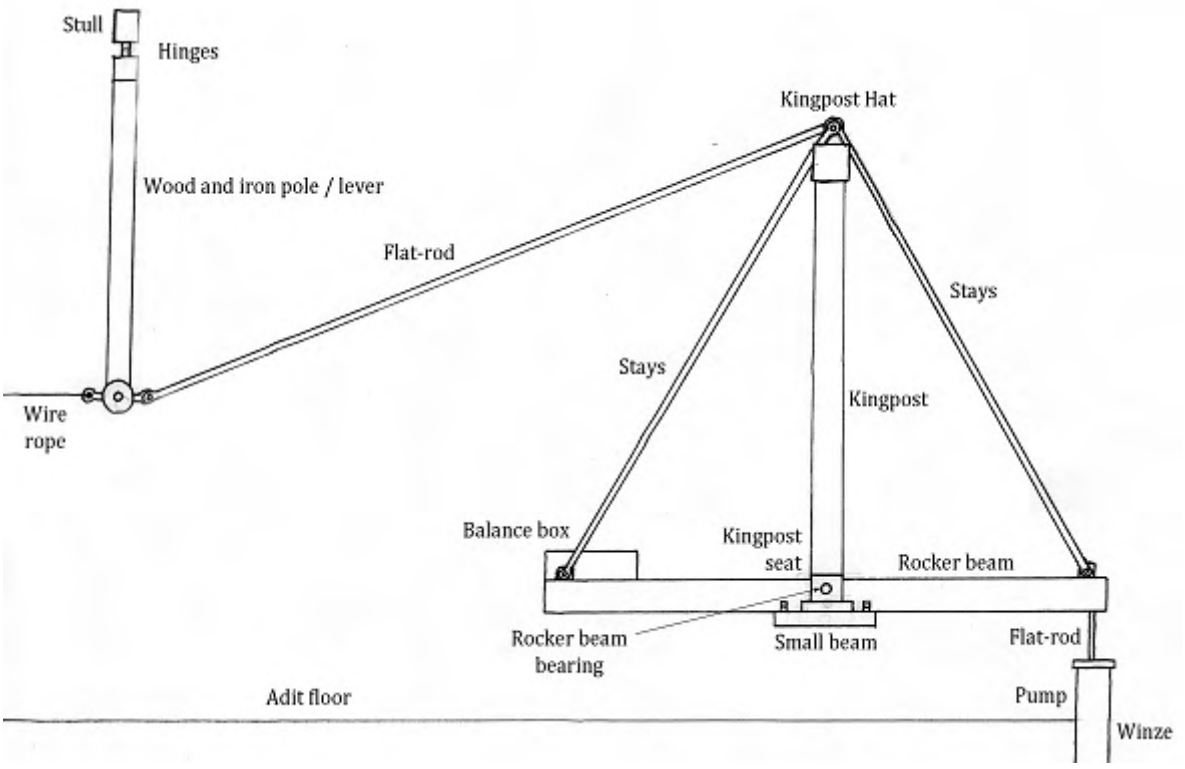
Tynyfron deep adit, 2012 ▹

From Tynyfron Mine, a tramway lead to Cwmrheidol Mine. Passing by the No. 9, or Deep, Adit of Cwmrheidol, the tramway terminated at the New Dressing-floors which were built above the lane and below the old dressing-floors at No. 6 Adit. Apparently driven *c*.1824, No. 6, or Alderson's, Adit served as the Deep Drainage Adit of Ystumtuen Mine until becoming a separate mine later on. Alderson's Adit had been in existence long before its recorded date of *c*.1824, as can be seen by the presence of initials within, dated 1760. The adit contains spectacular formations, tramways, stopes and ladders and leads almost a mile and a half underneath the workings and mines at Ystumtuen. Unfortunately, this spectacular adit has been securely grilled by a large wooden portcullis and access is only possible by abseiling down a small air shaft behind the portal nowadays.

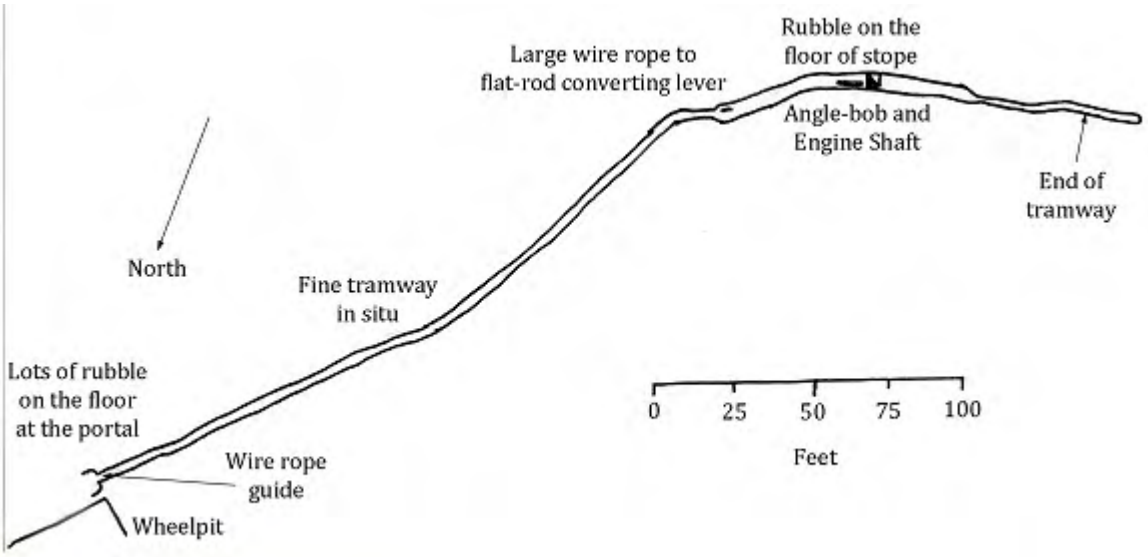
No. 9 Adit below has been cleared and the ochre pond outside drained, but the nicely-created adit leads to a collapse some 15 feet in. Timbers have been laid on top of steel arches along the adit, rising out of ochreous mud which is at least 3 feet deep. The late Mr Davies of Caehaidd farm was one of the last people to work in No. 9, the most recently closed working in the valley, and said that the ochre would bore holes through the leather of the miners' shoes within weeks.

Beyond the small scattered workings of Ystumtuen, Penrhiw, Bwlchgwyn, Llwynteifi and East Llwynteifi Mines along the hilltop, we descend back to the river Rheidol where it flows along the bottom of a deep ravine near Parson's Bridge. This was an old miner's footbridge which lead from the path east to Ysbyty Cynfyn to the west side of the ravine. Temple Mine lies down in the ravine, and must be one of the most scenic and wonderful mines in the area. The path is followed to the right from the fork at the western end of the footbridge, over a short trial adit below, and to the main mine site. The dressing-floors remain extensive, and a fine buddle pit can be seen hewn out of the rock above the river. A tramway trackbed can be followed from the ore-bins to the Middle, main Adit, which like the others, is grilled. Below the path, the massive 40 × 4-foot waterwheel pit can be seen rising out of the river. The tailrace arch is nicely

bricked, and the structure contains drawing machine pits and is most spectacular. The waterwheel drove a wire rope into the Deep Adit which lies alongside, and down the tunnel until reaching the stope. Here, a long lever device converted the wire rope to the still extant flat-rod. The lever also remains complete. The flat-rod leads to a large underground angle-bob at the collar of the engine shaft. A false floor covers the shaft but is easily avoided by means of a rock ledge around on the right. One half of the bob's rocker beam survives, and all of the iron remains stand unharmed, towering above the explorer. The Middle and Upper Adits met the same stope on the Temple Lode and the Middle Adit continues a fair distance on the far side, leading past an air receiver to a drift along the Castell Lode. The Deep Adit continues for a short distance on the far side of the stope but leads to a dead end.



△ Temple underground angle-bob. Not to scale



△ Temple Deep Adit

The descriptions I have given in this article are very brief; many more fascinating facts and artefacts remain in many of the workings in Cwm Rheidol. These rather forgotten mines are well worth visiting and hold much ancient, and also recent history. All workings are today a reminder of the effort and hope that many mining captains and owners put into their properties over the years. For more information on any of the mines in Cwm Rheidol, please contact me on rheilffordd@gmail.com. These fascinating sites well deserve the same respect as any at Dylife or Cwmystwyth, and will hopefully remain unharmed for future decades.

WARNING

Abandoned mine workings are dangerous. However inviting they may look, no one should enter an adit or a shaft unless properly equipped, trained, and with company. Never go underground alone in case an emergency arises – no one will know where to find you. There are many dangers underground, and not even the most experienced explorer can always spot them. The dangers include rotting false wooden floors spanning stopes, loose rock in the tunnel, and dangerous gases in tunnels with bad air circulation. Enjoy surface exploration, but even here take care – be aware that there may be an unguarded shaft in the vicinity of old workings.

Simon Timberlake

THE TANYRALLT BOILER

A project to conserve and display a c.140*-year-old Cornish engine boiler from Tanyrallt Mine, Talybont, near Aberystwyth*

HISTORY

This boiler, rescued in 2006 at the behest of S. J. S. Hughes of Talybont, was probably installed at the Tanyrallt Mine around 1873/4 in order to serve a Cornish pumping engine within the newly erected engine house. No contemporary picture of this house survives, although a B&W photograph of the stone-built remains with half of the square chimney stack still standing and the roofless external boiler house with boiler *in situ* (with its fire door and valve gear intact) was taken in 1967 by Simon Hughes.

The approximate date of installation of the steam engine and boiler (and probably therefore the date of its manufacture) is suggested by the fact that reports written on the mine by Liscombe & Company in *Mines in Cardiganshire, Montgomeryshire and Shropshire* and by Thomas Spargo in his *Mines in Wales* (1869/70) omit to mention this, yet just a few years later in 1874 this engine is referred to by Absalom Francis in

his *History of the Cardiganshire Mines* (info. Graham Levins 2010). Similarly the manufacture of this boiler by George Green at his Cambrian Foundry in Aberystwyth is not 100% certain, yet this seems by far the most likely explanation, given its similarity to the much larger (and still surviving though poorly preserved) Llwynmalus Mine boiler built by Green around 1850, and because of Green's personal involvement with the Talybont Mines around this time, such as Allt y Crib, where an underground steam engine was installed in 1879 (Hughes 1987).

Unusually perhaps the boiler was not removed when the mine was abandoned in 1891, and the steam engine dismantled, and one only guess that it may have been in a poor state, with a low scrap value, or else that this was left intentionally, perhaps for use as a water supply (tank) for agricultural purposes. Over the next 122 years this was gradually buried beneath collapsed masonry, with little sign of vandalism or further damage. The detail and condition was recorded in a side elevation drawing of the boiler by S. J. S. Hughes in 1970–71, by which time it appears to have lost its fire door, whilst a further photo of this taken in 1980 shows it in a pretty similar state to how we find it today, but lying alongside this is what appears to be the detached water inlet pipe (see below and also the catalogue illustration from the Harvey's Foundry, Hayle, Cornwall).

In 2006 the landowner demolished the remains of the engine house, but was persuaded to save the still *in situ* boiler. This was lifted on two slings suspended from the boom of a 360º earth-moving machine, and then transported to Tanyrallt Farm,

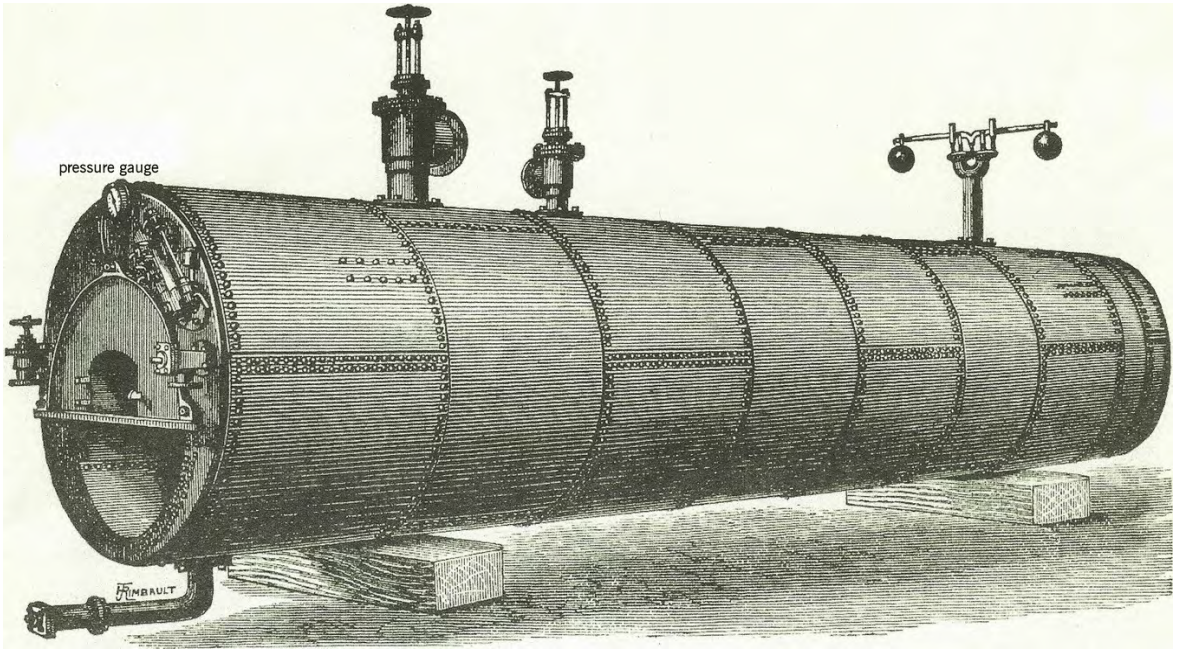
where it remained in the farm yard, awaiting collection until 2010. In 2008 the WMPT agreed in principle to take on the job of conservation and finding a suitable home for this boiler, this being one of only two surviving examples of boilers in Ceredigion, and possibly the only large item of Green's Foundry mining equipment still worthy of rescue for its eventual display and interpretation. This would stand as a memorial perhaps to a significant 19th-century industry of mining machinery manufacture local to Aberystwyth (during the 1870s when the mines were most active some seven local foundries were producing either finished or component parts for ore dressing machinery, waterwheels or engines (see Hughes 1987)).

At the Ceredigion Mines Forum meeting in 2009 the then curator of the Ceredigion Museum, Michael Freeman offered to enquire as to the possibility of transferring the boiler to a more secure location in Aberystwyth, and the Ceredigion CC Works Department on Bryn-y-Mor Road was suggested as an option. Unbeknown to the Trust this kind offer of a temporary home was granted, and the boiler was moved two years ago, since when it has rested on its side on wooden supports against the inside of the compound wall. It was 'located' again last November, following my enquiries to the present curator Carrie Canham. The rest of the story is found in the account below.

PRESENT DESCRIPTION OF THE BOILER

Apart from a number of small corrosion holes on the underside (see conservation report and plan below) the body of this 15 feet 6 inches (14.7m) long and 5 feet (1.5m) diameter cylindrical internal flue Cornish boiler appears to be intact. The sides of this were made from 25 overlapping ¼" (6mm) thick riveted iron plates of varying sizes (ranging from standard 3'8" × 2'4" to 2' × 1'4" for the smallest top plates, whilst both of the ends were made from single 5' diameter plates fixed onto an outer and inner ring, with the addition of 2' deep half-round plates riveted on top of these on the upper side of the boiler, the latter probably intended as reinforcement plates, perhaps an additional safety measure designed to prevent steam burst at the ends. At the front (fire door) end the internal flue (here approx. 2'4" diameter) was a-centrally located just 5–6" above the bottom of the boiler, the flue diameter narrowing to *c*.1'4" and rising to the mid-point of the boiler at the chimney end; this presumably a design to encourage the draw of the flue, increase the rate of temperature rise, and thus reduce boiling time. The tube for the internal flue was made up of three overlapping and riveted longitudinal flue plates.

Inside the upturned fire box at the front end could be seen three flat or gently arched wrought iron supports for the now missing fire bars which formed the coal grate. These supports appeared to be wedged into the sides of the flue approx. one third of the way up the opening, the area of the beneath these forming the ash bed or ash box. A worn groove in the end plate just beyond the circumference of the fire box opening was probably a design to take the rim of the sealing band of the circular fire door, this door probably being held by three small bolts when closed (three screw holes can be seen), with a larger upstanding bolt on the right-hand side supporting either the hinge for this door, or possibly another catch mechanism. These features can be seen more clearly on the Harvey's Foundry boiler (shown below), alongside the



all-important small air vent opening within the missing fire door. Three further bolts of various sizes, one on the right-hand side with an iron washer underneath it, can be seen within the reinforcement plate above the fire box. All of these bolts may have been inserted following the removal of still-functioning gauges or valves; the lower bolt on the right-hand side might reflect the position of a water gauge (originally a thickened glass and iron tube), whilst the one at the very top might have been for the dialled steam pressure gauge. The sheared bolt on the left-hand side might (according to the layout of the Harvey's boiler) have been for an additional steam valve.

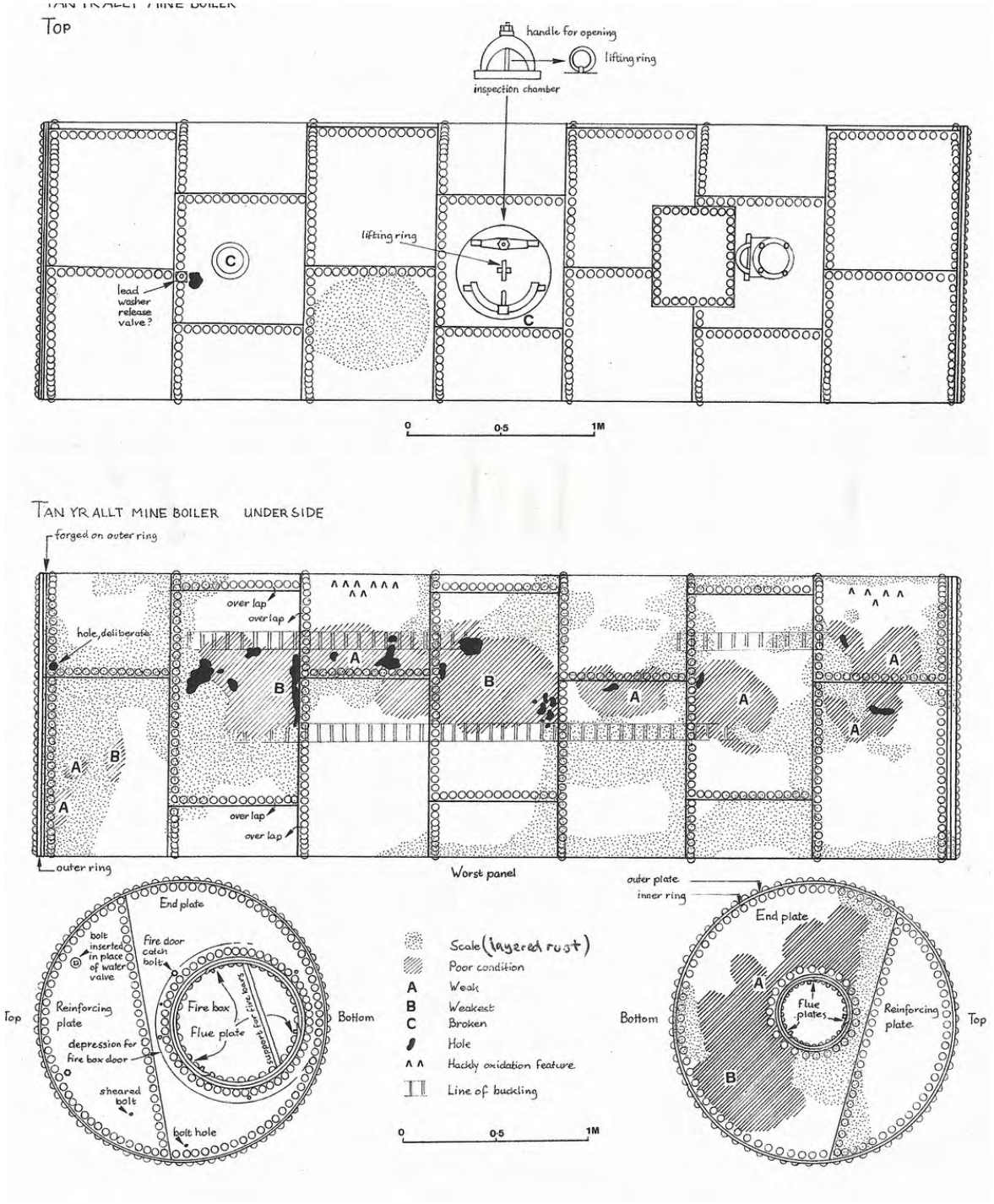
Along the top of the boiler two large-bore bolted pipe junctions (approx. 6–7" internal diameter) were recognized at either end. Both of these were probably for steam pipes, but only one of them (at the fire box end) remains in position. Both of these and a possible inspection chamber cover located within the middle of the boiler are mounted on smaller riveted top plates. However, the identification of the central cover as that of an inspection chamber remains uncertain. Nevertheless a strongly bolted bottom plate would certainly be required to seal a manhole in this position, where the steam pressures are greatest. This might explain the large size of the handles and bolts. At the far end (furthest from the fire box), an iron bolt and lead washer might indicate the position of another steam pressure safety valve, perhaps of the drop pressure type.

The position of the water inlet into the boiler remains a mystery, although the detached L-shaped pipe was probably the pipe which supplied this (NB the base of the Harvey's boiler). A small deliberate hole drilled into one of the plates at the front underside makes little sense as an inlet, and at present the arrangement for this remains a mystery.

The longitudinal double brick plinth supporting this boiler within the original boiler house has left its mark on the in the form of a pair of heat buckle marks on the underside of the iron plates. More than likely this distortion provides us with a clue as to the nature of the complexity of the flue system employed to bring to the boil and get the engine rapidly into steam. Typically this system involved the flue gases from the internal flue returning back along the exterior via bricked side flues, then back from the fire box beneath the underside of the boiler to the base of the chimney. Needless to say, this flue design vastly increased the output (BTU) of these high-pressure boilers, only to be surpassed by multiple internal flue boilers at the end of the nineteenth century (the latter known as the Lancashire boiler).

CONSERVATION CONDITION

A conservation condition survey of the Tanyrallt boiler was carried out at the Bryn-y-Mor yard on Friday 8th March by ST, assisted by Robert Ireland. Underside, top and end view annotated elevation plans which show the present condition of this ironwork are included here. These plans and a key were re-drawn by Brenda Craddock for WMPT, most of the comments being self-explanatory.



Perhaps the most important observation is the much greater degree of oxidation, corrosion and weakening of the ironwork on the underside, compared to the surprisingly solid upper exterior surface of the boiler. This corrosion may have its roots in any one, or perhaps all of the following causes: (1) the presence of acidic water left in, or else accumulating within the boiler following abandonment, (2) caustic ash left within the firebox and flue (much of this dating from the 1880s–90s is still present),

(3) the action of the original flue gases on the underside exterior of the boiler during use, (4) the post-abandonment rapid burial of the lower half of the boiler within soil, rubble and acidic mine waste (dump material?).

Most of the weakest areas on the underside of the iron plates appear to lie between the two slightly buckled ridges caused by the heat/ flue-gas distortion (see plan). Here some small areas within at least five of the seven rings of iron plates are just paper thin (1–2mm), or in some cases perforated completely (the largest holes are irregular but between 10–20 cms diameter). However, subsequent inspection of this appears to show that the solidity of the overall structure remains assured by virtue of the presence of internal iron ring bracing along the radial plate joins and the greater thickness of iron formed by the plate overlap and toughened lines of rivets. Problematical though is the considerable and aggressive iron oxide scaling and delamination taking place over some 30–40% of the underside surface (by contrast active scaling on the upper surface is less than 5% of surface area). Oxidation corrosion of this sort may well be greater as a result of the contact of the iron with moist sea air, yet it seems unlikely that the problem could be that much greater here in Aberystwyth than at the mine site itself.

The very easy removal of this loose scale with a scraper and by light tapping with a hammer seems also to guarantee the removal of efflorescing salts, leaving a clean, and in general a dry surface. Work carried out on a very small test area showed that the oxidised surface underneath could quite easily be wire brushed/ hand-sanded prior to red oxide painting.

Once stabilised, there seems little point in trying to repair/ fill the corrosion holes. The whole structure appears to be internally stable despite these, whilst the corrosion holes remain part of the objects history. The missing steam pipe junction which appears to have broken off during the removal of the boiler was retained and brought with the boiler to Aberystwyth. This was placed for safekeeping within the fire box, therefore a good case can be made for remounting this on a small plate, and then drilling and bolting this back into place.

THE FUTURE

Conservation working week-ends: The necessary conservation work in wire brushing and painting with red oxide primer (followed later perhaps by coats of a proprietary industrial type paint) can easily be undertaken by a small team of WMPT volunteers working at the Bryn-y-Mor yard, perhaps over 2–3 week-ends, and with the help of the yard machines in lifting and turning the boiler. Currently this work has to be undertaken during week days, given that it is closed at week-ends, although moving the boiler outside into a fenced-off area within the car park will enable week-end work to take place. When this happens, there will be a notification of suggested dates to WMPT members, so that work parties can be arranged.

A permanent home: A number of possible locations to permanently display this in Aberystwyth are still being investigated and discussed, and following the 2013 Ceredigion Mines Forum, Peter Austin of Ceredigion County Council and Carrie

Canham (Ceredigion Museum) have been very helpful in taking this forward. When permission is received to undertake this re-display, funding may be required to help erect a proper plinth, lighting and interpretation panels, almost certainly at an outside location, and ideally close to the foundry where it was made. The Science Museum PRISM Fund might be a suitable source to apply to for grant.

GEORGE GREEN AND ABERYSTWYTH'S INDUSTRIAL HERITAGE

For those interested in finding out more about George Green and Green's Cambrian Foundry in Alexandra Road (the site of which lies almost opposite the railway station in Aberystwyth) I would strongly recommend reading S.J.S. Hughes 'George Green, Engineer and Entrepeneur, 1824–1895' in *British Mining* No. 34, 1987. Almost all the original documentation relating to the works was lost when this burnt down in 1908; some references to other Aberystwyth foundries survive in the R. J. Ellis papers, whilst there is a reference to a copy of the Cambrian Foundry Prospectus for 1850–1856 (no. 55) amongst the Matthew Francis Druid Inn papers within the National Library of Wales. Even though Green's order books, plans and pattens are now lost, printed catalogues of the mining machinery made here would have been distributed both at home and abroad, and these may have included engraved drawings of the boiler type(s), as well as other items such as the Green's Self-acting Jigger and Green's Economiser (a device to greatly improve the efficiency of boilers), both of which appear to have been innovative improvements.

The rescue and eventual display of the Tanyrallt boiler will I hope stand testimony to George Green, Aberystwyth's very own 'Brunel', as well as this once important and now forgotten industry he represents.

ACKNOWLEDGEMENTS

The credit for rescuing this boiler should go to Simon Hughes of Talybont. In addition I would like to thank Graham Levins, Nigel Chapman and Robert Ireland for providing me with useful information relating to this and other boilers. Robert Protheroe Jones has supplied helpful directions regarding its conservation. Michael Freeman, Carrie Canham and Peter Austin of Ceredigion County Council have assisted in many ways. Brenda Craddock fine-drew the original plans.

Simon Hughes

TYPES OF BUDDLES AND THEIR VARIOUS FEATURES

During excavations at the Bwlch mine in 1993 it was necessary to identify the type of buddles that had been deployed: most of my mineral dressing handbooks were consulted, and the notes and analyses are worth repeating.

William Hooson, writing in 1767, describes buddles as being 'a kind of large trough, six or seven feet long, and two feet or three quarters of a yard wide; this is made of strong planks ...' which appears to be a form of what was later known as a strake or tye: neither word was known to Hooson. According to *Dennis*, the strake could be lined with cloth and used for gold recovery. I know these devices for the recovery of fine gold simply as sluice boxes.

The name 'buddle' dates from at least the 1550s when it was applied to simple washing troughs by Agricola, and such devices are known to date back into ancient times. The washing floors at Laurion, near Athens, employed these hydro principles and are known to date from before 413 BC. Of the other types of buddle, there were many varieties and patent versions, usually with the pulp being applied to a rotating table. I have not searched through the early texts as it is well beyond my area of expertise and is worthy of a study in its own right. Both *Hunt* and *Moissenet* clearly illustrate tyes, strakes, round buddles and other simple devices in use in Cardiganshire in the mid-19th century [**21**].([1]) The round convex buddle was first used about the year 1848 according to *Hunt*, p. 696, but, as *Smythe* describes them in the previous year this is clearly not the case. Other sources suggest Cwmmawr in 1838, which I am more inclined to believe. Initially, the name 'buddle' appears to be medieval, but Hoover has translated Agricola's *canalis*, a 'trough', as a 'buddle', whereas 'tye' or 'strake' would probably have been more appropriate, though not as widely understood. Hooson, in 1767, therefore appears to be the earliest use of that word, but the device described is clearly a strake or tie [**28**, **29**].

Buddles may be divided into three distinct groups:

A Flat Buddles, or more correctly Tables or Frames. Within this group must be included the **Welsh Buddle**, **Flat Buddle**, **Hand Buddle**, **Lisburne Buddle**, strakes and tyes etc. This type of buddle is the traditional method of freeing ore from impurities but was subject to nineteenth-century improvements. Stationary tables were made to reciprocate during the nineteenth century, resulting in

(1) Bracketed figures refer to the illustrations following the text on pp. 68–82. Names in *italic* are those of authors whose works are listed in the bibliography on pp. 66-7.

Wilfley, Frue, and Rittinger's tables, and a host of similar patent devices. These are not considered in this article.

B Concave Buddles, where the centre is lower than the periphery. The ore is applied to the outer edge and washes down towards the centre. As far as I am aware,no machinery of this nature was ever used in mid-Wales.

C Convex Buddles, where the centre is higher than the periphery. The ore is applied to the centre and washes down to the periphery. This type was universal throughout the Cardiganshire mining district, and those used at most mines fall into this category.

BORLASE'S BUDDLE [**2**]: A concave buddle 17' in diameter and 14" deep with an inclination of 1½ inches in the foot (12½%). *Goldsworthy* 107. An inclined circular rotating frame 24 feet in diameter and 6 in breadth that rotates once every 3 minutes. The pulp is fed directly from the stamps and light stuff is carried away immediately and deposited in ring launders, whilst the heavier products are washed off into receivers as a continuous process. Claimed to be highly cost-effective. *Goldsworthy* 109. Borlase's concave buddle is further illustrated and described as being suitable for enriching the heads from the **Round Buddle** after being broken up and thinned to a pulp in a mixer. The floor slopes to the centre at about 1 in 12 (8.33%): the greatest proportion of the ore is deposited around the edge where it is fed, and the waste runs into the well at the centre of the device from where it is run to the settling pits. *Davies* 304. It was easier to regulate than other similar machines on account of the button board being replaced with a mechanically lifted sliding ring at the centre. Plan and section, *Hunt* 768.

BORLASE'S INCLINED BUDDLE: A concave table 24 feet in diameter and 6 feet wide with its centre post set off-vertical so as to impart an inclination of 1 in 12 (8.33%) to the table. It is fed with pulp and water at its highest point, which washes off the gangue into collecting launders almost immediately. The ore is then washed back off to the centre of the table by jets of water at its lowest point, and flows into separate launders. The table makes one turn about every three minutes. The constantly varying inclination produces a spread of pulp from the circumference to the centre on the receiving side and back from the centre to the circumference on the washing-off side. The advantages of this machine are its great simplicity, 90% of the ore being saved at the first washing, whilst the waste was not worth re-treating. *Hunt* 769.

BROOKS' BUDDLE: Popular in Australia, mentioned but not described. It is not known if they were concave, convex or compound. *Goldsworthy* 109.

CARDIGANSHIRE BUDDLE: The name applied to the rotating version of the reciprocating **Lisburne Buddle** as designed by Captain Sanders of Esgairhir. *Mining and Smelting Magazine.*

CENTRE HEAD BUDDLE: An updated **Round Buddle**: plan and section, *Hunt* 766. It is worth noting that in *Smyth*'s description of 1848 the pulp is fed directly on to the table by way of a small double conical spreader. In later years the function of the spreader became more important and the centre head became more pronounced, with the pulp being applied by a perforated metal plate. *Eissler* in 1889 shows a Centre Head Buddle as a **Round Buddle**, whilst *Phillips & Darlington* show the more traditional **Round Buddle** in 1857. The transition from the small spreader to the large spreader therefore seems to have taken place in the 1860s or 70s.

COLLOM'S BUDDLE [**3**]: A patent compound **Convex Buddle** with the table having two different inclinations towards the periphery. It is known that one was introduced by Captain William Michell to reduce losses in the old mill at the Cwmystwyth Mine in 1876, and it proved so effective that others were added to the circuit in the following year: *Hughes*, Cwmystwyth 22, 23. These differ from regular buddles by dividing the revolving table into two parts: part of the product of the steeper table is washed on to the shallower table, which may also be arranged to hold mercury so as to amalgamate any free gold in the pulp. It is convenient to have the table about 25' in diameter and to revolve at 2 to 3 rpm. The table may be divided into more than two rings if it is desirable. *Eissler* 135.

COMMON BUDDLE: Shown in Pl. 12 of *Smyth*'s plan of the Goginan floors as being a long box type construction about half the length of a tye or about 8 feet long. It may be the same as an **Ordinary Buddle**, also referred to on p. 679 of that text.

COMPOUND BUDDLE: Not described, but mentioned generally in *Goldsworthy* 109. This appears to be a double inclination device such as employed in the **Collom Buddle**.

CONCAVE OR SLIME BUDDLE [**4**, **5**]: The general name for an inverted rotating conical table inclined towards the centre. Nicely illustrated in *Palmer & Neaverson* pp. 62, 64, and *Trounson* I, 52, 53 and 129.

CONVEX BUDDLE [**12**, **13**, **18**]: The general name for rotating conical tables inclined towards the periphery. *Goldsworthy* 106. A good illustration of such a table under construction is given as pl. 108, and in operation as pl. 113, at Nenthead, in *Raistrick & Roberts*. Further illustrated by *Palmer & Neaverson* pp. 60, 64 and *Trounson* I pp. 26, 87.

CORNISH BUDDLE [**6**, **7**]: A convex buddle about 24' diameter with a 7' run from the feeder cone to the edge. *Goldsworthy* 106. It would appear that it is in fact no different to a **Centre Head Buddle** according to *Bowes, Scott & Western* 74.

DASH BUDDLE: More properly a table, laid at an inclination of 2½ inches in 7 feet (2.9%) with a catch pit at the lower end. *Phillips & Darlington* 138. The above description matches exactly with *Smyth*'s account of the **Flat Buddle**.

DUMB BUDDLE: A 2.5 metre diameter settling pit used for catching and remixing pulp. It is well illustrated by *Palmer & Neaverson* p. 66 and *Trounson* 88.

EVANS'S BUDDLE: A variation on **Collom's Buddle** with a diameter of about 14 feet, an inclination towards the periphery of 1¼ inches in the foot (10.4%) and rotating once every 80 seconds. Its capacity is about one ton per hour. *Davies* 312.

FLAT BUDDLE [**8**, **9**]: The name applied by *Smyth*, with a drawing, to a table 10' wide by 7' long with a fall of 2½" (2.97%) in that length set to deliver into a triangular catch pit 2' deep. This was used to treat part of the product of the rough jigs. *Hughes,* Goginan p. 28.

GERMAN OR **RITTINGER'S BUDDLE** [**10**, **11**]: A convex buddle fitted with brushes. *Phillips & Darlington* 129. 16' in diameter and divided into 32 segments each of that terminates in a square chute through that the product is directed into circular launders fitted below the periphery. *Goldsworthy* 107.

HAND BUDDLE: A modification of the **Flat Buddle** described as being a wooden box 8 feet in length by 3 feet wide and from 2 to 2½ feet deep having its floor inclined about 2 feet in its length or 3" in 1 foot (25%). At the head of this box is a distributing board which supplies a thin and continuous stream of pulp into the buddle. Plan and section, *Hunt* 764. This may equate with the **Common Buddle** of *Smyth*. By 1900, the Hand Buddle was a rectangular wooden box with a sloping bottom. A stream of pulp, fed in by a head board at the upper end, gradually forms a deposit on the floor: a boy with a broom keeps the surface of the sediment even, so as to ensure regularity of action. After a thick deposit has accumulated, it is dug out in sections that decreases in richness from the head to the tail. *Foster* 588. Hooson, in 1747, describes a buddle as 'A large kind of trough, six or seven feet long and two feet or three quarters of a yard wide; this is made of strong planks.' This is therefore very little different from, possibly even the forerunner of, the strake and tye as illustrated by *Smyth* [**28**, **29**].

HUET & GEYLER'S BUDDLE: Huet and Geyler exhibited both **Concave** and **Convex Buddles** at Paris: they are mentioned but not described in any detail. *Goldsworthy* 109.

LEWIS'S BUDDLE: Popular in Australia, it is mentioned but not described in detail. *Goldsworthy* 109.

LINKENBACH BUDDLE [**14**, cf. **1**]]: Detailed description states that it is an improvement upon **Collom's Buddle**. Intended for the treatment of slimes and became popular in the mid-1880s. The table can be made of any diameter up to 10 or 12 yards and must be built on well settled, firm ground to prevent subsidence and cracking. A feature of this machine is that an access tunnel must be constructed under the centre of the table for access and maintenance. The table is roughly

constructed in brickwork or concrete and then faced with hard cement with an inclination of 1 in 12 (8.33%). There are four concentric channels surrounding the table to receive the products, which are washed off by sprayers and conveyed into the four channels by wooden spouts, and from there into four settling tanks. The speed is about one revolution every 2¼ minutes. The heads will usually contain 50% or more lead and are sufficiently pure for smelting, whilst the tails contain about 0.5% Pb. The ironwork for these machines was expensive, a 6-metre machine being quoted at £145. *Davies* 316. It is shown in section but appears to be greatly simplified in *Bowes, Scott & Western* 74. Herr Linkenbach was apparently the manager of the Silberau mine, near Clausthal in Germany,

LISBURNE BUDDLE [**15**, **16**, **17**]: More properly a frame. Apparently developed in 1855 by Captain Vigus of Frongoch as a reciprocating knife frame above a table: *Phillips & Darlington* 127. Further modifications were made by Captain James Sanders of the Esgairhir Mine near Talybont about the year 1862, who placed the knives on a rotating drum and called it the **Cardiganshire Buddle**: *Mining and Smelting Magazine* 321. The machine was useful for upgrading concentrates from fine jiggers or buddles but did not work on slimes. 2½ tons per hour of 15% heads could be dressed up to a product containing 50% Pb in a single pass: *Davies* 306. There are good photographs of a Sander's type machine, referred to as a 'Lisburn Buddle' in *Raistrick & Roberts* 100 & 101. According to *Hunt*, a more accurate correspondent, the buddle was invented in 1845 by the agents of the Lisburne Mines and this was later converted to a rotary motion by Captain Ball, formerly of the Goginan Mines, who named it the 'Impeller Buddle': plan and section, *Hunt* 765. This buddle appears to be a development of the **Trunking Buddle** in use at the Goginan floors whilst under the supervision of Captain Thomas Ball.

MUNDAY'S BUDDLE: Mentioned briefly as being in use at several gold claims in Victoria in *Goldsworthy* 109.

ORDINARY BUDDLE: Appears to be a long shallow box for working the fines from a tye according to *Smyth*, p. 679.

PAINE & STEPHENS BUDDLE [**19**]: A patent **Concave Buddle** designed to be used in pairs, one for coarse concentrates and the other for the finer. They have a diameter of 18 to 20 feet, slightly inclined downward to the centre, in which is an opening 2½ feet in diameter. *Eissler* 139.

RING BUDDLE [**20**]: A rather clever modification to a **convex buddle** whereby a moveable iron ring is fixed closely around the circumference of the table to enable the angle of repose of the contained products to be varied, thus adding another mode of regulation. Section only, *Hunt* 768.

ROTARY BUDDLE: Appears to be the same as the **Round Buddle** but is probably applicable to **centre head buddles** and all forms of rotary tables.

ROUND BUDDLE [**22**, **23**, **24**, **25**]: Apparently originally invented at the Cwmmawr Mine near Pontrhydfendigaid about 1838. It owed its popularity to ease of construction. A **Convex Buddle**, commonly 18' in diameter and rotating at 3–4 rpm, which treats1.5–2.0 tons per hour. Illustrations, *Phillips & Darlington* 126: *Smyth*. *Hunt* and *Smyth* put it *c.*10 years later. Nice description and illustration, *Eissler* 134. In later years its diameter varied from 14 to 22 feet and its depth from 12 to 18 inches with an inclination of 1 in 30 (3.33%), the poorer slimes requiring a greater diameter. The construction may be either of smooth planed boards or of cement laid upon concrete. The outflow of waste water takes place through a small sluice gate fitted with a button board. The heads and middles are re-buddled and the waste ought not to contain more than ½% lead and 1 to 1½% zinc. The heads can be enriched up to 50 or 60% Pb or 42% Zn in a single pass, and may be sold as they are, or dressed up to a higher grade in a dolly tub or in a specialised buddle such as **Borlase's** or **Collom's**. *Davies* 302. This buddle evidently fell into disrepute on the continent in the 1860s, unless it was modified, according to Moissenet in 1864. Slight details are provided by *Palmer* in *British Mining* 22 p. 41. There are particularly good illustrations of this type of machine in *Raistrick & Roberts* 96 to 99. The round convex buddle was first used in Cardiganshire about the year 1848, according to *Hunt* 696, but since *Smyth* describes them in the previous year this cannot be the case: the *Phillips & Darlington* reference suggests that it found rapid popularity. *Smyth* 677 further notes that this machine was tried in Cornwall many years ago but is now peculiar to Cardiganshire. A failing of this device is that it is not a continuous machine and has to be stopped in order for its content to be dug out.

RULE'S BUDDLE: A **Concave Buddle** without brushes but having the surface of the table roughened. It did not meet with favour as water consumption was thought to be rather high. *Goldsworthy* 108.

TAIL BUDDLE: Mentioned by *Smyth* 677 as being used to treat the middlings from the **round buddles**: but they are not shown on his plan of the Goginan dressing floors, Pl.12.

TRUNKING BUDDLE: Only a poor and brief mention is available in *Smyth*'s account of the Goginan dressing floors, but this would appear to be a mechanical table, probably an early mechanical frame that was later modified by Captain Vigus into the **Lisburne Buddle**. It treated the slime from the catch pit and its product was sent to the **Common Buddles** and then the dolly tubs. The text refers to separation being performed by revolving vanes, and the three devices at Goginan employed 9' by 14", 8' by 14", and 8' by 12" waterwheels. *Smyth* 679. This may well be the prototype of the knife buddle later referred to as the **Lisburne** and **Cardiganshire Buddle** supposed to have been developed at the Goginan Mine.

WELSH BUDDLE: More properly a table or frame rather than a buddle. This name was applied by *Moissenet* to a table used at Frongoch which was 15' wide by 8' 3" long

with a fall of about 7½ inches (7.5%) in its length. It relies on the same principles as the **Flat Buddle**, with the separation being performed manually with a hoe or brush, but the catch pit appears to have been replaced with a launder. The sole reference to this device is by *Moissenet* and its function is not analysed by Bick, Briggs et al. in *Bick*, Frongoch.

WILLIAMS'S BUDDLE: Has a convex conical floor made of cement with a pitch of 10½ inches in a 6-foot run (6.85%) from the feeder head to the periphery: it is cheap to construct and does not decay, but is not sparing in its use of water. *Goldsworthy* 108.

ZENNER'S OR ZENNOR BUDDLE [**30**]: A modification and improvement upon the German Buddle by Mr Zenner of Newcastle, the conical table being 16' in diameter with a 1 in 12 fall (8.33%) from the centre to the edge. The products are washed off with a mixture of brushes and water sprays and are caught in a circular trough arranged around the periphery. Its patentee claimed that its main advantages were that it was 7 times faster than an ordinary buddle and that it would clean slime up to 62.4% lead as opposed to 52.6% in the ordinary buddle. *Phillips & Darlington* 131. A conical wooden platform described in similar detail to the above, *Goldsworthy* 108.

ANALYSIS OF THE TYPE OF BUDDLE FOUND AT BWLCH

The two upper foundations were almost exactly 6.00 metres in diameter (19.68') with circular launders 489 millimetres (19.25") deep and 30 centimetres wide into which the product fell. These tables must therefore have been 17½ feet in diameter (5.33 metres).

The two lower foundations were 5.30 metres (17.38') in diameter, and the ring launder being from 4.80 to 5.20 metres in diameter suggests that the tables above them were probably 16' in diameter (4.87 metres).

Apart from the difference in dimensions, the upper and lower pits were identical in most respects.

It is also worth noting that during this present work not one item of metalwork was found in association with these pits, and it also appeared that the wooden superstructure had been cut off flush with the masonry. It was quite obvious that whatever machinery had been housed above these structures had been carefully salvaged. The last owner, James McIlquhan, took over the mine in 1885, and it would appear from the Mineral Statistics that his sole interest in the site was to salvage anything of value. McIlquhan appears to have completed this task by 1888, and the only artifacts left on the site were the boards from a **Round Buddle** which were sent to the Llywernog Mining Museum in the mid-1970s.

Immediately after 1885 McIlquhan was involved in the running of several mines. None of these were in production during his involvement, and at others he acted as manager for Thomas Ward & Co. of Sheffield. It is therefore clear that McIlquhan's

initial involvement with mid-Wales was as a salvor or scrapman, and it was not until the mid-1890s that he became involved in mineral production. The destiny of the salvaged buddles from Bwlch cannot be ascertained from the information that is available at present.

From the construction of the foundations it can be seen that the buddles were convex or compound-convex in nature. They were not **Linkenbach Buddles**, as there is no service tunnel beneath the base. Neither are they **Williams's Buddles**, which had a concrete or brick and cement floor that is likely to have survived intact.

Structurally, the following types of buddles must be considered as being suitable for mounting upon this type of foundation:

Collom's (25') available after 1876 and until at least 1889.
Evans's (14') were only available after 1894.
Rittinger's (16') available after 1857 until at least 1876.
Ring Buddles appear to only be available after 1887.
Zenner Buddles (16') available after 1857 through 1864 until at least 1876 and probably later.

However, the Ring Buddle and Evans's Buddle can be discounted as they were not available until after the mine had ceased working. Whilst Rittinger's Buddles are a possibility, they were considered to be very expensive pieces of machinery and are therefore less appealing than cheaper devices available at that time, when mineral prices were severely depressed.

Collom's Buddles appear to be too large to fit even into the larger pits and were probably too expensive to be affordable. The supporting members for this type of buddle were numerous, and were arranged radially around the circumference of the collecting launder: this does not tally with the physical remains at Bwlch.

The only remaining possibility is therefore Zenner's Buddle, first described by Phillips & Darlington in 1857 and was introduced at the Frongoch Mine prior to the time of Léon-Vivant Moissenet's visit in 1864. There is a further description of the buddle as being an improvement of the German Buddle in Ralph Goldsworthy's essay on 'The Best Mining Machinery', presented to the Cornwall Polytechnic Society in 1876.

Phillips and Darlington also voice the opinion that it was an improvement upon the German Buddle by Mr Zenner of Newcastle. By the time that Sir Robert Hunt prepared his volume *British Mining* in 1887, and also in Sir Clement le Neve Foster's *Ore and Stone Mining* of 1900, this buddle was not considered worthy of attention within the text and appears to be virtually obsolete.

In examining Moissenet's plan of the dressing floors at Frongoch certain similarities can be seen between the arrangements surrounding their Zenner Buddle and the buddle circles that were uncovered at Bwlch. The Zenner Buddle at Frongoch appears to be in the region of 8.50 or 9.00 metres diameter (27.8 to 29.5 feet) and is therefore somewhat larger than those at Bwlch: Frongoch, however, was equipped with only a single machine as opposed to the four at Bwlch. The Frongoch machine discharged into four catch pits; similarly, the upper buddles at Bwlch discharged into four pits which appear to have been Flat Buddles during an earlier phase of working. The two

lower buddles discharged their waste through a stone culvert directly into the four settling tanks.

It is also worth noting that Zenner's Buddle was considered a useful device for separating lead and zinc ores from the gangue and host rock that is probably why it was employed at Frongoch.

Raistrick & Roberts, in plate 108, reproduce a photograph of several 14-foot diameter circular tables being fabricated in the workshops at Nenthead Mine circa 1909, which serves to illustrate the point that these machines were of a fairly simple type that could be constructed by mine carpenters rather than of a type that was fabricated in a factory and then delivered to a mine in a ready-to-assemble form.

In examining the records of the concentrate produced from the Bwlch Mine it can be seen that its best grades were achieved in 1856, 1863 and 1880 and then gradually fell off over the following years. This probably equates to a refitting of the mill or the introduction of better machinery.

A further noteworthy point is that a batch of 6.8 tons of excellent grade (58.82%) zinc ore was sold in 1881, which suggests that the Bwlch United Mining Company Ltd introduced some specialised new machinery into the mill in 1879 or 1880. Whilst it is not recorded, I would suggest that this was due to the introduction of the Zenner Buddles into the circuit.

The four Zenner Buddles at Bwlch Mine would therefore have been in excellent condition, being four or five years old, and only having processed some 4500 tons of pulp to yield about 230 tons of concentrates, when they were salvaged by McIlquhan.

The first edition (1887) of the 1:2500 Ordnance map clearly shows a pair of buddle circles in the position of the two lower, smaller buddles. The second edition, revised in 1904, shows that the dressing floors had been salvaged.

There are discrepancies between the discoveries at Bwlch and the 1887 Ordnance map. It is quite clear from this map that there were three buddles on the lower floor at Bwlch, but the excavations only revealed the foundations of two such devices. The flat buddles that were later converted to pulp tanks are also shown on this map, but in rather poor detail; this is almost certainly on account of their being cut by the boundary of the two maps that cover the site.

LOCATIONS OF OTHER BUDDLE CIRCLES IN MID-WALES

During the mid-19th century, almost every mine in the district, trials excepted, had a set of buddles for separating the waste from the ore. Without undertaking extensive research, it may be estimated that all of the 200 productive sites had at least two buddles, usually four, and frequently more. It would not be unreasonable to assume that there were at least 500 buddle sites in the area at the turn of the century: the following schedule lists the better examples that have survived.

Abbey Consols. Appear to be remains buried under the fines dumps. Under no immediate threat. Now destroyed ?

Bronfloyd. Scheduled Ancient Monument. Not well exposed or defined.

Bryndyfi. Scheduled Ancient Monument. Probably the finest examples in the area.

Bronmwyn. Not under immediate threat. Well defined.

Blaenceulan. Not under immediate threat.

Bwlchglas. A poor late example cast in concrete.

Cwmystwyth. Round buddles long since destroyed, but old hand buddles survive on Copper Hill.

Cwm Brwyno. Mostly obscured by dump movement. Probably under threat in the long term.

Cwm Byr. Particularly fine examples in an as left condition. Possibly under threat.

Eaglebrook. There appear to be buddles buried under the dumps. SSSI: under no apparent threat.

Esgair Fraith. Fine examples undergoing excavations were recently destroyed by road-making works.

Frongoch. Under immediate threat. This and Dylife have confirmed use of the Zenner Buddle.

Glogfach. Appear to be remains encroached upon by the fines dumps. Uncertain future.

Llawrycwmbach. Poor condition. Not under immediate threat.

Llettyefanhen (Vaughan). Not under threat but unlikely to be cared for by the new owners. In poor condition.

Llywernog. One Round Buddle moved here from here from Bwlch but never rebuilt.

Temple. Under no threat. Isolated site owned by CCW. Excellent examples in a good setting.

West Cwmystwyth. Isolated and under no threat. Four intact examples in particularly good condition.

Ystrad Einion. Scheduled Ancient Monument. Very poorly restored – no interpretation.

Ystumtuen. Appears to be one recent example mostly buried by the slimes dump. Under threat.

There are signs of buddle circles at other sites, but the above are probably the most noteworthy examples in mid-Wales.

CONCLUSION

It is known that mineral extraction in the district dates from the Middle Bronze Age, about 1500 BC, by analysis of samples recovered from the Cwmystwyth, Nantyrarian, Cwmdarren, Llancynfelin and other mines. It has been hypothesised that there was also some Roman activity in these mines, but whilst it is likely, the extent cannot be accurately judged at the time of writing.

The greater proportion of remains in mid-Wales are undoubtedly those of the round buddle, and despite over forty years experience I have never seen one at work: the frames employed at the Tolgus tin works for recovering stream tin from the Red River at Camborne were the most archaic form that I came across in my career [**26**, **27**].

About the year 1880 the Bwlch plant was fitted with four Zenner Buddles, probably in an attempt to reduce losses through inefficiency and to obtain a better price for their produce. However, the quantity of ore available, combined with its market value, both of which were in decline, led to the closure of the mine in the mid-1880s. Zenner Buddles were also installed at Frongoch at around this time. The WMPT are undertaking a survey of these remains, and a summary of their findings appears in Graham Levins's article in this Newsletter, pp. 17-18.

Of the patent Collom Buddles that were installed in the Cwmystwyth mill there are no remains: the old mill was built over by Gamman in 1898. Whilst in use it was reported that it worked to advantage, and it is not known if it survived into the 1940s,

when much of the plant was either scrapped for the war effort or sold on to an active mine. Apparently, some of the jigs were sold to the Millclose mine in the early 1940s and the compressor and drills to Rhaiadr Quarries.

It appears that James McIlquhan salvaged the greater part of the Bwlch plant both within the mine and on the surface. The Zenner Buddles, after they had been carefully salvaged, must have been sold on to another mine site, but probably not in mid-Wales, as most mines were in decline in the 1890s.

The foundations of the Zenner Buddles at Bwlch and the product tanks, which were Hand Buddles during an earlier phase, are still in a remarkably good condition, and it was fortunate that finance was available to survey them accurately. They are unusual if not unique. However, it must be appreciated that every mine mill is different in its method and layout in one way or another.

My initial feelings at Bwlch in 1993 remain unchanged up to the present. The four buddle circles are in good condition but in a remarkably poor context, completely lacking the surrounding structures that are vital for any form of interpretation other than by experts. As part of the reclamation works, a thick layer of tailings was laid over this area with the well-worn justification that it could be easily salvaged at a later date.

The foundations of a single, much larger Zenner Buddle at the Frongoch Mine have already been mentioned: this is under threat by development, and is being properly investigated and recorded.

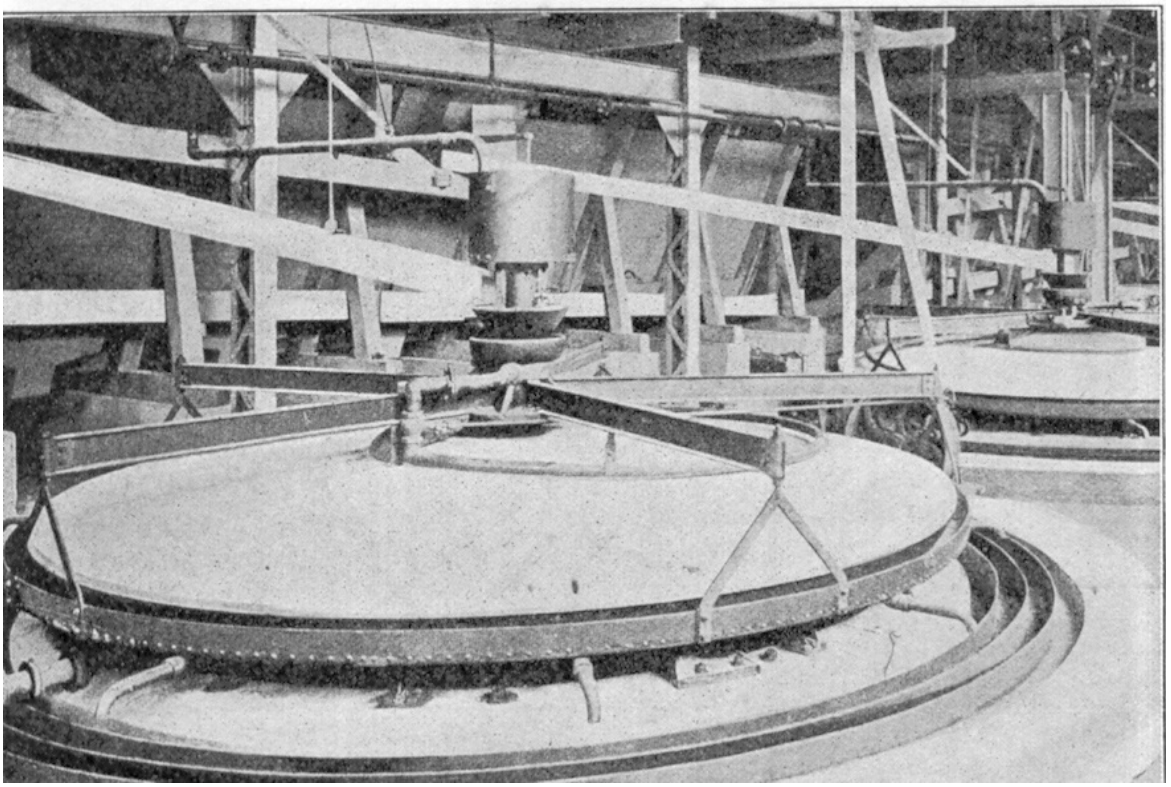
It would be a far wiser move to consolidate buddle circles on another site that still had the interpretable remains of a crusher house and wheelpit, a jigger house, buddle floors and slime pits, such as Bronfloyd, Bryndyfi or Temple.

The greater number of the visitors to Bwlch in 1993 accepted my arguments that it was a relatively new and unimportant mine, the greater part of which had been totally destroyed, and that it continued to discharge a wholly unacceptable level of pollution: it would be far better to direct limited resources towards the preservation of a more intact and less polluted site. The expensive remediation has had remarkably little effect on reducing the pollution of Nant Erfyn, and under the current directives it would appear that further works are necessary to raise the stream to the standards required by current European legislation.

BIBLIOGRAPHY AND FORMS OF REFERENCE

Anon., Engineer	Anon., *The Engineer*, August 1890, pp. 126, 146, 178.
Bick, Frongoch	Bick, D. E. et al., *Frongoch Lead and Zinc Mine* (*British Mining* 30: Northern Mines Research Society 1986)
Bick, Waller	Bick, D. E., *Waller's Description of the Mines in Cardiganshire* (Black Dwarf / Lightmoor 2004)
Bick & Davies	Bick, D. E., Davies, Philip Wyn, *Lewis Morris and the Cardiganshire Mines* (National Library of Wales 1995)

Bowes, Scott & Western	Catalogue of Mining Machinery, *c*.1900
Darlington	Darlington, J., 'The Cardiganshire Buddle': *The Mining and Smelting Magazine*, June 1864
Davies	Davies, E. H., *Machinery for Metalliferous Mines* (Crosby Lockwood & Son 1902)
Dennis	Dennis, W. H., *One hundred years of Metallurgy* (Duckworth 1963)
Earl	Earl, B., *Cornish Mining* (Barton 1968)
Eissler	Eissler, M., *The Metallurgy of Gold* (Crosby Lockwood & Son 1889)
Foster	Foster, C. le Neve, *Ore and Stone Mining* (Griffin 1900)
Goldsworthy	Goldsworthy, R., *The Best Mining Machinery* (Cornwall Polytechnic Society 1876)
Hughes, Cwmystwyth	Hughes, S. J. S., *The Cwmystwyth Mines* (*British Mining* 17: Northern Mines Research Society 1981)
Hughes, Goginan	Hughes, S. J. S., *The Goginan Mines* (*British Mining* 35: Northern Mines Research Society 1988)
Hunt	Hunt, R., *British Mining* (Crosby Lockwood & Son 1887)
Moissenet	Moissenet, L.-V., *Préparation mécanique du minerai de plomb aux mines de Lisburne, Cardiganshire*: *Annales des mines* VI/IX, 1866
Palmer	Palmer, M. *The Richest in all Wales* (*British Mining* 22: Northern Mines Research Society 1983)
Palmer & Neaverson	Palmer, M., Neaverson, P., *The Basset Mines* (*British Mining* 32: Northern Mines Research Society 1987)
Percy	Percy, J., *The Metallurgy of Lead* (John Murray 1870)
Phillips & Darlington	Phillips, Darlington, *Records of Mining* (Spon 1857)
Raistrick & Roberts	Raistrick, A., and Roberts, A., *Life and work of the Northern Lead Miner* (Sutton 1984, rpr. 1990)
Richards	Richards, R. H., *Ore Dressing* (McGraw-Hill 1909)
Richardson	Richardson, J. B., *Metal Mining* (Allen Lane 1974)
Smyth	Smyth, W. W., *The Mining District of Cardiganshire* (HMSO 1848)
Trounson	Trounson, J., *Mining in Cornwall 1850–1960* (Moorland *c*.1985)
Truscott	Truscott, S. J., *A Text Book of Ore Dressing* (Macmillan 1923)
Wiard	Wiard, Edward S., *Theory and Practice of Ore Dressing* (McGraw-Hill 1915)



△ **1** Bartsch Table (Truscott)

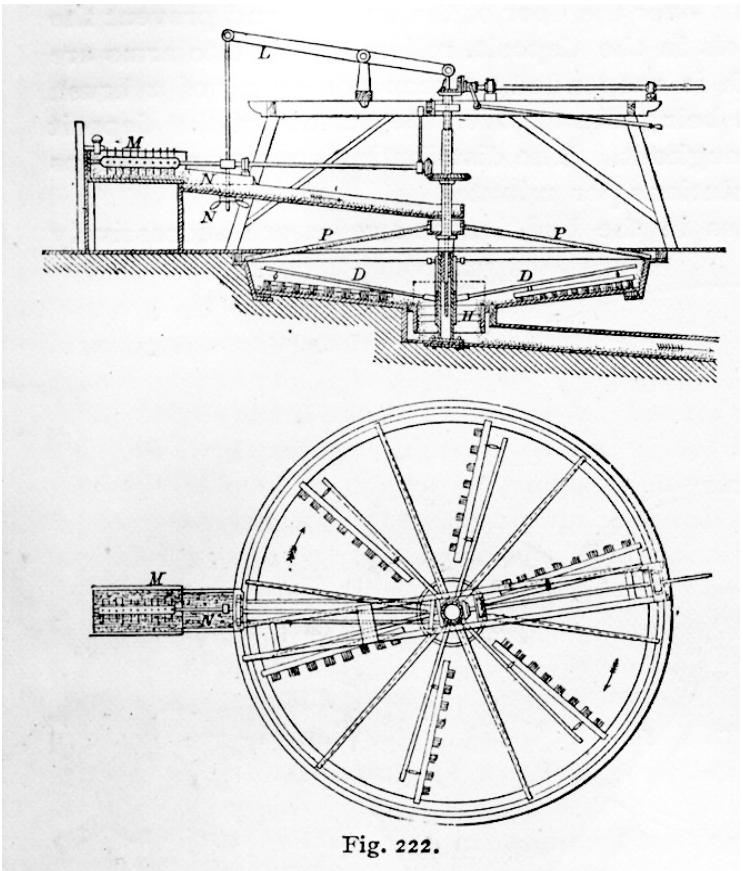


Fig. 222.

◁ **2** Borlase's Buddle

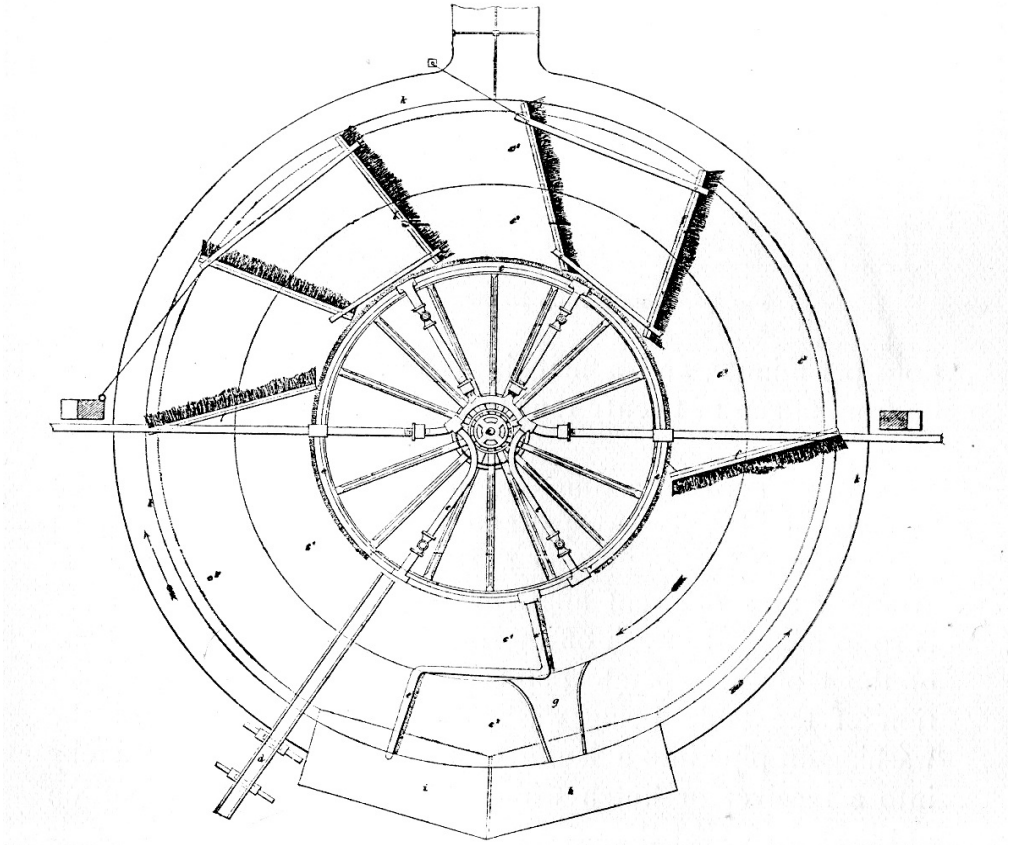
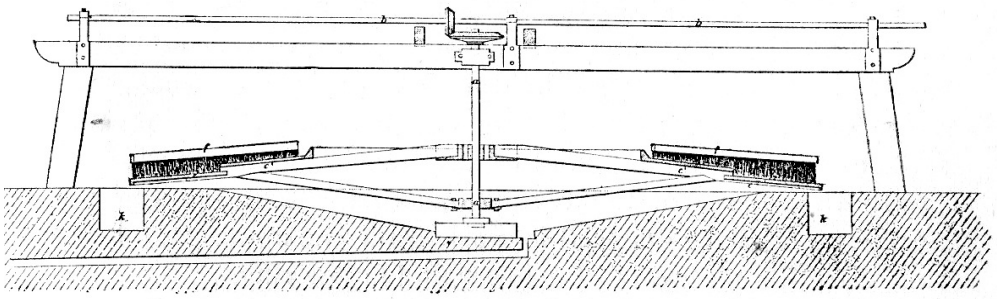


FIG. 67.—PLAN OF COLLOM'S BUDDLE.



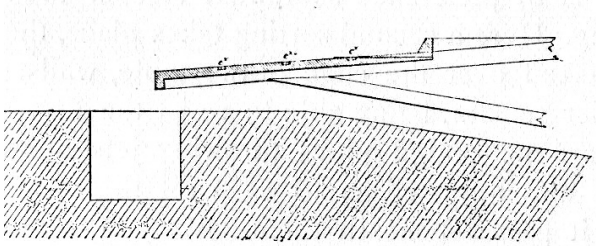


FIG. 68.—SECTION OF COLLOM'S BUDDLE.

△ **3** Collom's Buddle

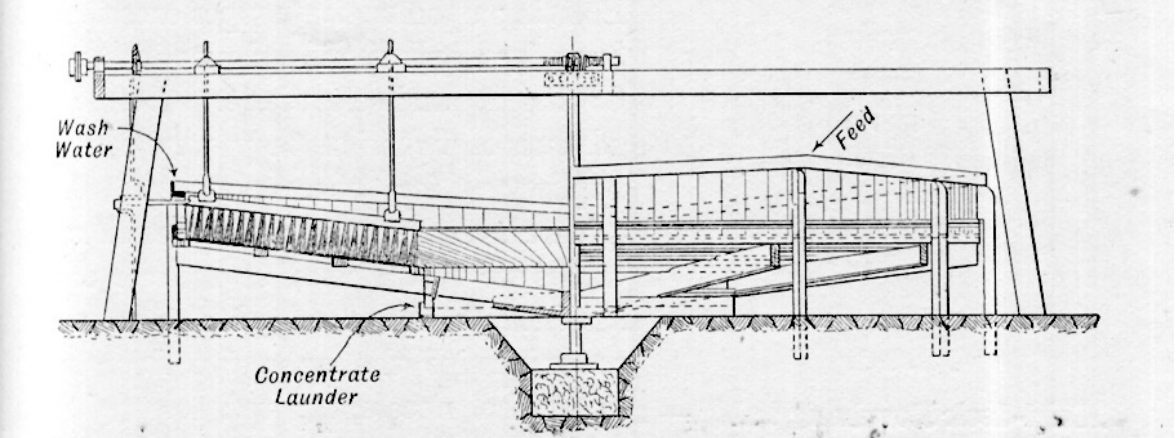


FIG. 241.

4 Concave Cornish Buddle (Truscott) ▵

▿ **5** Concave Round (Cornish) Buddle (Truscott)

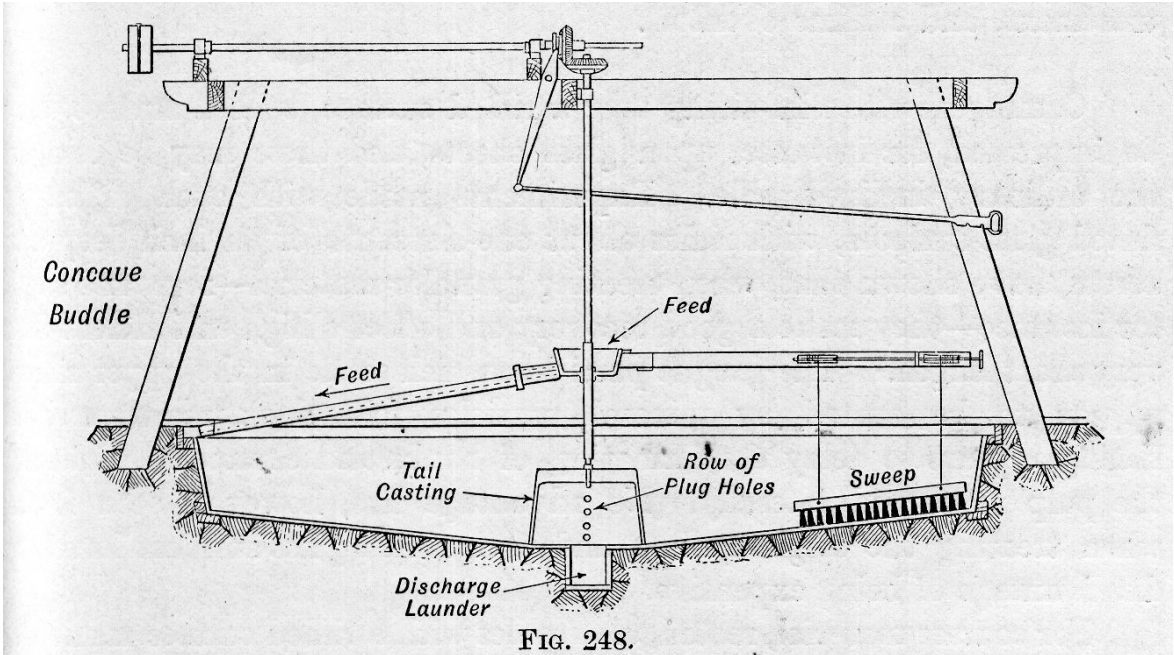


FIG. 248.

Concave Round Buddle.—Sectional Elevation (Holman Bros.). Shows radial feed arm and radial sweep arm (p. 342).

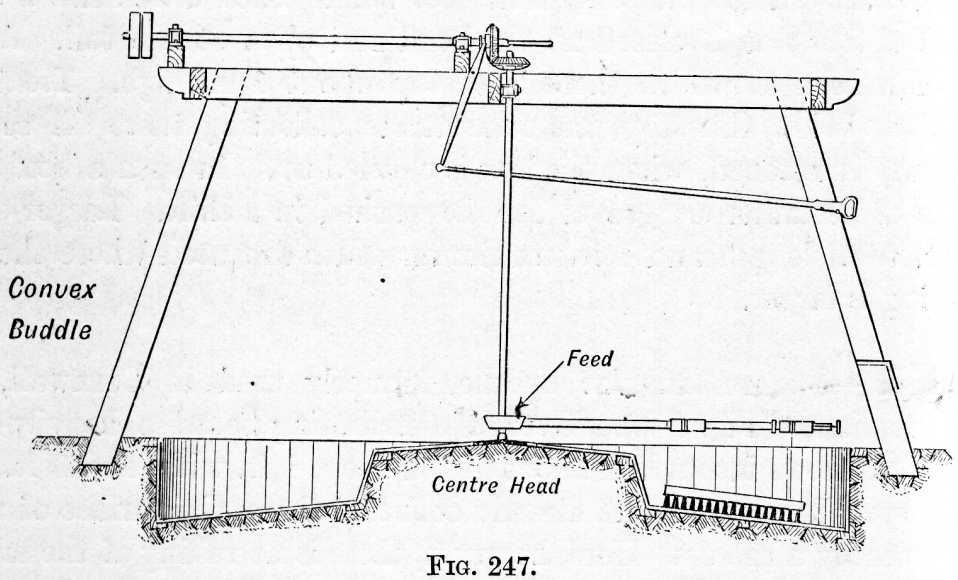
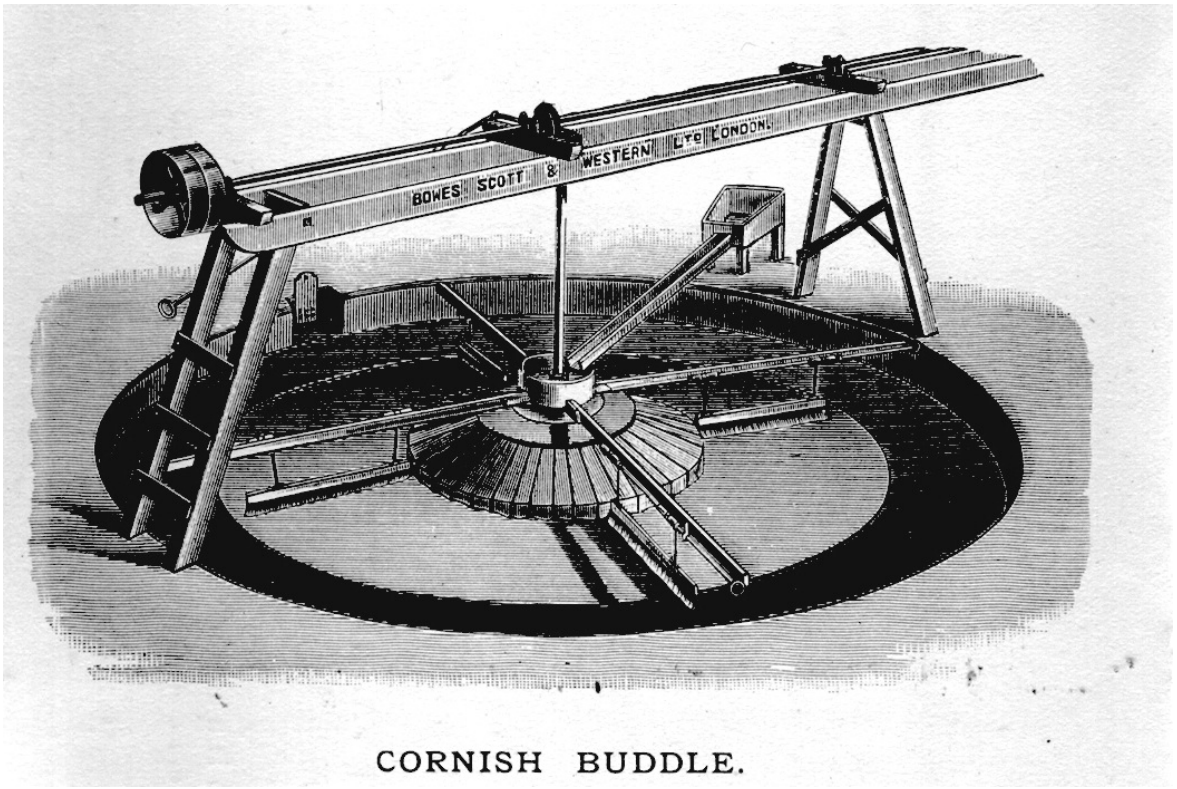


Fig. 247.

Convex Round Buddle.—Sectional Elevation (Holman Bros.). Shows sweep on radial arm, and the means whereby this sweep may be raised as the mineral bed collects (p. 341).

6 Convex Round (Cornish) Buddle (Truscott) ▵

▿ **7** Cornish Buddle



CORNISH BUDDLE.

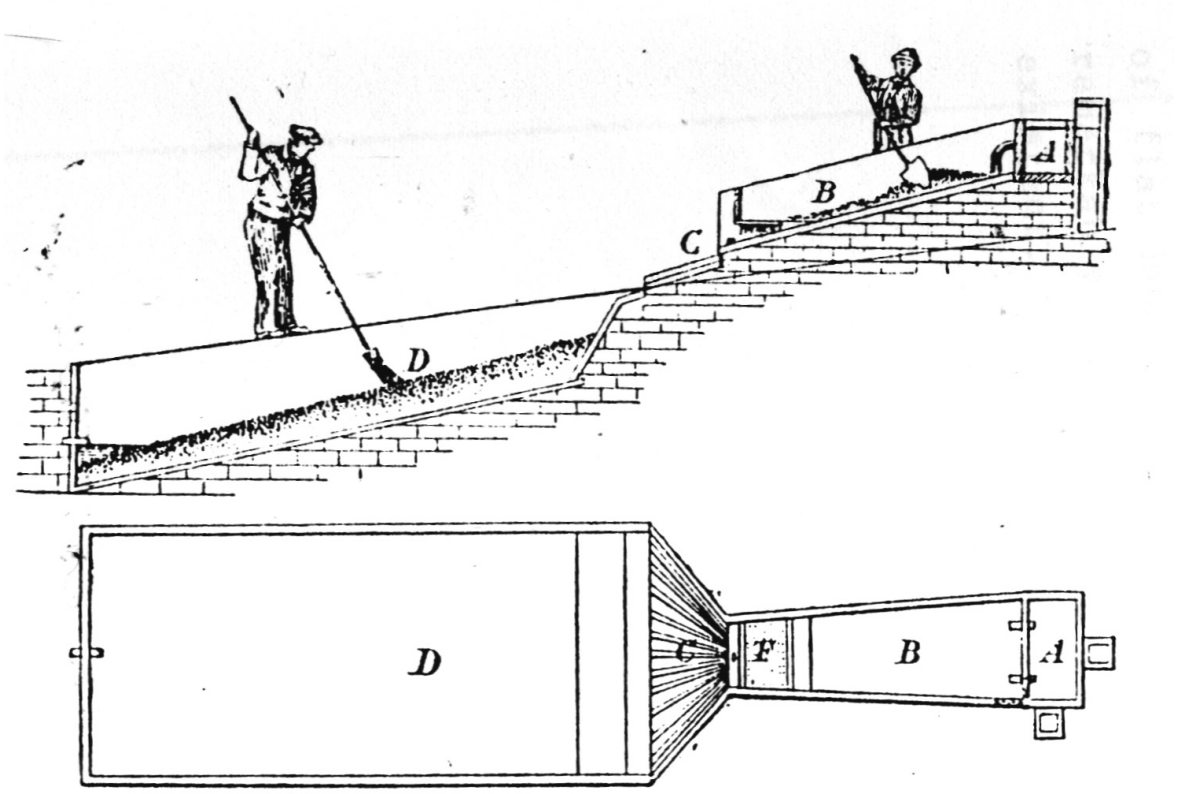
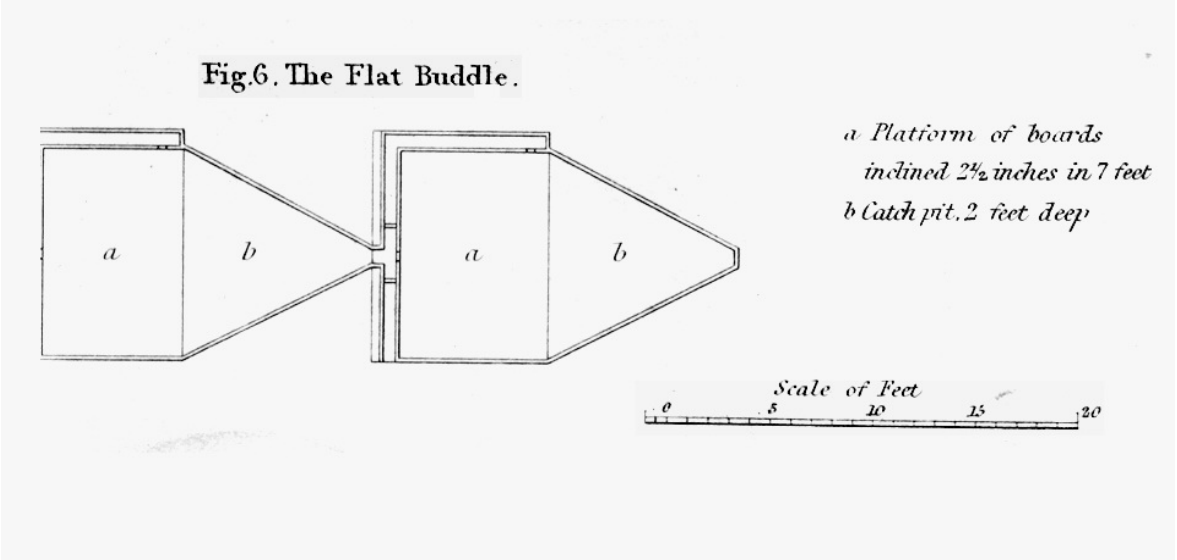
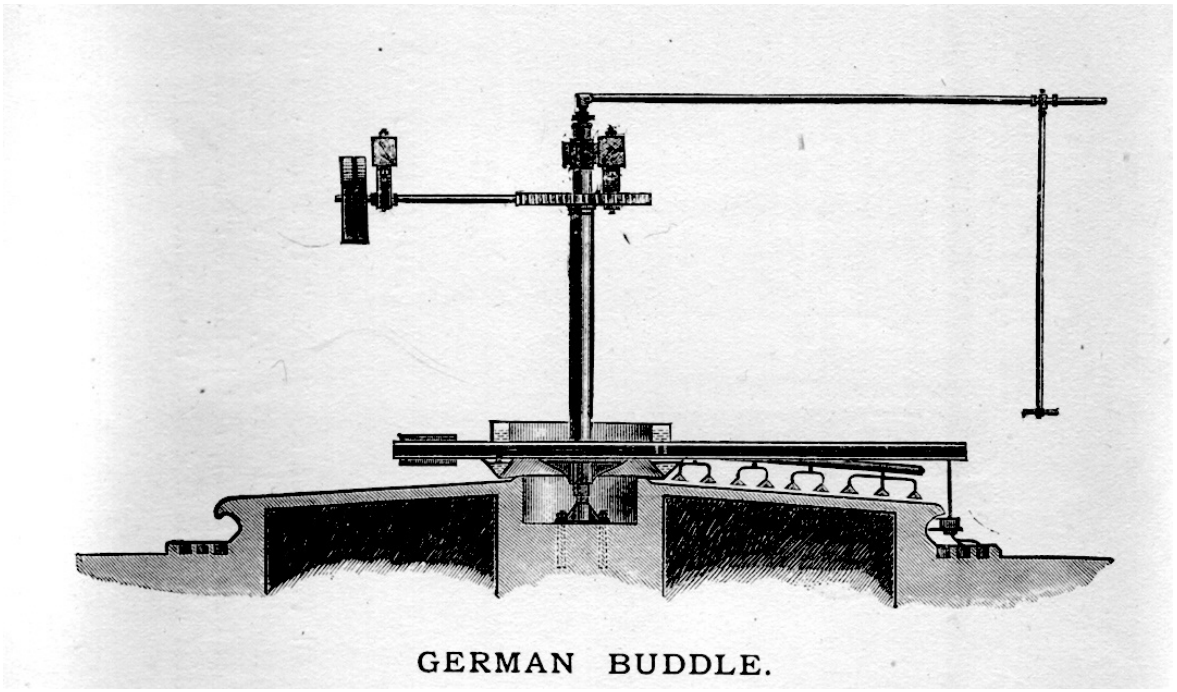


Fig. 217.

8 Flat Buddle (Hunt) ▵

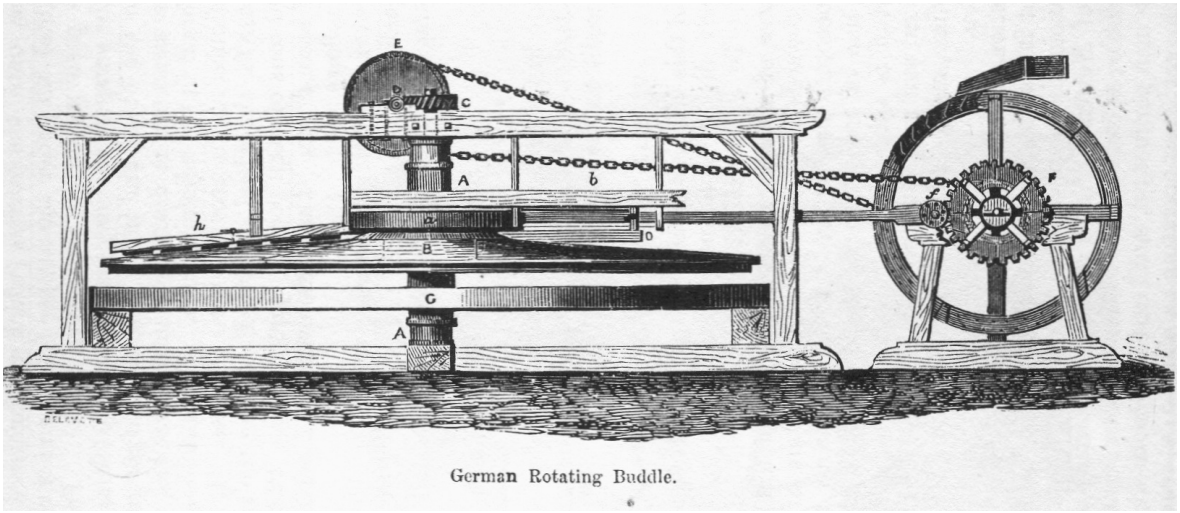
▿ **9** Flat Buddle (Smyth)

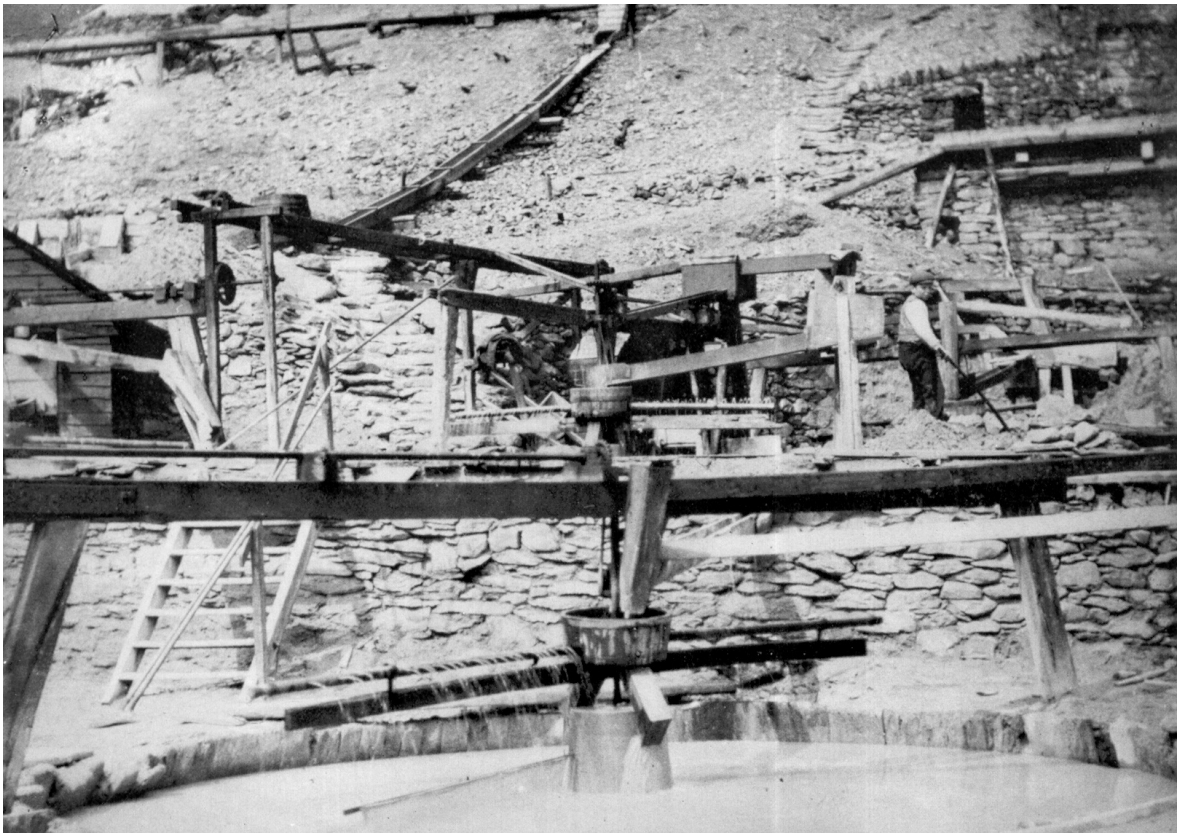




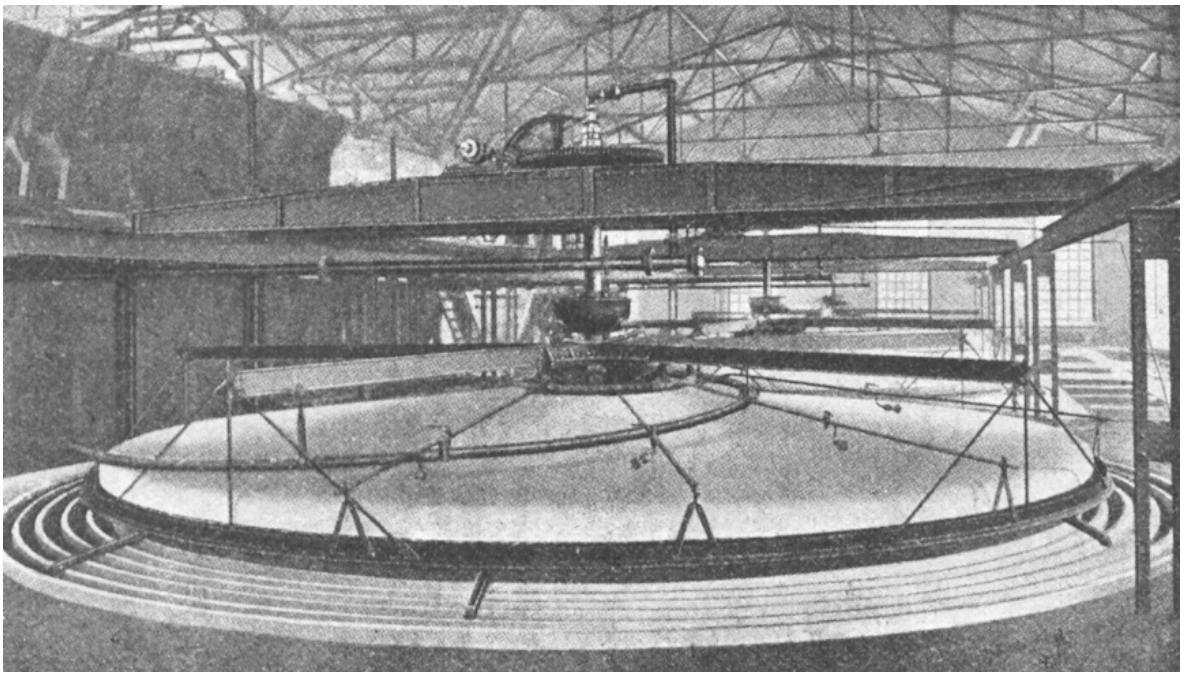
10 German Buddle ▵

▿ **11** German Table (Phillips and Darlington)



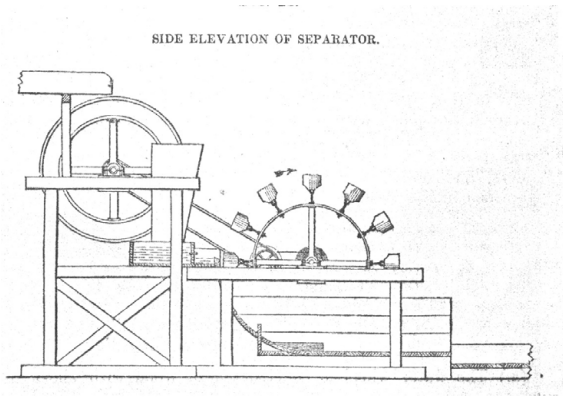


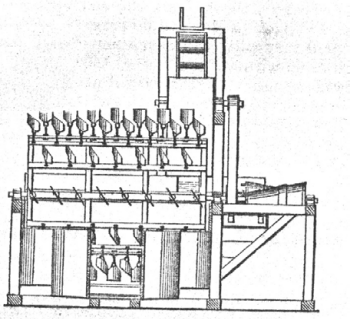
12, **13** Greenside Mine, Buddle △ ▽

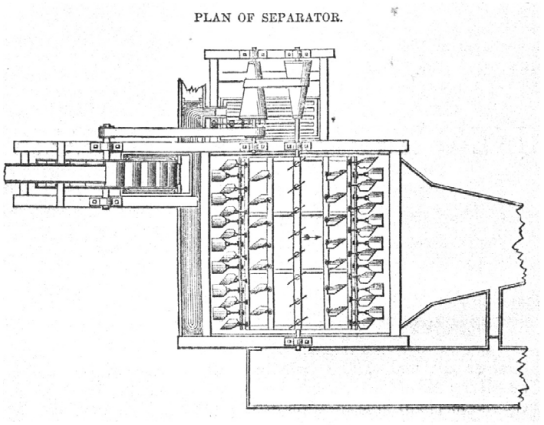


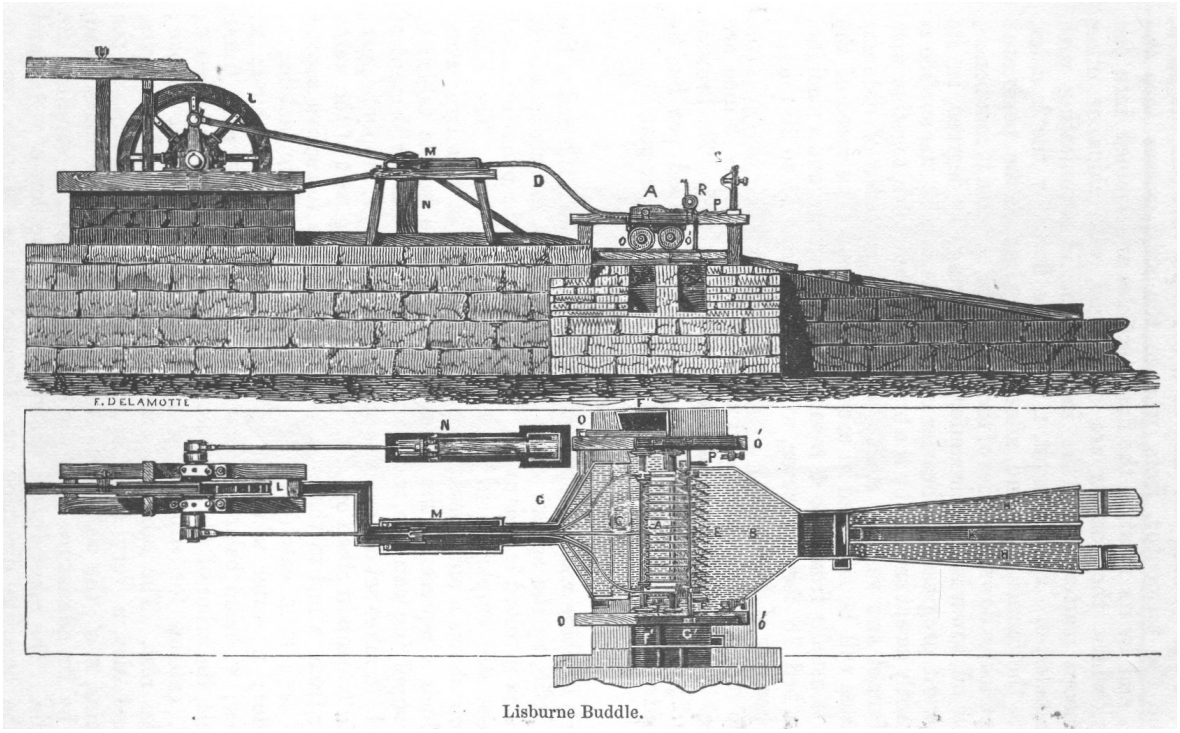
14 Linkenbach Table (Truscott) △

▽ **15** Knife Buddle (Mining & Smelting Magazine)



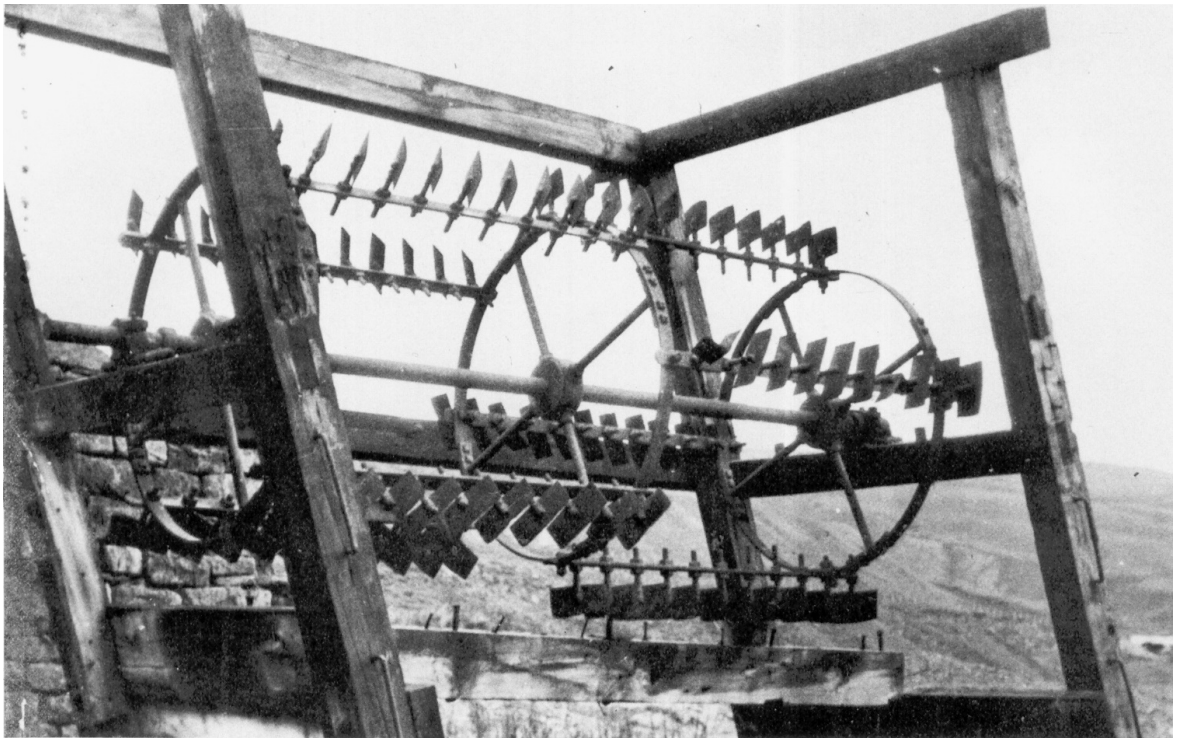


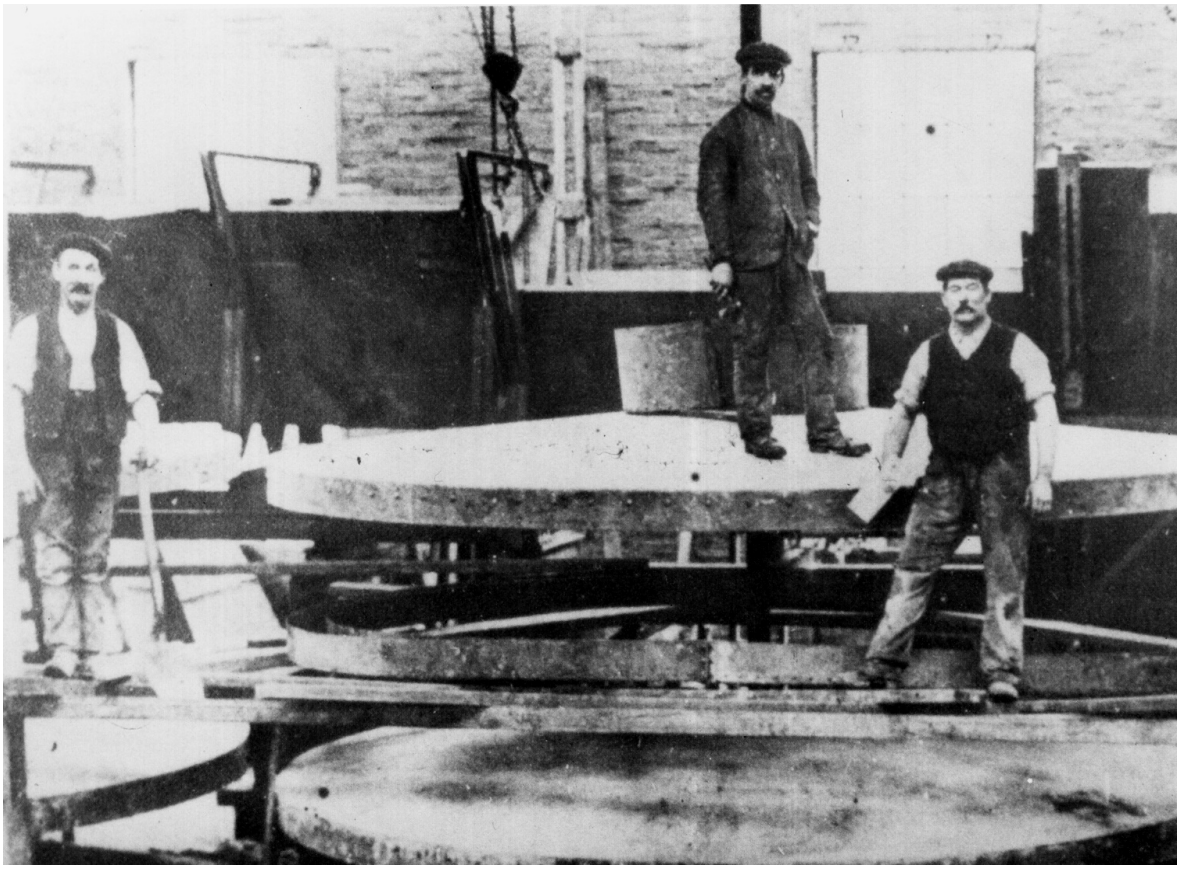




16 Lisburne Buddle (Phillips and Darlington) ▵

▿ **17** Lisburne Buddle (Coldberry Mine)





18 Nenthead Mine, Table △

▽ **19** Paine and Stephens Concave Buddle

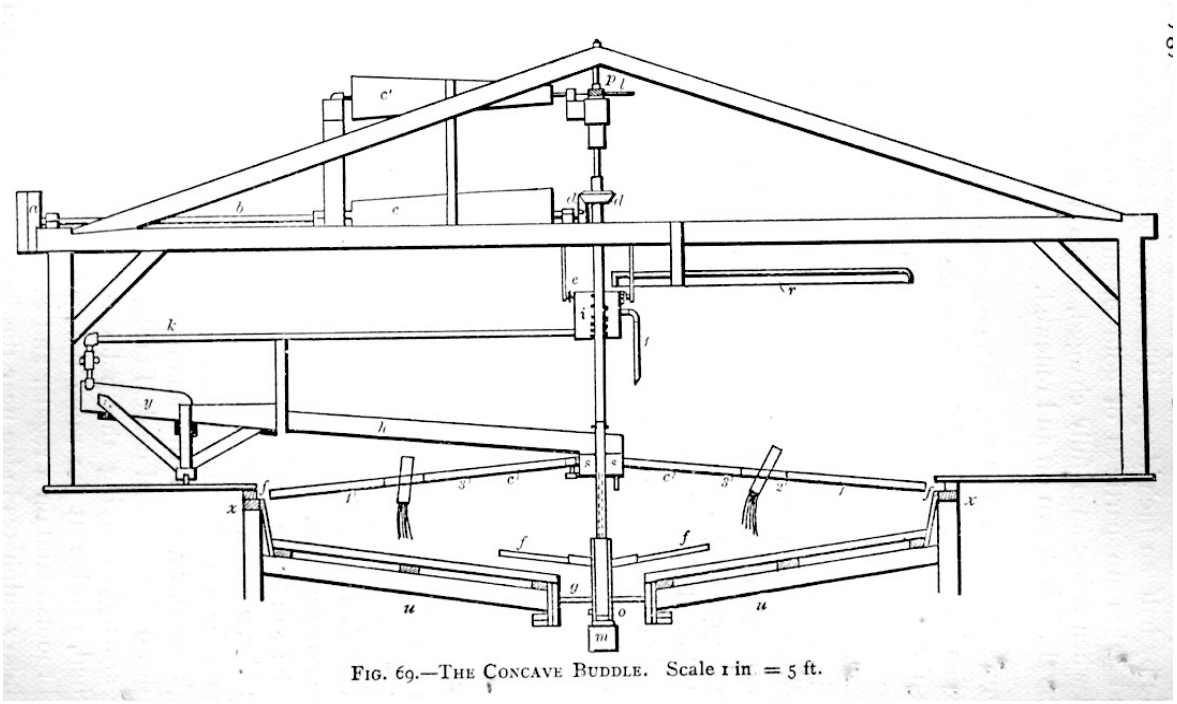


FIG. 69.—THE CONCAVE BUDDLE. Scale 1 in = 5 ft.

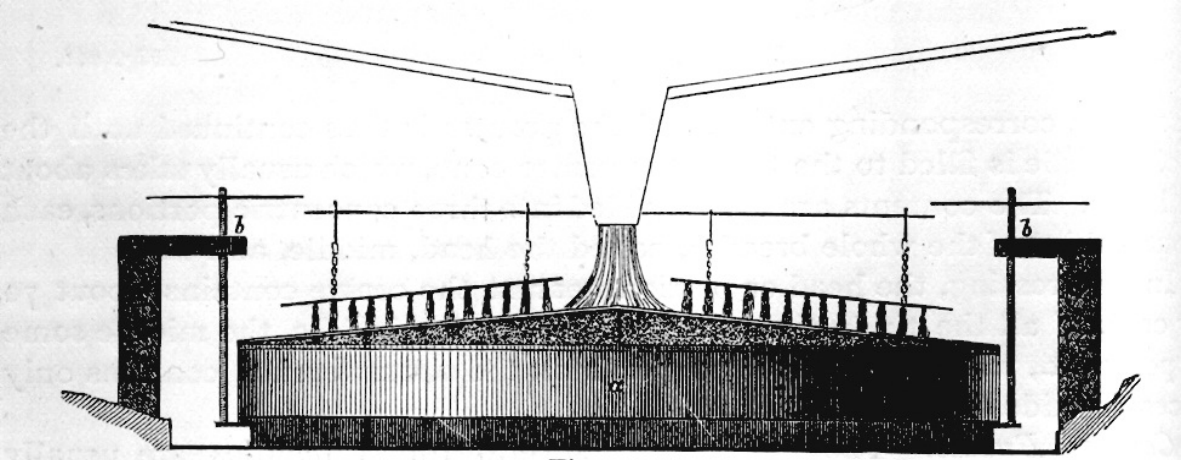


Fig. 223.

20 Ring Buddle ▵

▿ **21** Rocker Box

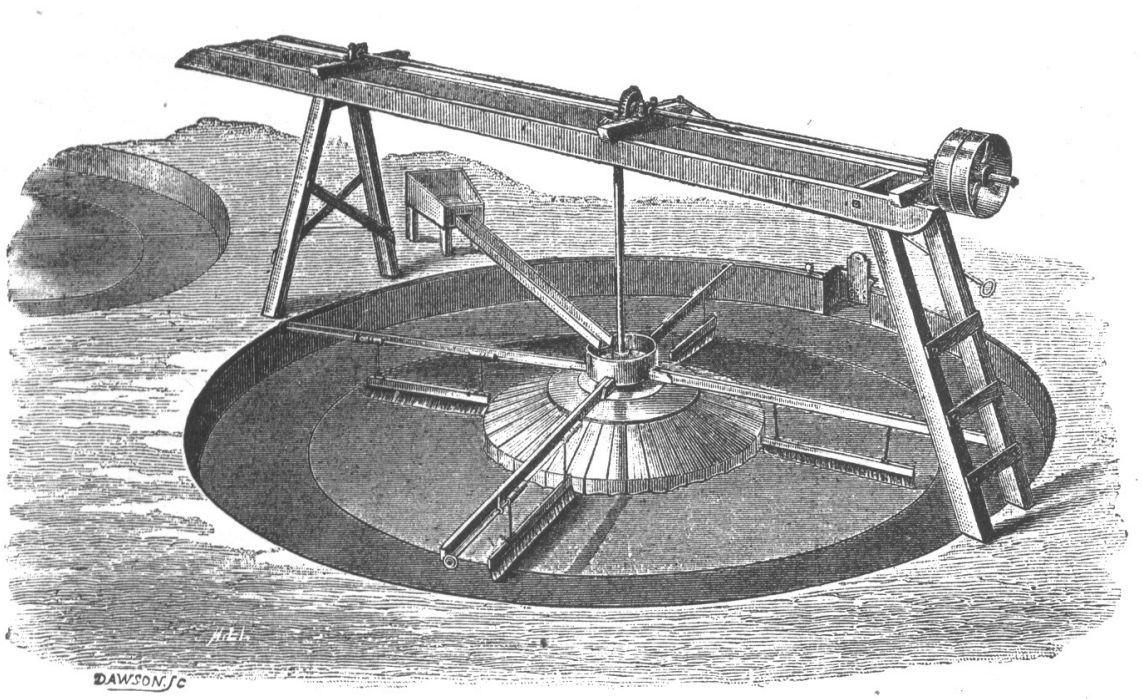
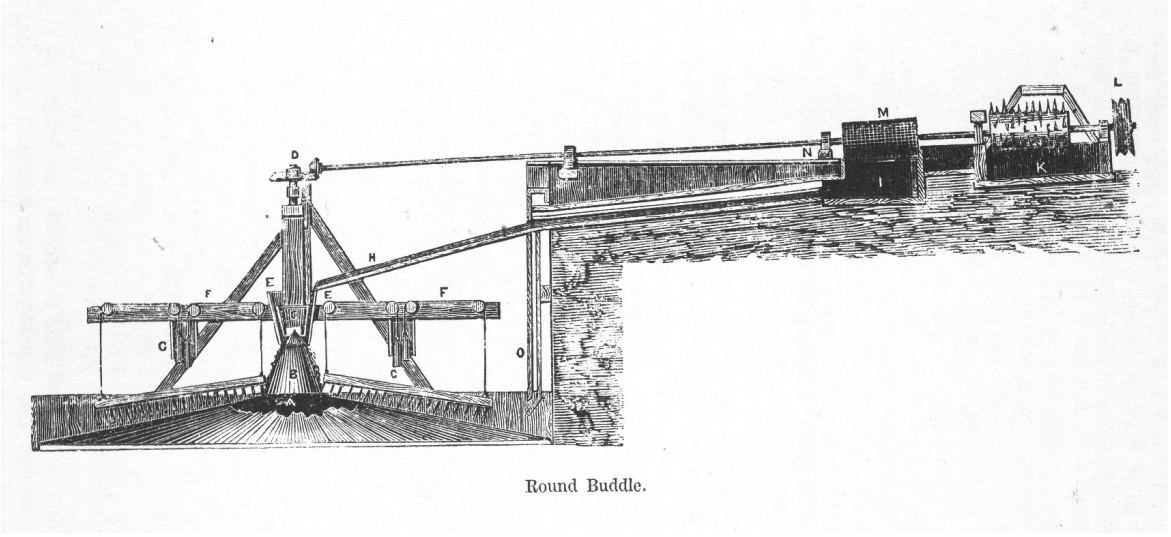


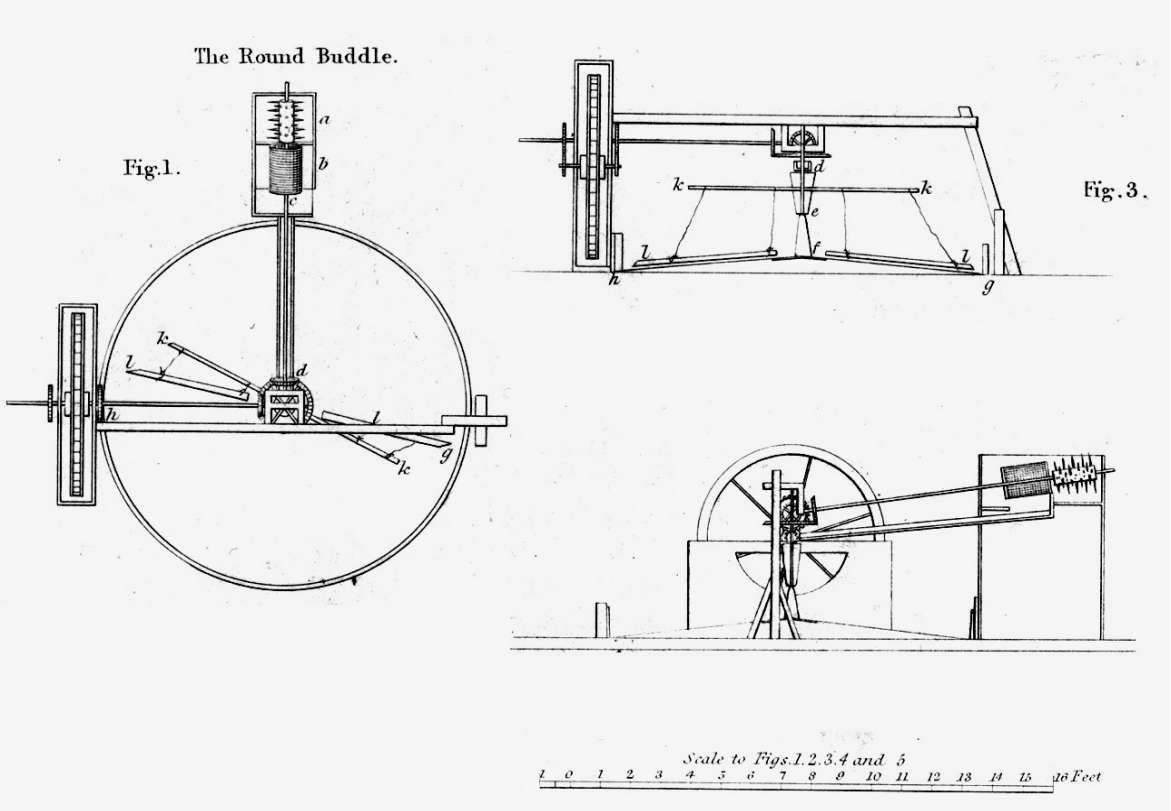
Fig. 65.—The Round Buddle.

22 Round Buddle (Eisler) ▵

▿ **23** Round Buddle (Phillips and Darlington)

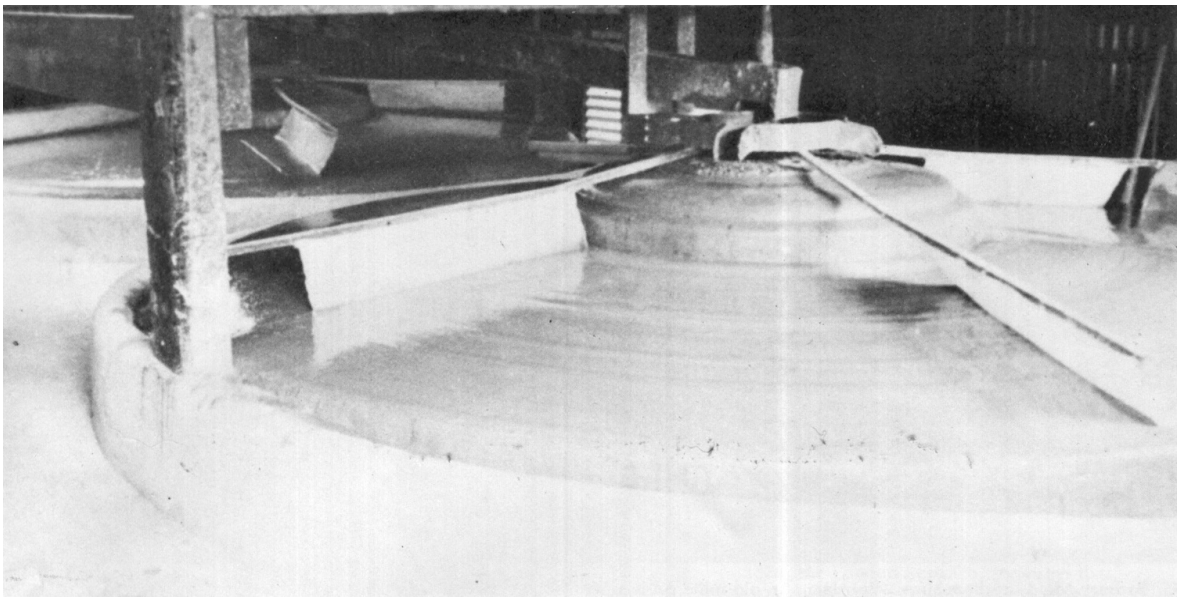


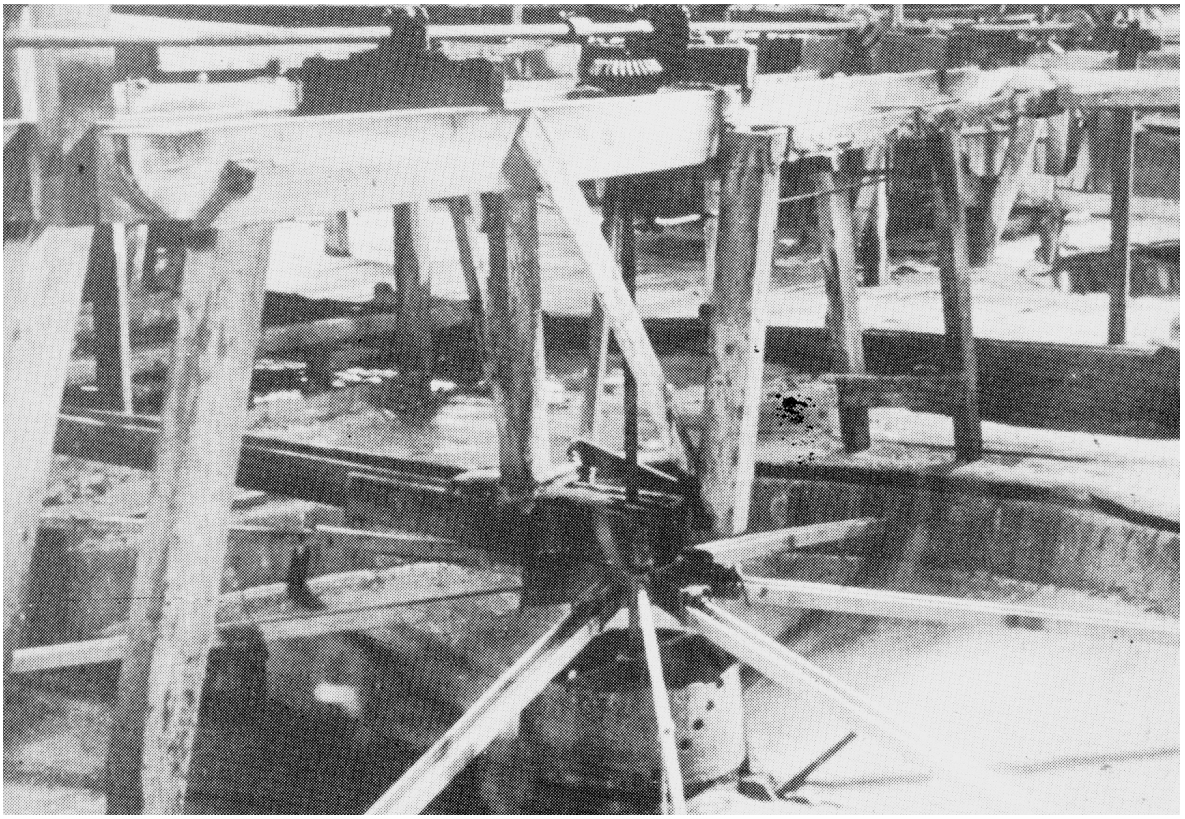
Round Buddle.



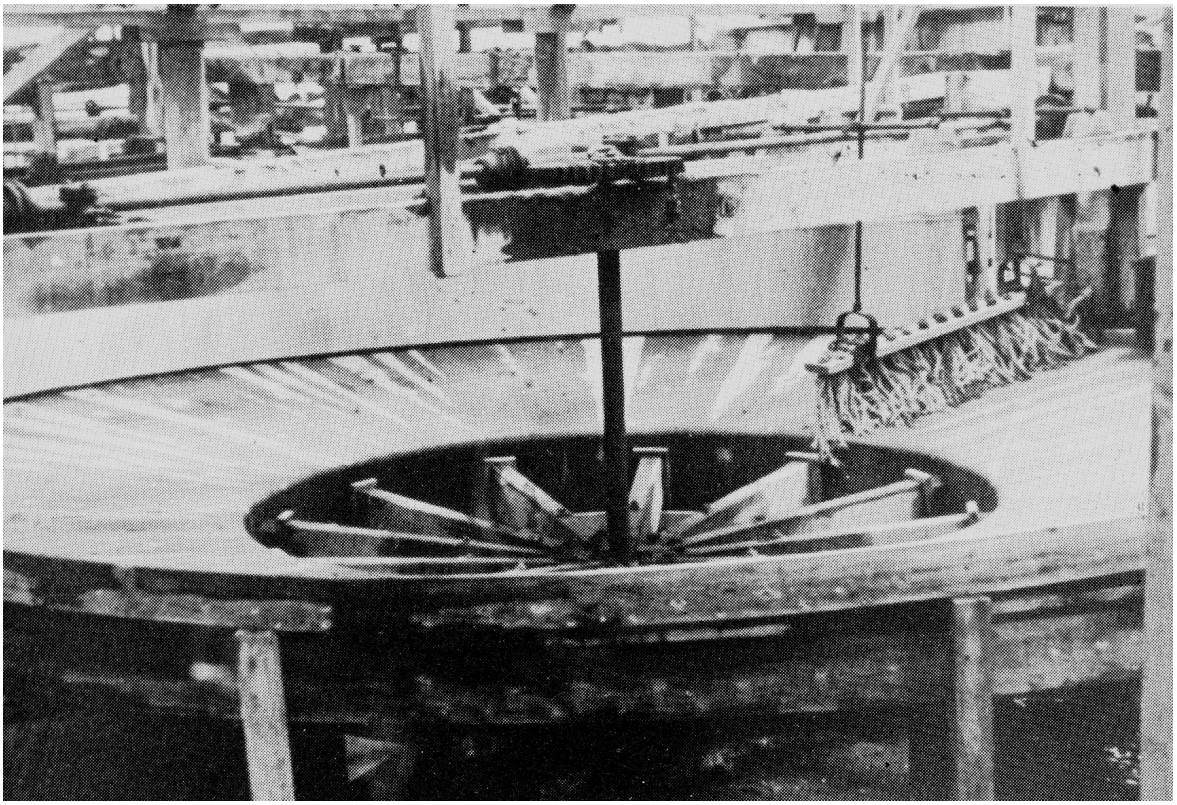
24 Round Buddle (Smyth) △

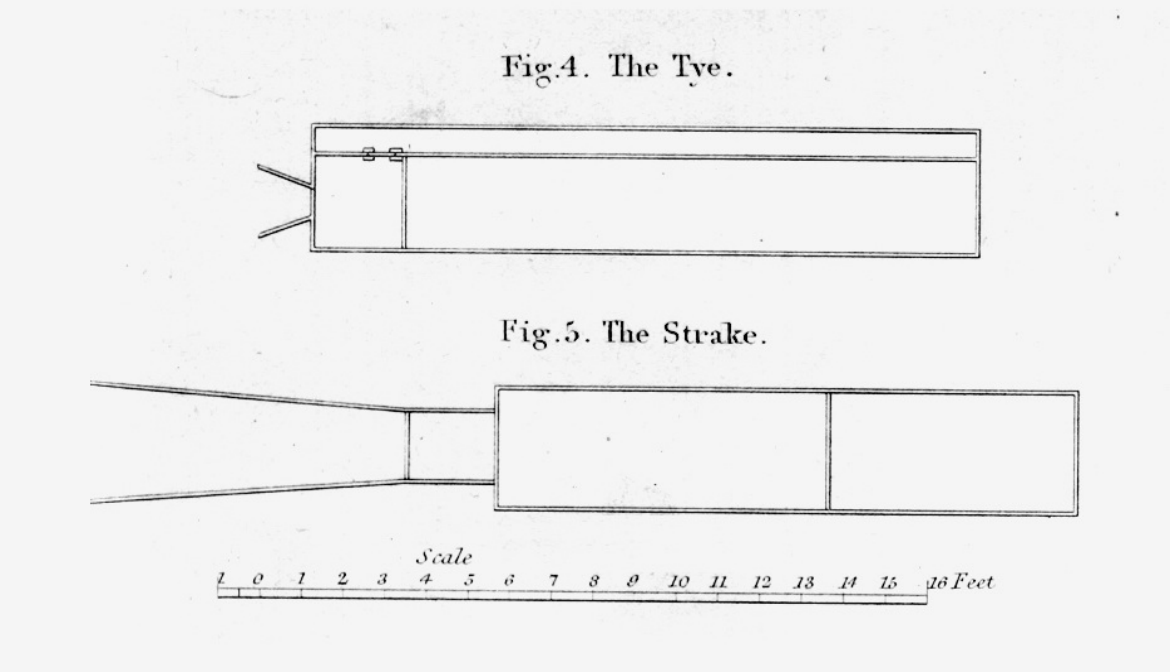
▽ **25** Buddle, Settlingstones Mine





26, **27** Tolgus Frames (Trounson) △ ▽





28, **29** Tye and Strake (Smyth) ▵

▿ **30** Zenner Buddle (Mining Journal)