

(MINE PRN 8339)
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ARCHAEOLOGICAL INVESTIGATIONS
AT
BWLCH MINE, CWMERFYN, DYFED

Simon J. S. Hughes.
October 1995.

INTRODUCTION.

1.

This report details the result of an archaeological excavation and survey, the supervision of which was assigned to me by Messrs Richards Moorehead & Laing on behalf of their clients, Ceredigion District Council.

Work commenced on the morning of the 17th of October and the reinstatement was completed on the afternoon of the 25th of October 1995 to the satisfaction of the landowner, Mr. Myrddin Hughes of Trawsant Farm, Cwmerfyn.

The contractor was T.M. Price of Cwmsebon, Cwmerfyn, who supplied the plant and operated the 3 tonne Yanmar excavator personally for the greater part of the duration of the works. In addition, Mr Price undertook a considerable amount of heavy shovelling despite suffering from influenza. The care and attention to detail which he displayed warrants mentioning.

The predominant features exposed during these works were the foundations of four buddles and through extensive research, the type of buddle which they supported appears to be the comparatively rare, in mid Wales, Zenner Buddle.

Another unusual feature which was re-used in association with the two upper buddles, were the remains of four hand buddles and a flat buddle which appear to have survived from an earlier phase of working.

The submission of this report was considerably delayed by the great difficulties presented in collating new data with old records, of which there is a considerable paucity.

Simon J.S. Hughes.
20th November 1995.

about 13,500 words

Description of work undertaken at Bwlch Mine: 17 - 25 Oct. '95.

Tuesday 17th: Work commenced with the excavation of the western portion of the kerb of the upper western buddle circle. Its position was clearly visible despite it being buried beneath about 30 cms. of jig tailings and coarse rock. It was also noticeable that a patch of turf had developed where the centre post had provided some nutrition in an otherwise hostile environment.

The buddle was partly filled with coarse grey tailings which overlay broken masonry, mixed with lime mortar, and stratified blue, grey and brown heavy clayey slimes. In the centre of the buddle, the remains of the 20 cm. diameter pitch pine bearing post were found. This was in a rather poorer condition than the rest of the woodwork but it did appear that it had been cut rather than broken or just rotted away.

At 48 cms. below the top of the kerb, in the position where boards were expected, flagstones had been laid in a uniform circle and mortared into position. It also became apparent that a low concentric wall had been built inside the flagged area thus forming a paved gutter.

Using the excavator to remove the bulk of the material, and a shovel to clear the gutter, the outlet was eventually uncovered.

Contrary to expectation, the sluice was not constructed in the traditional " button board " fashion, but simply used a piece of 20 cm. wide by 4 cm. thick pitch pine board set on end which still displayed the marks of a light ironwork strap used to lift it out of the wooden runners which were set 20 cms. back from the outer kerb.

Directly opposite the outlet, a section of silted up box launder was uncovered. This terminated opposite the outlet of the upper western buddle where it had been destroyed and it may very well have continued as far as the eastern buddle at one time. The base of the inside of the launder lay 42.9 cms. above the gutter and 40 cms. to the south of the outer kerb which was somewhat damaged at this point. Providing that the kerbs were level, the outside base of the launder appears to have been laid at the same level of the kerbs and may have supplied water to flush the product out of the gutter. It could not have supplied the pulp to the buddles and the silt contained within the launder appears to have been washed in after the site was abandoned.

It was noticeable that not one piece of ironwork was found in this area despite a vigilant watch being kept throughout the clearing operations.

At the close of day it had become quite obvious that these remains were not those of an ordinary round buddle.

Wednesday 18th: Following the uncovering of a virtually intact buddle circle, it was decided to expose the area immediately to the east where it was suspected that another similar structure existed.

Initial investigations showed that this was in fact the case but this example was in slightly better condition with the inner kerb being virtually intact.

The two buddle circles were virtually identical in all respects apart from the western one being 5.90 metres outside diameter whilst the eastern buddle was 5.98 metres in diameter. The inside diameters also varied slightly, the western buddle being 5.18 metres and the eastern 5.35 metres. The flagged gutter in the western buddle varied between 28 and 36 cms. wide and in the eastern buddle varied between 30 and 33 cms.

Another curious difference between the two buddles was that the outlet from the eastern buddle was set square to the centre whilst the outlet from the western buddle was slightly offset to the west of the centre line.

The sluice board, of the eastern buddle was of a very similar construction to that in the western one, but was set back 22 cms. from the kerb and was 26 cms. wide. Like the other sluice board, it was formed from a single piece of 4 cm. thick pitch pine.

Buddles usually have their superstructure held in place by wooden frames, these can be seen in the accompanying illustrations. The normal mode of construction of the superstructure appears to have been followed in the construction of both the upper buddles. That is, two 10 x 15 cm. (4x6") beams of pitch pine were set, set slightly off upright and inclined towards the centre posts, into the kerb so as to straddle the centre line of the devices. Unfortunately, both sets of supports had been cut off flush with the kerb so that their original height and inclination could not be ascertained. There do not appear to have been supports placed between the two buddles. Once again there were slight differences between the supports; Those on the western side of the western buddle were slightly larger than those on the eastern side of the eastern buddle, but not significantly so. The supports on the eastern side of the eastern buddle were set flush with the outer kerb whereas those on the western side of the western buddle were set into the outer kerb. Both supports were 38 cms. apart on their inner sides and as previously mentioned, straddled a line between the centre posts.

A curious feature which was noticed was that between the two supporting legs on the western side of the western buddle, the kerb had been constructed so as to incorporate a semi-circular niche. This may have been to house a gear, or pulley wheel but lacked any signs of lubricant, belt dressing or gear dressing compound. Any such gear or pulley housed in this niche would have been in the order of 50 to 60 cms. in diameter and would therefore have protruded over the gutter and into the buddle circle.

It can be further hypothesised that it may have been a bevelled gear which engaged upon a pinion fixed beneath a table so as to provide a reduced drive in the order of 10:1 +/- 10 %.

Following the uncovering of the two upper buddles, it was decided that the most logical progression was to follow their outlets beyond the sluice gates.

After removing a surface layer of jig tailings it became apparent that beyond the sluices, the outlet ran in a masonry culvert.

In the culvert leading out of the western buddle, the walls were 26 cms. apart but 48 cms. beyond the sluice they were beautifully radiused through 90° into a 30 cm. wide culvert. With sufficient of the top of the culvert cleared out it was possible to clear the rest out to floor level. I had expected to find a flagged floor and was suprised to find that pitch pine had been used which was still in an excellent state of preservation. The culvert from the upper western buddle was 40 cms. deep on this radiused bend and inclined away from the sluice gate at 4.2 % which equates to $\frac{1}{2}$ " in one foot.

In the culvert leading out of the eastern buddle, the walls were 22 cms. apart but 38 cms. beyond the sluice gate turned sharply through 90° into a 25 cm. wide culvert. Once again, from the sluice gate, the floor of the culvert was constructed from a single pitch pine plank inclined at 3.8 % or 0.456 of an inch in one foot.

Initially, it appeared that both buddles discharged into a common culvert which was slightly over seven metres long and between 24 and 30 cms. wide. However, as the culvert was cleared out it became apparent that there was a misalignment which had been rectified by kinking the middle portion of the culvert almost at its discharge point.

There is no rational explanation for this radiused kink; However, the northern wall of the eastern culvert is perfectly aligned with the southern wall of the western culvert and the kink may be due to masons building on the wrong sides of a setting out line. Alternatively, the reason may be for an altogether more complex reason which is worthy of consideration.

The grade of the western culvert is greater than that of the eastern culvert and if the two streams met head on eddying and losses of energy would cause precipitation of the suspended solids. With the radius incorporated into the end of the western culvert, there would be a tendency to direct the flow smoothly into the outlet with minimal interference to the pulp. It would also sweep the contents of the eastern culvert into the outlet. It is curious that there are two radiused bends in the western culvert whilst the eastern culvert has only one right angled bend incorporated into its construction. The differences appear to be intentional rather than a foible of the masons who constructed the system.

Furthermore; it is also possible that different products were being washed in the buddles which would have resulted in different pulp densities thus necessitating different grades to transport them. The contents of both halves of the culvert appeared to be identical and there is no way of discovering if either fraction had a different solid to water ratio when the apparatus was working.

The joint outlet from the culverts was set at right angles to their course but had been badly mutilated. It did appear that a sluice gate had been fitted but only a few pieces of timber were found and it was difficult to interpret the structure from these disturbed fragments.

Thursday 19th:

The day commenced with clearing the area around the common discharge of the culverts where it was assumed there had been a sluice gate. Using a shovel and trowel, the woodwork which was partly visible immediately to the west, was exposed to reveal a pitch pine table; 1.10 metres wide by 1.75 long with a fall of 37.6 cms. over its length. This equates to an inclination of 21.48 % or 2.57 inches in a foot. On its upper end, and both sides, this table was enclosed within walls, though the eastern side was badly damaged.

At its lower end, some damage had taken place but it appeared that an open launder may have been placed across its width. The centre plank was longer than those to either side of it and it is equally as possible that a baulk of timber may have been placed in this position onto which an extension of the table was fixed. However, at its upper end, the culvert wall from the western buddle had been built across the position where I would have expected a feeding device or launder. Without destroying this wall it was impossible to discover if the table was originally of a greater length.

There are two possible explanations for this table:-

1) This device predates the construction of the buddles and was used in the earlier mill circuit. In many ways it resembles a flat buddle and is in the correct position to have treated jig products. I am inclined to think that it was possibly a half size flat buddle.

2) The table was later utilised to catch the de-watered product which had settled, and was shovelled out of the concentric gutter around the buddles.

After initial investigations with a shovel, it was decided to use the excavator to expose any remains which lay to the west of this table in a bay which was 2.50 metres long by 1.75 metres wide. However, after removing tailings, masonry and mortar to a depth of about 1.75 metres, undisturbed soil was found and it was concluded that if any machinery had ever been erected in this bay, it had been removed when the mill was dismantled.

The next area to be excavated lay immediately below, and to the east of the discharge culverts from the upper buddles. Prior to excavation, a series of four depressions about 2 metres long by $1\frac{1}{2}$ metres wide were clearly visible which were initially thought to be more tables or similar devices. From west to east these were designated #1, #2, #3 and #4 being the most easterly.

After a thin layer of turf had been removed, three parallel walls were exposed which served to contain fines. It then became clear that in this area there had been four masonry tanks but there was no obvious sign of how they were fed.

The excavator was used to remove the bulk of the contents of the most westerly tank (#1) and the remainder was then removed with a shovel. The contents were a stratified mixture of beige, grey and blue clays which were obviously a dewatered pulp, probably from the upper buddle gutters as it was of a very similar character.

The floor of the #1 tank was flagged and inclined at 30.09 %, or 3.61 inches in a foot, towards a tapered outlet which was fitted with a button board sluice gate 20 cms. wide.

The #2 tank was of virtually identical construction with no indication of how the pulp was fed into it. The inclination was slightly less at 28.56 %, or 3.42 inches in a foot, towards the button board sluice gate, and the width of the outlet had been significantly reduced by placing a wide pitch pine board on either of the chamfered sides. The contents of the #2 tank were also a stratified mixture of grey and blue clays with very little beige, visually they appeared to have a greater mineral content than the #1 tank.

It was assumed that the #3 and #4 tanks were of similar construction but that their contents would get progressively richer in heavy minerals; For this reason it was decided that they were best left undisturbed.

At the lower end of the #1 and #2 tanks, on the discharge side of the button boards, a 20 cm. wide pitch pine plank, faced with thin sheet metal, had been laid along the front of the tanks and appeared to be some form of abrasion resistant shovelling or hoeing horizon.

The construction of the two tanks which were excavated was virtually identical but they did appear to date from before the upper buddle circles; however they were obviously incorporated into the last phase of the milling process.

The general layout of the tanks suggested that in their last phase the #1 tank could have been fed from the upper buddle gutters with a launder which has since been destroyed. There was no way that the #2, #3 and #4 tanks could have been fed from the concentric gutter and it must be assumed that their contents were delivered by higher level wooden launders which had also been destroyed.

The inclination of the tank bases is so steep that their previous use can only have been as Hand Buddles as described by Sir Robert Hunt. It would therefore seem probable that these tanks were originally lined with planks and that the launder, trough and distributing boards were destroyed during the construction of the buddle circles.

Unfortunately, as the overall dimensions of these tanks are relatively small, and as they lie on the border of the two Ordnance Survey plans of 1887, they are not shown clearly but are represented in a rather approximate form. An enlarged extract of the two plans is appended to this report in a unified form.

Sadly, there are no large scale plans of Bwlch Mine available before 1887, by which time the mine had closed.

Friday 20th: The excavator was moved from the upper floor to the lower floor in order that any surviving remains below the tanks could be exposed and examined. In the southeastern corner of the lower floors, a quick examination revealed that the boards exposed in the preliminary examination of February 1992 were not part of any structure.

A low depression, about 2 metres in front of the #2 tank was then investigated as it was suspected that another buddle lay in this area.

At about 40 cms. below the surface, under a mixture of jig tailings and fines, a circular kerb was discovered and further investigations showed that, like the upper buddles, a flagged gutter and inner kerb were present. The construction was very similar to the upper buddle but of lesser diameters; The outer kerb being only 5.30 metres and the inner kerb 4.80 metres with the gutter being 25 to 30 cms. wide. The true depth of the gutter was impossible to calculate on account of the kerbs having had their tops damage; However, when the sluice was uncovered it was remarkably intact and showed that the concentric gutter was only in the order of 27 to 28 cms. deep or about 20 cms. shallower than in the upper buddles.

When a sufficiently large portion of this buddle had been uncovered it was decided to investigate the area immediately to the west where a virtually identical set of foundations were discovered. The bulk of the excavation was dealt with by the excavator and the clay in the gutters was removed by hand.

It must be commented upon that there was a limited amount of space on the lower floor which meant that there was difficulty in creating a working area for the excavator, a working area for the dumper, and a place for stockpiling excavated materials whilst keeping the excavations open. This is reflected in the photographic records obtained during this phase of the work which are a series of close up views rather than broad perspectives.

With both the sluices exposed, the surface was stripped off in the anticipation of finding open channels to carry the product away but this was not the case and 15 cms. beyond the sluice gates the channels had been fitted with thick flagstone covers to form covered culverts.

After lifting some of the flagstones on the culvert out of the lower eastern buddle, the culvert turned through a sharply radiused 100° bend with a fall of 9.68 % given to the pitch pine floor in order to get the pulp to flow away.

In the lower western buddle, the mode of construction was similar except that in the culvert, the wooden floor fell at 19.11 % for a 1.7 metre run and then fell 30.90 cms. into the culvert leading out of the lower eastern buddle.

Beyond the junction, the culvert ran towards the slime pit but was not excavated on account of it being so deep that it would be dangerous to work in, and also that it would have meant dumping a large quantity of fill over areas of interest.

A visual examination was made by crawling into the culvert, head first, with a powerful lamp. The gradient was uniform for about 5 metres beyond the junction, i.e. about 9 or 10 %, and beyond that point a deposit of self leveling silt had been precipitated which blocked the culvert at its western end. At this point, the floor of the culvert can be extrapolated to be about 3 metres below the surface and therefore below the reach of the excavator.

It seems probable that this culvert from the two lower buddles leads into the slime pits but this could not be confirmed without removing their toxic contents to a depth of about 3.5 metres.

At the close of day, I felt that a tremendous amount of data had been gathered during the previous four days and that this needed further consideration over the weekend. The field slips needed piecing together and in order to do this I needed to survey several fixed points, obtain levels on all the gutters, culverts and launders Etc.

Saturday 21st: The day was fine and bright used to catch up with drawing, photography and to survey the site in detail in order to tie together the field notes and observations.

Sunday 22nd: Again, the day was fine and bright and was used to catch up with some more of the drawing and photographic work, and also to survey and level the site in greater detail.

No excavation work was carried out on either of these days which allowed the points of detail to be trowelled and brushed down to the original surfaces in order to be recorded.

Due to the fine weather, particularly on both the afternoons, there was a constant flow of local visitors who not only wanted to take photographs of the exposed masonry work but also wanted their function explained. Several of them also wanted me to commit myself as to the future of the remains and I had to explain that this was not in my remit and that any decisions would have to be made after the works had been completed.

Monday 23rd: The area to the west of the lower buddles was investigated with a series of pits and trenches but this proved to be remarkably unrewarding and provided more questions than answers.

It did confirm that the site had undergone at least one major modification and possibly several lesser changes.

It was anticipated that another buddle circle would be discovered in this area as one is shown quite clearly on the 1887 edition of the 1:2500 O.S. map; However, the search proved fruitless and if there are any such remains they must be further towards the western end of the lower floors in an area which would have required the duration of the works to be extended even further.

A metre and a half to the west of the lower western buddle, the foundations of a substantial wall were unearthed and followed south for several metres until a corner was found.

Just before the corner, the remains of another wall were discovered. This had obviously been demolished prior to the construction of the buddles. The mode of construction was normal for this locality, double skinned lime mortared with rubble fill. This wall had been carefully demolished and left with a relatively level top at 1.70 metres below the main wall to which it was joined. This low wall was only followed for $2\frac{1}{2}$ metres to the east as further work would have resulted in damage to the culvert leading out of the lower western buddle.

During the work of uncovering this wall, a 15 cm. square wooden box launder was discovered which was laid with a fall of 9.4 % towards the front wall of the lower floor. This launder was exposed for 5 metres but became too deep to follow any further.

The purpose of this box launder is difficult to explain. It must have been laid in position after the demolition of the original structure, and it must have come to surface close to the back wall of the lower floor. This area was investigated but found to be devoid of any indications of machinery. It is also possible that a vertical riser was located against the back wall and that the launder originated on the upper floors and was associated with the jiggers which appear to have been located immediately to the west of the buddles on the upper floor.

From the corner of the higher substantial wall, the excavation continued to the west, along the outer face, for 3 metres but uncovered nothing apart from another stone culvert 2.31 metres below the surface. Unfortunately, due to badly placed spoil heaps and a severe shortage of time, it was never discovered if this culvert penetrated through the wall and where it led thereafter. The section which was cut to examine the culvert cut across an access path and had to be backfilled immediately.

This culvert was constructed in a similar manner to the other culverts on this floor, i.e. with flagstone tops. A small quantity of water continued to flow along it though it was very heavily silted up and consequently it was difficult to be absolutely certain that the levels which were taken were absolutely accurate. The gradient was calculated to be 21 %.

The culvert was too deeply buried to examine in detail with any degree of safety. It appeared to head towards the slime pits and also to connect with the culvert from the two lower buddles but at this point would have been well beyond the reach of the excavator. The trench eventually collapsed to reveal the back of the slime pits which was noted to be a thin single skin construction of rather poor integrity.

Tuesday 24th:

This turned out to be the worst day of project with torrential rain and high winds throughout the day. The conditions were so bad that it proved to be difficult to take photographs even with fast film. As this was the last day of the excavation, I decided that the area to the south of the lower floor buddles ought to be examined to ascertain the position of the supposed waterwheel pit and also to examine another internal wall which could just about be seen.

A section was commenced at the mid point of the culvert from the lower eastern buddle and cut south towards the front wall of the lower floor. This revealed a wall which predated the buddles.

Having followed the wall for just over 4 metres south from the culvert, a recess was discovered. Unfortunately, the excavator was located in such a position that it could not be used to clear the recess and a system had to be adopted where the fill was dug out and loaded manually into the excavator bucket.

A flight of five steps were discovered leading from some form of basement up, just over 2 metres, to the level of the level of the lower floors. The walls and steps were constructed from good masonry bonded with lime mortar, the top of the steps were faced with pitch pine boards and the whole construction was curved in the same manner as if they had been contained within a tower. They were remarkably well preserved but led nowhere.

Beyond the stairway, the wall was followed for another metre before it joined the front wall of the lower floor. The front wall had been partly demolished, possibly to create a doorway, and despite an extensive search, there was no indication that there had ever been a wheelpit on this part of the site.

Wednesday 25th:

During the morning, the lower floors

had the flagstones replaced over the

culverts before they were covered over and this part of the site was re-instated and smoothed off with a blade.

A large stone was left standing proud of the surface over the position of the sluice gate out of the western buddle.

The excavator was then moved onto the upper floor and used to load the muckpile into the dumper which then carried it to, and dumped into the buddle pits.

During the excavations, materials of different nature had been stockpiled separately. The grey clayey slimes were dumped into the upper eastern buddle pit before being covered with soil. The jig tailings were dumped into the culvert and the two tanks which had been opened.

As re-locating markers, two lengths of 50 x 75 mm. joist were placed at the corners of the culverts prior to it being filled.

The remaining tailings were dumped into the upper western buddle and topped with a layer of soil.

Mr Myrddin Hughes of Trawsnant Farm visited the site during the mid afternoon and expressed his satisfaction with the re-instatement of the site.

Buddles may be divided into three distinct groups :-

1) Flat Buddles or more correctly Tables or Frames. Within this group must be included the Welsh Buddle, Hand Buddle, Cardiganshire Buddle, Lisburne Buddle, Strakes and Tyes Etc. This type of buddle is the traditional method of freeing ore from impurities. The name " buddle " dates from at least the 1550's 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 principals and are known to date from before 413 B.C.

2) Concave Buddles where the centre is lower than the periphery. As far as I am aware, machinery of this nature was never used in Mid Wales.

3) Convex Buddles where the centre is higher than the periphery. This type was universal throughout the Cardiganshire mining district, and those used at the Bwlch Mine, Cwmerfyn, must fall into this category.

Borlase's Buddle: A Concave Buddle 17' in diameter and 14" deep with an inclination of $1\frac{1}{2}$ inches in the foot ($12\frac{1}{2}\%$). PCS 107. An inclined circular rotating frame 24 feet in diameter and 6 in breadth which 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. PCS 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%) and 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. EHD 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 & Section. Hunt 768.

Borlase's Inclined Buddle: Consists of 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 retreating. Hunt 769.

Brooks' Buddle: Popular in Australia, mentioned but not described. It is not known if they were concave, convex or compound. PCS 109.

Cardiganshire Buddle: The name applied to the rotating version of the reciprocating Lisburne Buddle as designed by Captain Sanders of Esgairhir. M&SM.

Centre Head Buddle: An updated Round Buddle, with plan & section. Hunt 766. It is worth noting that in Smythe's description of 1848, that the pulp is fed directly onto 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 1860's or 70's.

Collom's Buddle: 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. BM17 - Cwmystwyth 22 & 23. These differ from ordinary buddles by dividing the revolving table into two parts, part of the product of the steeper table is washed onto 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 desireable. Eissler 135.

Common Buddle: Shown in Pl. 12 of Smythe'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 refered to in p679 that text.

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

Concave or Slime Buddle: The general name for an inverted rotating conical table inclined towards the centre. Nicely illustrated in Palmer & Neaverson BM32 p62 & 64. and Trounson I 52, 53 & 129

Convex Buddle: The general name for rotating conical tables inclined towards the periphery. PCS 106. A good illustration of such a table under construction is given as 108 and in operation , as 113, at Nenthead in Raistrick & Roberts. Further illustrated by Palmer & Neaverson in BM32 p60 & 64 and in Trounson I 26 & 87.

Cornish Buddle: A convex buddle about 24' diameter with a 7' run from the feeder cone to the edge. PCS 106. It would appear that it is in fact no different to a Centre Head Buddle according to BSW 74.

Dash Buddle: More properly a table laid at an inclination of $2\frac{1}{2}$ inches in 7 feet (2.9%) with a catch pit at the lower end. P&D 138. The above description matches exactly with WW Smythe'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 in BM32 p66 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 $1\frac{1}{4}$ inches in the foot (10.4%) and rotating once every 80 seconds. Its capacity is about one ton per hour. EHD 312.

Flat Buddle: The name applied by Smythe, with a drawing, to a table 10' wide by 7' long with a fall of $2\frac{1}{2}$ " (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. BM35 p28.

German or Rittinger's Buddle: A convex buddle fitted with brushes. P&D 129. 16' in diameter and divided into 32 segments each of which terminates in a square chute through which the product is directed into circular launders fitted below the periphery. PCS 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 $2\frac{1}{2}$ 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 & Section. Hunt 764. This may equate with the Common Buddle of Smythe. By 1900, the Hand Buddle was a rectangular wooden box with a sloping bottom. A stream of pulp being fed in by a head board at the upper end and 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 which decreases in richness from the head to the tail. CLNF 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, possibly even the forerunner, of the Strake and Tye as illustrated by Smythe.

Huet & Geyler's Buddle: Exhibited both concave and convex buddles at Paris, they are mentioned but not described in any detail. PCS 109.

Lewis's Buddle: Popular in Australia, it is mentioned but not described in detail. PCS 109.

Linkenbach Buddle: Detailed description states that it is an improvement upon Collom's Buddle. Intended for the treatment of slimes and became popular in the mid 1880's. 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 maintainance. 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 $2\frac{1}{4}$ 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 expemsive, a 6 metre machine being quoted at £ 145. EHD 316. It is shown in section but appears to be greatly simplified in BSW 74.

Lisburne Buddle: More properly a frame. Apparently developed in 1855 by Captain Vigus of Frongochas a reciprocating knife frame above a table. P&D 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. M&SM 321. The machine was useful for upgrading concentrates from fine jiggers or buddles but did not work on slimes. $2\frac{1}{2}$ tons per hour of 15 % heads could be dressed up to a product containing 50 % Pb in a single pass. EHD 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 & Section. Hunt 765. This buddle appears to be a development of the Trunking Buddle which was 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 PCS 109.

Ordinary Buddle: Appears to be a long shallow box for working the fines from a Tye according to Smythe p 679.

Paine & Stevens Buddle: 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 $2\frac{1}{2}$ feet in diameter. Eissler 139.

Ring Buddle: A rather clever modification to a convex buddle where 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: Apparently, invented at the Cwmmawr Mine near Pontrhydfendigaid about the year 1838. It owed its popularity to ease of construction. A convex buddle, commonly 18' in diameter and rotates at 3 - 4 rpm. which treats 1.5 - 2.0 tons per hour. illustration. P&D 126. Nice description and illustration in Eissler 134. In later years its diameter varied from 14 to 22 feet and from 12 to 18 inches in depth with an inclination of 1 in 30 (3.33%), the poorer slimes requiring 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 slice gate fitted with a button board. The heads and middles are re-buddled and the waste ought not to contain more than $\frac{1}{2}$ % lead and 1 to $1\frac{1}{2}$ % zinc. The heads can be enriched up to 50 or 60 % Pb or 42 % Zn, in a single pass, and 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. EHD 302. They evidently fell into disrepute on the continent in the 1860's unless it was modified, according to Moissenet in 1864. Slight details are provided by Palmer in BM22 p41. 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 as Smythe describes them in the previous year this cannot be the case.

Smythe further notes that this machine was tried in Cornwall many years ago but is now perculiar to Cardiganshire. 677. 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. PCS 108.

Tail Buddle: Mentioned by Smythe as being used to treat the middlings from the round buddles, however they are not shown on his plan of the Goginan dressing floors. 677 & Pl.12.

Trunking Buddle: Only a poor and brief mentionn is available in Smythe's account of the Goginan dressing floors but it would appear to be a mechanical table, probably an early mechanical frame which 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 an 8' by 12" waterwheels. Smythe 679.

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 $7\frac{1}{2}$ 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 BM30.

Williams's Buddle: Has a convex conical floor made of cement with a pitch of $10\frac{1}{2}$ inches in the 6 foot (6.85%) run 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. PCS 108.

Zenner's or Zennor Buddle: A modification and improvement upon the German Buddle by Mr Zenner of Newcastle, the conical table being 16' diam 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. P&D 131. A conical wooden platform described in similar detail to above. PCS 108.

- Bick. D.E.B. et al. Frongoch Lead & Zinc Mine. NMRS. 1986.
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- Davies. E.H. Machinery for Metalliferous Mines. C-L. 1902.
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- Eissler. M. The Metallurgy of Gold. C-L. 1889.
- Foster. C. le N. Ore & Stone Mining. Griffin. 1900.
- Goldsworthy. R. The Best Mining Machinery. CPS. 1876.
- Hughes. S.J.S. The Cwmystwyth Mine. NMRS. 1981.
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- Moissenet. L. Preparation Mecanique du Mineral. A de M. 1866.
- Palmer. M. The Richest in all Wales. NMRS. 1983.
- Palmer & Neaverson. The Basset Mines. NMRS. 1987.
- Phillips & Darlington. Records of Mining. Spon. 1857.
- Raistrick & Roberts. Life of the Northern Miner. NMRS. 1984.
- Richardson. J.B. Metal Mining. Allen Lane. 1974.

Smythe. W.W. The Mining District of Cardiganshire. HMSO. 1848.

Trounson. J. Mining in Cornwall 1850 - 1960. Moorland. c 1985.

Truscott. S.J. A Text Book of Ore Dressing. Macmillan. 1923.

The two upper foundations were almost exactly 6.00 metres in diameter (19.68') with circular launders 489 millimetres deep (19.25") and 30 centimetres wide into which the product fell. These tables must therefore have been $17\frac{1}{2}$ 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' 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 artifact left on the site were the boards from a Round Buddle which were sent to the Llywernog Mining Museum in the mid 1970's.

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 1890's that he became involved in mineral production. The destiny of the salvaged buddles from Bwlch cannot be ascertained from the information which is available at the 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 which 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 Buddles can be discounted as they were not available until after the mine had ceased working.

Whilst Rittingers are a possibility, they were considered to be very expensive pieces of machinery and are therefore less appealing than cheaper devices which were 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 arranged radially around the circumference of the collecting launder which does not tally with the physical remains at Bwlch.

The only remaining possibility is therefore Zenner's Buddle which was first described by Phillips & Darlington in 1857 and was introduced at the Frongoch Mine prior to the time of Leon 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 & 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 & 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 which 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, however, Frongoch was only equipped with 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 which 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 which could be constructed by mine carpenters rather than of a type which 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 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 which was 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 which 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 which cover the site.

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 list the better examples which have survived :-

Abbey Consols.	Appear to be remains buried under the fines dumps. Under no immediate threat.
Bronfloyd.	Scheduled Ancient Monument. Not well exposed or defined.
Bryndyfi.	Scheduled Ancient Monument. Probably the finest example in the area.
Bronmwyn.	Not under immediate threat. Well defined.
Blaenceulan.	Not under immediate threat.
Bwlchglas.	Scheduled Ancient Monument. 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 roadmaking works.
Frongoch.	Under immediate threat. Only positive location of Zenner Buddle.
Glogfach.	Appear to be remains encroached upon by the fines dumps. Uncertain future.
Llawrycwmbach.	Poor condition. Not under immediate threat.
Llettyefanhen.	Not under threat but unlikely to be cared for by the new owners. In poor condition.
Llywernog.	Scheduled Ancient Monument. Round Buddle moved to here from Bwlch.
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.

DESCRIPTION & SCHEDULE OF PHOTOGRAPHS TO ACCOMPANY REPORT.

In all of the photographs, apart from general perspectives, three scales are used:-

The red and white ranging rod is divided into 50 cm. units.

The black and white scale bar is divided into 2.5 cm. units.

A white scale rule 30 cms. long.

SHEET No. 1.

- 1 Commencement of work on the upper floors.
 - 2 Re-instated upper floors showing pegs set into culverts.
 - 3 Distant shot showing re-instated lower floors and the two buddle circles on the upper floors.
 - 4 Distant shot showing re-instated lower floors, the two buddle circles on the upper floors, and the spoil heap to the west of the buddle circles.
-

SHEET No. 2.

- 5 Western buddle on upper floor facing northeast showing paved gutter within the kerb and the outlet into the open culvert.
- 6 Eastern buddle on upper floor facing northeast. Note that the inner kerb is in a better state of preservation than its neighbour. Also, that set into the kerb to the right of the ranging rod, the wooden legs which supported the superstructure are visible.

7 A general view of the two buddles on the upper floor showing the open culvert and the offset opposite its discharge point.

8 A general view of the two buddles on the upper floor.

SHEET No. 3.

9 The western buddle on the upper floor showing the remains of the centre post, the sluice, and on the left of the frame - the remains of the legs which supported the superstructure.

10 The eastern buddle on the upper floor showing the remains of the centre post, the sluice gate, the culvert, and the corner of the edge of the flat buddle.

11 The western buddle undergoing excavation, the flagged gutter and remains of the centre post are clearly visible.

12 The western buddle after excavation. Notice that remarkably little of the inner kerb was left intact.

SHEET No. 4.

13 The outlet of the western buddle on the upper floor showing the sluice gate, open culvert with radiused bend and pitch pine floor. On the left of the frame, the remains of the flat buddle can be seen and that the culvert wall has been built over its upper end. The scale bar in this frame is 30 cm.

14 Detail of the masonry on the eastern side of the eastern buddle on the upper floor with one of the supporting legs clearly visible on the right of the frame.

15 Detail of the masonry and outlet to the western buddle on the upper floor with the flagstones forming the base of the gutter. Note that the footings of the inner kerb are just about visible in front of the outlet.

16 Detail of the masonry on the western side of the western buddle clearly showing the flagstones forming the floor of the gutter and the two wooden legs set inboard of the outer kerb. The gear niche can just about be seen between the wooden posts on top of the outer kerb.

SHEET No. 5.

17 Detail of the outlet of the western buddle on the upper floor. Note that the sluice gate still prevents the drainage of the gutter, and the radiused bend in the open culvert behind the sluice.

18 Detail of the outlet of the eastern buddle on the upper floor, facing north. As with its neighbouring buddle, the sluice gate still functions. The square bend in the open culvert behind the sluice can be seen. Note that the inner kerb is more intact than that of the neighbouring buddle and casts a heavy shadow over the gutter.

19 Further detail of the outlet from the gutter of the eastern buddle on the upper floor taken at right angles to the previous frame, i.e. facing east. The depth of the gutter between the inner and outer kerbs can be better gauged in this frame. The high quality of the masonry in the outer kerb of this buddle is illustrated particularly well, as is the mode of construction of the inner kerb.

20 Detailed view of the flagstones forming the floor of the concentric gutter. This frame also illustrates the good fit between the flagstones and, at the bottom of the frame, the lime mortar upon which the inner kerb was built.

SHEET No. 6.

21 A detailed view of the flat buddle facing east. The wall behind the scale bar has been badly damaged. The two pieces of plank behind the scale bar were recovered from under the broken masonry and placed in this position. There is no doubt that the lower piece is in its original position; the upper piece was fixed to the lower one by means of a separate tongue but appears to be shorter than the same piece on the opposite side - see frame 22.

22 The flat buddle facing west showing the better preserved edge and the culvert wall built across its upper end. The amount of disturbance to the boards is more evident in this frame than in the previous one. Also visible, in the lower right hand part of the frame, is the groove cut into the board for accepting the tongue.

23 A general view facing down the centre line of the flat buddle. Note along the upper edge of the frame, the outline of the two buddle circles on the lower floor.

24 The area to the east of the flat buddle after the culvert from the two buddles on the upper floor had been excavated. The greater part of the masonry had been destroyed and interpretation was difficult. On the right hand side of the frame, T.M. Price is manually removing the contents of the western, #1, tank into the bucket of the excavator. The outline of the lower western buddle is clearly visible in the background.

SHEET No. 7.

25 The flat buddle from the front end showing how the bed of pitch pine boards had been disturbed prior to this excavation. In the background are the remnants of the development dumps.

26 The western, #1, tank viewed from its upper end showing the masonry walls, paved floor and button board sluice. In the bottom left hand corner is the mangled remains of the end of the culvert from the two buddles on the upper floor. The outlet from the #2 tank can be seen immediately below the frame number.

27 Dewatered slimes overlying broken masonry, intermixed with jig tailings and mortar, near the slime pits on the lower floor. The capstone of the most western stone culvert can be seen at the bottom of the frame. This culvert was followed but the section was so deep that it became unstable and was not safe to enter. It was therefore abandoned prematurely.

SHEET No.8.

28 A view of the #1 tank from the front whilst it was being cleaned out. To its left can be seen the flat buddle. In the foreground, the button board sluice can be clearly seen and the splayed outlet, with pitch pine floor, leading onto the metal faced plank at the very bottom of the frame. The excavator is parked over the top end of the, then, unexcavated #2 tank.

29 A more distant view of the #1 tank showing its paved floor, the button board sluice, and the partly excavated #2 tank to its left. To its right is the flat buddle.

30 On the left hand side of the frame is the culvert leading from the two buddles on the upper floor with the mid point radius commencing at the end of the ranging rod. The combined outlet from these culverts runs parallel with the ranging rod but is not well defined. The pitch pine floor can just about be made out as can the remains of some sort of sluice device. In the bottom right hand corner of the frame, the paved base of the #1 tank can be seen.

31 A distant view of the tanks and flat buddle. Nothing was discovered in the pit behind the remains of the rusty car. The lower eastern buddle was uncovered in the pit which was being excavated when this photograph was taken. The muckpile from the excavations on the upper floor can be seen to the right of the dumper and immediately in front of the tree.

SHEET No. 9.

32 A general view of the western end of the lower floors showing the section cut along an old wall and the box launder which was discovered. The front wall of the building is marked by the pile of masonry beyond the excavator. In the upper left hand side of the frame, the broken masonry marks the position of the slime pits which were not excavated on account of the toxic nature of the contents and the close proximity of the stream. The outline of the lower western buddle can be seen immediately to the right of the launder. The outlet to this buddle can be seen by the hand tools in front of the excavator.

33 Another general view of the lower western buddle showing the outer kerb and the outlet.

34 A detailed view of the outlet from the lower western buddle. The outer kerb and sluice gate can be seen in the right hand part of the frame. The capstone over the culvert is in its original position but that covering the junction has been lifted for further investigations. The scale bar is placed on the capstone over the deeper culvert leading from the lower eastern buddle.

35 The outlet from the lower western buddle with the scale bar placed on top of the sluice board. The capstone is visible above the scale bar.

SHEET No. 10.

36 The outlet from the lower eastern buddle after it had been dug out and the capstones lifted. This photograph is taken facing west. The sluice can be seen set inwards from the outer kerb. The pitch pine floor of the culvert can be seen where the slimes have been cleared out, the depth of slimes can be seen immediately below the scale bar. Slightly beyond the scale bar, the culvert has been left as found with the capstones in place.

37 The outlet from the lower eastern buddle after it had been cleared out. This photograph is taken facing north and much of the culvert is in heavy shade. The outer kerb and paved floor of the gutter can be seen in the foreground. The wooden floor commences at the sluice, in the position of the scale bar.

38 The staircase located seven metres north of the lower buddles in the position where it was expected to find a wheelpit. The bottom step can be seen to lie a metre below the surface, and it would seem that this structure dates from an earlier phase than the buddles. Above the 15 cm. scale bar, the edge of the second step can be seen to protrude from the fill. The front wall of the lower floor can be seen to the left of the stairwell. Where the walls have been protected from the elements by being buried, they are in a remarkably good state of preservation.

39 The same staircase as illustrated in frame 38 after it had been cleared out and brushed down. The top step, below the 15 cm. scale bar, is at the same elevation as the top of the outer kerbs of the lower buddles. The section was continued to about a metre below the bottom step, but nothing further was found. Note the construction being pitch pine laid on masonry.

SHEET No. 11.

40 The lower floors following their re-instatement on the morning of Wednesday the 25th of October. The wall which is visible at the furthest end of the bladed area is the eastern wall of the slime pits whilst the low mound of broken masonry on the right marks the position of the front wall of the lower floors.

41 A distant view of the lower floors being re-instated.
 The front wall of the lower floors can be clearly seen just beyond the excavator. To the left of the excavator, the square, partitioned, building are the remains of the slime pits which were not excavated on account of their close noxious contents and their close proximity to the stream, which can be seen in the background.

42 The re-instatement of the flat buddle and hand buddle, later used as tanks. The two pegs used to mark the position of the culvert connecting the two upper floor buddles can be clearly seen in this frame.

43 A more distant view of the re-instatement of the flat buddle and tanks area between the upper and lower floors with part of the lower floors visible in the bottom right hand corner of the frame. The re-instatement of the upper floors can also be seen to have been completed.













25



26



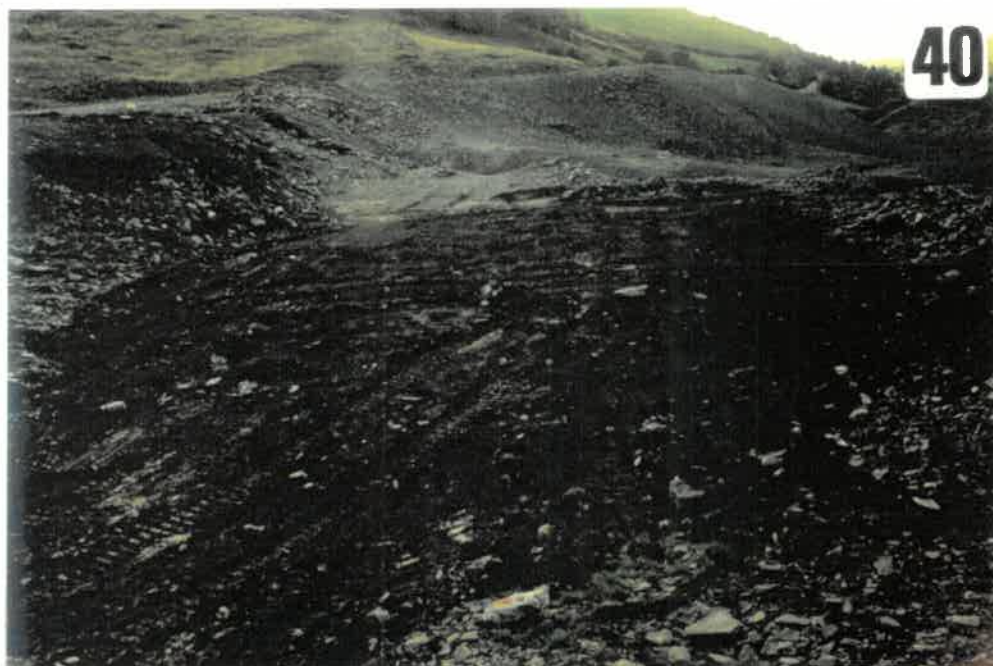
27





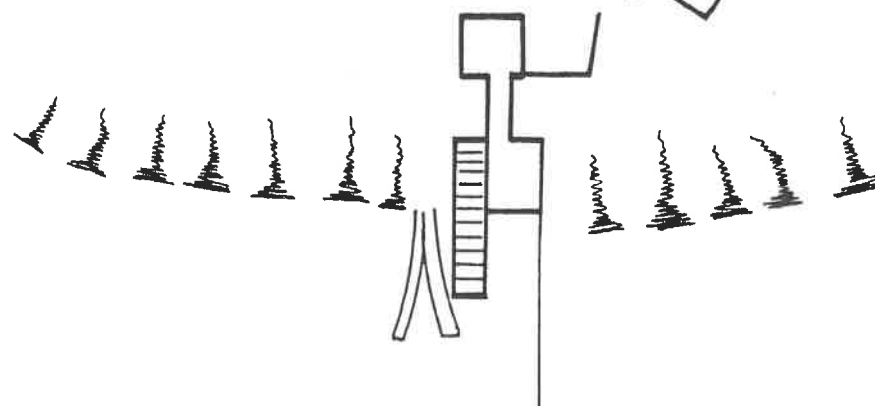
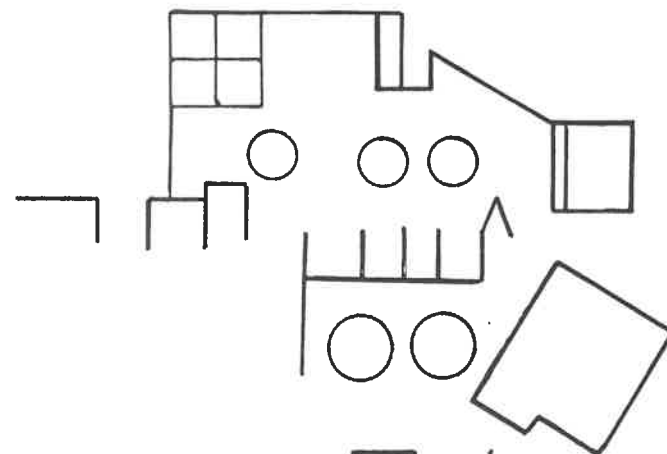
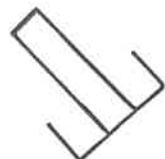






1 Bwlch Mine from 1887 O.S. Maps - Cardiganshire VII 6 & 10.

An enlargement of the two parts of the first edition O.S. map which covers the area which was investigated during these works. The greater part of the southern section fell victim to stone extraction in the 1970's but the larger buddles survived. To the north of these there is an inaccurate representation of the old hand buddles which were then being used as buddle product tanks. Only the eastern-most tank is shown with a pointed end. The smaller, lower floor, buddles are shown in their correct position as are the slime pits. The outlet from the slime pits appears to lie to their north and discharges directly into the stream - this was not investigated. To the north of the lower floor buddles, a long narrow building is shown which was thought to be a wheel pit but the excavations proved that this was not the case.



BWLCH MINE
from
1887 O.S. Maps
Cardiganshire
VII-6+10
1:2500 1st Ed.



2 Surface arrangement of Bwlch Mine: Taken from " The Goginan Mines " by S.J.S. Hughes (1988) showing the general layout of the surface at the time of closure.

THE GOGINAN MINES

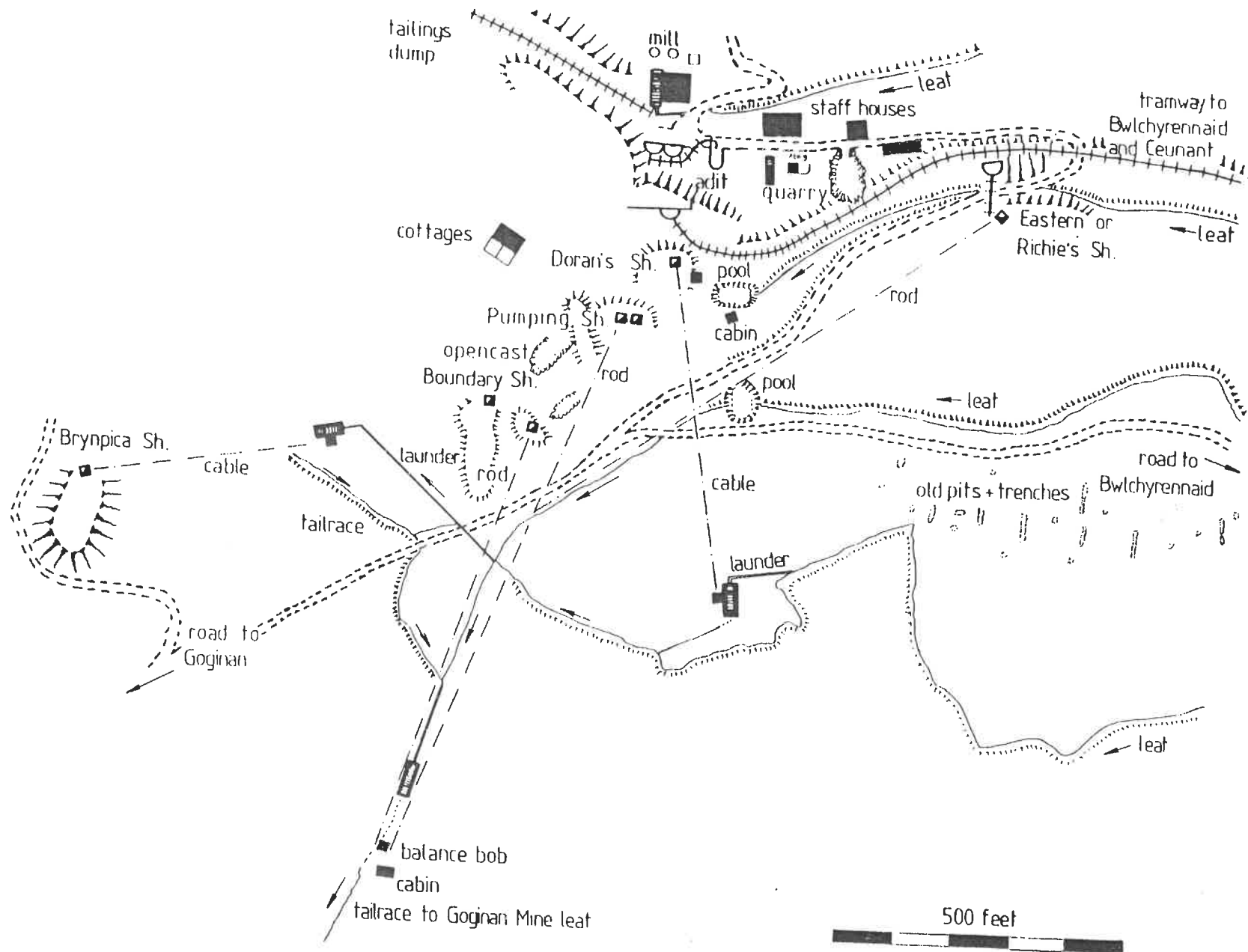
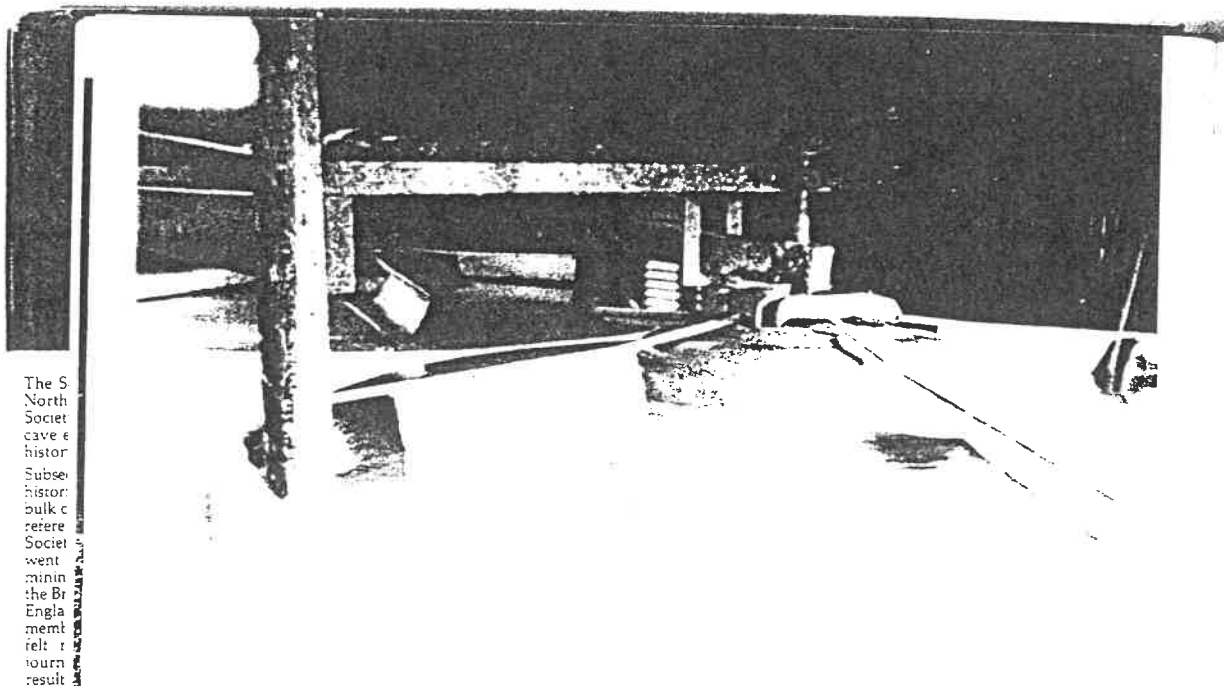


Fig. 15. Surface arrangement of Bwlch Mine

3 (97) Settlingstones Mine: From Raistrick & Roberts. An unusual design of centre head buddle which lacks the usual form of superstructure. Unlike fig. 98, this variation uses cloths mounted on the sweeper arms.

4 (98) Greenside Mine: From Raistrick & Roberts. An excellent illustration of the classic form of the Round Buddle. The text is somewhat inaccurate in its explanation; The power to operate the device is provided by the shaft which runs from the left of the frame to the centre post, the bevel gears can just about be discerned above the superstructure. The pulp is fed to the machine by the pale coloured launder which runs from the right of the frame to the distributor cone, mounted above the sweep arms, from where it is spread on the buddle head by the nozzles that the authors assumed provided the power. This is clearly not the case. Note also that the sweep arms are not fitted with cloth, or brush, sweepers and that they appear to utilise sprayer bars in their place. Another buddle can be seen behind this which also utilises the sprayer bar system. The buddle in the foreground is almost full. The crude masonry construction of the kerb can be clearly seen in this illustration.



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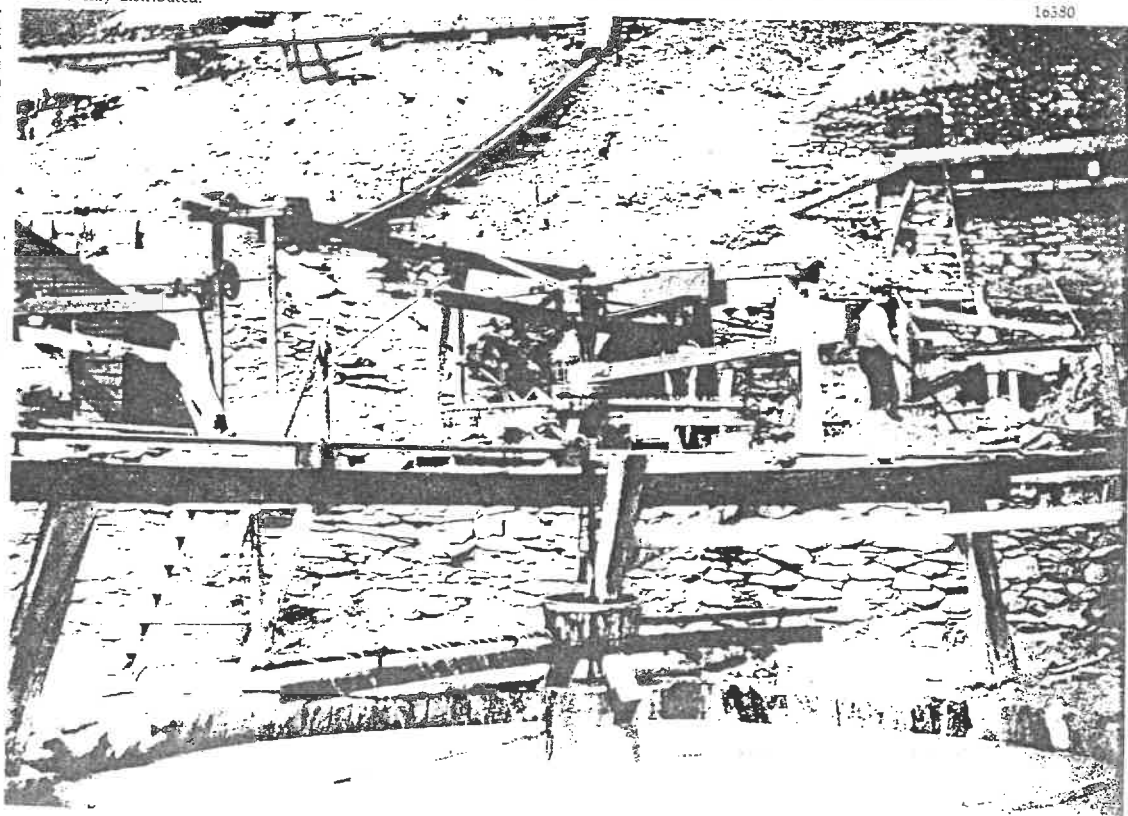
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97. Settlingstones Mine. A circular buddle in action. Mechanical stirrers helped the ore to flow evenly downwards. The heavy ore is dropped first, near the centre, and lighter waste outwards and downwards towards the edge.

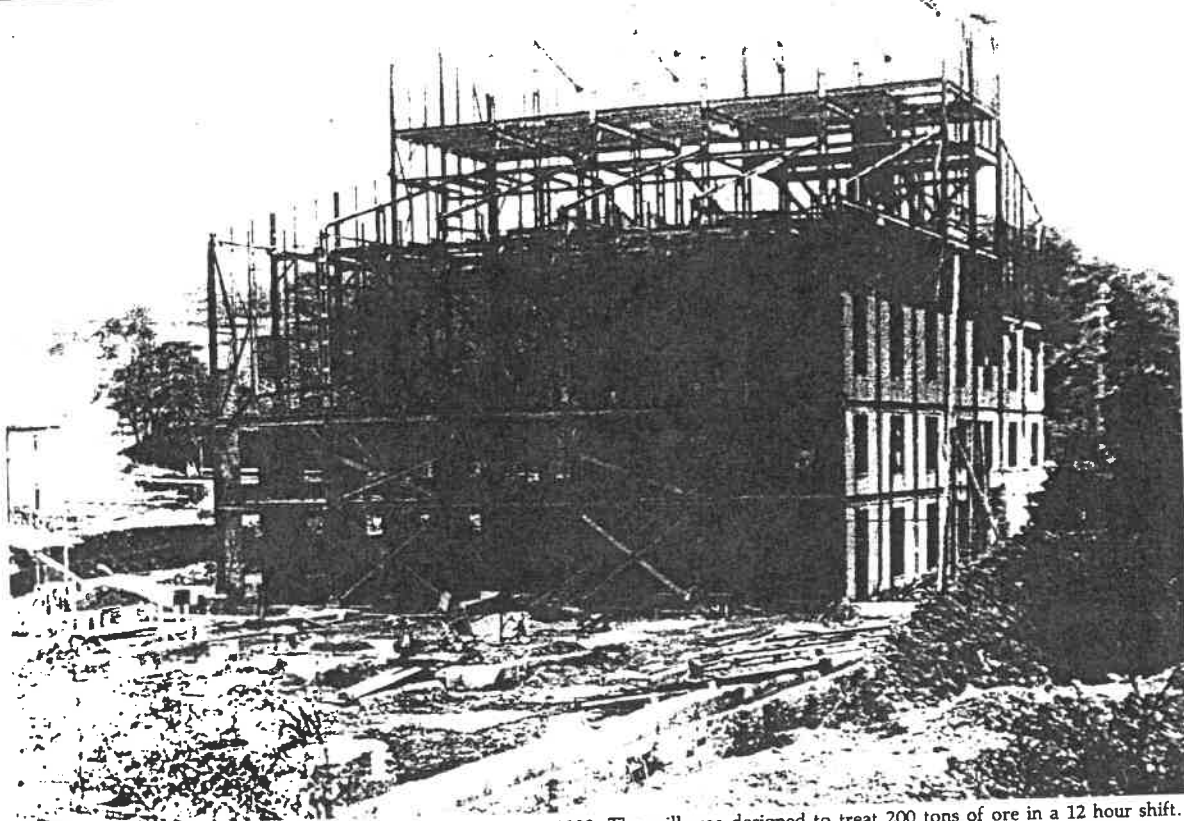
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98. Greenside Mine, Helvellyn. In this circular buddle, the slurry was delivered through nozzles fixed at a right angle to the end of the short delivery arms. The nozzles transmitted just enough power to keep the arms moving round, which ensured that the ore was evenly distributed.

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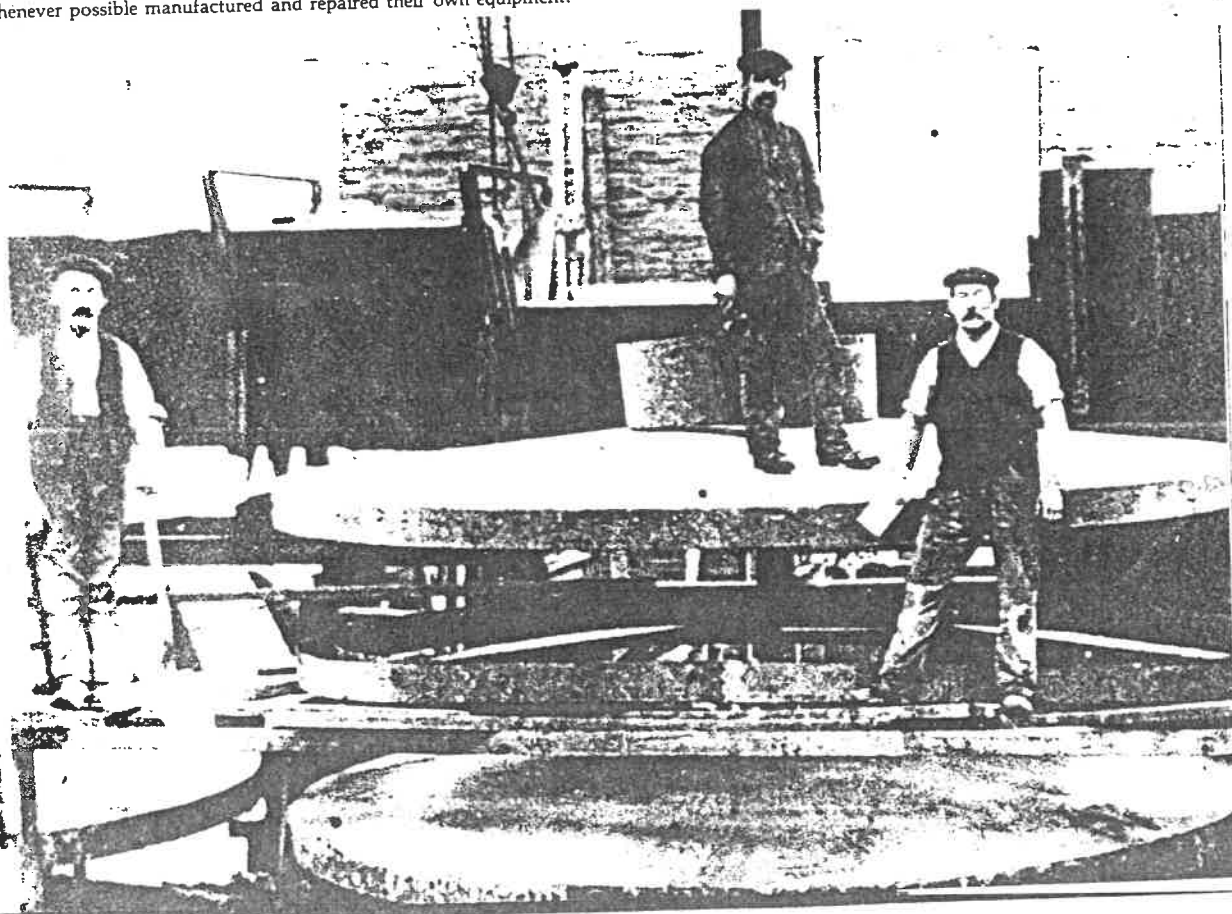


5 (108) Nenthead: From Raistrick & Roberts. An illustration of circular tables being manufactured circa 1910 when the mill was being reconstructed. This serves to illustrate how simple it was to construct this type of device, and that they were still being employed at this late date.



107. Nenthead. The New Dressing Mill under construction in 1909. The mill was designed to treat 200 tons of ore in a 12 hour shift. After crushing and picking, the bouse was dealt with by 38 jigs, the slimes from which passed to 48 tables 22 of these were shaking tables (photograph 112) and there were 10 vanning tables, 16 revolving tables (photograph 113) and a magnetic separator for iron. 5852

108. Nenthead. Circular tables being prepared for use, in the Rampgill workshops. In order to cut costs, the mining companies whenever possible manufactured and repaired their own equipment. 5382



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6 (p60) Convex centre head buddles as described by Palmer & Neaverson. As explained within the text of this report, the Round Buddle later became known as the Centre Head or Cornish Buddle but were in essence the same device.

6a Fig. 65 from Martin Eissler's " Metallurgy of Gold " of 1889 showing a round buddle. Dawson's fine engraving was syndicated by Crosby Lockwood and appeared in several other contemporary volumes including E.H. Davies's " Machinery for Metalliferous Mines " but not in Hunt's " British Mining ".

These were by far the most common form of buddle to be used in the metalliferous mines of mid Wales and, as described within the text, there were probably in excess of 500 of these devices working in the area during the 1870's.

There was certainly one of these machines working at Bwlch, and probably more in the 1840's through to the 1870's, and the remains of the kerb and buddle boards were taken away to the Llywernog Mining Museum in the mid 1970's.

The four buddle circles uncovered by the recent excavations are clearly not for Round Buddles and belong to a totally different type of device.

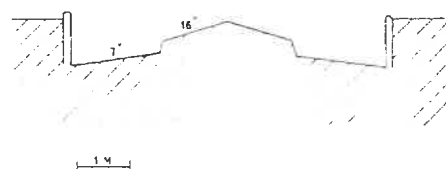
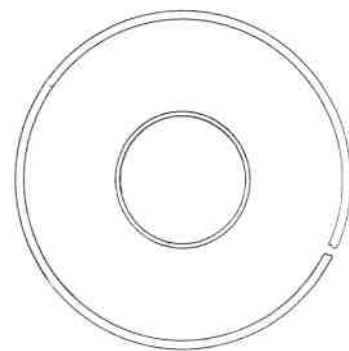
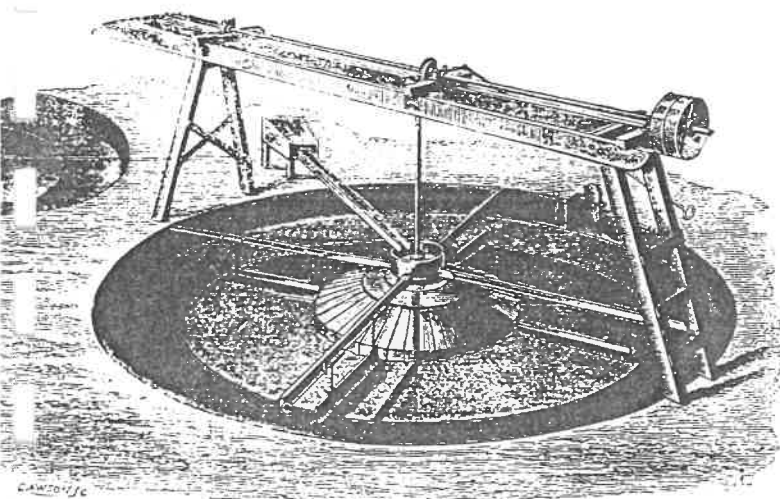
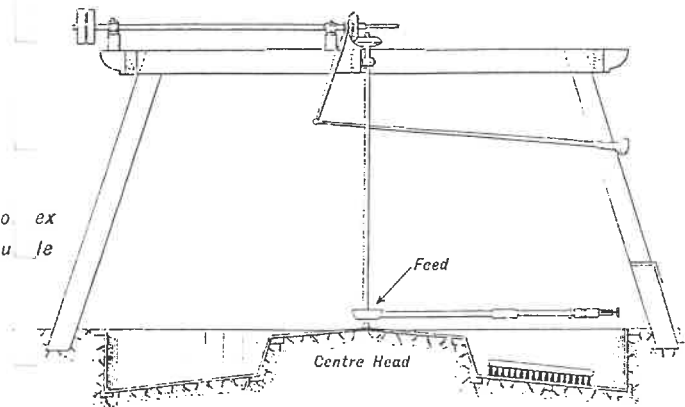
Carn Brea had a natural fall which was conducive to dressing processes requiring gravitational flow to minimise handling. The only disadvantage of the site was the lack of water which they overcame by constructing an aqueduct to carry water pumped from Thomas' shaft to three surface reservoirs to the north of the stamps engine. This aqueduct ran alongside the tramway they laid to bring tinstone from their producing shafts to the new dressing floors. Water was conserved by recirculation from the bottom of the dressing floors where settling tanks were built underground. It was pumped back by means of a secondary beam on the stamps engine.



PLATE XXX (Left) Thomas' Shaft pump house bob wall in 1986.

FIG 31 (Left) Convex centre head buddle, from J T Truscott Text Book of Ore Dressing, 1923 and E H Davies Machinery for Metalliferous Mines, 1902.

FIG 32 (Below) Cross section of West Basset convex buddle.



7 (51) A concave buddle for upgrading tin ore at the Tolgus plant as illustrated by Trounson. Note that in this buddle, the separated products are delivered to the centre of the device whereas in the convex buddle the products are delivered to the periphery of the buddle. This particular model has a static bed with a rotating distributor. The arms are turned by line shafting and bevel gears with the pulp being fed to the distributor head by a launder from where it flows down the rotating lightweight launders to the circumference and separates as it flows back to the centre. The products are then caught from the centre of the machine by launders.

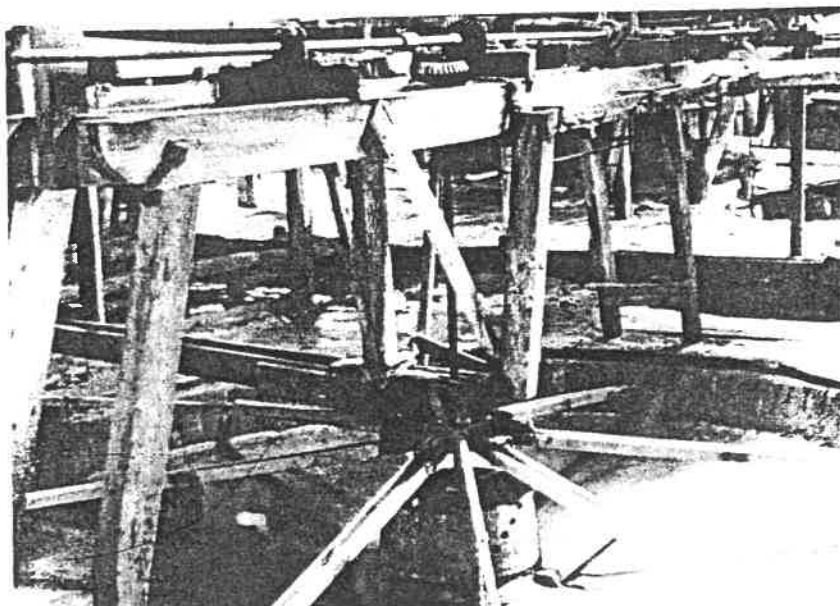
8 (52) Another form of concave buddle for upgrading very fine grained tin ore at the Tolgus plant as illustrated by Trounson. Note that in this buddle, the separated products are delivered to the centre of the device whereas in the convex buddle the products are delivered to the periphery of the buddle. Note that in this model, the whole table is rotated slowly by means of a worm gear on the line shaft which engages on a gear. The whole of this rotating table is supported by the wooden " spider " which is actually a series of boxes to catch the different grade product for further treatment by other methods. The separation of the mineral from the waste gangue can be seen in the dark streaks flowing down the table. The brush, on the right hand side of the frame, served to sweep the concentrate into its appropriate bin. I was fortunate enough to observe both of these machines in operation in the mid 1960's before the plant was demolished.



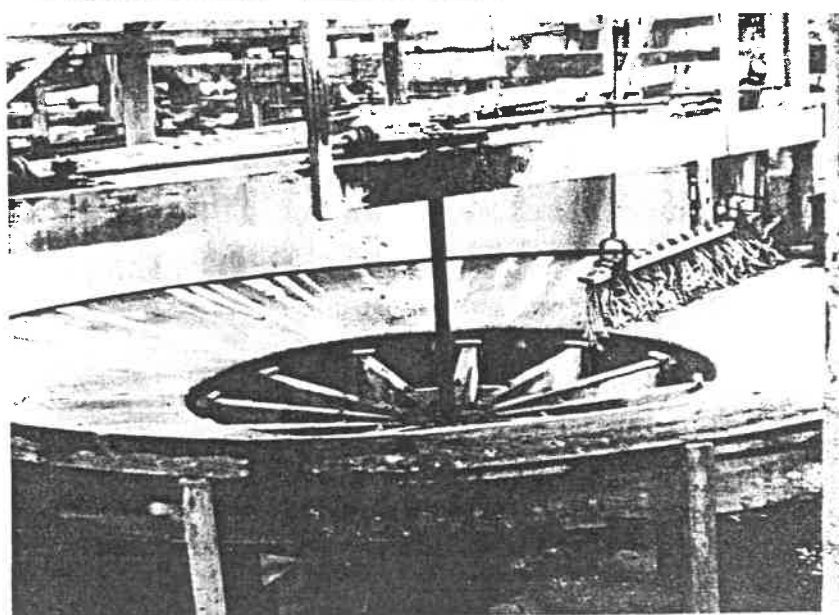
by Lancashire-type
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the very fine tin contained in the
effluent flowing from the mines
and which, for a variety of reasons,
could not be caught by the mines
themselves. One of the last of
these tin streams to remain in
operation was the plant at Tuck-
ingmill owned by the Tolgus Tin
Stamping Company and before it
was dismantled in the winter of
1973-4 a number of photographs
were commissioned for the Tre-
vithick Society for record pur-
poses. This picture shows a
concave buddle for up-grading fine
tin.

52 A round frame for treating
very fine tin.

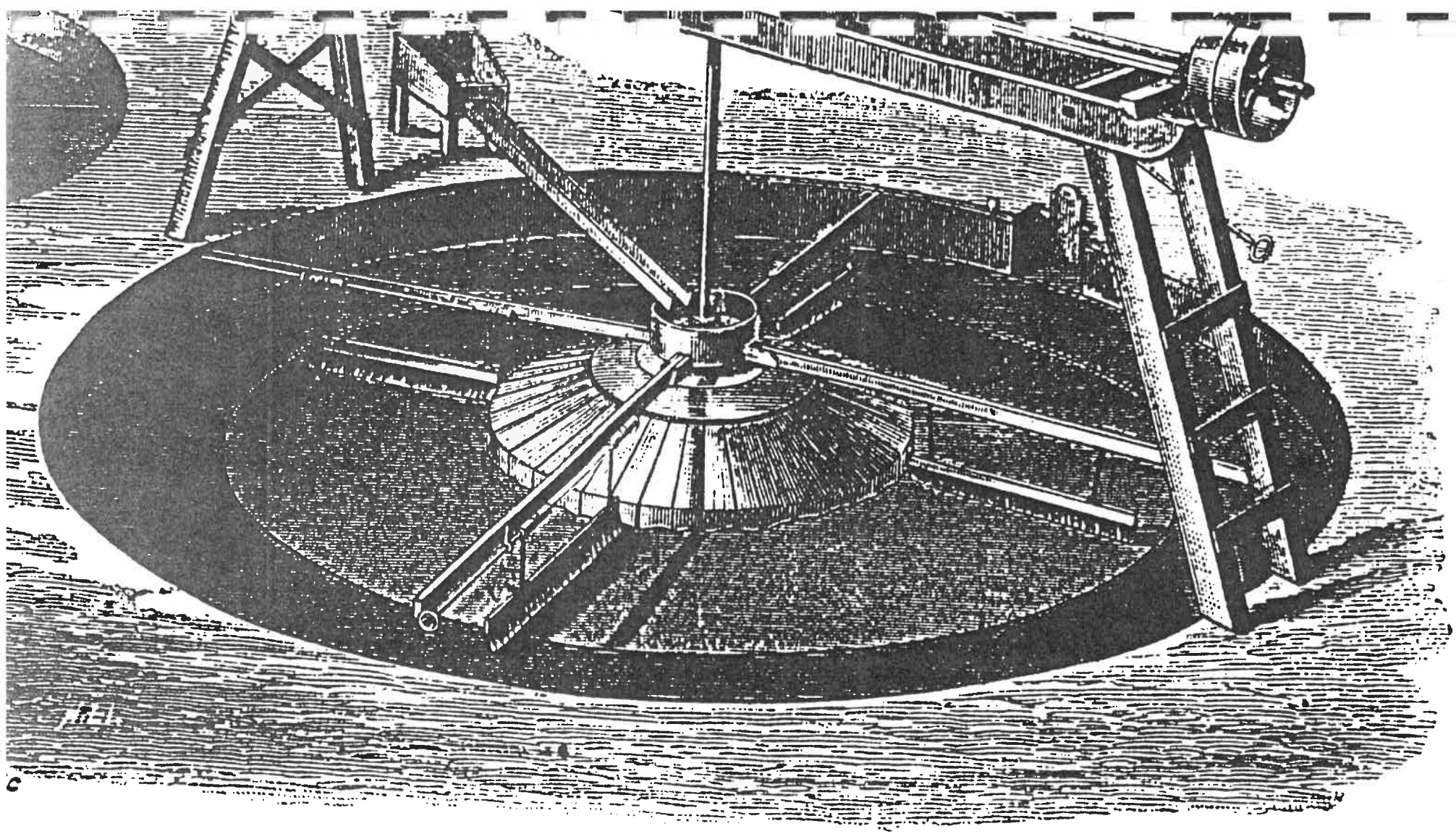


FIG. 65.—THE ROUND BUDDLE.

9 Figure 217 from Sir Robert Hunt's " British Mining ". This illustration is his representation of a Hand Buddle of the latter half of the 19th century :-

" This buddle usually consists of a wooden box, D, about 8 feet in length, 3 feet wide, and from 2 to 2½ feet deep, sunk in the ground, and having an inclination of about 2 feet in its whole length. At the head of this box a distributing board, C, is placed, which is in communication with the trough B and a water launder A. The stuff is thrown into the trough B, when it is stirred by the buddler's assistant. The fine slime then passes through a perforated plate to the distributing-board C, and from thence in a thin and uniform stream into the buddle D, where the buddler carefully and continually sweeps the slime and water across the buddle and somewhat against the direction of the current, with the view of freeing the grains of ore from any viscid matter which may accompany them, and depositing them at the head of the buddle. In the tail board at the lower end of the buddle is a vertical row of holes a few inches apart, through which the surplus water flows, and which holes one after the other are stopped up with plugs as the stuff rises in the box. About 9 inches in length of water is kept between the stuff and the tail board, with a view of preventing the escape of any valuable stuff through the holes. Four and a half buddlesfull are generally finished by two boys in ten hours. The buddle when filled is arbitrarily divided perpendicularly into four parts - the "head", "fore middle head", "middle head", and the "tail". The head, which generally occupies about one-third of the buddle, is then re-buddled and divided into four parts as before, the head being tossed and thereby rendered fit for the smelting furnace."

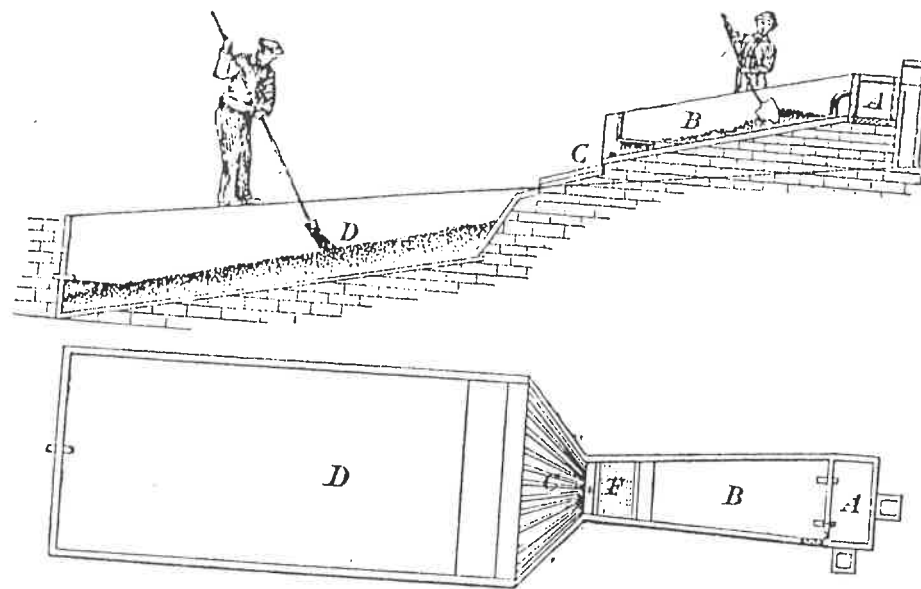


Fig. 217.

10 A 19th century stylised engraving of two boys working a rocker box, an altogether smaller version of a flat or hand buddle which was sufficiently portable to be carried from one site to another. Despite an extensive search, very few details of flat buddles are available, illustrations and drawings are remarkably rare, whilst photographs appear to be totally non existent.

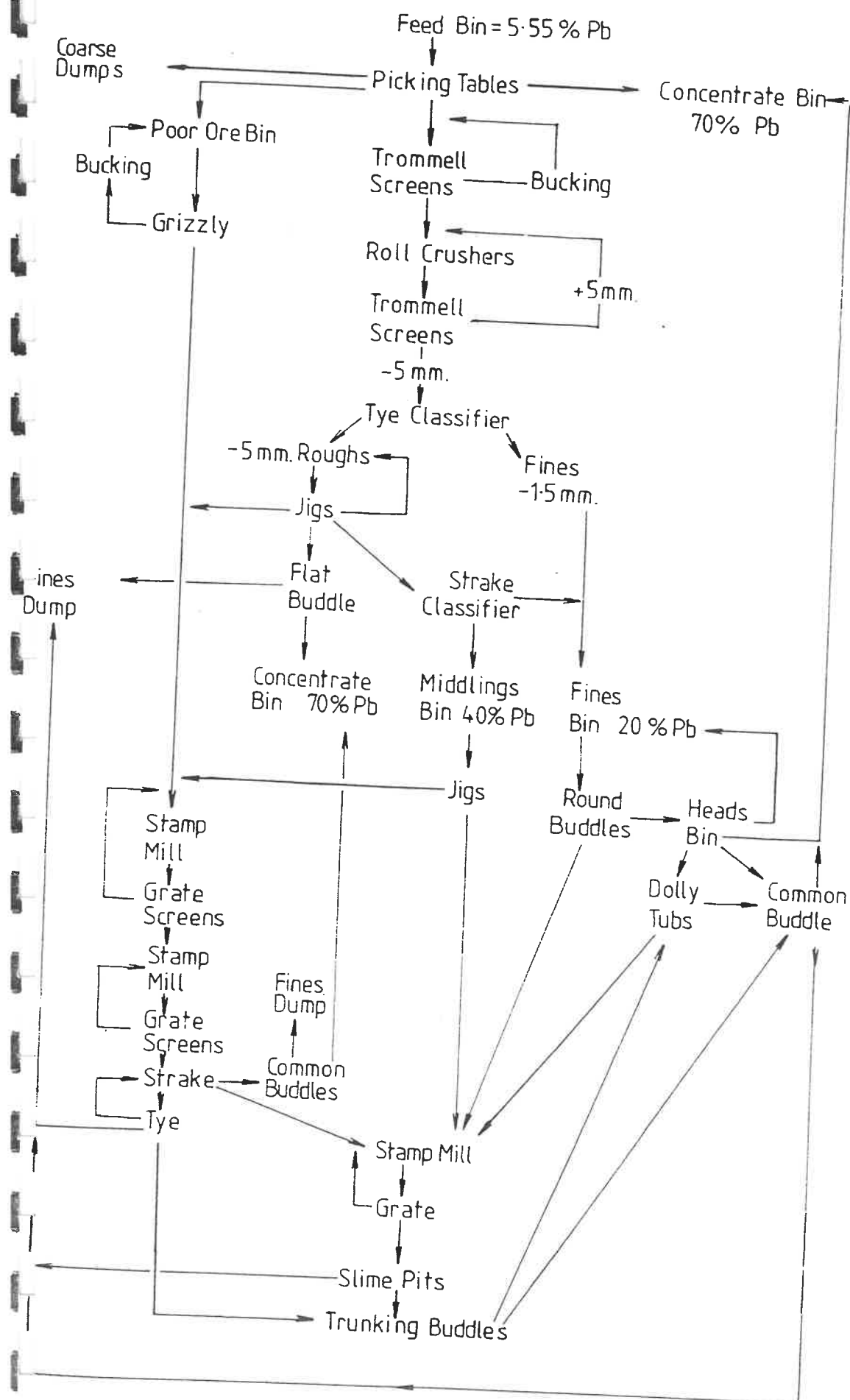


10 Flowsheet of the dressing mill at Goginan mine in 1847 from " The Goginan Mines " by S.J.S. Hughes (1988) and based on W.W. Smythe's description of the processes used in ore concentration.

Note the usage and sequence of flat buddles, round buddles, common buddles and trunking buddles in separating the mineral from the gangue; Also that the Tyes and Strakes, which are essentially tables or frames, are used as product classifiers rather than for mineral separation.

Note also, that the middlings are returned to the circuit in most instances.

Fig. 12.
Flowsheet
Mine Mill



11 Enlarged section of a German Rotating Buddle taken from page 130 of Phillips & Darlington's " Records of Mining & Metallurgy (1857). This section illustrates the machine in its original form as developed by Rittinger at Clausthal but by 1857 it had been improved by Zenner.

A is the axis for the table which also gives it support.

B is a conical table 16 feet in diameter.

C, D, E & F are the driving mechanism.

f is a small pinion working a crankshaft to impart the motion to -

h the sweeping brush.

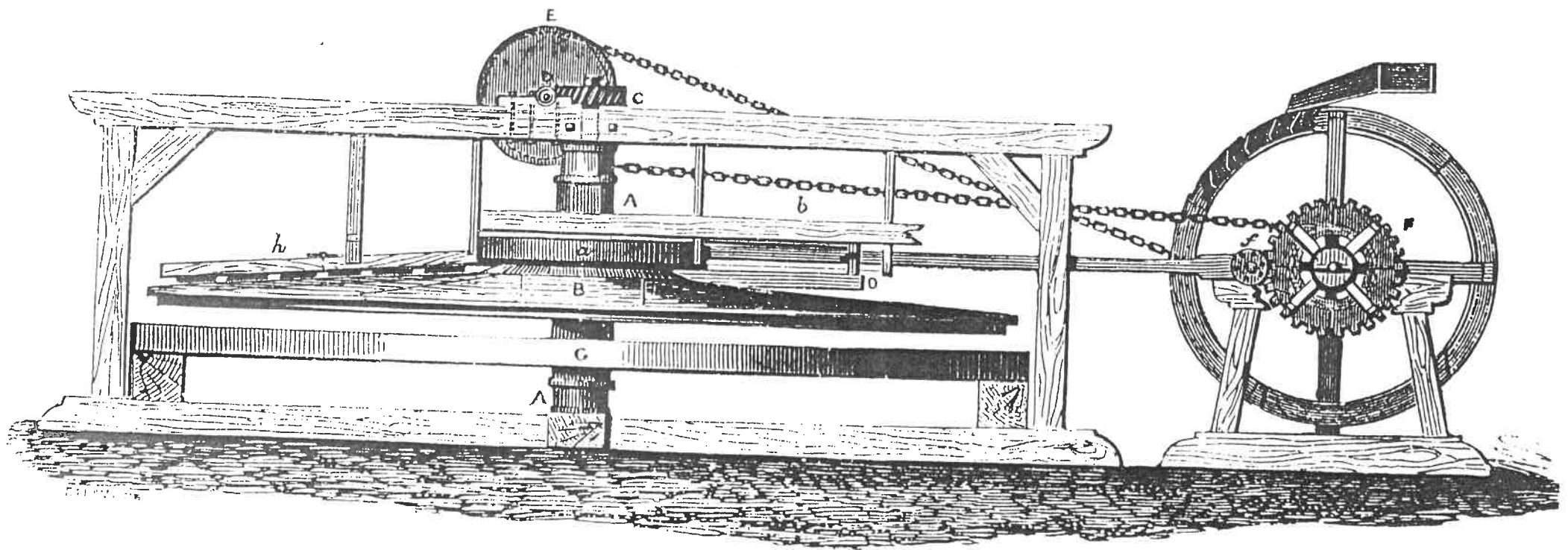
G is a sheet iron ring launder to catch the products.

a is a circular trough of sheet iron to receive and distribute the pulp to be separated and -

b is the launder which supplies the pulp to this trough.

o is a launder to supply water to the sweeping brush.

In tests performed upon two alliquots of slime ore containing about 8 % lead, the Round Buddle took 609 hours to perform the same work as was performed in 86 hours on the Zenner Buddle, or about 1/7th of the time. The product of the Round Buddle contained 52.6 % lead and left 2 % lead in the waste; whilst the product of the Zenner Buddle contained 62.4 % lead and left 1.8 % lead in the waste.



German Rotating Buddle.

PLANS AND SECTIONS OF BWLCH MINE UPPER & LOWER DRESSING FLOORS

- 1 Plan of Upper Floors, Culverts & Tanks at 1:50
- 2 Plan of Lower Floors, Culverts & Slime Pit at 1:50
- 3 North - South Section across Upper Eastern Buddle and
#2 Tank at 1:50

KEY TO PLANS & SECTIONS.

Known Remains of Last Structure

Projected Remains of Last Structure

Known Remains of Previous Structure

Projected Remains of Previous Structure

Masonry

Spot Heights

PLANS AND SECTIONS OF BWLCH MINE UPPER & LOWER DRESSING FLOORS

- 1 Plan of Upper Floors, Culverts & Tanks at 1:50
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- 3 North - South Section across Upper Eastern Buddle and #2 Tank at 1:50

KEY TO PLANS & SECTIONS.

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Projected Remains of Last Structure 

Known Remains of Previous Structure 

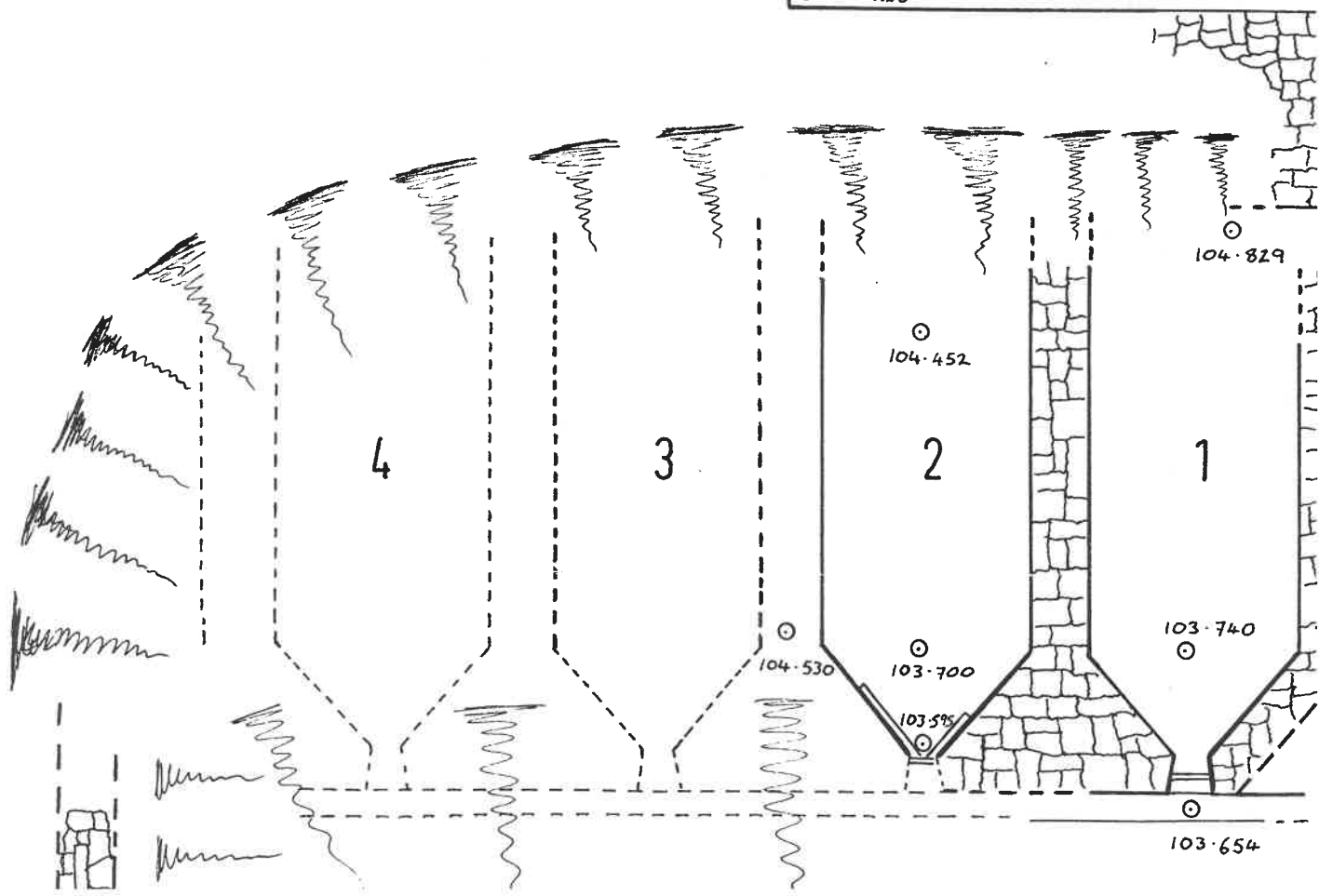
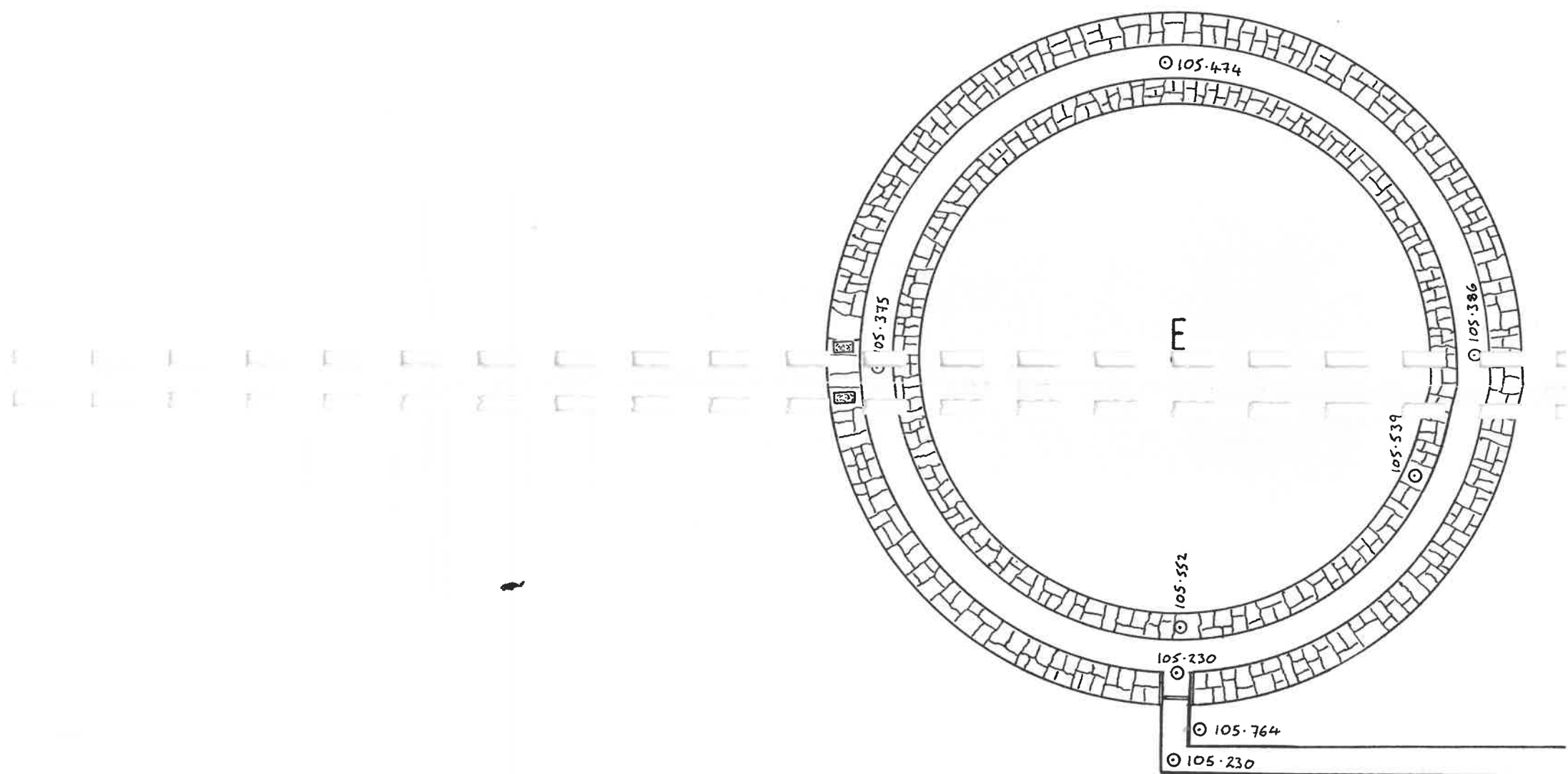
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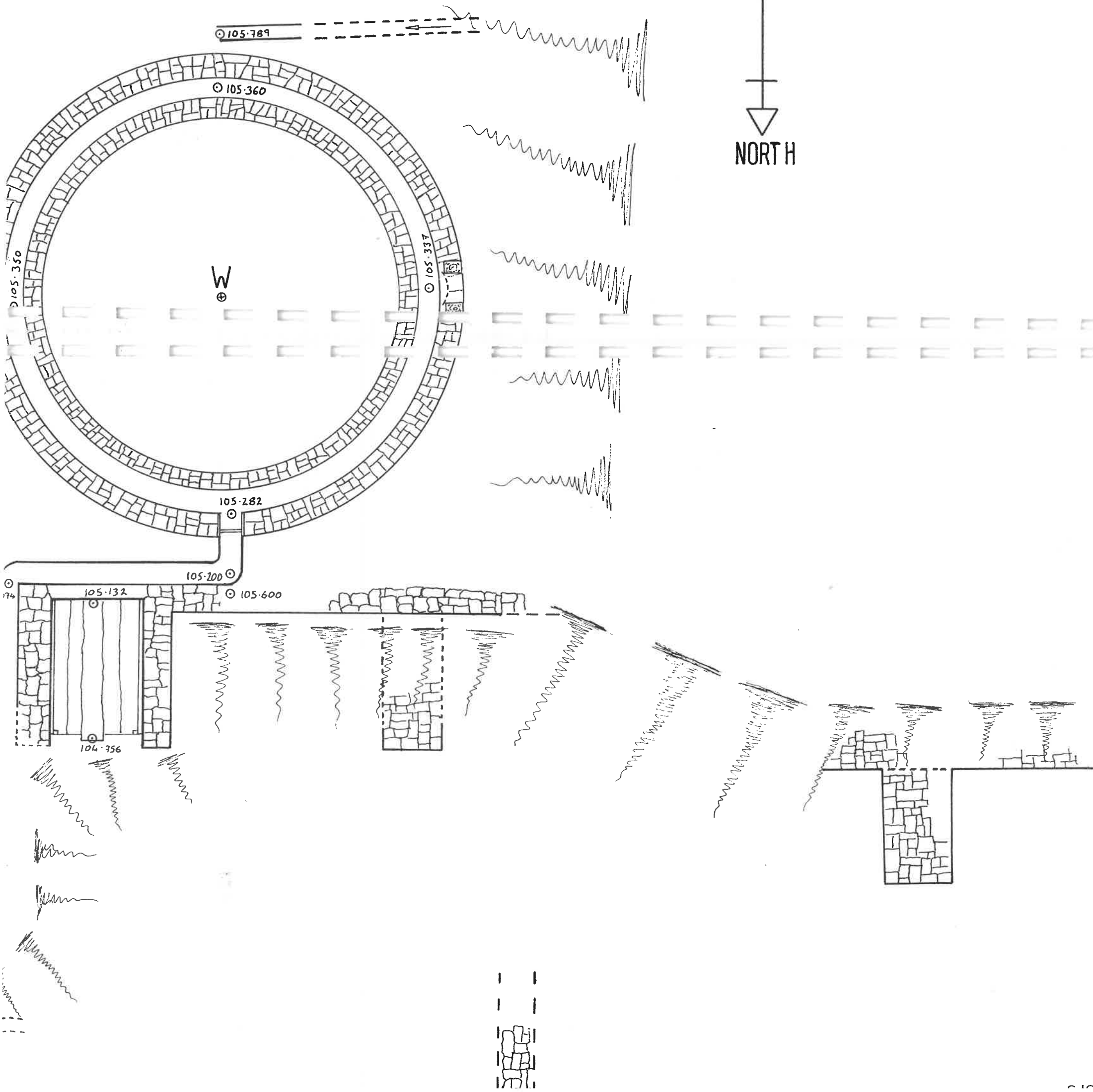


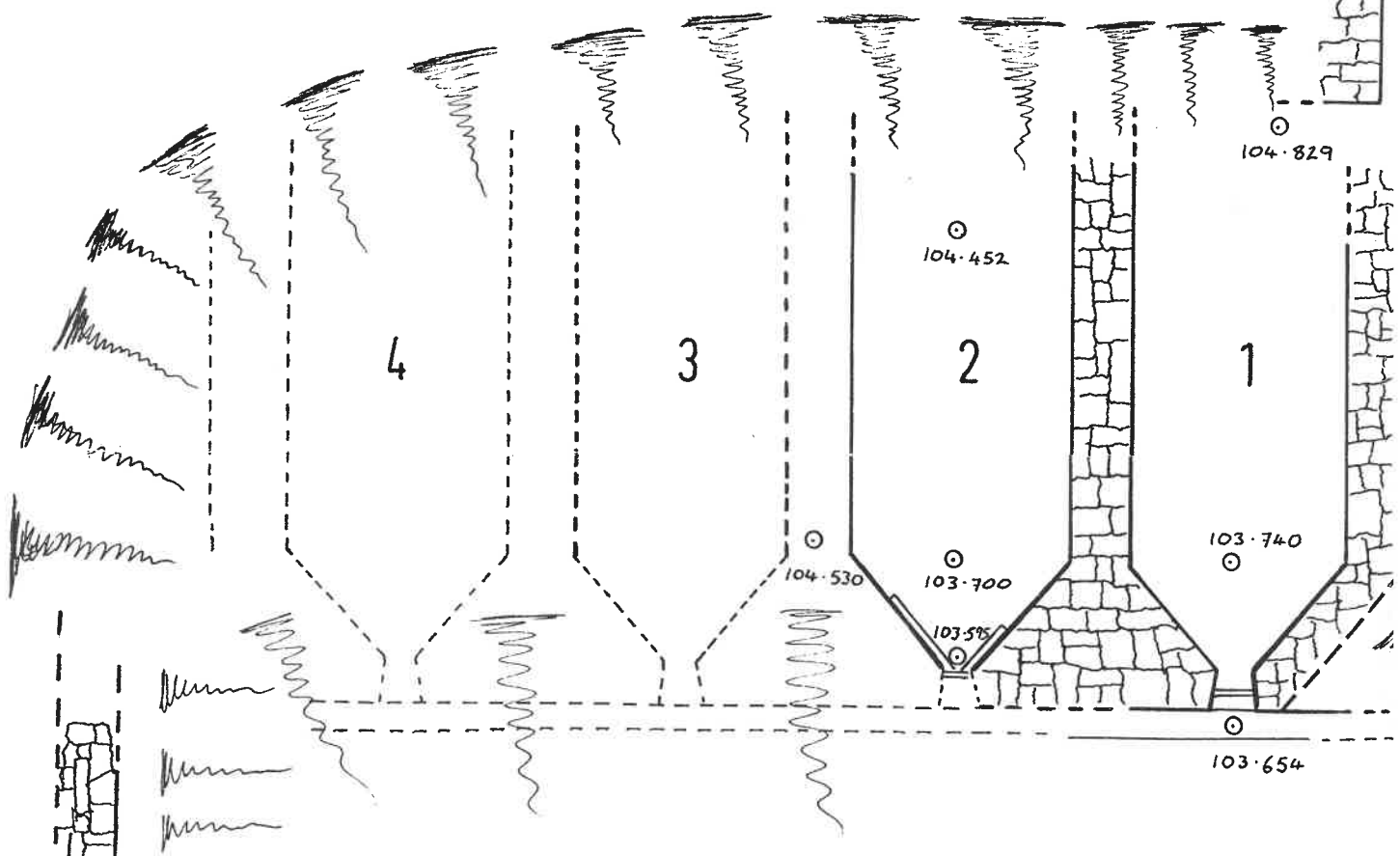
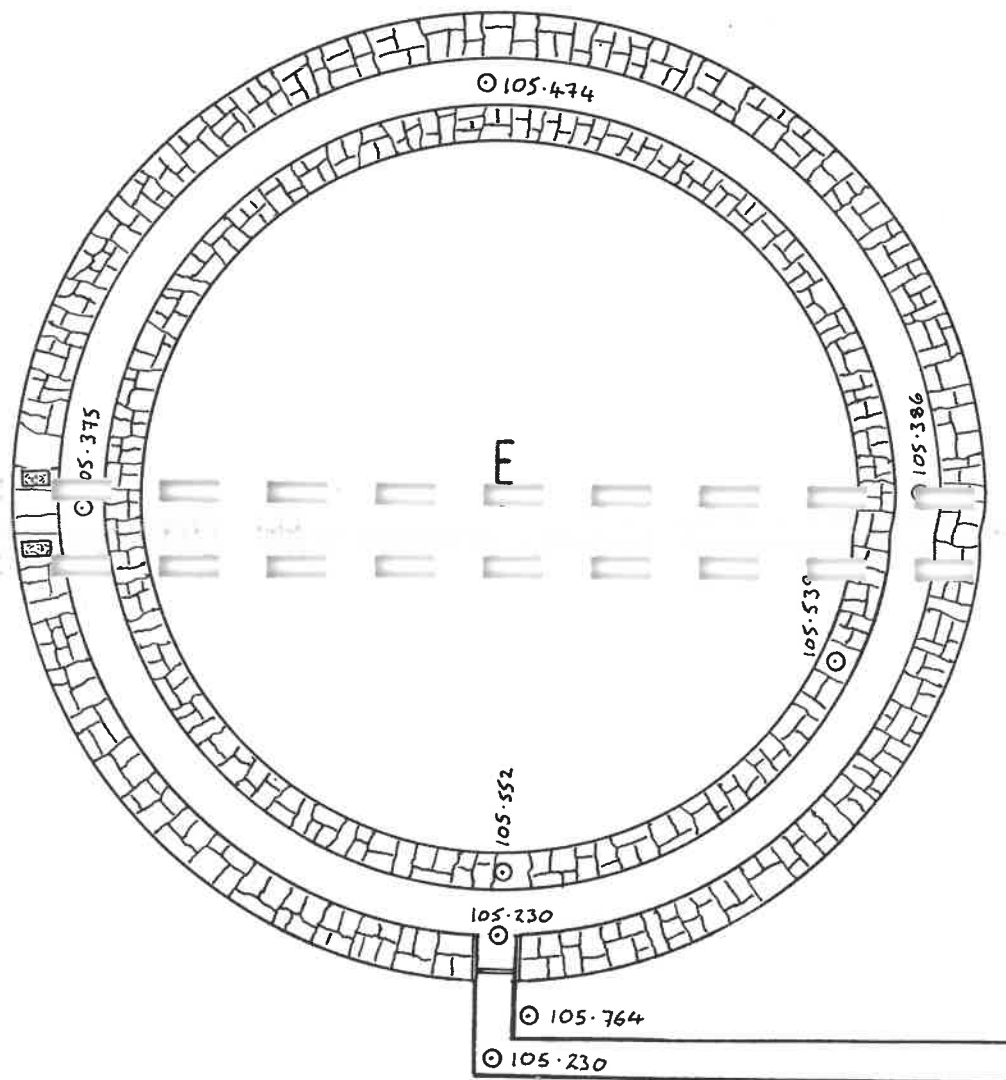
Spot Heights

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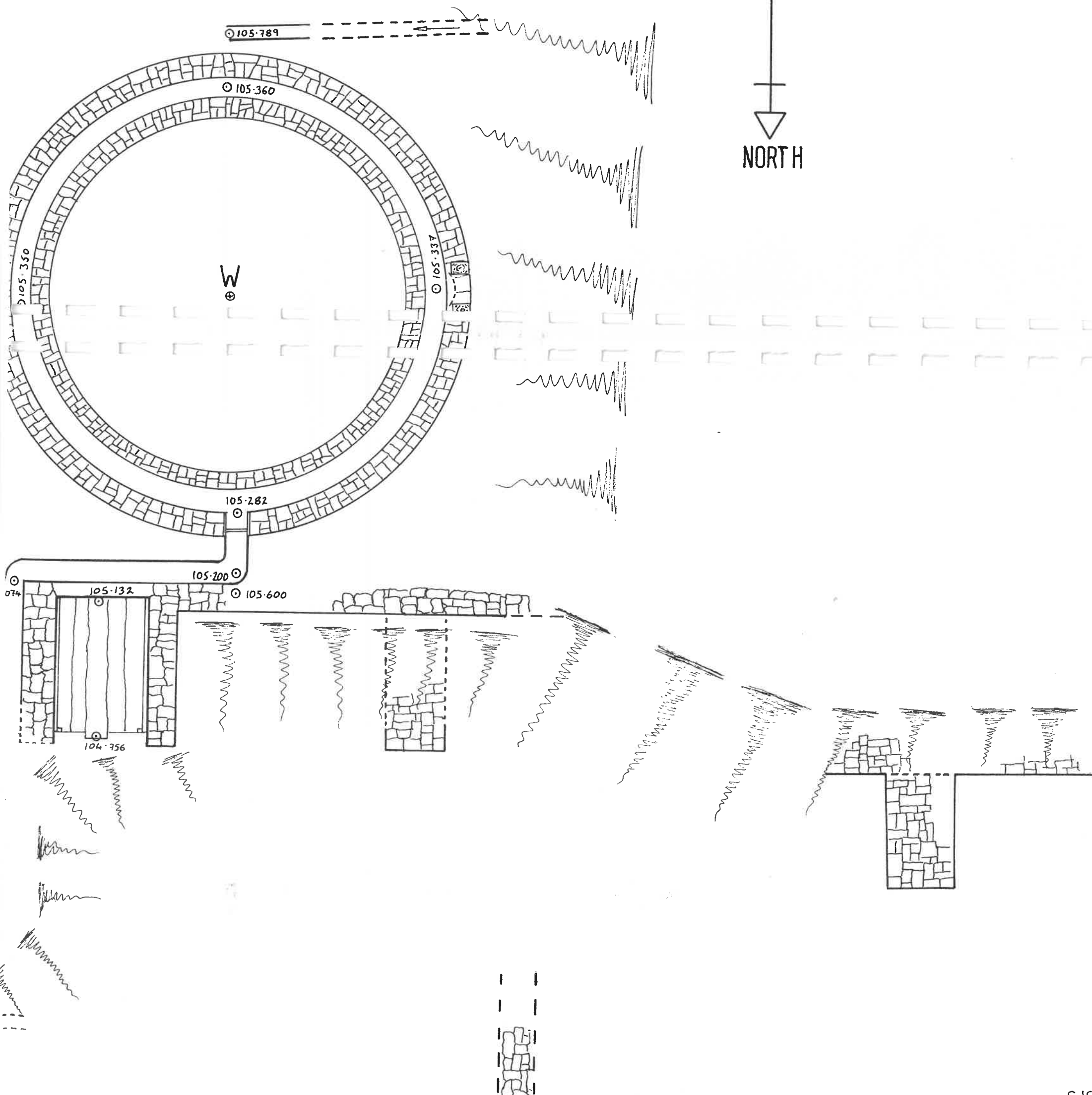


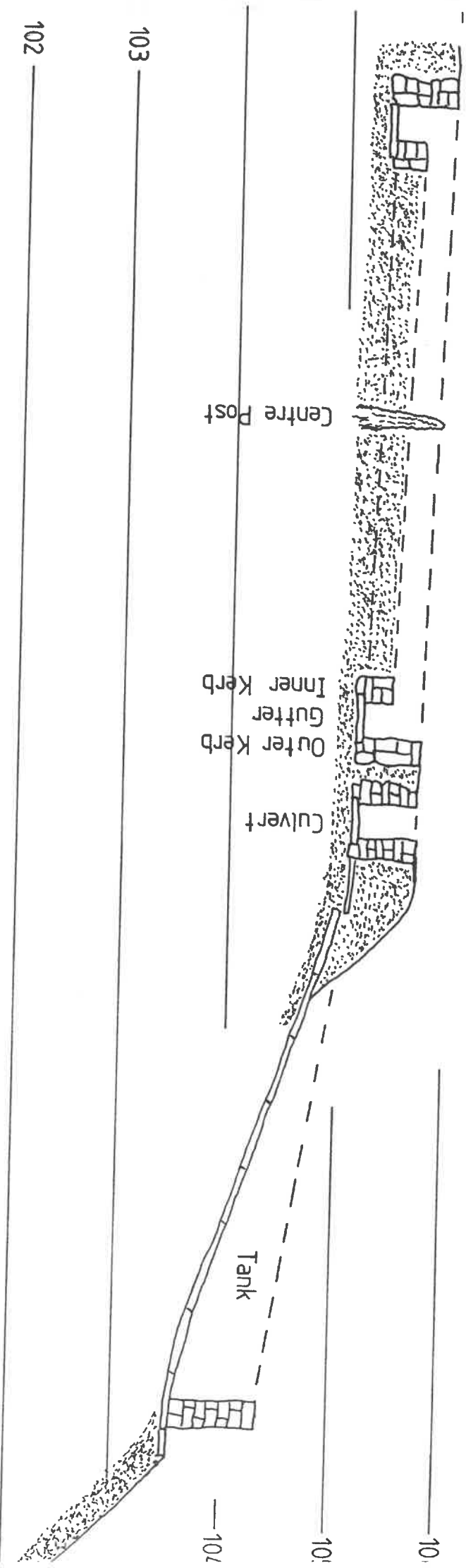
BWLCH MINE - CEREDIGION.
UPPER FLOORS
OCTOBER 1995
1:50





BWLCH MINE - CEREDIGION.
UPPER FLOORS
OCTOBER 1995
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CONCLUSION.

It is known that mineral extraction in the Goginan and Cwmerfyn district dates from the Middle Bronze Age, about 1800 B.C., by samples recovered from the Nantyrarian Mine. It has been hypothesised that there was also some Roman activity in these mines but this cannot be proven at the time of writing.

Archival research has not shown any evidence of the Bwlch Mine having been worked earlier than the mid 17th century, and it was not until the mid 19th century that any significant mineral production took place.

About the year 1880, the plant was fitted with four Zenner Buddles, probably in an attempt to reduce losses through inefficiency and 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 1880's.

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

The foundations of the Zenner Buddles 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.

There are the foundations of a single, much larger, Zenner Buddle at the Frongoch Mine, but this is under threat by development and has never been properly investigated or recorded.

During the excavation, there was a steady flow of visitors to the site, which was impossible to curtail. Without exception, they expressed the opinion that the remains were an impressive relic of a bygone age and industry and showed a desire to consolidate and conserve the remains in situ.

My initial feelings, from that time to the present, remain unchanged; The four buddle circles are in a good condition, but a remarkably poor context and completely lack the surrounding structures that are vital for any form of interpretation, other than by experts. It would be a far wiser move to consolidate buddle circles on another site which still had the interpretable remains of a crusher house & wheelpit, a jigger house, buddle floors and slime pits, such as Bronfloyd. Bryndyfi or Temple.

The greater number of these visitors accepted my argument that Bwlch was a relatively new and unimportant mine, the greater part of which had been totally destroyed and which 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 mine site.

Also, that with this detailed survey, and archival data, it would not be a difficult task to rebuild any of these remains; Either, at full scale on an appropriate site, such as the Llywernog Mining Museum, or as a 1:50 or 1:25 scale model for display at the Ceredigion Museum.

GLOSSARY OF TECHNICAL WORDS USED WITHIN THIS REPORT.

BLENDE Also known as Zinc Blende. The sulphide ore of zinc frequently found in association with galena. Its density is usually around 3.95 tonnes per cubic metre - dependant on impurities. Ideally a combination of 67 % Zn with 33 % S but frequently contains up to 25 % Fe and 2.5 % Cd. Its gravity is so low as to make it difficult to separate it from the gangue by dressing in a hydrogravity mill and the concentrates from such a plant frequently grade as low as 35 - 40 % metallic zinc.

BOX LAUNDER A simple wooden box, sometimes fitted with a lid and sometimes without, used to convey pulp or water by gravity from one location to another.

BUDDLE A device for separating particles of mineral ore from the pulp containing the ore, gangue and host rock. There are many types of buddle, the most common being further described and analysed within this report. They were formerly essential for the separation of the sub 500 micron pulp but had been displaced by better methods by the turn of the century.

BUTTON BOARD A sluice board, which has holes drilled through it which can be stopped up with pegs, thus enabling regulation of the level of discharge to a precise degree giving improved control over the separation of the liquor and precipitate.

CLASSIFIER A device to sort mixed particles into similar sizes. For coarser particles a series of rotating screens, called a trommel, is traditionally used. The finer particles can then be further classified in strakes and tyes by hydrogravity, i.e. the rate of settlement in water.

CONCENTRATE The final heavy product which was sold by the mine to the smelters for reduction into metal. Its form would either be as lump, granules or powder depending on which process, if any, it had passed through. It was traded in long tons of 20 x 120 lb. or 21 x 112 lb. bags to compensate for moisture content. Such a bag would contain about $1\frac{1}{2}$ gallons of lead concentrate or $3\frac{1}{2}$ gallons of zinc concentrate.

GALENA The commonest ore of lead, a simple sulphide compound weighing around 7.4 tonnes per cubic metre. When absolutely pure, galena contains 86.6 % Pb with 13.4 % S but impurities usually dilute the content to < 80 % Pb. The normal impurities in mid Wales are silver, antimony, copper and a number of other elements. The normal grade of lead concentrate sold by the local mines was 75 % Pb +/- 3 %. Its density is so great as to make separation by hydrogravity a relatively easy task.

GANGUE The generic name for the valueless minerals which accompany the ore minerals in the lode. Quartz, calcite, ferroan dolomite and host rock inclusions being the most common in mid Wales. Gangue minerals are usually in the lower ranges of specific gravities, typically 2.8 to 3.0 tonnes per cubic metre. As these minerals are only 75 % of the density of blende, as opposed to 40 % of the density of galena, they are more easily separated from the galena concentrate but tend to contaminate the blende concentrate.

HEADS The most valuable portion of the separated ore, which is either sent to be further upgraded or deemed to have reached a marketable grade, in which case they are termed concentrates, and are then packed in bags to be sold for smelting.

JIGGERS A device, or series of devices, for separating coarse (1 - 2 mm.) classified granules of ore and gangue. Normally in the form of a large box filled with water to which is imparted a pulse by means of a plunger. The strength of the pulse is regulated so that the gangue will remain suspended whilst the heavier ore overcomes the pulse and sinks to the bottom of the jig. Good feed classification is essential.

MIDDLES That mineral which lies between the heads and tails which is too rich to discard but cannot be sold without further treatment. The middles are usually returned to the mill circuit or put through a separate circuit so as to further divide them with the middles, or middlings, again being returned to the circuit to avoid losses.

PULP The whole of the ore and gangue, ground and mixed with water to a density, or consistency, in keeping with the requirements of the machine in which it is to be treated.

SLIME The very finest product of the various crushing mills or processes. Technically, all particles of less than 30 microns ($30/1000^{\text{th}}$ of one millimetre). Due to Brownian movement, all such particles tend to form a colloid and are virtually impossible to treat in a conventional hydrogravitational mill circuit. They are consigned to a slime pit where the 15 - 30 micron particles will eventually fall out of the suspension and form a heavy clayey sludge. The sub 15 micron particles were normally lost with the process water, as a colloid, regardless of their mineral content. Slimes normally contain a percentage of heavy metals, 3 or 4 % being typical. Due to the tiny particle size, the surface area, and the consequent availability of their residual metal content, means that they present the greatest ecological hazard on abandoned mine sites.

STRAKE An archaic form of box classifier.

TAILS Also referred to as tailings. The worthless part of the pulp from which no further ore can be economically extracted. They are usually discarded into a tailings lagoon or a tailings dump. Jig tailings are coarser than buddle tailings which are predominantly slimes.

TAIL BOARD An alternative name for the button board.

TYE An archaic form of box classifier.