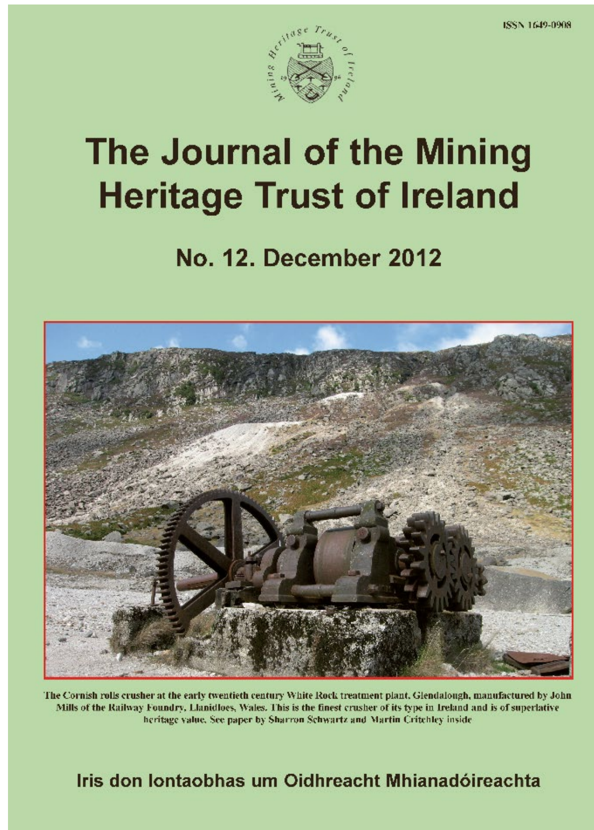

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THE LEAD ORE DRESSING FLOORS AT GLENDALOUGH AND GLENDASAN, COUNTY WICKLOW 1825-1923: A HISTORY, SURVEY AND INTERPRETATION OF EXTANT REMAINS

Sharron P. Schwartz and Martin F. Critchley

Abstract: This article highlights the considerable archaeological and heritage value of the dressing floors of the former Luganure silver-lead mines worked by the Mining Company of Ireland (1824-1890) situated in the parallel valleys of Glendalough and Glendasan and separated by Camaderry Mountain. It also discusses a small early twentieth century treatment plant in Glendalough. During the nineteenth century the Luganure mines were Ireland's most important lead mining centre, leaving behind an exceptionally well-preserved relict rural-industrial landscape, particularly with regard to the dressing floors which are the focus of this paper. These are the most complete lead ore processing sites in Ireland and are comparable in importance to many contemporaneous lead dressing floors in uplands regions of neighbouring Britain. The archaeology takes on added significance in the case of these sites, as the documentary record is slight at best due to the absence of most of the Mining Company of Ireland's records, leaving the historian with pared down half yearly reports of shareholders' meetings which do not contain much technical detail and often lump all the sites together as the Luganure Mines. Although the mines lay close to the Seven Churches (Glendalough), a tourist trap that was well photographed in the Victorian period, no nineteenth century photographs of the nearby mines have yet been discovered that might aid an understanding of surviving features. Perhaps they were unaesthetically pleasing to many Victorians, such as the walker 'descending the dale-head past the mines', who thought that they 'rather spoiled it' (BW 1879); contemporary maps contain sparse detail and no archaeological excavations have ever been conducted. This paper interprets the remarkable assemblage of features at these dressing floors based on documentary sources, aerial photographs, historic mapping, detailed surveying and field study and attempts to set their archaeology within a comparative context with similar contemporaneous sites in Britain. Finally, it makes a plea for an increased salience and improved listing regimen in Ireland for important post-1700 industrial landscapes that are of considerable heritage value. *Journal of the Mining Heritage Trust of Ireland*, **12**, 2012, 5-52.

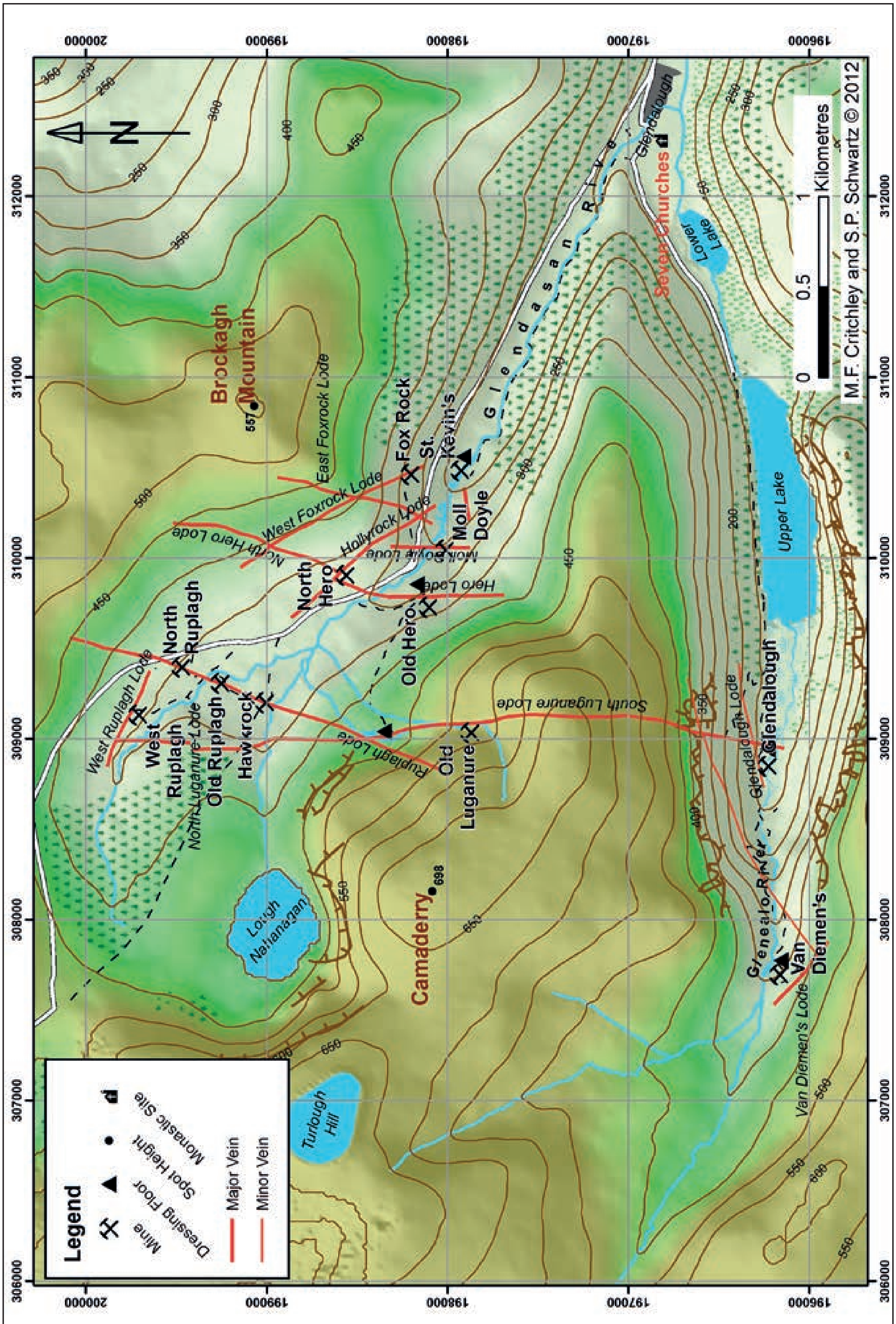
A BRIEF HISTORY OF THE LUGANURE MINES

Current narratives of the Glendalough area in County Wicklow focus almost exclusively on its monastic heritage. Yet, from the thirteenth century the area has been witness to significant industry. This was firstly in the shape of extensive charcoal production to feed iron smelters, a 'smash and grab' operation, particularly in the seventeenth and eighteenth centuries, that laid waste to the landscape by denuding it of its deciduous tree cover. Secondly, and more recently, the area has seen deep lode hard rock mining and mineral processing, firstly by the Mining Company of Ireland (MCI) (Cowman 2007), and then by various enterprises spanning several decades initiated by the Wynne family who purchased the mines and land from the MCI in the late nineteenth century. Industrial activity through the ages has profoundly shaped the geomorphology of this area, yet is a largely neglected narrative.

The Mining Company of Ireland (1824-1891) was set up as a joint stock company of £200,000 divided into 20,000 shares of £10 each (£140,000 issued) and received Royal Assent in July 1824 during the London stock market boom of 1824-25. With its motto, 'Industry, Economy and Perseverance', it was initiated by a group of philanthropic gentlemen and its list of patrons, directors and shareholders read like a roll call of the most eminent Irish landed families, politicians, industrialists and commercial traders for much of the nineteenth century. The MCI were, on the whole, fortunate in their choice of mines, for they managed to select some of the best prospects in the island, including the Slieveardagh Collieries in County Tipperary, the Knockmahon copper mines at Waterford, and the Ballycorus lead mine and smelting works near Dublin. Their Wicklow mines became the richest and most successful lead producers in Ireland, with Hall noting that about 80 per cent of all nineteenth century Irish lead production was accounted for by the Luganure Mines (Hall 1921, 55).

In 1825 the MCI acquired the lead mine and materials of the Glendalough Mine Company. This company had been set up by geologist, Thomas Weaver of Cronebane[1] who is credited with the discovery of the South Luganure Lode which he had commenced working in 1807 (Stephens 1812). Fraser noted in 1801 that a lode of lead had been discovered near the Seven Churches in Glendalough, which is a probable reference to Weaver's activities (Fraser 1801, 14). In June of 1809 Weaver

1 Weaver was a shareholder and resident manager of the Associated Irish Mine Company at Avoca, Co. Wicklow.



Map 1. The Luganure Mines in the valleys of Glendalough and Glendasan showing the location of the main lodes, mines and dressing floors

formed a partnership with the Reverend James Symes of Ballyarthur, Ovoca, and John and/or Peter LaTouche of Bellevue, Delgany (and of the Dublin banking dynasty) to sink mines at 'Glendalough and Shangeen', with a total investment of £1,000, each partner holding twenty shares (PRO Dublin).[2] The Glendalough Mine Company agreed to dispose of their possession to the MCI as a going concern and all materials, ore on hand and machinery were transferred in exchange for 900 shares in the MCI (MC 1825); £4943 5s 4d was paid by the MCI for the Glendalough Royalty and £2375 for the mines and materials.[3] Over the course of the next six decades, the MCI thoroughly explored their mineral sett known collectively as the Luganure Mines, opening workings on lodes in Glendasan, including South Luganure, Ruplagh and West Ruplagh, East and West Fox Rock, Hollyrock, Moll Doyle, Hero and North Hero. In the neighbouring valley of Glendalough, the South Luganure Lode was worked where it continued SW from the Glendasan valley and outcropped high up in the side of the mountain. The Glendalough Lode and those at Van Diemen's Land were also exploited (see Map 1).

The mines attained their zenith in the 1850s and 60s. The price of lead rose sharply in the early 1850s and remained relatively constant (not experiencing the huge peaks and troughs of previous decades) until the 1870s. It was during this period that the workings on both sides of Camaderry were connected by an adit driven through the mountain. Following a decline in the price of lead due to the chill wind of foreign competition from the 1870s onwards, in 1890 the mines and estate of Glendalough were advertised for sale by the MCI and were purchased at auction by Mr Wynne of Ballybrophy for £3,450 (FJ 1890); liquidators were appointed in March 1891 (FJ 1892). The Wynnes, an Irish family of mining engineers and entrepreneurs with mining concerns in Central Europe and North Africa, stated their intention to continue mining and that they did, with varying degrees of success, up until their company (the Wicklow Mining Company Ltd.) set up in 1900, was finally removed from the companies register in 1975.[4] Continually stymied by a lack of capital, workings were on a smaller scale than during the MCI era. It seems that the Wynnes stripped the mines of all merchantable materials such as waterwheels, stamps, crushers, horse whims, tramways, wagons, capstans, flat rods and other machinery before WW1, hence the reason why there is not a good survival of artefacts from the MCI era. At some contemporary remote Welsh lead mines there is good survival of nineteenth century metal artefacts, as it was probably not considered worth the cost of breaking and transporting these to be sold as scrap. By contrast, the majority of the metal artefacts on the Luganure mines date from the Wynne's mid-twentieth century enterprises, which are not the focus of this paper.

The relative success of the MCI's Luganure mines was largely due to the area's geomorphology, the mineral lodes being exposed by the fortuitous effects of glaciation, with the main lode that ran through Camaderry Mountain for example, accessed via cliff face adits. This meant that fewer deep shafts had to be developed, saving on pumping and winding costs.[5] The water escaped freely at the mouths of various adits and the lodestuff was cheaply hauled to the surface along tramways, principally by mules, then transported to the valley floors for processing. Steam power was therefore not deployed by the MCI at Luganure in contrast to many of their other operations in Ireland. Waterpower was recognised early on in major mining areas to be a more effective method of motive power than the use of human or animal power and 'it undoubtedly shaped the landscape and the development of industry throughout the British Isles' (Watts 2000, 5). In common with many lead mines in remote and upland areas of the Pennines, Derbyshire and Wales, extensive use was made of waterpower at the Luganure mines. The water was obtained from the glacial corrie at Lough Nahanagan, source of the Glendasan River, and the Glenealo River that flowed into the Upper Lake in Glendalough. This was delivered via a sophisticated network of reservoirs, leats and weirs to power vertical wheels that could transmit power either through an axle or via a ring gear to drive belts or gears for pumping and winding machinery, stamping mills and a host of other appliances.

Another major factor in the relative success of the Luganure mines lay in the fact that the MCI was a large and wealthy company, able to spread profit and loss across several other mining enterprises in Ireland. A smaller operation would not have withstood the vagaries and fluctuations of the nineteenth century mineral market and periods when the mines proved less productive. A detailed history of these and other Wicklow mines is being prepared and will appear in a future publication entitled, *Mining 'the Garden of Ireland': Wicklow's Metal Mines and Mining Communities* (Schwartz and Critchley, forthcoming).

DRESSING THE LEAD ORE: A HISTORY OF NINETEENTH CENTURY METHODS

Before any ore can be smelted, it has to be dressed to eliminate gangue (waste) material, to remove other uneconomic metallic minerals, separate closely occurring minerals and to reduce it to a proper size.[6] When brought to the surface, broken ore contains material ranging from large lumps to fine particles, but for successful smelting no lumps larger than about four inches (10cm) were normally permitted and for hydro-metallurgical processes, fineness was always necessary, sometimes even complete pulverisation (Truscott 1923, 2-4). The Luganure mines worked low temperature hydrothermal

2 Weaver named 'an old trial at head of Great Ravine on Luganure Vein' as well as an 'old drift' (located above First Adit) on a plan dated 1814, strongly suggesting that these workings predate his activity in the valley and are thus eighteenth century or earlier in derivation.

3 Terms vary. The MCI report of 1825 states that they had bought out an unnamed company for £826 /4/3, 798 shares, 30 tons of ore and mine materials.

4 The St Kevin's Lead and Zinc Company that mined Foxrock in the late 1950s was a Canadian subsidiary of the Wicklow Mining Company Ltd.

5 There were shafts pumped by flat rods run off water wheels at Old Hero, North Mine, Hawk Rock and Moll Doyle (Glendasan) and Ennis' Shaft (Van Diemen's Land), while horse whims were also used on some of the shafts.

6 Also of importance is the regular character of the lead concentrate passing through a particular dressing floor that was supplied to a smelter. The regular mechanical and chemical nature of the concentrate meant that in the provision of flux, the margin of safety could be substantially reduced and the charges therefore made up more economically.

lode deposits that formed in fractures in the host rocks (granite) by crystallisation from metal-rich brines during the late phase emplacement of the granite. The most common lead bearing mineral is galena[7] (lead sulphide), bound up primarily in a quartz gangue, and there are varying quantities of sphalerite (zinc sulphide) and chalcopyrite (copper sulphide) present in the two valleys (see Moreton and Green 2007 for details of the supergene minerals present).

The Luganure lead ore is also argentiferous, Jukes and Du Noyer (1869) noting that the galena from the Luganure Lode yielded about 11 oz of silver per ton after dressing, although a sample of the Mineral Statistics for 1862 and 1867 only indicate 6-7 oz per ton of concentrates. This was not particularly rich, as Kilbricken (County Clare) ores contained 120 oz per ton and Shallee (County Tipperary) 25 oz per ton (Homans 1860, 1090). Indeed, dressed ore containing over 30 oz of silver per ton, or about 0.1%, was considered valuable (Hall 1921, 3). The silver in the Luganure galena may present itself as isomorphous sulphide (Ag_2S) within the crystalline matrix of galena, or a discrete silver-bearing mineral such as argentite, stephanite or native silver. In the former case, the loss of silver in the dressing process is proportionate to the loss of lead, but in the latter, the loss of silver greatly exceeds that of lead as it is finer to begin with and much lighter and more brittle, so that it is driven into the finest slime and easily carried away on the surface of water. Silver was extracted at the Ballycorus smelting works near Dublin (Normoyle 2006) by the Pattison Process.[8] Ore from disseminated lead deposits may contain as little as 3-4 per cent of lead, but smelting was rarely undertaken upon material containing 10 per cent or less metallic lead, as this would not permit the proper collection of the silver generally present. Although it is difficult to ascertain the lead content acceptable to nineteenth century smelters as marketing conditions varied enormously, reverberatory furnaces commonly processed lead concentrate with a metallic content averaging 40-60 per cent and occasionally demanded that this be over 70 per cent (Truscott 1923, 2-4). Concentrate averaging 60-75 per cent metal was processed at the MCI's Ballycorus smelter in the years 1850-1880 (calculated from the Mineral Statistics).[9]

It is impossible to understand or to interpret the form and function of nineteenth century dressing floors with little or limited knowledge of ore dressing techniques or the machinery employed. This section therefore provides a brief synopsis of the main methods of nineteenth century lead ore dressing and discusses most of the key types of equipment that were in use at British and Irish mines. Although regional differences occurred in the type and layout of machinery used for dressing the ore, the basic mechanism for separating the ore from its waste matrix or 'gangue' was universal: the gradual reduction of the ore into particles of similar size which could be washed or settled out in water according to their specific gravity. For galena this was 7.2-7.7 and for quartz, 2.5-2.8. The process could not be achieved in one simple stage, hence the different apparatus for settling out the ore from its gangue in various successive settling operations. Key to successful concentration was not to grind brittle ores like copper and lead too finely at the very start of the process, for two reasons. Firstly, irregular sized particles prevented separation by specific gravity, meaning a lot of fines escaped. Secondly, the treatment of fines required more labour and time and hence was more costly, thereby reducing profit margins. Throughout the nineteenth century, ways were sought to improve the efficiency of ore dressing to eliminate waste, speed up throughput, save labour and increase profitability. Many improvements resulted from the introduction of innovative machinery.

In order to prepare it for smelting, the ore passed through five general phases of treatment which are detailed below.

1) ***Sorting***. Lodestuff was roughly sorted underground by the tributers who had mined it to avoid having to transport unwanted gangue materials to the surface. Although this task was performed by candle light, tributers were very adept at selecting only the best ore (often by judging its weight) as they usually had to pay for its transport to the surface either via kibble up a shaft, or by tram to an adit mouth. 'Deads' (waste rocks) were stacked onto platforms in stoped out sections of the mine. On many lead mines the mined ore when brought to the surface was stored in a 'bouse team' (from 'bouse' the northern England dialect word for ore), also known as an ore bin or hopper, prior to being washed.

2) ***Washing***. The ore fragments had to be cleansed of mud to reveal the ore before any processing could commence. On arrival at the surface the very largest lumps of ore were usually 'ragged' by use of a 10 lb sledge hammer to reduce them in size. The next stage of the operation was termed 'grating' which washed, sized and sorted the ore. In its crudest fashion, this was achieved by use of a series of riddles (large sieves with various sized meshes) into which the ore was placed and then agitated violently in water to separate the ore from the gangue and to size it. Ore dressers soon became very adept at picking out the valuable mineral by its specific colour, lustre, appearance and weight. 'Prills' (lumps) of pure galena were easily separated on the sieves, crushed to a proper size and 'sent to pile' (ready for smelting). Larger pieces were washed in a rectangular buddle, a simple declivity in the ground and the metalliferous mud was caught in a slime or 'slitch' pit for settling out and further treatment. After grating, the ores would have been sorted into four lots:

- 'deads' containing little or no ore that was thrown away on spoil heaps
- 'drage', ore mixed with gangue that required hand sorting
- 'halvans', poorer ore that required crushing
- 'prills', pure lumps of ore requiring no further processing

7 Galena is often well crystallised and freshly cleaved specimens exhibit a strong metallic lustre, which tarnishes over time.

8 The Pattison process extracted silver by crystallisation at a different temperature than lead. It was only the fact that the MCI was mining large tonnages of lead at their Wicklow mines that made it worthwhile to process the fines and to extract the silver at the smelter (FJ 1853) and in 1859 it was reported to the MCI shareholders that the extraction of silver at the Ballycorus works was 'a very valuable adjunct to the Luganure Mines' (FJ 1859)

9 Galena (lead sulphide) contains no more than 86 per cent metallic lead.

Figure 1. Grating lead ore in the North-East Pennines c.1805-1820. Reproduced with kind permission of the Science Museum

On some mines in Britain, such as those in Cardiganshire (Ceredigion), Wales, the washing of the ore became a fully integrated part of the 'bouse team' (Palmer and Neaverson 1989) with a large grate of parallel iron bars spaced about half an inch apart located directly below it, at the end of which was a wooden board or slide (Figure 1). The ore was washed in a strong current of water and raked over on the grate. Small fragments fell through into a pit below and the remainder was drawn onto the picking board and sorted (Forster 1883, 175). The largest pieces of mixed ore requiring reduction were sent to the spallers and cobbers, the gangue fragments thrown away, the prills 'sent to pile' (ready for smelting) and the contents of the pit and smaller fragments of mixed ore were sent to the crusher. Later, this first stage of the dressing process was mechanised by the introduction of a wash kiln that included a built in trommel (see below) to classify the ore. These were highly popular on smaller Welsh lead mines and ensured a rapid and more even through put and processing of ore.

3) ***Reduction***. Prior to mechanisation, hand labour was employed on 'drage' by 'spalling' 'cobbing' and 'bucking' (terms acquired from the Cornish mines) undertaken on a flat dressing area that was cobbled to provide a firm striking surface; the extensive cobbled dressing floors at the South Caradon copper mine in Cornwall are an excellent example. Spalling was undertaken using a 6 lb sledge hammer to reduce the ore to fist sized lumps. These were then cobbed, using a chisel edged hammer weighing some 3 lbs to chip the ore away from its waste matrix on an anvil. 'Bucking', performed with a flat headed square hammer on an anvil or 'buck stone', reduced the ore to a gravel like consistency ready for classification. Depending on the mineral being processed, the reduction process could have been completely mechanised by means of a stone breaker, rolls crusher and stamps.

The stone breaker was invented in the United States in 1858 by Eli W. Blake. Lodestuff was fed into a crushing hopper and broken between a pair of iron jaws, one being fixed, the other actuated by knee-joint levers, to the size of road-metal. The jaws were operated by a belt drive powered by a waterwheel or steam engine. The rolls crusher were the brainchild of mining doyen, John Taylor. In 1796 he built an improvised set at Wheal Friendship, near Tavistock in Devon, on an occasion when the surface workers struck and in 1806 an improved version was installed at nearby Wheal Crowndale (Collins 1912, 268). Dubbed 'Cornish rolls', this type of crusher soon found its way on to numerous mines in Cornwall and

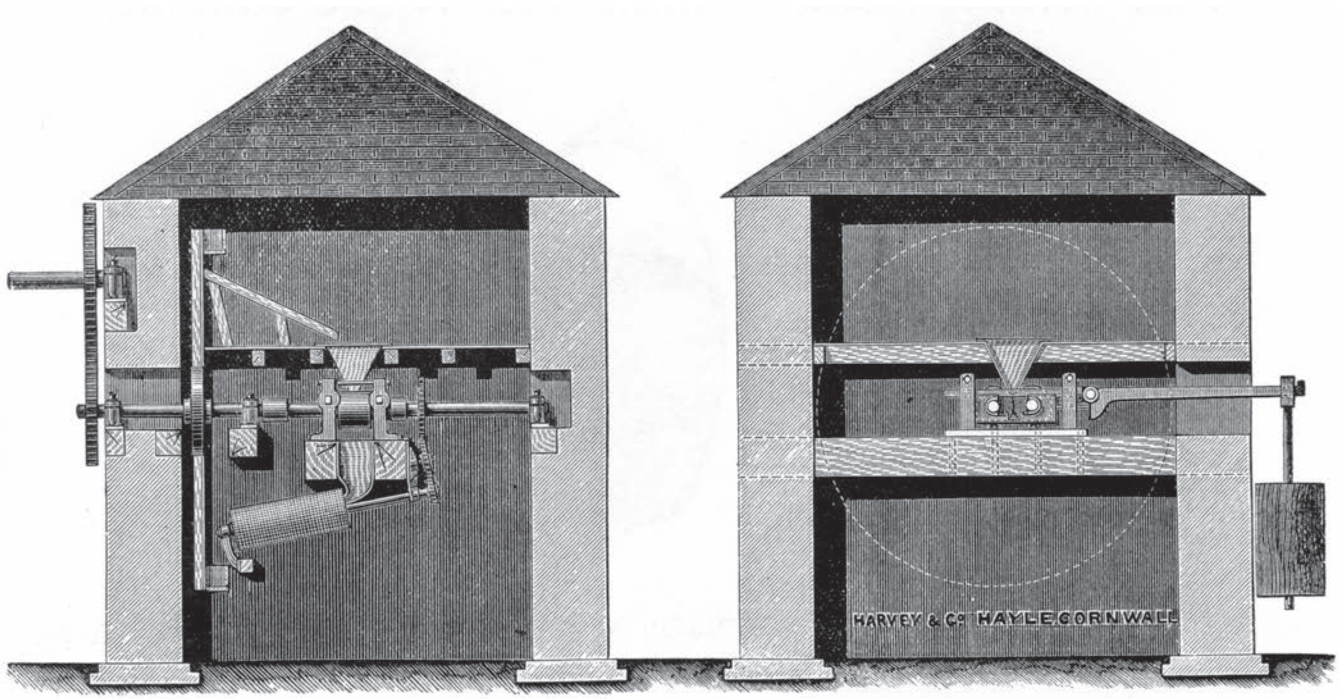


Figure 2. Cornish rolls crusher accommodated in a two storey house similar in design to those installed at the Luganure Mines. Note the triangular ore hopper in the top storey, the trommel in the bottom storey (left) and weights suspended outside the building to provide tension for the rollers (Barton n/d)

elsewhere, superseding the upright cylinder stone crushers known in the Americas as 'Chilean mills' that were, for example, widely employed on the Peak District mines. These consisted of a large stone pivoted by a horizontal axle to a rotating vertical wooden centre post drawn around by human or animal power, the ore to be crushed laid in the path of the stone (Burt 1982, 21). Cornish rolls performed medium sized crushing and were very effective on brittle minerals like lead and copper; importantly, they replaced the need for bucking, a largely female task, and were thus labour saving.[10] They required about 10-20 hp and could handle about 4-8 tons of stuff per hour (Truscott 1923, 57). Those powered by a waterwheel were usually accommodated in a two or three storied building, sturdily built to resist the vibrations of the machinery (Figure 2).

The apparatus consisted of a pair of iron cylinders sheathed with chilled cast iron 'tyres' placed horizontally and nearly in contact and that were connected together by spur wheels of equal diameter, so that surfaces revolved towards each other with equal velocities. In earlier models, the two wheels were not geared together and motion was given to just one of the rollers, either by steam or waterwheel, allowing it to be moved round by the friction of the material against it. Experience proved it was better to gear both rollers and in later designs, one roll revolved in fixed bearings, the other in a moveable bearing-and-bracket assembly held in position by compression (Lynch and Rowland 2005, 60). The diameter of the rolls varied from 13-34-inch and the length or breadth of face from 12-24-inch (Lock 1890, 314). In the early models weights regulated pressure and thus controlled the size of the crushed material passing through the rollers and were suspended on the end of long levers that often projected outside the building through slots in the wall, while some designs accommodated the weights inside the house; later models used springs to regulate pressure on the rolls.

Ore was fed into a hopper in the upper storey where it fell through onto the rolls to be crushed to a fine gravel and then passed into an inclined revolving cylindrical sieve named a trommel, sited below the rolls on the lower storey. The finer fragments of ore passed through the screen of the trommel, but fragments not crushed small enough passed along the trommel to be lifted up via a Raff wheel into the hopper again to be re-crushed. The early crushers could only process lodestuff already reduced by hand labour/stone breaker and much larger machines with multiple rollers were later devised to ensure a more efficient through-put of ore and a more evenly sized product able to process the lodestuff direct from the washing floor. Cornish rolls came to be regarded as the best constructed and the most efficient in operation and resulted in the least fines to be lost during subsequent treatment.

Cornish stamps (Figure 3) were widely employed on British tin mines where the finely disseminated cassiterite had to be pulverised to liberate it from its gangue matrix and on copper mines where the ore was bound up in hard quartz gangue, but they were less common on lead mines. In 1778 it was recommended that lead ore ought to be 'bucked and jigged, and very seldom carried to the strêke, or stamps, except when it be very scarce and thin in the stone; but when it is so poor as to make bucking and jigging improper and costly, then it is scarce worth the trouble of stamping…' (Pryce 1778, 243). Stamps were mainly used in the nineteenth century for crushing 'halvans' or poorer ores and the 'chats' from jigging

10 They were initially resisted on many Cornish mines for putting women out of work (Schwartz 2000).

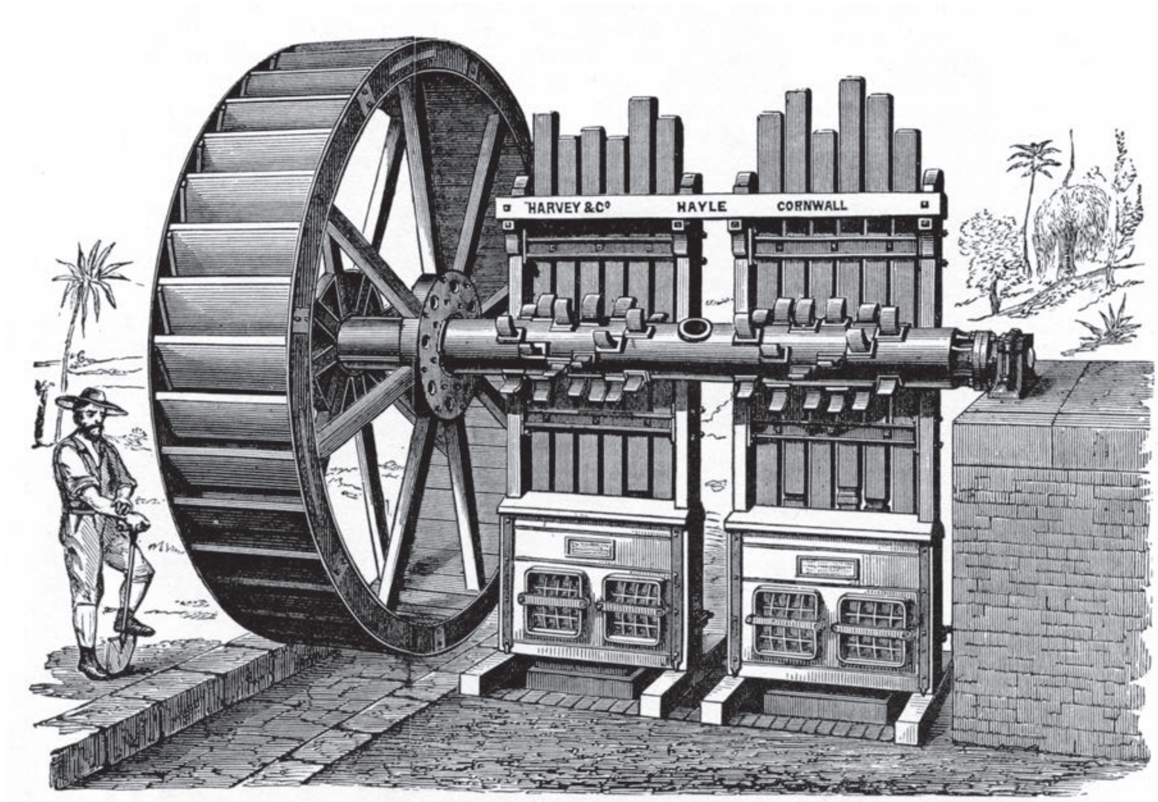


Figure 3. Twelve head of Cornish stamps manufactured by Harvey's of Hayle, Cornwall, and driven by a waterwheel, similar in design to those in use at the Luganure Mines (Barton n/d)

operations. Among nineteenth century lead mines in Cornwall and Devon using stamps were East Tamar, Herodsfoot, New Crow Hill, Redmoor, Tamar Silver Lead Mine, Wheal Exmouth, Wheal Mary Ann, Wheal Penrose and Wheal Trelawney. Some of the Cardiganshire mines also employed stamps for the same purpose, for example the John Taylor run Frongoch and Goginan mines and they were also used at his Grassington mine in Yorkshire. The London Lead Company sometimes used stamps for dressing ore in addition to re-treating slags at smelting mills. Ure (1866, 41) notes that those around Alston Moor were water powered. However, many of the large lead mines in the north of England relied on Cornish rolls for re-crushing rather than stamps, such as the Derwent Mines but also the Laxey Mine in the Isle of Man.

The Cornish stamps comprised a number of huge pestles or 'stems' of wood with iron heads supported vertically in a heavy framework of wood. The heads normally weighed between 200-300 kg each, were commonly arranged in sets of 4-6 and each head could deliver 50-60 blows per minute, although 40-50 was more common. Fixed to the upper part of the stem was a 'tappet' which engaged a 'cam' attached to a horizontal shaft or 'barrel' powered by a water wheel (five cams per stamp head). As the barrel rotated, the cam lifted the stem upward (via the tappet); as the cam disengaged the stem and head fell back under its own weight to pulverise the ore placed beneath. Cam-lifted stamps were limited by the speed at which they could run, but were well suited to water power. The ore was fed into the 'mortar', essentially a box into which a flow of water was directed and which had an opening at the back to receive the ore. This was passed from a hopper above down an inclined plane of wooden planks. The mortar box had a perforated metal screen at the front. This specially fabricated metal screen was of sheet iron (sometimes copper) in which a series of holes were punched and which was held in a plate of cast iron with a central rectangular opening for the screen which could be replaced once worn away by the action of sands or acid water. The size of the screen varied and was dependent on the type of ore being processed and how fine it was to be pulverised. The perforations for lead stamping were generally larger than those for copper and certainly much larger than for tin, the holes of which were usually less than 1 mm in diameter (Moissenet 1858, 83-84). As the ore was pulverised, particles of ground ore splashed against the perforated screen which in effect sieved them.

The muddy sands passed out through the perforated screen down a discharge plank (a board down which the stamped material ran to be deposited according to its specific gravity in strips or sometimes a dumb buddle). Depending on the nature of the ground, the base of the mortar boxes were constructed of fragments of very hard quartzose schist of various sizes with finer gravel on top which was packed within a square wooden frame. Upon installation, stamping was undertaken for some four to five hours using killas (metamorphosed slates) which turned to a clay like substance filling the voids between the quartzose fragments. Iron filings and urine were sometimes added to the clay like mixture to bind the whole together to form a permanent solid base for the stamp heads.

4) ***Classification***. This was necessary to sort the ore into particles of similar size which could be washed or settled out in water according to their specific gravity. Methods of classification remained fairly primitive throughout the

nineteenth century (Palmer and Neaverson 1989, 24). The largest particles of ore (1.4 mm to around 50 mm) could be graded relatively easily using simple sieving techniques. However, smaller sands and slimes, resisting such simple sieving techniques, required complex classifying devices on the principle of differential suspension in water.

Manual methods of classifying large crushed material included the use of flat bottomed sieves and a trommel. The former, simple hand held circular sieves known as 'riddles', were 18-20 inches wide and 6 inches deep with variable sized meshes of copper or iron wire held together by a hoop of oak. These enabled the crudest method of classification and were in use throughout the nineteenth century, especially on smaller mines. Riddles were later replaced by flat sieves mounted in a vertical series and operated by a central rod on larger mines. More common was the revolving trommel, usually constructed of perforated iron or copper sheet. At first these were hand operated and of a single gauge, the lodestuff being carried from one to another of these devices with a finer screen. These simple hand operated devices were very well suited for the preliminary sizing of coarser ground copper and lead ores. Later trommels were mechanised and contained mesh of various sizes to classify the lodestuff and could be up to twenty feet in length.

The simplest method to classify finely crushed material was in a series of classifying pits of increasing dimensions and decreasing inclination on an almost horizontal floor. Water flowed rapidly through the first pit and then, by a process of overspill passed more slowly into succeeding pits which increased in size. The coarser, heavy grained stuff was deposited in the first pit and the lighter material was carried to succeeding pits where the rate of flow and agitation of the water was reduced. A further degree of separation was achieved within each pit as the heavier metallic particles sank to the bottom while the sludge and the lighter gangue remained on top. Classification pits had their drawbacks, as they were very labour intensive, took up a lot of space and they had to be periodically stopped to drain them and dig out the accumulated stuff, causing an interruption to the crushing operations. Yet, some smaller British lead mines continued to use a system of settling tanks well into the late nineteenth century. Labour and space saving fine classifiers such as the partially mechanised pyramidal trough and cone classifiers were later refinements.

5) ***Concentration***. Separation and concentration of classified larger fragments of lodestuff was effected by 'jigging', while the finer materials were treated in a variety of buddles. These processes were highly labour intensive during the nineteenth century and many were gradually mechanised to speed up through-put, save labour and eliminate waste. Crushed ore was jigged to enable pieces of ore and gangue to be successfully separated by maximising the differences in specific gravity. The crudest and cheapest form of jigging was by using a hand held sieve similar to that used for sizing. Made of a circular hoop of oak with a wire mesh bottom, these measured 18-20 inches in diameter and were about 6 inches deep. The sieve was filled with a mixture of lodestuff and then violently agitated in water, held either in a tub or a simple vat in the ground. The heavier pieces of ore accumulated in the bottom of the sieve, the mixed ore and gangue in the middle and the sterile upper layer of quartz gangue rose to the top. The sieve was periodically lifted out of the water and the gangue scraped off with a 'limp' (a half moon shaped iron shovel). The middle layer invariably contained small bits of galena mixed with gangue and so they were either put aside for further crushing, either by hand or in a stamping mill and then reclassified.

The succeeding separation was again conducted in the jig or in a buddle, depending on the size of the material obtained. The concentration of fat ore in the bottom of the sieve could be removed, but often it was left in the sieve and mixed slimes that had fallen through the sieve and collected in the drained vat were scooped onto the top layer of ore in the sieve. The vat was filled with fresh water and the layer of ore acted as a filter, allowing only the heaviest metalliferous particles to pass through into the vat. The gangue was trapped at the top allowing it to be removed with a limp. This was either thrown away as waste, or sent as 'buddler's offal' for further washing, while the heaviest particles that had sunk to the bottom of the vat were processed by buddling. Water and metalliferous sludge was swirled round to encourage the lighter particles to rise to the top where they could be tipped away or sent for further processing in a buddle.

This application was the precursor to the kieve or 'dolly tub', a deep cylindrical wooden tub some three feet eight inches in diameter that was used to re-treat the finest slimes from jigs or buddles by a process known as 'tozing' (tossing). The kieve was almost half filled with water and shovelfuls of material were slowly introduced down either side. The contents were constantly stirred with a shovel in a circular motion until the water rose to within around two inches of the top of the tub. The contents were then 'packed', a simple process which took anywhere between 15 minutes to one hour whereby the side of the kieve was steadily thumped by an iron bumping-bar to aid the subsidence of the heavier metalliferous particles. When the packing was completed, the water was siphoned off into a nearby kieve, the top sand skimmed off and sent to be buddled and the fat ore that had sunk to the bottom shovelled out and sent to pile for smelting. Kieves were easily mechanised by

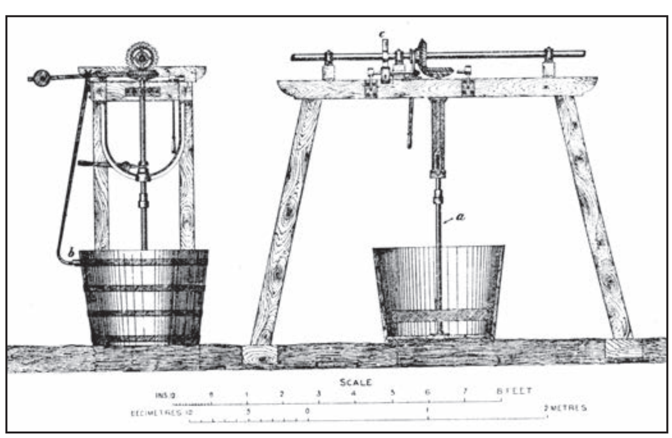


Figure 4. A mechanised kieve or 'dolly tub' used for concentrating fine slimes

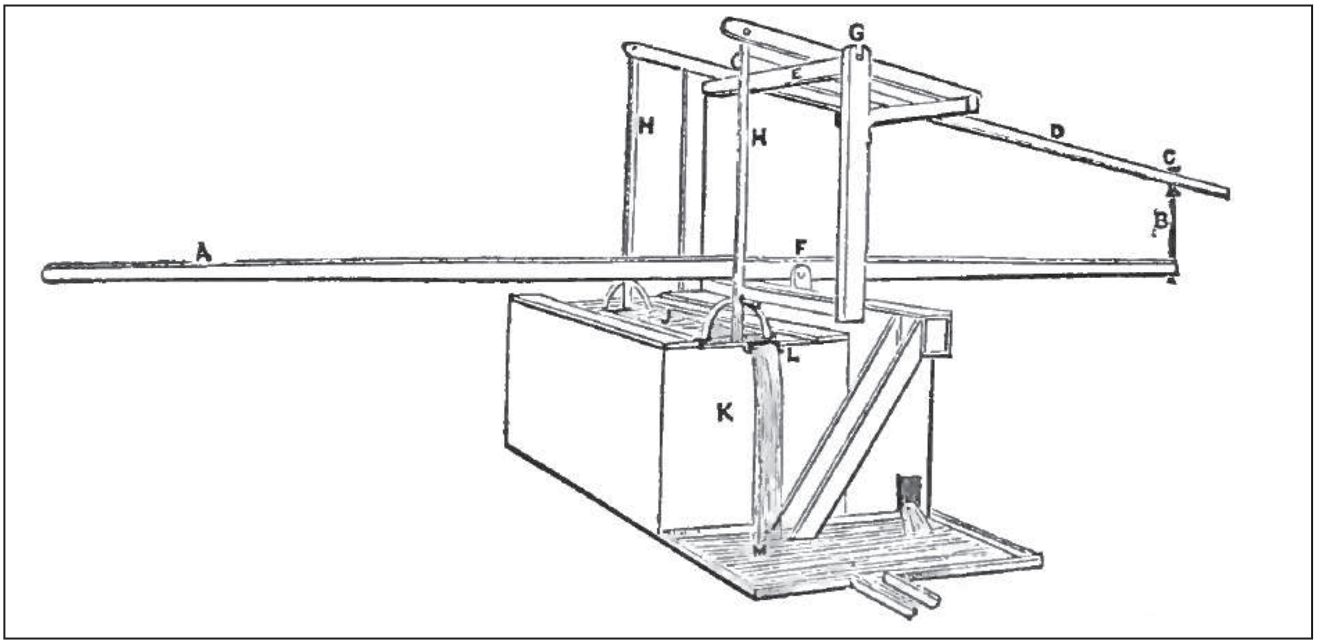


Figure 5. A hand operated brake jig. The brake jig was operated by a wooden lever (A) having its axis at (F). A piece of wrought iron (B) is attached to the end of lever (A) and its upper end passes freely through a slot opening in lever (D) with two shoulder projections (C). (E) is the axis of lever (D) and (G) the framework connected with it and that support the iron rods (H) attached to the rectangular sieve (J). (K) is the hutch or tub which forms the cistern for the sieve, from which a chute (L) for the overflow water protrudes. The fines are collected in a slitch pit (M) as well as receiving ore from the hutch. The apparatus was set in motion by simply jerking lever (A) up and down

installing a central vertical shaft with stirring blades like those of a propeller at the bottom, operated by a crankshaft run from a waterwheel or engine (Figure 4). Wooden mallets worked by machinery driven by water or steam power were also installed to speed up the packing process and to obviate the need for manual labour (Henderson 1858).

Jigging boxes or 'hutches' were of many different designs, introduced to maintain a constant through-put of ore and were the main method of separating those ores that were less finely reduced, such as lead and copper. They operated on the simple law that when two bodies of equal volume and of different specific gravities are dropped at the same instant from the same height into a volume of water, the one of the greater weight will sink faster than the other, leaving it behind, and arriving first at the bottom (Davies 1902, 291). The simplest design, the brake jig, comprised the traditional hand sieve in a square wooden frame attached to a simple overhead lever mounted on two fixed supports on either side of the sieve that was suspended above a tub of water (Figure 5). Reconstructed examples can be seen at the Killhope lead mine in the North Pennines and the Minera lead mine at Wrexham, Wales. The operator simply jerked the lever up and down to immerse the sieve in the water. Clean water entered the bottom of the hutch via a square pipe and momentarily lifted the particles of ore and gangue, while the muddy waste was carried off through a similar pipe fitted with discharging apertures at the opposite side of the tub (Lock 1890, 340). Small fragments of galena fell through the sieve, the larger prices becoming trapped on the mesh, while the lighter gangue rose to the top allowing a workman to skim this off with a 'limp'. The top skimmings were discarded to the spoil heaps, the middle skimmings containing mixed ore and gangue were left on the sieve with the crop ore and were re-jigged with a charge of new material. The process was continued until sufficient separation of the ore from the gangue was made. The middlings or 'chats', were sent to the stamps, the crop ore sent to pile and the metalliferous slimes that collected in the jigging tubs were dug out and, if rich enough, sent to pile, or if not sufficiently cleansed of impurities, treated by buddles. The fines carried off in the discharge water were settled out in tanks.

The first mechanised brake jiggers were introduced at the Duke of Devonshire's Grassington Moor lead mine in Yorkshire by Cornishman, Captain John Barratt. These were worked by a small waterwheel and were deemed more efficient in terms of labour and quality of ore obtained than that achieved by manual operations. Their introduction marked the rapid diffusion of the mechanical sieve and trommel classifiers to feed the jigs with accurately classified material. In 1828, Captain Thomas Petherick of Fowey Consols Mine in Cornwall (Lewis 1997, 38-41), set about developing a mechanised hydraulic jig (QMR 1832; SM, 1834). 'Petherick's Separator' kept the sieve stationary but moved the water up and down in the hutch by means of a plunger operated by a rod activated by a rocking beam run by a crank on a flywheel that was easily driven by a waterwheel. The hutch was filled with water to a point just below a lid that covered it and that contained circular holes to accommodate up to eight sieves filled with material to be dressed; the bottom of the sieve was suspended just above water level (Hunt 1864, 852-3). The sieves were simply replaced when layered, a less arduous task for the boys previously employed at manual hutches. Petherick patented his Separator in 1830 (with a further patent following modifications in 1832) that produced a higher quality product at a reduced labour cost (The Penny Cyclopaedia 1839, 245).

It is tempting to speculate that the MCI might have used 'Petherick's hutches' at their mines, as he was the elder brother of John and William, both MCI mine captains. Later inventions included continual jiggers which built on the design of Petherick's separator making use of multiple sieves of different mesh, but all continued to employ the basic techniques first developed in the manual jigging hutch. Further modifications and improvements resulted in later pneumatic jigging hutches in which pulses of water were generated by compressed air.

Buddles, an ancient device used to concentrate sands and metalliferous slimes by using the difference in specific gravity of ore and gangue, retained their popularity as a relatively cheap and effective method of concentration throughout the nineteenth century at most lead mines in Britain and Ireland. Buddles came in a variety of shapes and forms, but one of the most common was the trunking or square buddle (also known as the hand buddle), reputed to be one of the most effective of all the early buddles. It was a rectangular box of varying dimensions and capacity sunk below ground level, with the lower side being flush with the surface, the floor having a definite slope. A hopper was erected at the top end into which material was thrown by shovel and constantly washed out by a strong stream of water on to a triangular inclined plane fitted with strips in a fan-shape that distributed the material. The spaces between the strips acted as channels where the feed material split up and formed a flowing coating, the same width as the buddle. This was then evenly distributed by falling on to a small, narrow sloping board the same width as the buddle.

Alternatively, a large 'jagging' board was placed at the head of the buddle onto which sands were placed directly and down over which water was directed. An ore dresser would constantly make small channels, parallel to the axis of the buddle, in the material with the edge of his shovel to aid flow and distribution. A boy was also employed to work the buddle to ensure that the deposits formed a level inclined plane, usually with the aid of a long handled broom. Material was divided into the head, fore-middle head, hind middle head and tail (Henderson 1858). The water carrying fine slimes escaped from the lower end of the buddle through holes pierced in the 'tailboard' a wooden partition which formed the foot of the buddle. Plugs were placed in these holes in the tailboard as the level of deposited material grew. An underground launder carried away the waste water (Moissenet 1858, 28). The rich heads were usually sent to kieves for tozing.

A running or nicking buddle was somewhat similar in design to the lower half of the trunking buddle, the main differences being that a trunking buddle employed a slightly inclined board at the head of the trough making it easier to brush or rake the ore against the flow of water and the running buddle had no pit, but was set into the ground and lined with a stone or wooden floor. The running buddle was used to further concentrate the clean ore from the trunking process; by reworking the various grades of material several times by brushing the material against the current of water, a very effective cleaning of the ore was effected with little loss of ore with the gangue. Most large mines would have employed separate running buddles so the trunking buddles could be kept fully employed.

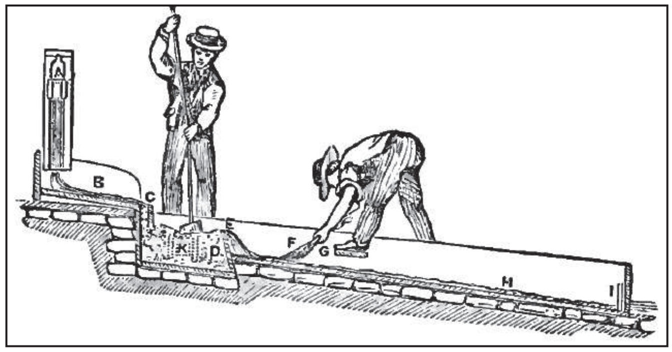


Figure 6. The tye was often used for cleaning hutchwork. An inflow of water (A) flows into the head of the tye (B) and down over a partition board (C). The stuff is introduced into a cistern (D) and flows down over the inclined front (E) and is agitated by a broom (F). Heads are deposited between (E) and (G), middlings from (G) to (H) and the tailings at (I)

Tyes comprised a large wooden channel which incorporated a strong head of water (Figure 6). Into this flow a workman slowly added shovelfuls of material. The heavy particles settled at the head of the channel and deposition was aided by working the material with a shovel or broom. A box that was deeper and larger than the wooden channel caused the material to slow down which aided separation of the ore. A workman constantly agitated the material in the box, periodically removing the roughs (poor coarse sands) that were retreated in a separate channel. Gangue and slimes were carried to the tail of the tye and run off into slime pits. These tanks, usually rectangular in shape, were about 8-10 yards long, one yard in breadth and about 2-3 feet deep. At one end, a small opening close to the top allowed the water to discharge and the heavier slime to settle in the bottom. When one tank was full, the muddy water was turned into the other one and the accumulated material dug out and sent to the buddles for separation (Forster 1883, 177). Tyes were gradually replaced by round buddles.

Strips were commonly used to treat the sands coming off the Cornish stamps. Along the front of the stamp battery was planking about one metre wide, laid either perpendicular or parallel to the stamps axle. The stamped material ran off into these strips, one half of which received material while the other half was dug out. Movable stops fed the sands alternatively to each half. Some of the strips were uniform in length (about 10 metres) while some were interrupted by a couple of drops in height to produce an effect of several strips laid end to end. At the lowest end, vertical partitions containing two slots into which a cross piece was placed created a moveable stop that raised the level of deposited material in the strip. Water and slimes ran over the top of this and were channelled into a launder and run into a slimes pit. The strips separated out material into three broad grades: crop sands or 'heads' of fine enriched material; 'middlings' that were less rich, and 'tails', larger grained material often mixed with slimes. Crop sands from the strips sometimes passed directly to a square buddle for further processing. Alternatively, the three different grades of sands could be treated in round buddles and there were often three of these to allow for the rotating of treatments (Moissenet 1858, 29).

Mechanisation of the trunking buddle came early in the nineteenth century with the introduction of the knife and then impeller buddles. These were fitted with paddles and knives often powered by a crank run off a stamps waterwheel, or by an independent waterwheel. Knife buddles were employed in many of the Welsh lead mines. In the impeller buddle, a rotating cylinder with projecting blades was placed obliquely across the buddle board which was slightly curved to accommodate the rotating action of the knives. As the material fed in at one end gradually traversed the length of the board by the propelling action of the knives, a highly efficient separation of the ore was effected.

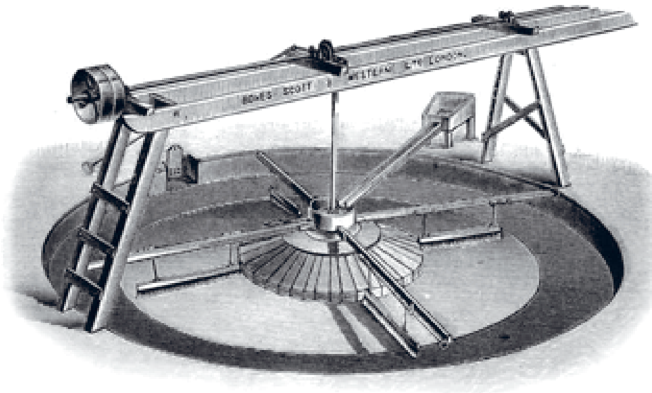


Figure 7. A convex circular buddle used for concentrating sands

Mechanised circular buddles marked a new approach to dressing sands and slimes. They were particularly prevalent on Cornish tin mines where the lodestuff was finely pulverised to release the cassiterite. Insufficiently washed ore was mixed with water and fed onto a convex buddle, one of the most common types of buddle also known as a 'centre head' buddle, so-called because it had a centre cone of wood or cast iron that supported a bearing that turned a vertical iron shaft powered by a drive shaft run from a stamps waterwheel or steam engine (Figure 7). The ore slurry was fed in at the centre of the buddle via a wooden launder to a sheet metal box with sides that reached just below the top of the central cone. The box had a series of perforations in its base through which the slurry passed onto the sloping surface of the buddle. Known from at least the 1820s, these circular pits employed rotating brushes (often made of heather) suspended by cords attached to two wooden arms anchored into two metal crosspieces projecting from the feed box. The brushes spread the ore to avoid channels being formed by the flowing water and moved at right angles to the run of the water, which was radially down slope. The brooms were gradually raised as the buddle filled up. Gravity graded the slurry, leaving the heavier and richest ore nearest the centre. Surplus water flowed out of the buddle through a vertical slot in the outer rim containing a button hole launder that led to channels for the discharge of excess water. When the buddle was full of sediment, it was emptied by hand digging in concentric sections: the ore concentrate lying nearest the centre sent to pile, the waste at the outer circumference discarded and the mixed grades between reworked. Early examples had cobbles or wooden decking in the pit and later built ones were cement faced on concrete. The finer the sand/slimes, the larger the buddle was, with the sizes ranging from fourteen feet to twenty five feet.

The concave buddle was often used to concentrate the heads from convex buddles or very fine ore mixed with considerable amounts of gangue. The main difference between a convex and a concave buddle was that in the latter the conical table sloped upwards from the centre to the sides and material was discharged by pipes around the circumference of the buddle. Revolving brushes prevented water channels forming and the stuff flowed evenly towards the centre to a discharge point. The speed of the material increased towards the centre and this apparatus was therefore considered better at carrying away large amounts of lighter gangue. Round buddles were far more efficient than square buddles in that they were virtually self acting and thus labour saving.

The round frame, the bowl of which rotated, was invented in Germany in the eighteenth century and much improved in Cornwall and the NE of England. It was a free standing piece of equipment constructed of wood and either concave, with the bed sloping inward from the periphery, or convex, with the bed sloping outward from the centre. Both types were supported on an umbrella framework radiating from a central spindle that powered the device, generally from a worm drive from above but often by bevel gearing, and did not require a great deal of power which could have been generated by water or steam. The ore pulp was distributed via an annular peripheral launder to about 75 per cent of the deck that revolved at about 15 revolutions per hour. As the pulp flowed across the deck, the heaviest particles settled whilst the lighter material was carried to an annular tailings launder. Brushes were employed to ensure an even distribution of the material but small jets of water were used to separate the different grades of deposited material. The whole process was continuous with a capacity to treat between 5 and 10 tonnes of fine ore a day, grading it into three fractions: heads, middlings and tails, which were discharged into separate launders. Dressing operations therefore did not need to be interrupted while a buddle was dug out, thus ensuring a more efficient throughput of ore. Round frames saved on labour costs, took up less space and much less ore went to waste.

Other mechanised versions of concentrating sands and slimes included shaking tables and the frue vanner that steadily began to replace buddles and round frames. By the mid-twentieth century shaking tables had largely replaced vanners, to become the preferred method for the gravity separation of fine sands. The application of a repetitive 'bump' to a bed of ore particles and water on a sloping surface, as an aid to separation and retention, was well established on German lead and copper mines in the very early nineteenth century. Shaking tables were also in use on British lead mines from at least the mid-nineteenth century and probably earlier, for example, they were introduced at the Tamar Silver-Lead Mine (also known as Tamar Consols), Bere Alston, Devon, in May 1844 by Percival Norton Johnson and at Treweatha lead mine, near Menheniot, Cornwall, in the 1860's. The first tables were actually imported from Germany, but a model was known to have existed in the Royal Geological Society of Cornwall's Museum at Penzance in 1824, and possibly even in 1816 (Schwartz 2000, 95). An early type of 'bumping table' was also reported as being designed by Robert Stagg and in use at the Nenthead lead mines in 1828. But the design of the first continuously operating shaking table, in 1857, is widely credited to the pioneering Austrian mineral processor, Peter von Rittinger (1811-1872).

Shaking tables performed a continuous separation on minerals of differing specific gravity by moving a mixture of particles in water forwards along an elongated sideways sloping deck surface rectangular or trapezoid in shape, and usually fitted with a series of tapering parallel ridges or 'riffles'. The table was supported from beneath on flexible bearers so that it could be shaken back and forth in the direction of the riffles. Feed ore particles and water were introduced at the upper back end of the table. A repeating end bump mechanism caused the particles to move forward while the 'riffles' on the deck surface held particles on the table in a layer, hindering them from moving too quickly sideways ('downhill') in the water flow. Shuffling by the bumping motion also encouraged the heavier ore particles to settle to the bottom of the mineral layer while an additional, gentle sideways flow of wash water naturally carried lighter materials further down the slope than the heavier ones. Compartmented troughs with movable collecting trays were positioned beneath the opposite (down slope and adjacent) edges of the deck to receive the concentrate, middlings and tailings (KEM). Late nineteenth century improved shaking table designs include that created by Arthur R. Wilfley in Colorado in 1896 and the Holman-James table manufactured by the Cornish engineering firm, Holman Bros. of Camborne, around the turn of the twentieth century. Shaking tables are still widely employed in mills today.

The Frue Vanner invented in 1874 by W. B Frue, Superintendent of the Silver Islet Mine, Ontario, Canada, was first mentioned in the *Mining Journal* in 1875 (MJ 1875, 469). One of the first ones installed at a British mine was at Wheal Seton, Camborne, Cornwall, in 1879. This apparatus received crushed orestuff from the stamps via a distributor about four feet from its upper end that discharged onto a continuous rubber belt that passed over rollers to form the surface of an inclined plane. The belt containing the ore was continually shaken as it travelled upwards and subjected to small jets of water which gradually washed the gangue off the bottom of the belt. The heavier ore adhering to the belt was deposited into a box containing water as it travelled over the top roller. Additionally, numerous specialised devices were developed in the nineteenth century to recover slimes from settling pits, including slime trunks, rag and hand frames, machine frames and slime frames that operated on the same principles as jigs and buddles. These proved very successful on tin and lead mines in particular, where the ore could be concentrated to a high level. One such item of equipment was the rack or rag frame, a simple device which had the added bonus of not being labour intensive, with one boy able to watch over 20 such frames. A launder bringing the slimes from the buddles passed between two rows of the slime frames, set back to back, and the delivery to each frame was distributed by a fluted spreader that flowed uniformly in a gentle stream over the surface of an inclined frame that was divided at the middle into two halves by a 5-inch step; the waste flowed off at the bottom of the frame into a launder. The stuff deposited on the frame was then flushed off at successive intervals of a few minutes each, by a self-acting contrivance consisting of two rocking troughs which were gradually filled with clear water from a launder. When full, they overbalanced, discharging their whole contents suddenly upon the top of each half of the frame. The tipping movement of the troughs triggered the immediate opening of the covers of two launders, one at the foot of each half of the frame, into which the stuff deposited on the frame was washed by the discharge of water, the two halves being kept separate because the greater portion of the ore was retained on the upper half of the frame.

Despite the various technological innovations to dressing operations, it was not uncommon on nineteenth century mines to find cutting edge machinery existing cheek by jowl with equipment and processes that had been in existence for centuries. Presently, the best collection of authentic ore dressing equipment clearly showing the progression of the technology through the nineteenth and twentieth centuries on British mines, is at King Edward Mine, Cornwall, a part of the Cornwall and west Devon Mining Landscape World Heritage Site. Reconstructions of lead mining apparatus may be seen at Killhope, the North of England Lead Mining Museum and Minera Lead Mines and Country Park, Wrexham, Wales.

LOCATION, LOCATION, LOCATION!

There are numerous extant dressing floors situated on the Luganure mines dating from the nineteenth century. Several of these are shaft head primary dressing floors consisting of little more than a rectangular cobbled area used for the initial sorting of ore to avoid the cost of transporting useless 'gangue' materials to the main dressing floors. Excellent examples survive at Van Diemen's Land, Harold's Shaft (North Hero) and Bog Shaft (West Ruplagh). The Griffith Valuation (1852-3) notes two ore crushing mills: one in Camaderry townland and another with a forge in the townland of Brockagh (AAI). The latter we believe to be a reference to the Old Ruplagh site, where a MCI map by J.J. Byrne dated 1852 records a 'forge and mine yard'. This crushing mill is recorded in 1874 in the Griffith Valuation Cancellation Book as 'in ruins'; by 1888 it had been converted to a house lived in by Peter Windsor and noted to have been 'in a very remote locality known as "Rupple"'(VO). The two main dressing floors serving the Luganure mines were Old Hero (Glendasan) which dates from the late-1820s-early 1830s and contained the crushing mill noted by Griffith and the other constructed between the Upper Lake and the head of the Glendalough valley (also in Camaderry) in the mid-1850s.

Where best to build a dressing floor was chosen with several important factors in mind:

- Distance from the hoisting shaft or tramway adit
- Provision of water for powering machinery and dressing operations
- A definite slope for gravity assisted operations and an area sufficient to contain the dressing operations

Dressing floors were usually laid out close to the shaft or adit where the ore was being brought to the surface. Tramways were sometimes constructed to transport ore to the dressing floor, as at Bryn Dyfi in Wales, where it was brought in from almost a kilometre away. At Old Hero, Glendasan, all of the above considerations were readily achievable, with a good supply of water for dressing and powering machinery brought in via a carefully constructed leat from the Glendasan River and the dressing floors laid out on the rocky hillside below the Old Hero engine shaft that was, initially, among the most active mines in the valley. At Glendalough however, the terrain and particularly the fluvial geomorphology, made things more challenging. Here, the floors were laid out at the head of the valley on fairly flat terrain interspersed with large glacial boulders (the works were actually built around some of these), on ground between the meandering channels of the Glenealo River that was subject to flash flooding.

Although an abundance of water could be obtained in all but the driest spells from the Glenealo River, the lack of slope meant that there was insufficient 'head' or power to turn the wheels. In order to remedy this shortcoming, a reservoir was built above the floors to collect and store water from the Glenealo River. This was probably allowed to fill up overnight and then released during each working day to turn the wheels for the rolls crusher and the stamps. It is testament to the skills of contemporary engineering that sufficient head of water was achieved to drive 16 head of stamps, which was, apparently, quite unusual on water powered stamping batteries (Moissenet 1858, 20-21). Inclined tramways delivered the ore from cliff face adits high above the dressing floor in the valley below.

Dressing floors were undoubtedly as well engineered as possible, but they were purely utilitarian and money was never expended in making them look beautiful or in providing much in the way of comforts for the workforce. Indeed, many of the surface features including wooden sheds and launders were unsightly, shabby and ephemeral in nature. Due to the organic nature of ore dressing operations, it was not uncommon to find parts of dressing floors disused or decaying as new methods came into use and old ones phased out. Most sites betray signs of multi-phase activity and would have been noisy, dirty hives of activity employing many surface labourers tasked with breaking the ore, digging out buddles, barrowing the material round the site and operating the various pieces of dressing equipment and machinery. Today they are eerily silent and many are being slowly reclaimed by rivers that were once their life blood. Understanding fluvial geomorphology in particular is often vital in determining how best to protect numerous abandoned dressing floors for this in turn has an impact on the wider geomorphology; for example the transportation of mineral rich sedimentation by rivers can impact on soils, water quality and biota (for more information on the potential risks of abandoned mine sites, see EPA 2009). Finally, as Palmer (1994, 79) reminds us: 'The many remains of dressing floors which survive in today's landscape are but ground level indications of a vast superstructure which grew up unplanned and disappeared equally quickly when the mine was disused, leaving only foundations or structures set in the ground', posing acute challenges for the industrial archaeologist.

HISTORICAL DESCRIPTIONS OF THE GLENDALOUGH AND GLENDASAN DRESSING FLOORS

Fortunately, we have discovered three eye witness accounts of the Luganure mines' nineteenth century dressing floors to augment the information that is contained within the twice yearly MCI shareholders' meeting reports and on contemporary maps and a report of the early twentieth century treatment plant operated by the Wynnes. One must, however, be alert to the fact that such sources inevitably contain their own biases and nothing can compensate for careful excavation and archaeological science (Cranstone 1989, 40) which has never been applied to the Wicklow lead mines. The 1854 account relates specifically to the Hero dressing floor; the other two, in 1860 and 1866, refer to Glendalough and the fourth, dated 1917, to the White Rock plant at Glendalough.

The 1854 report was written by John Sproule, an Irishman whose name had 'for many years been associated with the agricultural and industrial literature of Ireland' (BNL 1854). Sproule was the author of *A Treatise of Agriculture Suited to the Soil and Climate of Ireland* (1830) and was awarded a medal for his prize winning essay on manures by the Royal Agricultural Society. He was the editor of the *Irish Farmer's Magazine*, a regular contributor to the *Agricultural and Industrial Journal* of the Royal Improvement Society of Ireland and a promoter and superintendent of the Irish Beet Sugar Company set up in 1851 with a factory at Mountmellick (BNL 1843; FJ, 1851 and 1852). Sproule was the prefect candidate to be the editor of the proceedings of the prestigious Industrial Exhibition held in Dublin in 1853, penning many of the critical dissertations on various industrial and agricultural topics himself (Sproule 1854). He wrote a detailed account entitled 'The Preparation and Concentration of the Ores to Fit them for Smelting', noting that the series of operations that he described 'is as nearly possible that followed at the Luganure Mines, near the Seven Churches, in the County of Wicklow'. His description is undoubtedly the most detailed of the three.

Sproule commences his observations by noting how the ore was brought to the surface looking like 'a mass of rubbish out of a quarry'. He states that the mechanical operations fell into three types: crushing, sifting and concentration by washing. 'The object of the first process is to bring the whole of the ore to a convenient state of comminution; that of sifting to classify the sizes of grains; and the washing to remove as much of the gangue from the ore.' He notes that the first operation to which the ore was subjected was grating, which consisted of 'sorting the ore by means of sieves made like the common sieves (also known as riddles) used for screening gravel for mortar'. Oversize pieces were washed in a stream of water, which he stated flowed 'into a pool in which the fine mud washed off is caught'. The ore was spalled and cobbed and then sorted into three lots: '… the first consisting of veinstone or gangue, and containing no ore, or only so small a quantity that it would not pay for its extraction which is accordingly thrown away as waste; the second, called halvans, the poor ore, which consists of so intimate a mixture of veinstone and ore that the latter cannot be separated without a series of mechanical processes; the third, the sorted mine or fat ore, consisting of the pieces of pure ore, or that which contains virtually no gangue.

Sproule then describes how the fine portion, which had passed through the sieves during grating that he terms 'miners' smalls', was then subjected to jigging '… in a square box with a sieve bottom; this box is then placed in a tub of water, and jerked up and down in the water by means of a lever of swing'. He describes the water entering the bottom of the box, how the heavy metallic parts sank to the bottom of the tub and sieve and that a workman removed the gangue from the top layer of the sieve with a shovel, '… and unless it is worth jigging again, [the gangue] is rejected'. The upper portion of the material that had fallen through the sieve and collected in the bottom of the tub was much poorer and also considered as halvans. Sproule's description clearly relates to manual jigging hutches and not a mechanised variety. Following jigging, there were three classes of ore: the fat ore, halvans and jigged smalls which were treated separately by another series of operations.

Interestingly, Sproule states that the fat ore was sent to the stamps (even though most smelters would accept ore fragments up to four inches in size), which he describes in detail as consisting of: 'A number of huge pestles of wood, armed at their lower ends with masses of iron, and supported vertically in a framework of wood so as to be moveable up and down. The motion is effected by means of a horizontal axis, turned by a water-wheel, and having a number of wipers projecting from it, which in their revolution catch a projecting shoulder of the pestles and toss them up, and then allow them to fall into a long cavity, the bottom of which is covered with iron. Into this cavity the ore is put, and is crushed by the falling of the pestles, the stamped ore being carried away by a current of water flowing underneath the pestles, and deposited in its course according to its relative richness, thus effecting a first washing'.

A battery of Cornish stamps was mentioned in MCI reports as having been installed in 1850 'to pulverise the poorer ores called halvans, accumulated during the past workings'. These performed so well that additional stamps were ordered in 1851 (FJ 1851). A well worn short shank 'shoe' (the iron end of the stamp) that fitted into a wooden lifter (Figure 8) has been found at Luganure Adit, but it seems more likely that the 1851 reference is to a battery installed at Hero. Smyth (1853, 358) notes a stamps of 16-head had been erected during the five years before 1853 and indeed, no Cornish stamps were depicted on the Hero dressing floor on a MCI map dated July 8th 1846 that shows only the Cornish rolls crusher on site (Figure 9). Sproule also notes that instead of these, 'stamp-crushing cylinders may be employed, and with much greater effect, except where the gangue is too hard, in which case the stamps are best adapted for crushing the ore into fine powder'. This refers to a Cornish rolls crusher, and the MCI spent £1001 1s 2d in 1836 on 'a new crushing mill for dressing ores' (MCI Reports), probably erected at Hero, but might also refer to the crusher known to have existed at the Ruplagh mine which was discovered in 1835 and was then being developed.

Figure 8. A well-worn short shank stamp shoe found in the vicinity of Luganure Adit where there was an early dressing floor. See the Perran Foundry Catalogue for similar examples (Trevithick Society 1986, p.13)

The crushed stuff obtained by either of these methods Sproule notes was next buddled:

> The crushed ore from stampers or cylinders is placed in the box, and is continually agitated by a workman with a shovel; the stream of water carrying away the finer particles into the cistern where it is deposited, forming what is called slime or slitch, whilst the coarser particles remain in the box, and are removed from time to time.

The rich and coarse ore obtained by this method was laid aside in heaps, or in mining parlance 'sent to pile' under the name 'crop ore'. Coarser fragments of mixed ore and gangue (middlings) would be dug out and jigged, and the rich heads '… tossed or tozed when only like a coarse sand' in a kieve. Insufficiently cleansed ore was washed in a flat buddle which Sproule notes differed little from a trunking buddle. The middle skimmings from jigging the mixed stuff from the trunking buddle were sent to the stamps. The slimes from the trunks were washed in a nicking buddle and the clean slime sent to pile. This resulted in three types of clean ore: the crop ore jigged and washed, the clean slime from the nicking buddles which was separated from the crop ore and the slime from the skimmings of the crop ore, crushed and washed. Sproule notes that the halvans and smalls were treated in exactly the same way, and he states that it was usual to mix them both together when crushed by the Cornish stamps. 'In this way there are from five to six different qualities of ore produced at the mine, the difference between them consisting merely in the amount of gangue they contain'. The jigging and other processes created a certain quantity of fine matter that he terms sludge that was carried away in water. This was 'not allowed to go to waste, but is made to pass through a series of pits called buddle holes or slime pits, where it deposits, and after a time is collected and washed, forming another quality of slime ore'.

Sproule's description contains at least two pertinent observations. The first is that the ore dressing process was overwhelmingly manual, quite primitive and highly labour intensive, of the kind employed on many smaller British lead mines in the early nineteenth century. Interestingly, he does not mention female labour. Women had been employed on the

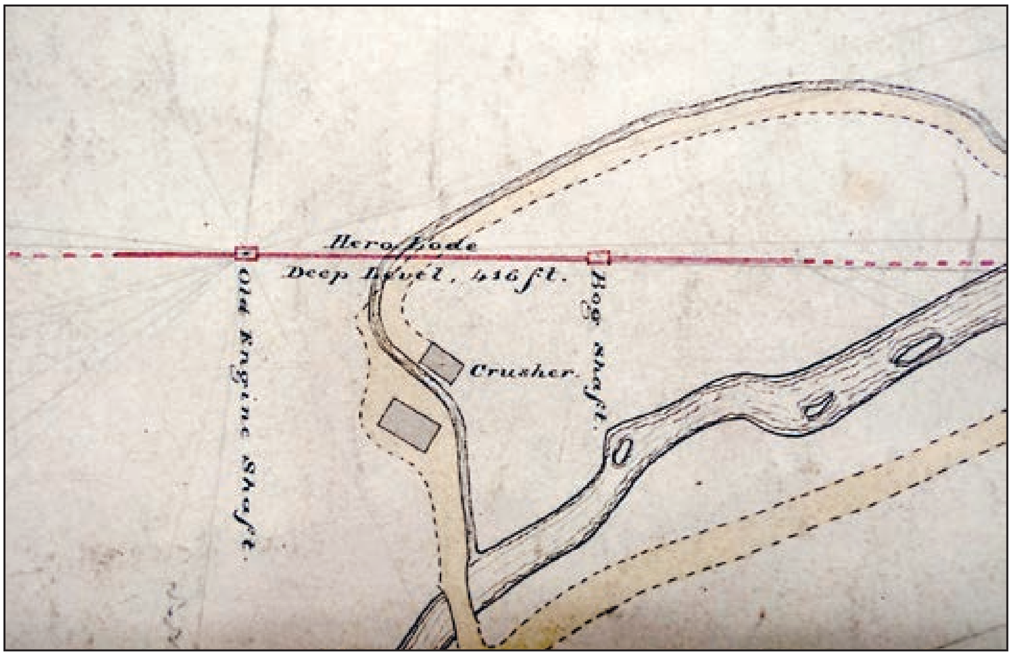


Figure 9. Section of a MCI mine plan dated July 1846 showing the Old Hero dressing floor which is located in the townland of Camaderry (otherwise known as Seven Churches). Note the leat bringing in water to feed the Cornish rolls crusher, housed in the rectangle on the right. The rectangle on the left is the 'mine yard'

Peak District, Yorkshire and Pennine lead mines prior to the nineteenth century and on the copper mines of Anglesey, Wales, where they were known as 'copper ladies'. An army of females, colloquially known as 'bal maidens' in Cornwall and Devon, undertook the spalling, cobbing and bucking of various types of ores at the height of the industrial revolution (Schwartz, 2000). Females were certainly employed at the surface of numerous Irish mines (see Schwartz and Critchley 2011), but there is documentary evidence to suggest that they appeared not to have worked at the Hero dressing floor performing the tasks described by Sproule above. Cornishman, Captain Richards, grumbled to Frederick Roper, who interviewed him in 1841 for the *Children's Employment Commission*, that he had tried 'all in his power to persuade the poor people in the neighbourhood of Luganure to let the children, boys and girls, come to work at dressing the ore'. He had even offered to advance them money to purchase suitable clothing to enable them to begin work, without effect. 'A few boys were sent in the summer, but no girls… the girls would not go, and will not work.' Richards stated that 'they are too proud' which he attributed to laziness 'and this too although they have but a bare subsistence' (BPP, 1842, 857). It appears, at least in the early 1840s, that mainly adult males were employed on the Luganure dressing floor 'on contract work' and Richards states that they were constantly changing hands, highlighting the problems of promoting an industrial enterprise in what was, a largely agrarian area and among a peasantry not accustomed to this type of labour.

Secondly, Sproule states that the Luganure lead dressing process was somewhat inefficient and notes the difference in approach to ore dressing on mines in Britain and in Continental Europe. In Britain, where fuel (primarily coal for smelting) was inexpensive and where up to a third of the lead ore was lost during the dressing process, 'the washing was not in general as perfect as that on the Continent where scarcely one-half per cent is left in the waste'. Indeed, as fuel was not particularly cheap in Ireland, he opined that '… it might be worth our while to adopt the Continental system, which has grown up under circumstances more similar to our own than to those of England'.

The dressing floor that was laid out in 1855 in Glendalough following the discovery of a new mine there in 1853 was initially not that much different to that observed by Sproule at Hero in terms of equipment. Progress in setting up this floor was impeded by the 'most vexatious harassing' by the 'proprietors of the soil' in the locality who were quick to resort to legal proceedings against the company for injury to their cattle and who, as was wittingly remarked at a shareholders' meeting, 'looked upon the company as a sort of mine which they in turn could work for their profit' (FJ 1854). Perhaps the Glendalough landowners had been emboldened by the case brought at Brockagh Bridge by Captain Thomas W. Hugo (a large local landowner), in the autumn of 1852, forcing the MCI to reach a compromise with him for a sum of £260 including court costs, for damages he alleged arose on his lands in Glendasan valley that he was, somewhat ironically, renting to the MCI (MJ 1852).[11]

Consequently, once the MCI began to develop the mine in Glendalough they had been unable to erect crushing machines for fear of damage, were presented with exorbitant demands to permit the construction of roads and accommodation and had resorted to deploying a boat to convey the undressed ore across the Upper Lake in order to transport it to the Hero dressing floors.[12] This prompted the company to enter into a lien on the district, '… which would prevent the interference,

11 Hugo claimed compensation for the removal of the surface soil of part of the lands of Brockagh; inundations of the River Glendasan which destroyed the vegetation in the valley; the impregnation of the river by the ore of the mines; the destruction of pasturelands and the cutting away of the bog on the mountain. A map drawn by J. J. Byrne of Dublin in August 1852 depicting the extent of damaged lands in Glendasan is probably related to this court case (GSI Archive).

12 In 1863 there is a reference to fish poisoning at Glendalough that perhaps prompted the company to build the tailings dam to prevent contaminants from entering the Upper Lake.

annoyance, and losses to which the company had hitherto been subject'. A sum of £4,000 was paid to purchase the land at Glendalough and the interest of the proprietors, Messrs' Byrne (FJ 1856). Progress was then made in building the Glendalough dressing floor and the MCI reports record an expenditure of £1002 15s 10d during 1855 'for a new crusher and other machinery for raising and dressing the ores at the Glendalough Valley' (FJ 1856). In 1856, a further £814 19s was spent in development work underground and in extending the dressing floors and machines at the new Glendalough Mine (FJ 1857).

Just a few years after the Glendalough dressing floor was laid out, it was the subject of an article written by Harry Napier Draper F.C.S., F.I.C., M.R.I.A (1837-1892) who visited it in 1860, the year in which MCI reports notes that there had been, 'some improved arrangements introduced in the preparation and dressing of the ores' (FJ 1860). Born in Hereford, England, to Carter Eben Draper and Eleanor Gorton, he became a very wealthy Dublin businessman and a leading and well published research chemist who invented colourless iodine and Draper's Dichroic Ink. He was just twenty three when he wrote his contribution on the Luganure lead mines for a scholarly textbook entitled, *Recreative Science: A Record and Remembrance of Intellectual Observation* (Draper 1860).

Walking from Laragh past the Seven Churches and along the mine road above the shoreline of the Upper Lake towards the head of the valley, Draper passed dozens of miners going to their work and observed 'their wives and daughters carrying their breakfasts, and the candles with which they light the mine'. He expressed his pleasure in passing neat cottages (built by the MCI) with flower beds, a marked improvement on the cesspool that customarily graced the exterior of many an Irish cabin. On arrival at the head of the valley, he was instantly stuck by the 'very large water-wheel, turned by the mountain stream, which rushes down the ravine in front, and the several immense heaps of what appears to be fine white gravel, but which is really the debris of the mine'. He then describes how further on he came upon several men busily engaged with hammers upon a huge heap of glistening stone, 'which it is not difficult to tell is the lead ore', and which refers to the initial manual reduction of lodestuff.

Draper describes the method by which the galena, after having been dug out, was transported to the dressing floor:

> … [the galena] is placed in trucks, two of which are attached to either end of a long chain, which passes over a pulley. The trucks run upon two parallel lines of railway down the side of the hill, in such a manner that the two descending trucks laden with ore shall draw up to the entrance, or "level", of the mine, the two others which had been relieved of their load. Down they come, with a speed which every moment increases until the very level ground is reached…

He describes a gravity operated inclined tramway of a kind that was widely used on the Welsh slate mines and elsewhere, including Ireland, where, for example, a 3 ft gauge inclined tramway served Carr's Face Quarry in the Mourne Mountains, County Down.[13] Some inclines like that at Glendalough were of the double track variety, but it was usual, over longer distances, to operate on the three rail principle as was the case with Carr's Face Quarry Incline. In a gravity balance system, two parallel tracks are employed with an ascending gang of tubs on one track and a descending gang on the adjacent track. A single cable was attached to both gangs and wound round a large horizontal winding drum several times to ensure there was sufficient friction for the brake to slow the rotation of the drum – and therefore the wagons – without the cable slipping. The weight of the loaded descending tubs lifted the ascending empties. The 'driver' operated a hand brake on the drum to control the speed of descent. This form of cable railway was used primarily to move loads downhill and required a wider space than a stationary engine-driven incline, but had the advantage of not requiring external power and therefore cost less to operate. Another eye witness account of the Glendalough inclined tramway was made in the same year in a tourist handbook. The author observed the dressing works at his feet manned by 'poor pale faced miners who regarded him with lustreless eye', while some eight hundred feet above him were the mine levels: 'Up and down a tramway – almost a perpendicular line, awful to look at – waggons are rattling by at a fearful speed' (Powell 1860, 71). The two inclined tramways serving the First and Second Adits are clearly depicted on a map surveyed and drawn by Captain G. J. Bailey in 1868 (see Figure 13).

Draper then provides what is possibly the only nineteenth century eye witness account of a working Cornish rolls crusher in Ireland:

> A terrible engine is this, unrelenting, remorseless, crushing the tough galena into fragments, with as little difficulty as a grocer's mill grinds coffee-beans… the building which contains the crushing-machine is two-storied, and it is into the upper story that the ore-laden trucks are made to pass. We now know the secret of the water-wheel, for entering down stairs we see two flexible iron cylinders moving, by a cunning arrangement of cogged wheels, in opposite directions. These cylinders, which are "case hardened," or superficially converted into steel, are so close together, that an ordinary pencil passed between them would emerge as a flat band, and this contiguity is kept up by means of a heavy weight, or "bob" attached to the extremity of a lever, which bears upon one of them. The ore supplied from above, through a hopper, comes down in a steady, gradual stream, falling fairly between the cylinders, and is soon reduced to fragments… the crushed ore falls into a tubular sieve, which, being gently

13 This tramway worked on the three-rail principle. The central rail ran the entire length of the incline and at half way or passing places the rails opened out to form two independent passing loops (similar to those on a conventional single-track railway), each with their own rails. After the wagons had crossed they resumed the journey using the common middle rail.

> inclined, allows those fragments which do not pass through its meshes to slide into a bucket placed to receive them.

We therefore learn that the Glendalough crusher was not of the more modern, multiple rolls variety, meaning the lodestuff would always had to have been manually reduced beforehand; there is no evidence to suggest that a stone crusher was ever installed at either of the MCI's Wicklow dressing floors. His next description of the dressing process is of particular interest, as it notes how the finely crushed ore that had been graded by the trommel was swept by an attendant boy into a wooden gutter or channel and the imperfectly crushed ore passed into the bucket, 'which when full, a signal is given: it is hauled up to undergo a repetition of the process; and this is continued until the whole is reduced to an uniform condition of fineness'. Draper noted how a considerable amount of quartz remained intermixed with the crushed ore which had to be removed and that this process was achieved by utilising the difference in specific gravity between lead and quartz:

> After passing from the sieve, the crushed ore meets in the gutter or channel with a stream of water, which having already turned the water-wheel, is further made to wash the ore, and still come along pretty rapidly and with some force. Very soon the effect of its action is manifest. At intervals along the water course are lateral openings into shallow tanks, and here are stationed men, armed with instruments like a rake minus the teeth, who draw into the reservoirs the galena which accumulates in the channel. Towards the upper extremity of this simple washing apparatus, are found lumps of galena, but as we go lower down, we find that these diminish in size, until, having denigrated into a mere plumbeous sand, the lead ceases altogether, and in its stead we come upon nothing but the rejected quartz, the particles of which, in the same manner, grow small by degrees, and finally dwindle into dust.

Draper has described a fairly primitive form of classification in a series of tyes situated in front of the Cornish rolls crusher house where the heaviest particles of galena were deposited (the crop), diminishing in size to a plumbeous sand (the roughs) and finally the rejected fine quartz sand (slimes). The crop, that yielded rich sands and some poor coarse sands mixed with fragments of galena and quartz was dug out and sent for treatment in what Draper describes as 'a series of oblong boxes, which have a jerking motion communicated to them'. These of course were jigs and were filled with the mixed ore and quartz (presumably after sizing by sieve or trommel), 'and in the same way as shaking a basket of chips and halfpence would determine the subsidence of the latter to the bottom, does the galena separate itself from the less heavy quartz, which is removed from time to time to make room for a new supply'. What type of jigs Draper saw is not recorded, but given that there was no mention of a classifier to feed the jigging hutches, they might not have been mechanised. The process described above by Draper is highly similar to that

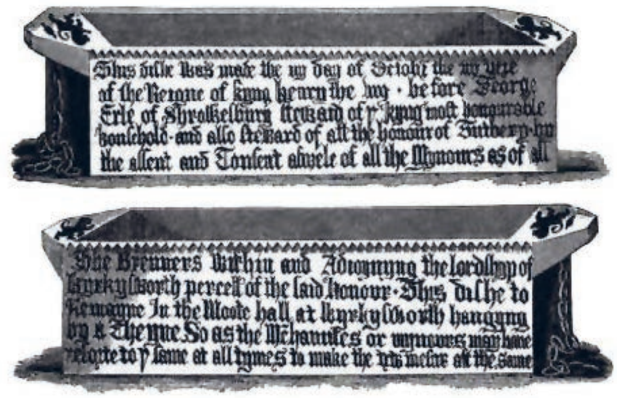


Figure 10. The coffin shaped 'Wirksworth Dish' was presented to the Peak District miners by Henry Vlll in 1513 and was used to calibrate the oak wood dishes used by the Barmaster for measuring ore in the field

used at the Drakewalls Mine, Calstock, Cornwall in 1855, where hand sorted and reduced tin ore was passed through a Cornish rolls then upgraded by tyes, sieves and jigs (Moissenet 1858, 63).

Unfortunately, Draper skates over the latter parts of the ore dressing process and merely states that:

> … when removed from the washing tubs, the galena is placed in heaps, each of which is the share of a miner. With the correct weighing and transference of the ore to long coffin-shaped boxes, in which, securely padlocked, it is conveyed to the smelting works, the mechanical part of its treatment ends, and it bids farewell to the mine.

However, his reference to a coffin shaped box is of particular interest, for this echoes an ancient practice that was associated particularly with the Peak District mining region (Derbyshire), where, on 'counting day' attended by the Barmaster and company officials, the Lord's due or 'dish' was measured in 'a coffin shaped wooden vessel' (Gregory 1932) (Figure 10).[14] Interestingly, the *Derby Mercury* of 1803 carried a 'wanted' advertisement for a person who was 'thoroughly qualified to undertake the Superintendence and Management of Working a Lead Mine in the County of Wicklow in Ireland' (DM 1803) alerting us to the probable presence of pre-MCI migration networks.[15] Indeed, the measuring custom observed by Draper at Glendalough might indicate that some degree of cultural and technical diffusion from this important and historic lead mining region of England to the Wicklow mines

14 The 'dish' was the official way of measuring ore in all British mining areas. A full dish in Derbyshire weighed about 65lbs (29.5 kgs) of dressed lead ore. A standard bronze prototype dubbed 'the Wirksworth Dish' was presented to the Peak District miners by Henry Vlll in 1513 and is preserved in the Moot Hall at Wirksworth. It was used to calibrate the oak wood dishes used by the Barmaster in the field.

15 This is likely to relate to workings in neighbouring Glenmalure where a map dated 1841, drawn by John Hill of Dublin, but based on a map drawn by Thomas Weaver in 1812 of the Ballinafunshogue workings in Glenmalure, depicts a section labelled 'Englishman's Driving' (R284 GSI Archive).

Figure 11. Weighing the lead concentrate and placing it into bags for transportation by mule to the smelter. This early nineteenth century scene from the North-East Pennines would have been repeated on the lead mines of County Wicklow. Reproduced by kind permission of the Science Museum

had previously occurred. He has, however, confused the process of measuring the Lord's dish with the transport of the ore to the Ballycorus smelter. The dressed ore would not have been conveyed there in the coffin shaped measuring dish, but would have been weighed and placed into bags (see Figure 11).

Accompanying Draper's description of the ore dressing process at Glendalough is an etching entitled *Luganure Lead Mine, County Wicklow, Ireland* (Figure 12). It is instantly recognisable as the Glendalough dressing floor and depicts the head of the ravine, the mine road and the Glenealo River cascading down a series of waterfalls with great accuracy. A group of buildings are shown that include the Cornish rolls crusher house operated by a waterwheel as described by Draper in his accompanying article. A launder atop a tall wooden trestle, leading from a reservoir higher up the valley, feeds the overshot crusher house waterwheel. To the right of the crusher house are a series of one storey buildings, some with loft space, connected to a high wall that now form part of the walled complex dubbed 'The Miners' Village'. The far group of buildings appear to be stables, judging by the long doorways and small windows on either side. The area in front of the crusher house is occupied by two rectangular open sided sheds, two smaller square open sided buildings right outside the crusher house and two tramways, one of which is above ground and erected on wooden trestles, the ground level one shown sporting a mine wagon. Two men, one sitting and one standing brandishing a shovel, appear in the foreground close to what seems to be a pile of ore. Two large glacial boulders frame the etching and what appears to be a culvert is depicted in the centre.

This is the only known nineteenth century visual depiction of the Glendalough dressing floor but unfortunately it raises an important question: namely the etching and Draper's description of how the Cornish rolls crusher was fed with ore, conflict.

> … Down they [the wagons] come, with a speed which every moment increases until the level ground is reached, and even then they have sufficient inertia to propel them right up to the shed in which is situated the crushing-machine…

Firstly, the lodestuff would never have been taken straight from the levels down the inclined tramway into the crusher. It would had to have been washed, grated and manually reduced prior to this. Indeed, Draper noted seeing men labouring with

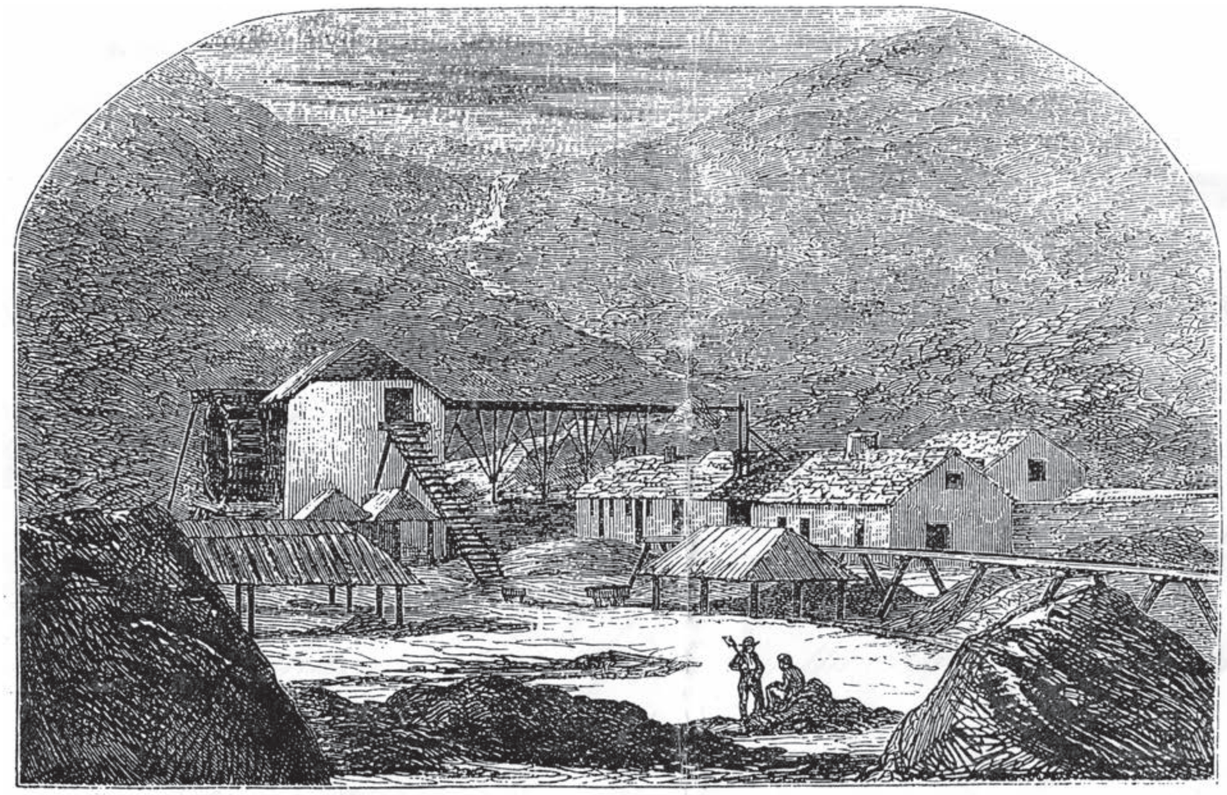


Figure 12. The only known nineteenth century depiction of the Luganure Mines is this etching dating from 1860, of the Glendalough dressing floor showing the Cornish rolls crusher (in its lime-washed two storied house) driven by an overshot waterwheel fed by a launder from the reservoir higher up the valley. Various buildings on the right are associated with the 'mine yard' and the open-sided wooden sheds and piles of ore give an indication of the shabby nature of nineteenth century dressing floors. The fact that the tramway leading from the primary dressing floor (that was on a cobbled raised platform out of frame), poses a question of how the hopper was fed with ore. It seems very unlikely that it was carried up the ladderway leading into the top storey of the building

hammers over piles of galena, obviously doing just that. Secondly, the image depicts what looks to be a type of ladderway leading from ground level up to a doorway sited at the top right of the crusher building which is most definitely not 'a shed'. There is no tramway leading into the top storey of the crusher.

When possible, similar two storey crusher houses were usually built into the slope of a hill, such as the superlative extant example constructed in 1859 at the Baravore Mine in neighbouring Glenmalure (Chester and Burns 2001) to accommodate a Cornish rolls crusher powered by a 32 ft waterwheel (IT 1860). This arrangement meant that ore could be trammed or wheel barrowed straight into the hopper in the top storey, direct from the primary dressing floor. Glendalough, with its lack of slope, did not possess this topographical advantage. It seems inconceivable that the ore was hauled or carried up a ladderway to feed the hopper on a mine that produced 1,003 tons of lead in the first six months of 1859 alone (IT 1859). A photograph of a Cornish rolls crusher house built in 1869 at Richmans dressing floor, Moonta Mines, South Australia, clearly demonstrates how a similar lack of slope there was overcome. A wooden tramway, which could easily be mistaken for a ladderway similar to that in the etching, can be seen running up to the top storey of the crusher (Drew and Connell 1993, 152) and it is this type of system that must surely have been deployed at Glendalough.

Six years later William Brenton Symons, born at Gwennap, Cornwall, in 1832, the son of land and mineral surveyor and lithographer, Robert Symons, visited the Luganure mines and the Glendalough dressing floor and provided a brief, but very useful account of operations there. Resident at Truro, he was a noted lithographer, assayer, draughtsman, surveyor and mineralogist and produced the much acclaimed *Geological Map of the Caradon and Ludcott Mining District* in 1863 that was published in conjunction with a book printed in the same year entitled *The History and Progress of Mining in the Caradon and Liskeard Districts*. In 1866 he wrote a series of articles on the Wicklow Mining District that appeared in the *Irish Industrial Magazine*, one of which relates to the MCI's lead mines in Wicklow (Symons 1866).

He states that the dressing floors were formerly at the head of Glendasan, but that subsequent to the opening of the new mine at Glendalough it had been found more advantageous to dress the ores there. In 1856 Cornishman, Captain John Phillips Clemes, had completed 'an undertaking of magnitude and difficulty', namely the connection via First Adit high in the glaciated cliff face of Glendalough, with Richards' Adit (later known as Hawkrock Adit) that had been driven from the neighbouring valley of Glendasan, the portal of which is sited over 2.5 kilometres away (FJ 1857).[16] Effectively, this meant that the majority of the ore stoped in the workings within Camaderry Mountain could be sent along First Adit in Glendalough and/or dropped by chutes into the Second Adit level, to be trammed from either level by mule and transported down to the dressing floor via the inclined tramways. This was cheaper and more convenient than having to transport the lodestuff by cart to the Hero dressing floor from either Richards' or Luganure Adits. Symons marvelled at this tramway, noting that it was,

> … an interesting and novel sight to stand at the bottom of the ravine or barranco, and, on looking up, to see the wagons appear at the mouth of the levels, which come out in the face of the cliff… It is curious to watch the wagons going up and down the nearly perpendicular and seemingly aerial tramway, and observe them deposit their burdens and immediately rush up the rails again. This tramway goes up the cliff to the height of 600 feet, bringing down the whole product of the mines.

He describes the Glendalough dressing floor as being situated immediately under the commencement of the ravine, surrounded on all sides but the east 'by frowning precipices, 1000 feet high':

> They are thus so secluded and hid from observation that they are quite invisible until you actually enter them; once there, you will find them compact and well laid out. There is a crusher worked by a water wheel; there are also stamps, and several patent jiggers. The most interesting machine on the floors is a new round buddle, similar to some used in Wales, which itself rotates, and separates the ore into three parts, each part falling into a separate receiver. This avoids the usual labour required to empty the buddle, as heretofore done and enables the machine to work constantly. There are 70 hands employed on the floors and 250 in the ends and stopes.

His mention to 'patent jigs' suggest that the manual ones described by Draper had been replaced by a mechanised variety, doubtless driven from a drive shaft run off the crusher's waterwheel. Moreover, these jigs were probably fed with mechanically classified material as many comparable operations in Wales and England installed this machinery during the 1870s, including the Cardiganshire (Ceredigion) mines of Ystrad Einion and Bronfloyd and Tankerville in Shropshire. The 'round buddle' Symons mentions is a round frame, the bowl of which rotated and not the brushes (as in a convex or concave buddle).[17] The one observed by Symons was probably sited in a shed in the vicinity of the crusher or more likely, the Cornish stamps battery and powered by a drive shaft run off one of the waterwheels.[18] It was ideally suited to the Glendalough dressing floor, where space was at a premium. Symons had obviously seen this equipment in use in Wales, having only the previous year inspected and drawn up plans of the Minera lead district in Wrexham (FRO; Brooke 1991).

The MCI was certainly a progressive company, willing to embrace innovative technologies to improve the concentration of ore but only if these were proven to be cost effective. This is borne out by the fact that just a year after Symons wrote his account, Captain James Crase, formerly an Agent at Cooks Kitchen mine in Cornwall, was requested by the company to engage the most thoroughly competent ore dressers that could be found and who were fully acquainted with the most recent processes for the economic and successful dressing of ores. Captain Crase travelled to Cornwall and selected Captain Pascoe and his son. In order that the ore dressing process at their Knockmahon copper mines in Waterford should be carried out in conformity with the latest scientific methods, the MCI sent Captains Pascoe and Crase along with the then Company Secretary, Robert Heron, to Belgium and Prussia 'in order that all the great ore dressing establishments should be inspected and the fullest knowledge of the processes obtained'. Undoubtedly, some of their observations would have been pertinent to many of the company's other dressing floors (FJ 1869).

It is not known whether the Old Hero dressing floor stopped treating ore completely by the mid-1860s, in light of the presence of the crushing mill at Ruplagh where lodestuff was still being raised from the North Mine, but it had clearly declined in importance as it is not depicted on a map drawn in 1860 by Frederick Richards, whereas the Glendalough one is (see Figure 33). In 1867 it was reported that the company had been working Luganure for over forty years and there was some falling off in produce. To compensate for this, Old Ruplagh was re-opened having been abandoned after the lower levels of the mine flooded during a drought in 1844 that prevented the pumping waterwheel from working (Smyth 1853, 354). Additionally, a new mine, Foxrock (in Glendasan) was discovered, leading to an expenditure of £1,744 5s 2d in 1869 on an extension of works and searches. However, the majority of this money was spent constructing new buddles on the dressing floors, cutting watercourses and altering the dam at Lough Nahanagan with the object of providing a continuous

16 There is a difference in the levels of the two adits: Richards' Adit driven first towards Glendalough, is two metres lower, but the majority of the workings post 1853 were to the south of Shallow Adit at Old Luganure, with much of the stoping above and north of Richards' Adit having occurred prior to this. Any ore wrought above or from Richards' Adit would have been dropped down ore chutes to First Adit and transported to Glendalough. Waste from stoping and drivage seems to have been transported out of Luganure Adit and dumped over the site of an early dressing floor where large spoil heaps may still be seen.

17 Symons does not note which type of round frame it was; convex tables were commonplace on many British mines except Cornwall, where the concave type was the norm and was generally of 18 ft external diameter and 8 ft internal diameter, performing one revolution every 4 minutes. Given that the management of the Luganure Mines was Cornish, there is a likelihood that the round frame might have been ordered from there and of the concave variety.

18 The launder delivering water to the stamps wheel ran from a take off point at the opposite side of the reservoir to that feeding the crusher.

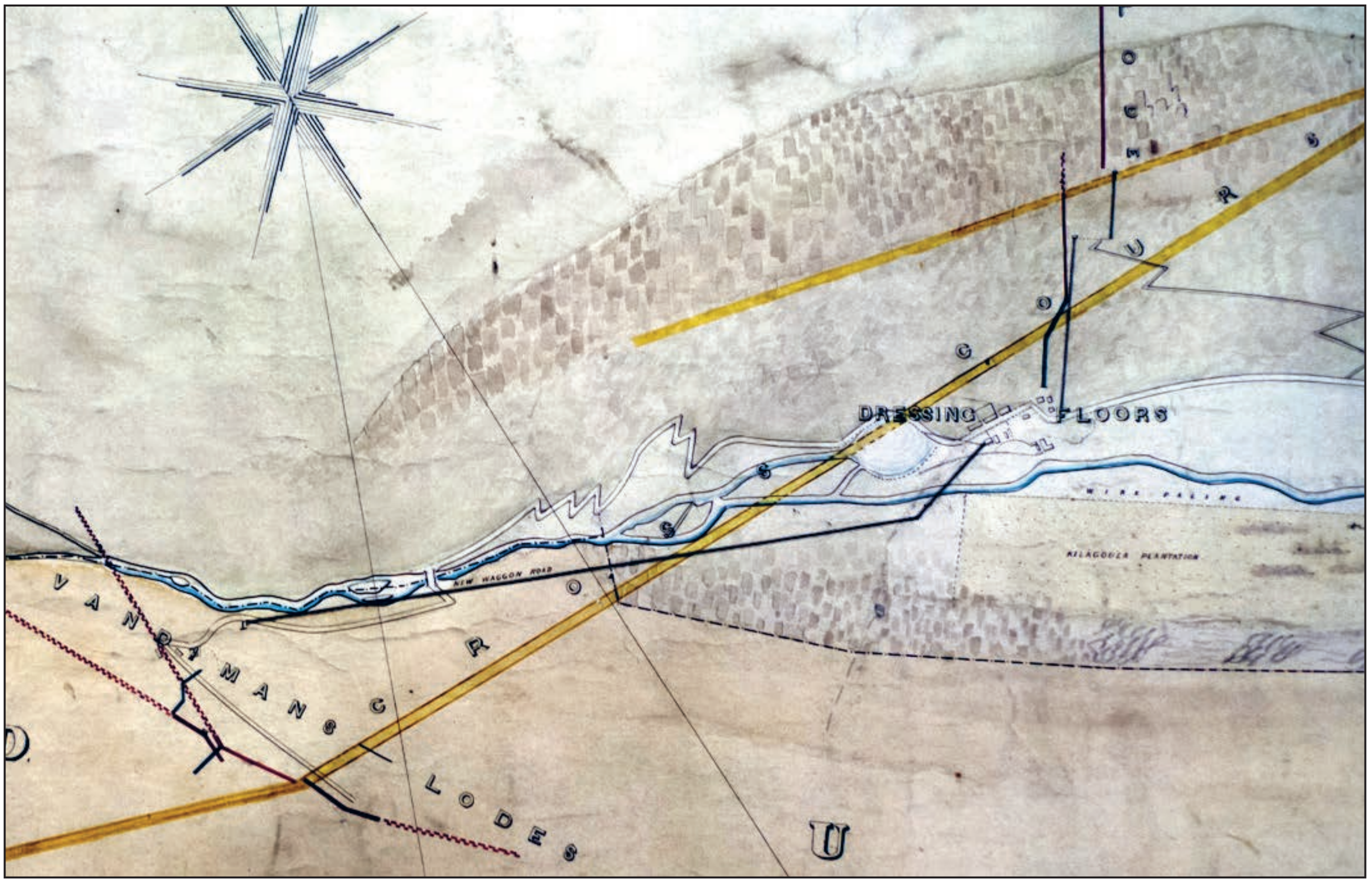


Figure 13. Section of a MCI map dated 1868, drawn by Captain G.J. Bailey. The inclined tramway from Van Diemen's Land depicted as a black line, can be seen running almost parallel to the Glenealo River from a drumhouse and waterwheel before turning left towards the Cornish rolls crusher house. The inclined tramways from the cliff portals of First and Second Adits may also be seen top right (as two black lines one above the other) heading towards the primary dressing floor

supply of water-power in summer time (FJ 1870). This undoubtedly resulted in the modernisation of the fairly primitive dressing floor at Hero described by Sproule that had been almost abandoned for well over a decade. The improvements included the introduction of more efficient round buddles, three of which are depicted in a line on a rectangular platform leading away from the stamps battery on a company map dated 1873.

At the beginning of 1868 a new mine was discovered, the economical working of which created considerable logistical difficulties. The mine was inspected by London-based John Arthur Phillips F.R.S., F.G.S., a native of Polgooth near St Austell, Cornwall, and a graduate of the prestigious École des Mines de Paris, as well as Cornishmen, Captain Charles Crase and Captain Bryant. The logistical difficulties are suggested in the sobriquet given to the area where the mine was situated - Van Diemen's Land[19] - and all three urged patience, as although the mine was considered to be an excellent prospect, considerable time was thought necessary to bring it into full production. Sited on the remote moorland in the lonely Glenealo Valley above the Valley of Glendalough meant that it was in a very unfavourable spot for transporting large quantities of lead ore down to the dressing floors and for bringing up materials, inducing the Board to build another inclined tramway (FJ 1869). A feat of Victorian engineering, the inclined tramway was partially powered by a waterwheel. This was sited at the Van Diemen's Land end and was necessary in order to raise materials (it not being a true gravity assisted tramway). The tramway was completed in 1868-70 at a cost of £2,300. The ore raised at Van Diemen's Land was subjected to a primary dressing (being grated, spalled and cobbed) on a cobbled rectangular dressing floor and the sorted ores were transported by the tramway down to the Glendalough dressing floor for further processing. The 1868 map by G. J. Bailey shows the track at the bottom of the incline turning to run towards the Cornish rolls crusher house (Figure 13). Ore and materials were conveyed at the very modest rate of 2d per ton instead of the several shillings it cost to cart these up and down the zig-zag mine road. With horses often being in short supply in County Wicklow and local hauliers quick to charge inflated prices for their services, without the tramway it was considered almost impossible to economically operate Van Diemen's Land Mine (FJ 1870).

In about 1872, a new mine captain named James Mitchell arrived at the Luganure Mines. He had acquired many years of experience working in Chile and in mines elsewhere in the world and was a moderniser, responsible for a complete overhaul of the lead mines. Van Diemen's Land Mine had turned out to be less rich than expected, all the mines had fallen off in richness and productivity and the company had

19 The former name for Tasmania, which was then a penal colony.

been making a considerable loss prior to his arrival. At the January 1875 shareholders' meeting, those present were pleased to learn that Luganure was then the 'brightest feather in the company's cap' (FJ 1875). In 1875 Mitchell invented a mode of dressing leading to an increase in the quantity of ore that was the most complete and successful the directors had ever seen. The Hero dressing floors were entirely remodelled and new and improved labour-saving and more efficient dressing machinery that required less space was erected at a moderate cost. This resulted in two or three boys being able to do what it took nine men to do before, suggesting that his improvements probably utilised mechanisation or self acting equipment that required light, rather than heavy manual labour required of men, and might have included some form of self acting slime frame to catch the fines (which were of course argentiferous). Additionally, Mitchell authorised the construction of a large new forge-house in 1875 that occupied a central position between the New Hero Mine and the Hero dressing floors (FJ 1876; WNL 1876). In 1877, £424 9s 2d was spent constructing a siphon and making necessary repairs to the weirs and watercourses at Lough Nahanagan following a flood (FJ 1877). The following year £212 16s 4d was expended in erecting a new crusher house, a new jigger and machinery 'for the more economical dressing of the halvans ore', presumably at Hero, where a new shaft was in the process of being sunk on the Hero Lode in 1876 (WNL 1877). No other documented improvements or modifications are recorded as having been made to either dressing floor thereafter.

Following the purchase of the MCI mines and holdings by the Wynnes, a small plant was set up at White Rock (Glendalough) in 1913 to retreat the MCI waste dumps for their lead and zinc content. It operated for a decade. In August 1917, at the height of WW1, the Ministry of Munitions sent Cornishman, Henry F. Collins, to inspect the Luganure Mines in order to report whether these were vital to the war effort and therefore worthy of reworking with capital aid. The small dressing plant formed a part of his report. Collins, the son of mining engineer, J. H. Collins, who followed his illustrious father into mining engineering, authoring *The Metallurgy of Lead and Silver* (1899), expressed his surprise that the plant was powered by a horizontal suction gas engine and producer (Figure 14) given the potential for water power in the valley.

In 1866, German engineer, Nikolaus August Otto (1832-1891), was awarded a patent for his 'free piston atmospheric gas engine', which was designed and built in conjunction with engineer, Eugen Langen (1833–1895), at their works N.A. Otto & Cie., Cologne. The following year they unveiled this engine at the Paris Exhibition, winning the Grand Prize. The Otto-Langen engine became the world's first commercially successful internal combustion engine design and by 1869 was being manufactured in Germany and in Britain (by Crossley Bros. in Manchester). It became even more widely used after the introduction of the improved 'four-stroke' Otto gas engine in 1876 and later advanced designs were manufactured by Cornish engineers, Tangyes of Birmingham. The horizontal suction gas engine was fuelled by a mixture of air and coal gas, generated by burning coal (or peat) on site in a producer, a cylindrical, vertically mounted retort made of

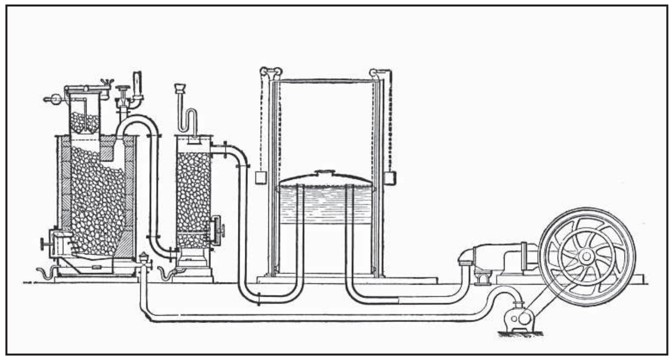


Figure 14. Diagram of a horizontal suction gas engine and producer, a type of engine first designed by German engineer, Nikolaus August Otto in 1866. Using coal or peat as a fuel to produce gas mixed with air, this engine was well suited to small scale enterprises such as the Wynne's Glendalough treatment plant

refractory clay encased within a metal jacket and insulated by a layer of sand (Mathot 1905, 176-178).[20] The first recorded use of an engine of this type in Ireland was in 1885-7 when one was installed on Tory Island, Donegal, to produce gas to power a lighthouse and fog horns (Rynne 2006, 78) and they soon found their way into numerous Irish factories, waterworks and engineering works. This engine offered an economical and efficient alternative source of industrial power for small-scale, remote and rural enterprises such as the Wynne's treatment plant. Presumably, given the family's connections with Prussia, where Albert Augustus Wynne and Wyndham H. Wynne had been directing mines and metallurgical works, it was an engine type familiar to them and is currently the only known documented example of such an engine in use on an Irish mine.

Collins recorded the maximum capacity of the plant to have been 15 tons per day and about 75 tons per week, the yield being about 12 cwts of dressed galena and 1¼ tons of blende per week. He considered that better results could have been obtained by a much more extensive picking out of waste rock that existed in large quantities in the old MCI dumps. Collins observed the jigs to be under loaded and thought the input to the mill could have been doubled by erecting a larger set of rolls actually available at the site. The problems of increasing and speeding up throughput were compounded by the absence of Captain John B. Wynne, a qualified mining engineer, who was in France. His elderly father, Albert Augustus, then 85 and resident 10 miles away, was unable to undertake much in the way of detailed direction. Collins concluded his report by stating that reopening the Luganure Mines was unlikely to tempt investors, 'but from the point of view of developing Home Mineral Resources, the government may legitimately assume risk and invest capital to establish a dead industry in a

20 In suction producers, air and water vapour at atmospheric pressure were drawn through the incandescent fuel by the inhaling or suction action of the engine, due to the partial vacuum produced in the engine cylinder during the suction stroke of the piston. The gas was cooled and purified in a scrubber and supplied to the engine at a pressure of from 2 to 3 ounces. The volume of gas in a suction producer was therefore never in excess of that required by the engine, and consequently it was not necessary to provide a holder, the gas being drawn directly from the producer to the engine cylinder.

Figure 15. General view of the Hero dressing floor, Glendasan. The grey-white finger dumps of spoil from Old Hero Engine shaft can be seen behind the walled compound known as the mine yard, constructed of granite blocks on top of a massive platform of random moorstone built into the slope of the hill

deserted countryside' to produce a raw material vital to the war effort (Collins 1917). The Ministry of Munitions, however, declined to invest in the Luganure Mines, and the White Rock plant made a loss of £19 on the four months prior to November 1919, falling victim to the decline in the price of lead and zinc concentrates after WW1. It closed in 1923.

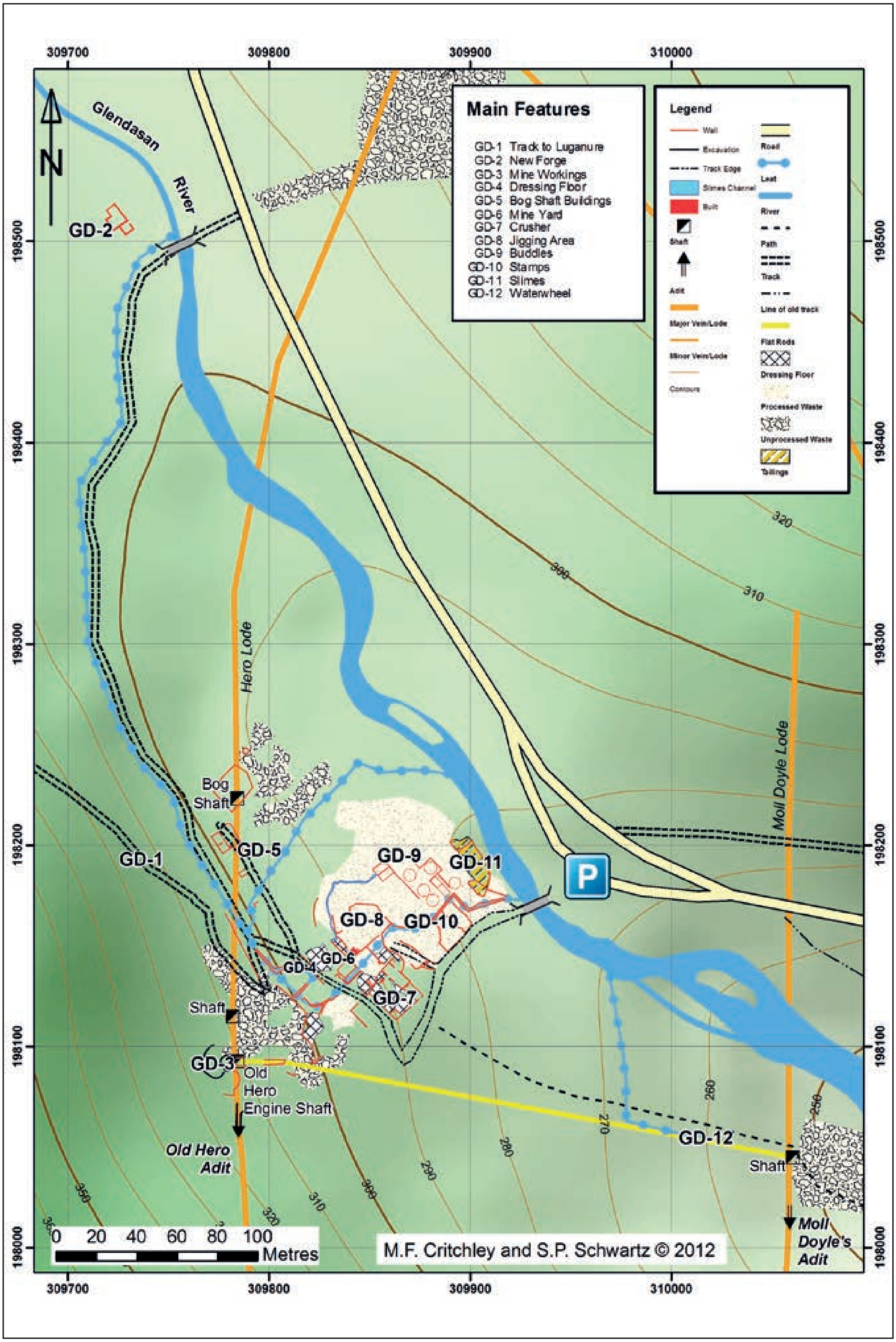
There has been a previous attempt to explain the assemblage of extant features on these dressing floors by Linda Heidkamp (2003), but this contains many errors and misinterprets or omits numerous features which, if left uncorrected, could have deleterious consequences for the future preservation and conservation of certain features on the Glendalough dressing floor in particular. The following section offers a comparative analysis with contemporaneous lead dressing floors in Britain and seeks to correct and to dispel the many errors about the layout, form and function of both dressing floors. An overview map for each valley lists the basic features, with each ascribed a unique ID. Detailed maps of the dressing floors use the unique ID shown in the relevant overview map with letter suffixes, i.e., A, B, C, and so forth, to indicate sub-features. GL refers to Glendalough, GD to Glendasan. All features are depicted in bold brackets in the text below.[21]

AN INVENTORY AND INTERPRETATION OF DISCRETE FEATURES: OLD HERO DRESSING FLOOR, GLENDASAN

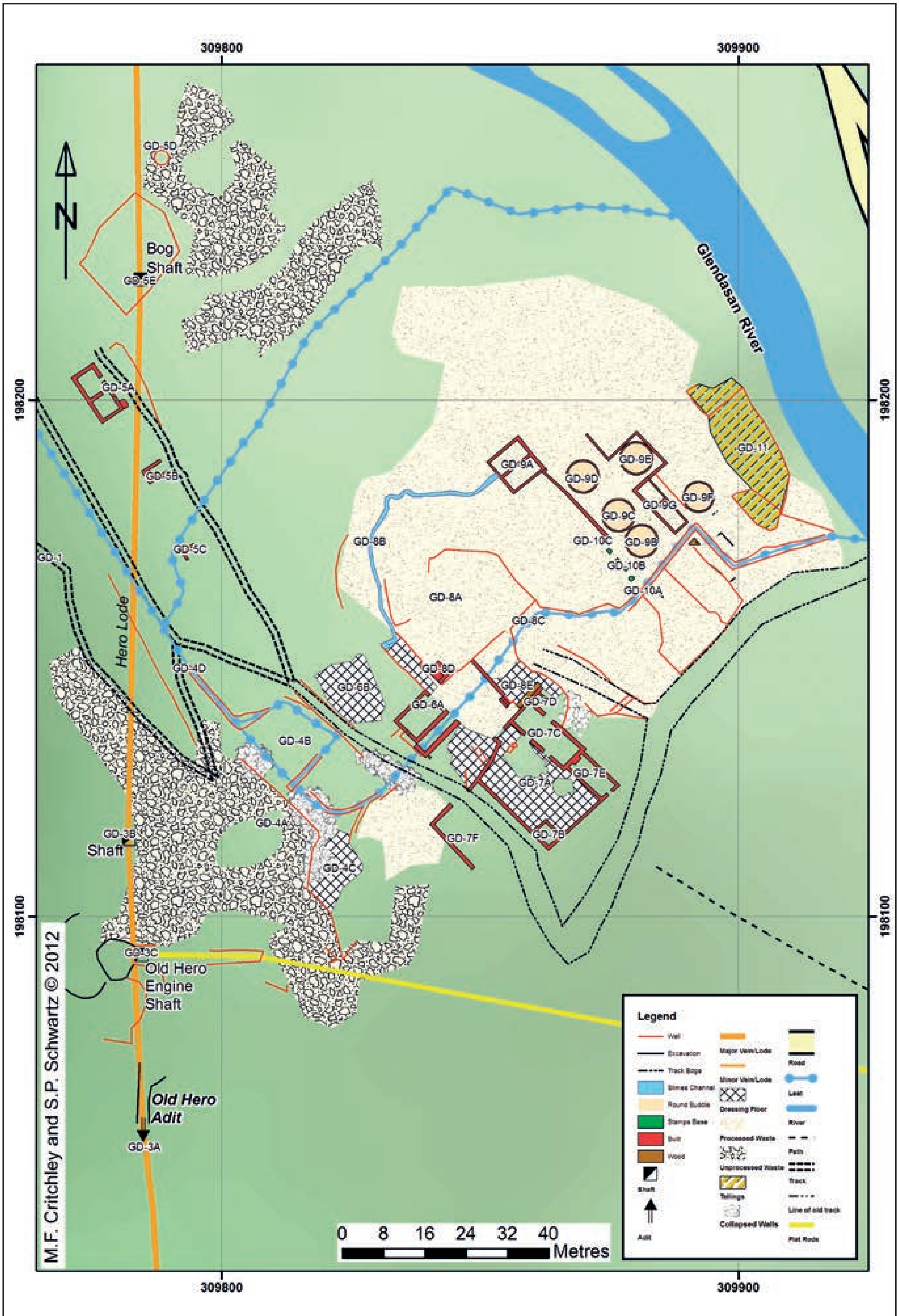
Mine road from Old Luganure Mine

A road from the inaccessible Old Luganure Mine to the Seven Churches was opened in 1826 to facilitate the passage of carts conveying ore and to replace the practice of men or mules carrying materials for a distance of over a mile. A new section was created from Luganure to link with the St Kevin's Way which was repaired and upgraded. The section of mine road **(GD-1)** from Old Hero dressing floor to Luganure is very similar in design to the later mine roads in Glendalough, with granite boulders lining the sides of a metalled surface with a ditch to one side and occasional culverts formed of flat granite slabs to conduct streams and storm waters beneath the road. The road from Seven Churches to Hollywood (now the R756) was first planned in 1828 and the Commissioners for Public Works advanced the Treasurer of County Wicklow a considerable sum towards completing the works. However, there were delays and the MCI finally appealed to the Grand Jury to gain authorisation to build the road from Seven Churches to Hero for the sum presented to Wicklow by the

21 Our surveys are commensurate with an English Heritage Level 3 survey and took place in two phases between January and September 2012. The first phase consisted of a desktop study of all known historical documentary sources, existing maps and aerial photographs, which were compiled in a GIS and the main features identified. During the second phase, detailed surveying of the dressing floor features at Glendasan and Glendalough was undertaken using a South 355R Total Station belonging to the Mining Heritage Trust of Ireland. The Glendalough dressing floors had been laser scanned by Gridpoint Solutions Ltd. in early 2010 and these data were made available to us by the Wicklow Mountains National Park. The 3D laser point cloud scan was used as the basis for the mapping of built features using on-screen digitising in the GIS. Detailed tape measurements and drawings of features at both dressing floors were also prepared in the field and used to refine the mapping where necessary (see Schwartz and Critchley 2012 for a more precise methodology).



Map 2. Overview of the Hero dressing floor in the Glendasan Valley based on field surveying showing the various discrete features



Map 3. Detailed map of the various elements of the Old Hero dressing floor at Glendasan

Commissioners for Public Works in 1829.

***Old Hero Engine Shaft* (GD-3C)**

Above the dressing floor, and dominating views of the site (Figure 15), are the distinctive finger dumps of Whim (Old Hero Engine) Shaft which has run-in at the surface forming a cone-shaped depression with an opening to the east leading to a stone lined channel. This channel is believed to have contained the flat rods which operated the water pumps in the shaft and are shown on the First Series Six-Inch map. These were installed between 1829 and 1833 when the mine was developed below the 30 fathom level (in 1828 MCI reports state that there had been no occasion to yet resort to waterpower). The rods ran uphill powered by a waterwheel midway between Hero and Moll Doyle, the pit of which is extant **(GD-12)**. A flat area immediately behind (west) the shaft has been cut back into the rock (the drill marks are visible in the granite) probably to accommodate a horse whim plat, used for winding materials up and down the shaft. Given the flashy hydrology of the area, the hillside above the shaft bears the unmistakable signs of watercourses being directed into walled channels for diverting storm waters around the hillside and away from the shaft to prevent flooding. Two shafts developed in the 1820s and now buried below the finger dumps, are located in the area between Old Engine Shaft and Footway Shaft.

***Old Hero Adit* (GD-3A)**

The stone walling of the entrance portal is partially visible, but the adit has run in. Water is percolating through the collapse.

***Footway Shaft* (GD-3B)**

This open shaft immediately behind (west of) the main spoil heaps dates from the 1820s. This shaft was used by the men to gain access to the workings and is driven on an incline along the mineral lode which can be clearly seen at the shaft head dipping some 70-80 degrees to the west.

Leat from the Glendasan River

The leat runs for approximately 500m from a take off point at the Glendasan River and follows a curve in the level contours on the east side of Camaderry to the dressing floor at Old Hero where it was carefully diverted through the works to power two large waterwheels and also used for dressing purposes. It discharged into the Glendasan River by the bridge carrying the mine road. Remnants of the original weir and dam wall that would have controlled seasonal water flows in the Glendasan River and into the leat can be seen close to the wooden bridge by the new forge **(GD-2)**. The site of a sluice gate positioned midway between the weir and Hero dressing floor is extant and consists of two tie rods rising above the water level and an adjacent wall used as a local isolation point to control and maintain a regular rate of flow through the site. An emergency overflow route was created just before the leat entered the dressing floor to prevent flooding. As Lough Nahanagan acted as a natural reservoir allowing a constant water supply (except in periods of acute drought or sub zero temperatures), there was no need to construct reservoirs immediately above the Hero dressing floors, in contrast to the floors at Glendalough. As the leat entered the dressing floors it seems to have split, with one branch flowing downhill in a crude stone channel at the edge of the dressing floor **(GD-4B)** presumably to feed the jigs (the precise course of which is now indeterminable). The other branch was conducted along the back of the dressing floor, via a long vanished wooden launder, where it supplied the grating operations. The water then flowed into a stone channel (80cm wide) that curved to line up with the crusher house waterwheel, entering a wooden launder that crossed over the road below on trestles, to feed the overshot waterwheel. Another stone channel merged with this one before the water entered the wooden launder, perhaps conveying additional water that was pumped down from Old Hero Engine Shaft. The main stone channel has been partially obscured by debris being dumped on top of it from the terrace above, probably during the early twentieth century trials undertaken by the Wynnes.

It is estimated that the original leat was approximately one metre wide and would have provided a head pressure to the wheel at the Cornish rolls crusher **(GD-6A)** of approximately six metres. If the leat supplied $1m^3/s$ (1,000 l/s) of water, this wheel could have developed a shaft horsepower of approximately 35kW (47 hp), more than adequate, as the rolls crusher would only have required 10-20 hp. Some refurbishment of the dam wall at the Glendasan River has occurred during water management studies carried out by ESB Turlough Hill and water level markers are present on the upstream side of the bridge. Within the last decade, the leat has been cleared following the rehabilitation of the St Kevin's Way Pilgrim route and now functions as a drain conducting water back into the river, rather than supplying water to the Hero dressing floors as originally intended.

***Primary dressing floors* (GD-4A and GD-4B)**

Two terraces atop massive revetment walls of moorstone contained the primary ore dressing operations which are now covered with gravel and stones obscuring the cobbling that must surely exist beneath. The upper terrace (**GD-4A)** seems to have been the area where the raw lodestone was dumped to be ragged, as the road from Luganure also entered the dressing floors here. The ore then appears to have been sent down (possibly via a wooden slide) to a picking grate on the terrace beneath **(GD-4B)**, where a rectangular declivity 1.2m wide, of which about 9m (of a possible 14m in length), is visible. The water was fed in from the leat along the back of this terrace to convey water to the grate where the ore was picked and sorted for spalling and cobbing. Waste water from the grating process seems to have been conducted into a stone channel that ran along the front of the dressing floor, but its destination is now not obvious due to the collapse of part of the revetment wall at the front of the terrace. To the south is a well preserved cobbled dressing area partially covered by debris **(GD-4C)**.

***Bog Shaft enclosure and spoil heaps* (GD-5E)**

A misshapen square enclosure of randomly coursed moorstone with an entrance in the southern wall leading to a flat interior seems to enclose Bog Shaft (presumably timbered over and invisible) which would have been worked by means of a horse whim. This shaft is shown on the first edition OS Map (1838) and is contemporaneous to the Whim (Old Engine Shaft) and Footway Shafts further up the hill. As the lode outcrop would have been visible higher up the hill, Bog Shaft was undoubtedly developed to further test the Hero Lode to the north. A map believed to date from about 1829/30 shows little development on Bog Shaft compared to Whim (Old Engine) Shaft that was down to the 40 fathom level. Some lode material seems to have been dressed at Bog Shaft as there are small heaps of quartz gangue in several locations and what might be a fragment of a crudely laid cobbled dressing area. A small circular enclosure **(GD-5D)** (2.8m diameter) built to a height of approximately a third of a metre around a flat granite outcrop below one of the spoil heaps might have been a temporary store for ore that had been, or was to be, dressed. Development at Bog Shaft was probably suspended in the early 1830s when work was scaled back at Hero due to the low price of lead. As the shaft eventually attained a depth of about 75 fathoms (137m) and plans show significant areas of stoping to the north, it was revived most likely during the 1840s as Smyth (1853) notes that one of the productive parts of the Hero Lode was where a 'bunch' of ore was discovered close to two portions or junctions of the lode near Bog Shaft. During the revival of activity at Bog Shaft, lodestone would have been trammed through the workings and raised to the surface at Old Engine Shaft that lay closer to the dressing floors, so the Bog Shaft area appears to be a fossilised remnant of 1820s activity.

Two roomed moorstone building **(GD-5A)**
A track leads from the vicinity of the Cornish rolls crusher **(GD-6A)** to a platform at the back of which is a two roomed building constructed of moorstone eroded to a height of less than one metre in places, accessed by a door in the NE end. An internal doorway leads into the second room containing a window and its SE corner has been buttressed to prevent it from collapsing. There is no trace of a fireplace, but the building is much despoiled and its function is therefore uncertain. A small granite boulder outside the doorway of the building contains triangular bore holes and imbedded drill bits which seems to suggest it might have been a blacksmith's shop, but there are no traces of a stone anvil base or a forge. Alternatively, it might have served as a rudimentary miners' dry (a place where men changed and stored their clothes) and materials' store due to its proximity to Bog Shaft.

Moorstone building **(GD-5B)**
Of indeterminate function, this narrow rectangular building that has a door in its NE end and no obvious signs of any windows is sited along the same trackway leading to building **GD-5A**. Its walling is eroded to about a height of 1m and it might have served as a tool shed.

Shelter **(GD-5C)**
The lower walling (about half a metre in height) of a crescent shaped structure of indeterminable function, crudely built of moorstone up against a boulder is located close to building **GD-5B** described above. It could predate mining activity or have served as a very early rudimentary shelter for the dressing floor workforce.

Cobbled platform **(GD-6B)**
A cobbled platform partially covered by debris and contained by a low revetment wall to the north close to the Cornish rolls crusher house appears to be another dressing area.

Figure 16. The extant remains of the Cornish rolls crusher house and the emerging stone and framework of a jigging platform sited in front. The wheelpit is to the far left

Cornish rolls crusher house and waterwheel pit **(GD-6A)**
The Cornish rolls crusher house is sited below the massive revetment walls of the primary dressing floor and the mine road up to Luganure that passed between it and the walling. The building has been badly damaged, possibly taking the rolls crusher and the waterwheel out; only the lower parts of the walling remain and a partially extant wheel pit on the southern side. Nevertheless, enough of the masonry survives to determine that this witnessed multi-phase development, borne out by the documentary record. The first crusher house was probably erected in 1837 and in 1878 a 'new crusher house' was built at the same time as a new jigger. The house was two storied and appears to have had a slate roof sloping down from the wall on the south east side through which the waterwheel axle passed. It seems to have been similar in design to the old crusher house at Baravore in the neighbouring valley of Glenmalure (which was built in the mid- to late-1840s and possibly modelled on the Glendasan one). The wall between the waterwheel and the crusher which formed the highest part of the building has been completely destroyed down to ground level. There is an extant doorway in the north eastern front wall at ground level through which the crushed material that passed out of the trommel was taken to the jigging hutches. Another door in the south western back wall led from a platform into the top storey to charge the ore hopper. A doorway beneath this has been blocked up, suggesting that the ground level behind the building has been altered, making this door redundant. A square aperture in the north eastern front wall (80 cm x 55 cm) might have taken a drive shaft from the water wheel through to the jigging area that was sited on a cobbled platform directly in front (Figure 16). Given that it was probably installed in 1837, this crusher was most likely of the older, two cylinder variety.

The extant wheel pit at the south east side of the crusher is two metres wide, although in-filled with debris from the masonry walling of the crusher. Several square granite blocks each bearing a three inch (7.6 cm) hole in their centre have been located in, or close to, the crusher house. At least three of these are in situ, built into the thick granite wall of the wheel pit; directly below one such holed stone is an extant crow hole used as an access point for tightening a nut on a metal bolt that ran down the centre of the stone above. These bolts secured the heavy wooden frame of the wheel which was overshot and (judging by the four metre difference in elevation of the ground at the launder take off point on the hill slope above), estimated to have been in the region of 24 feet diameter and about four feet in width (based on the width of the feed leat). Quantities of hardened grease on a couple of the large granite blocks of the walling denote the approximate point above where the drive shaft of the wheel would have passed though the wall and into the crusher house.

Jigging area **(GD-8)**

Jigging hutches were sited on the cobbled platform in front of the Cornish rolls crusher. It is likely that this area has undergone several phases of development but all historic mapping shows two rectangular structures in this area. Mechanised jiggers were employed at some stage, as a drive shaft aperture can be seen in the front of the crusher house on the lower left hand side closest to the waterwheel. There is good survival of a square tiered masonry plinth **(GD-8D)** approximately 3.4m by 3m containing exposed wooden planks which appear to have been the platform of a jigging hutch, perhaps the new jigger referred to as installed in 1878 (see Figure 16). Fragments of iron sieve screen (with a mesh of approximately 4.5 mm) with small fragments of galena fused into the mesh and fragments of the metal frames of the hutches have been found here. Considerable amounts of similarly sized rejected quartz fragments may be seen in the immediate vicinity of the jigging area.

Running buddle **(GD-8E)**

The remains of a rectangular structure built up against the wall of a building **(GD-7D)** to the rear of the mine yard **(GD-7)** looks suspiciously like a running or nicking buddle constructed of vertical wooden boards set into the ground, close to the set of steps leading away from the cobbled area between the mine yard and the Cornish rolls crusher **(GD-6A)**. This was constructed in the 1870s when the floors were remodelled and was probably used to treat the metalliferous sludge and sand that accumulated in the jigging hutches, the heads of which were then probably concentrated in a kieve. A hole in the wall below the platform containing the buddle seems to have accommodated a square wooden launder that probably carried away the excess water and slimes. The vicinity of the buddle is covered by a very fine sandy material.

Slimes leat **(GD-8B)**

A channel formed by simple rock clearance to accommodate a wooden launder conveyed the slimes and excess water from the jigging operations downhill at the edge of the dressing floor to be deposited into two rectangular slime pits **(GD-9A).**

Terraced area **(GD-8A)**

Revetment walling of massive moorstone boulders contains a sloping area that is now covered with quartz gravel from the jigging operations through which sections of wooden planking and truncated posts are emerging. The platform is much eroded in its centre highlighting the damage being caused by the passage of storm water through the site. Material coming out of the Cornish rolls crusher was sometimes sent to buddles or tyes to separate out the heads, middlings and tailings (as at Glendalough, see below). This would have been an ideal place to accommodate square buddles using the slope of the hill to upgrade the material coming out of the crusher house prior to being jigged. A section of rail (almost two metres long) with an encrusted rusted chair attached emerged here after recent heavy rain; at least one other chair has been discovered, pointing to the probable presence of a short section of tram that conveyed jigged smalls and halvans down hill to the platform by the Cornish stamps **(GD-10)**.

Figure 17. The 'mine yard' with probable ore store (centre left) and mine office in the far right corner. The truncated building in the foreground is the crusher house

Mine yard and buildings **(GD-7)**

The most prominent buildings on site are those built in and around a walled enclosure constructed of randomly coursed granite (around 1.5 metres high in places) atop a massive rectangular foundation of moorstone boulders built into the slope of the hill (Figure 17). This complex includes a cobbled yard and three unroofed buildings, two of which contain fireplaces. A walled yard on a mine site is quite unusual in a British context (exceptions were the mine yards at Mona Mine and Parys Mountain, Anglesey, Wales which were the administrative hubs of both mines) although at mines such as South Caradon in Cornwall buildings were often constructed in a square to create an enclosure that could be gated. A multitude of equipment and materials needed to be securely stored close to the mine and dressing floor, including wagons, timber, tallow, pitch, tar, lime-wash, linseed oil, steel, iron, copper wire, leather, India rubber, rope of various kinds, copper and iron nails and a variety of mining tools and equipment. Owen Griffiths (1897) notes that the counting office, an assay office, stables, smithy, sawpit and other workshops, as well as the mine bell, were contained in the Mona yard, but of particular interest is his observation of a storehouse containing gunpowder, fuse caps, candles and brown paper. Our survey of the relict mining landscape has revealed no sign of a building that is an obvious candidate to be a nineteenth century powder house or an explosives' store. Such buildings were usually solidly built and purposely constructed away from the main workings in case of an accident; many, such as the reconstructed example at the Glengowla silver-lead mine in Galway, were circular with a conical roof. So it could well be that valuable mining

Figure 18. The Old Hero dressing floor at Glendasan, depicted on a MCI plan drawn by Captain G.J. Bailey in 1868

equipment and materials were deliberately kept under lock and key in the mine yards at Glendasan and Glendalough to deter theft and petty pilfering and particularly to prevent explosives from falling into the wrong hands, given the periodic episodes of political disturbance in Ireland during the nineteenth century.

The Glendasan yard shows signs of multi-phase development that is confirmed by nineteenth century mapping. Prior to 1868, the mine road that entered the dressing floor via a wooden bridge over the Glendasan River travelled uphill and swung right, passing below the massive granite platform atop which is the extant mine yard (Figure 18) and seemed to pass through the works between the Cornish rolls crusher house **(GD-6A)** and the current entranceway into the yard. The MCI map of 1868 depicts the yard as being part of an enclosed rectangular structure split into three sections; one section **(GD-7A)** (the extant cobbled part), is slightly larger than the other two. A rectangular building divided into two is shown built on to the NE corner of the cobbled area (which appears to have been demolished later on). After the Glendasan floors were resuscitated and remodelled in 1869, the direction of the mine road was changed. By 1873 the rectangular enclosure had been breached in its SE wall and the mine road is shown entering it. A small square building **(GD-7B)** (noted on the OS second edition 6-inch map of 1889 that identifies this as the mine office), has been added into the SW corner of the cobbled area (see Figure 20). This building, plastered and with a sloping slate roof (fragments of which may be detected nearby) is similar in design to that at Glendalough, but contained a fireplace opposite the doorway and two windows looking out onto the yard (Figure 19). The other extant building **(GD-7C)**, a larger rectangular structure built onto the eastern side of the yard containing a door leading onto a cobbled platform at the back and that has two large openings leading into the mine yard is also depicted. Slate fragments can be seen in the vicinity of the building suggesting it also had a slated roof, but if the two openings leading into the yard are doorways, it strangely had no windows and is unlikely to have been a miners' dry or a dinner room. Its most likely function therefore, was a place to store mine materials and probably the ore prior to it being weighed and transported to the smelter (note the mine road formerly ran up beneath this building and later a track was maintained that terminated below the cobbled platform protruding from the back of this building that would have facilitated the loading of ore into carts).

Figure 19. This office was built in the 'mine yard' after the Old Hero dressing floors were revived in the late 1860s

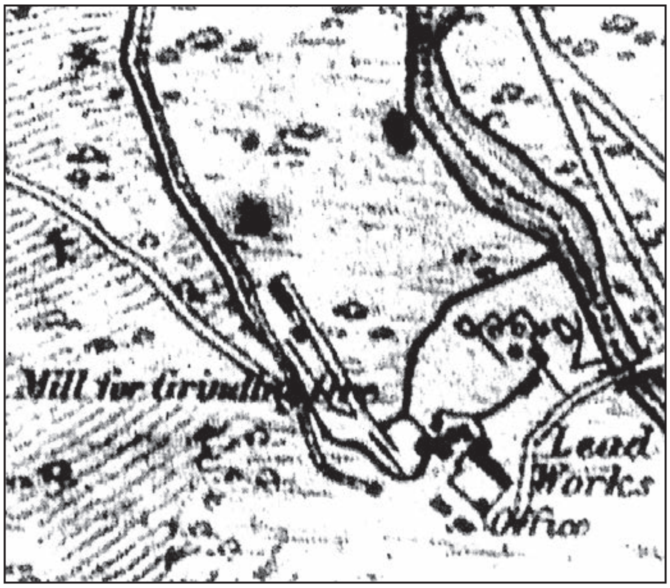


Figure 20. The OS Second Edition 6-inch map, c1889 showing the new layout of the Hero dressing floor

The OS second edition 6-inch map also shows that by 1889 the layout had changed yet again. The rectangular structure has been divided with the segment on the western side now containing two detached buildings and the walled cobbled area below now entered by a new gateway in the wall opposite the crusher house. The archaeology confirms this to be the case. Uneven masonry betrays the breach made in the NW wall of the old rectangular enclosure and the substantive remains of moorstone walling that formed the back of a former building(s) **(GD-7F)** is extant but the remaining walling has disappeared. There is a strong suspicion that one of these buildings might formerly have been a forge, as large amounts of clinker that has obviously originated in an industrial hearth rather than a domestic fireplace, is strewn about the road and hill slope. An inventory compiled of the mines in 1869 states that there was a forge at Hero blown by a 36-inch bellows. Captain Mitchell had a new forge **(GD-2)** built in a central position between Old and New Hero in 1875 (which is extant), so the Old Hero forge might well have been demolished when that was completed. Fragments of scrap metal are evident and the boggy ground is very iron stained.

The 1889 6-inch map also reveals that the area between the jigging hutches **(GD-8)**, the crusher **(GD-6)** and the mine yard **(GD-7)** has undergone significant modification, probably undertaken by Captain Mitchell in 1874 (Figure 20). Four buildings are depicted here, two of which seem to be the jigging sheds in front of the crusher, but two larger rectangular buildings have been constructed, one close to the crusher and another close to the platform containing the running buddle **(GD-6C)**. A small building **(GD-7D)** (the truncated remains of which are extant) has been built on to the back of building **(GD-7C)**. Another long rectangular building **(GD-7E)** has been added below the front of the massive granite eastern foundation walling of the yard. It had a slated roof sloping away from the mine yard and a fireplace with a brick chimney breast at the end opposite the doorway. As it was heated it might have functioned as a dinner room or a dry. There were two windows in the front wall facing towards the road. An early twentieth century photograph of the Glendasan valley shows the dressing floors in the far distance and it appears that the yard wall and buildings within appear to have been lime-washed, a common practice as lime-wash has fireproofing qualities, is breathable, anti-bacterial and insecticidal.

Prior to the probable arrival of the Cornish rolls crusher in 1837, all of the ore was being reduced manually. Therefore, there is a strong likelihood that the area now forming the cobbled yard was a former dressing floor, the level platform above being the place where the raw ore was dumped to be washed and ragged. When mechanisation arrived in 1837, the dressing layout was completely altered as a leat needed to be brought in to provide water to power the crusher and the extant terraced platforms above the crusher house were constructed.

Settling pits **(GD-9A)**

Two rectangular pits with an interior width of 3.1m by 6.3m received the muddy water from the jigging (and possibly grating) operations higher up the site. Their depth is difficult to ascertain due to deposition of sands and gravel, but they are approximately 1m deep, so could theoretically contain 20 cubic metres of slimes (70-80 tons of mixed quartz and galena).

Cornish stamps **(GD-10)**

Four square rusted concretions and embedded fragments of a heavy wooden frame denote the footprint of what was most probably a 16 head battery of stamps **(GD-10B)**. One of the stamp bases has been badly eroded by storm water scouring, causing it to topple over revealing the fragments of quartzose schist that were packed inside a wooden box frame (the one next to the toppled base is superbly preserved) to form the solid base for the stamp heads (Figure 21). This stamp battery was likely to have been installed in 1851 to crush halvan ores and probably also chats from the jiggers. The stamps were powered by a waterwheel, likely in the region of 24 feet in diameter, the badly eroded pit of which is just discernible

Figure 21. One of four rusted concretions, this one still within its wooden box frame, denoting the base of one of the Cornish stamp batteries, which is a highly rare example of nineteenth century stamp bed formation

alongside the stamp bases. The water that had passed over the waterwheel of the Cornish rolls crusher above was delivered in a wooden launder to this wheel that was either overshot or breastshot. The stamps were fed from a platform above which appears to have been connected to the jigging area higher up the site by a small tramway. These stamp bases (and also those at Glendalough) are a highly rare example providing archaeological evidence for the process of stamp bed formation witnessed and described by Moissenet (1858) in Cornwall and are therefore of very high heritage value.

Level rectangular area

An area opposite the stamps water wheel to the SE has been purposely cleared where a massive rectangular baulk of wood set in the ground clearly secured a sizeable item of machinery, further betrayed by accumulations of grease in a line on the ground. Additional splatters of grease on a nearby boulder suggest an item of machinery containing a part that span with some motion probably run by a drive shaft from the stamps' water wheel.

***Buddles* (GD-9)**

Three buddles **(GD-9B)**, **(GD-9C)** and **(GD-9D)** are shown on the 1873 map on the platform below the Cornish stamps and were installed when the Glendasan dressing floor was rehabilitated in 1869. The 25-inch OS Map of 1889 depicts only two of these three buddles, but another **(GD-9E)** is shown on the square platform that protrudes in front. The faint masonry outlines of these three round buddles roughly 5.6m to 5.9m in diameter confirms that two **(GD-9B)** and **(GD-9C)** were set close together nearest the stamps, the other **(GD-9D)** slightly further away. These were mechanised, denoted by the fragments of wooden bases of a line shafting that led from the stamps waterwheel to rotate the feed distributors and sweep arms of the buddles. The overflow water from the buddles seems to have been channelled into two shallow tanks **(GD-9G)** that occupy the area in front of the pair on the NE side. These are 2.6m wide, with the larger of the two 5.8m in length and the other 4.7m.

The buddle **(GD-9E)** on the square protruding platform is better defined and 5.9m in diameter. This seems to have been of concave design, as a wooden launder runs from beneath it to emerge at the base of the rubble masonry wall forming the platform on which it is sited, to a work area below and this buddle might have been upgrading slimes from the two settling tanks **(GD-9G)** nearby. The vertical slots that supported posts for a roof in this work area are extant and possibly covered an area containing kieves to concentrate the fine slimes from the buddles (a semi-circular fragment of wood that possibly formed the base of a kieve was discovered near this area). A further convex buddle **(GD-9F)** (5.5m diameter) with its wooden central cone intact (Figure 22), is sited close by but is not depicted on the 1889 map, possibly because it was covered by a shed. It is being eroded by storm waters flowing across it and was probably powered by a small independent waterwheel fed by the leat running through the site. Fragments of wood (there is good preservation of wooden features throughout this dressing floor) and in situ planking show that areas close to the buddles were formerly covered with decking, where heaps of ore were piled up on being dug out of the buddles to await further dressing. This buddle floor is unique in Ireland and is of significant heritage value.

Figure 22. Convex centre head buddle with its wooden cone still intact. The buddle floor at Old Hero is of high heritage value

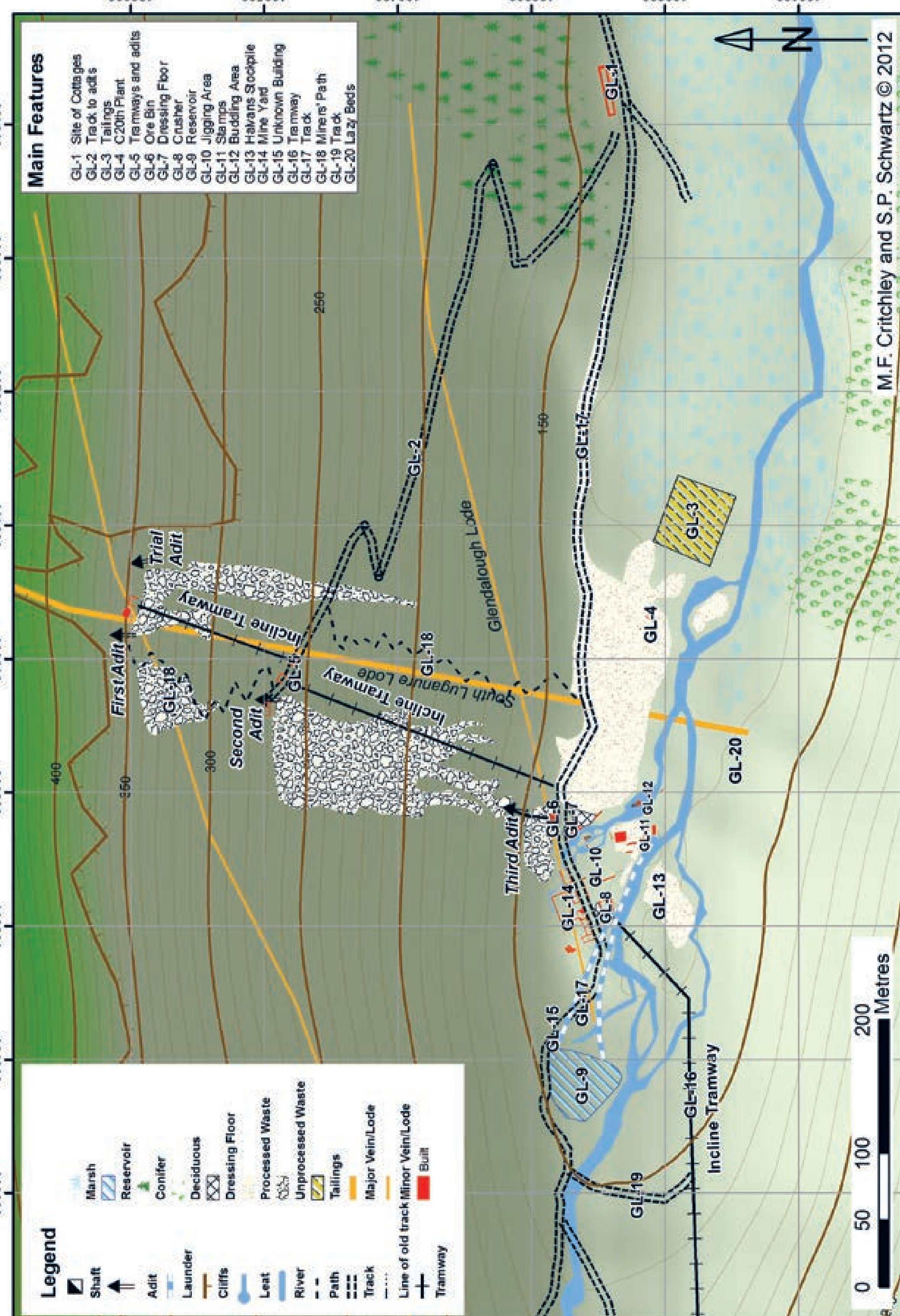
***Slimes treatment area, tailings and revetment walling* (GD-11)**

The flat area below the circular buddles might well have contained self acting slime frames or rag frames for catching the fine ore that had escaped the buddles as it contains numerous fragments of wooden debris, posts and timber planks buried end on in the ground. Rag frames did not require much labour at all, were cheap to install, very effective on fines that would previously have been lost in the discharge effluent and therefore helped to cut down on lead pollution. Such devices might have represented a key aspect of Captain Mitchell's labour saving devices for thorough treatment of the ore. The area nearest the Glendasan River contains the detritus of the dressing operations in the form of masses of slime held back behind a solidly-built revetment wall of random moorstone now somewhat eroded in places by river scouring. The leat that ran through the site eventually discharged into the Glendasan River close to the present concrete bridge.

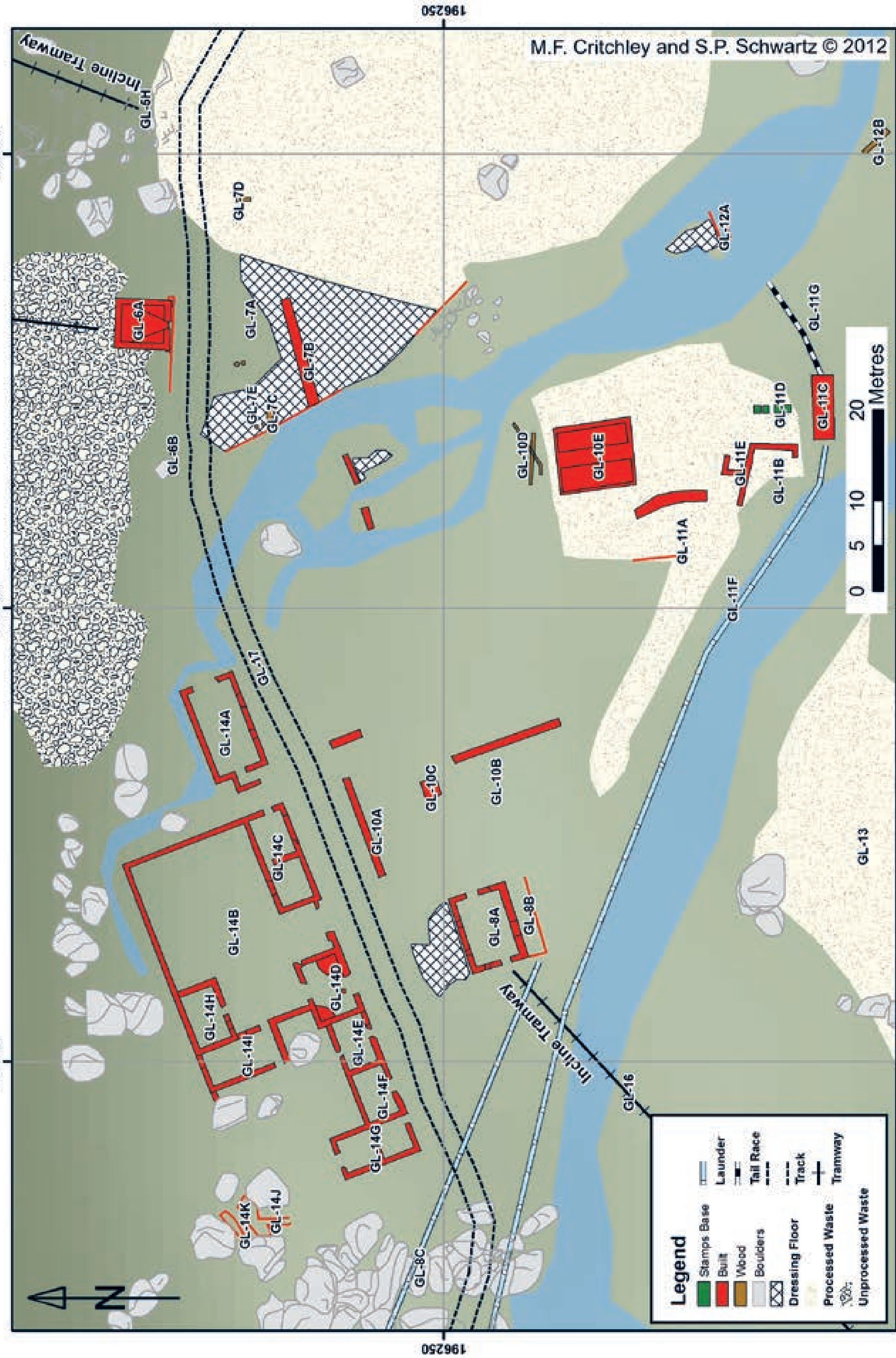
AN INVENTORY AND INTERPRETATION OF DISCRETE FEATURES: GLENDALOUGH DRESSING FLOOR

***Tailings dam* (GL-3)**

A square dam to the SE of the dressing floors can be clearly seen today above the Upper Lake (Figure 23). MCI maps show that this dam was created sometime between 1868 and 1873 and it is also depicted on the 25-inch OS Map of 1889. Effluent from the dressing floors was purposely diverted into this, probably via a launder, to capture the fine material in suspension and thus prevent lead from escaping into the lough. This feature demonstrates that the MCI went to great lengths to prevent legal action by local tenants claiming damages due to lead poisoning.



Map 4. Overview of the Glendalough dressing floor and related features



Map 5. The discrete elements of the Glendalough dressing floor

Figure 23. The square outline of the MCI tailings dam (centre right), built to prevent lead contaminating the lake. The halvans dumps are opposite the crusher on the right

Figure 24. Cornish rolls crusher manufactured by John Mills of the Railway Foundry, Llanidloes, Wales. This is the finest crusher of its type in Ireland

***Cornish rolls crusher and early twentieth century mill* (GL-4)**

Beyond the spoil heaps at the southern end of the site is undoubtedly the finest example of a Cornish rolls crusher in Ireland and which rivals any contemporaneous extant examples in neighbouring Britain and which was a component of the Wynnes' small early twentieth century treatment plant (Figure 24).[22] It was manufactured by John Mills (1843-1922), an engineer born in Trefeglwys, in the former county of Montgomeryshire (now part of north Powys), Wales, who became the owner of the Railway Foundry, Llanidloes. Mills gained his experience as an engine smith in Wolverhampton, Staffordshire (PRO London, 1871 Census) and moved to Llanidloes around 1872, taking over the running of the Railway Foundry before 1881 (PRO London, 1881 Census). His company supplied waterwheels, dressing plant and other mining equipment to numerous Welsh lead mines, including Van and Nantiago, but it is not known whether this crusher was supplied direct to the Wynnes, or if it was moved from elsewhere or purchased second-hand. As the Mills crusher was obviously working when Collins visited the plant in 1917, it cannot be the one used by the MCI at Glendalough which were possibly the much larger set of rolls which Collins saw lying redundant at the site.

The Mills crusher was sited inside a large wooden shed, the outline of which is discernible on the ground, and it has survived relatively intact on its concrete loading, although the wooden base bearing the axle has rotted causing the fly wheel to partially collapse. The cast iron rolls have replaceable steel tyres, the bearing-and-bracket assembly of one of the rollers held in position by high compression springs. The ore hopper has been removed, but its iron sides with their sacrificial plates still intact, lie nearby. The brass-work of the bearings is gone but the gears and shafts are in good condition. The crusher was cast in sections for ease of transport and the various parts have been clearly numbered to aid reassembly.

Four concrete bases to the south of the crusher might be the loadings for the bumping mechanism of shaking tables. The lower walling of a rectangular breeze block building possibly served as an office within the shed. A concrete base bearing four cut off iron bolts with a fly wheel slot close to the crusher probably accommodated the gas engine and in line with this is another loading to the side of the crusher that served as a support for an axle bearing that has been removed. To the east lies a concrete rectangle about 8.5 metres in width by 4.3 metres in length and beyond this, a further rectangular area of about 8.5m by 4.6m covered with slimes. Water for the engine and for dressing purposes was conveyed from the old reservoir to the plant via a wooden launder erected on trestles that ran between the spoil heaps and the Glenealo River. Several of the truncated posts that carried this launder may still be seen close to the river. The wooden shed enclosing the plant was

22 A smaller example may be seen in the 1950s gravity mill at Glendasan.

destroyed in a storm in 1935.

***Inclined tramway* (GL-5)**

A gravity assisted inclined tramway led down from First Adit to a platform close to the Second Adit, a drop of about 80 metres at a gradient of almost 1:1. From here wagons of stuff were trammed along a short wooden platform to the top of another incline track that led down to the dressing floor, a drop of about 130 metres at a gradient of 1:2. The base of the tramway **(GL-5H)** is just to the south of the cobbled primary dressing floor platform **(GL-7)** and a track (possibly the former route of a short section of tramway) that leads toward the bouse team **(GL-6)** and is marked by a low revetment wall, above which is a rectangular flat section where the wagons were landed. The tracks of both inclines were built, at least for parts of the route, on wooden tresses above the boulders and all along their courses are pieces of the wooden sleepers, rail spikes, iron chairs for securing the rail and triangular shaped drill holes in the granite boulders which probably secured cable stays. A double flanged iron sheave wheel 48 cm in diameter and a fragment of flat rope 9 cm in width, were discovered near the top of the incline at the Second Adit and a fragment of iron rail close to the top of the incline at First Adit.

On a platform above Second Adit, built on the route of a very steep miners' zig zag pathway (**GL-18**) that led from the valley floor right up to First Adit, is a large coil of rusting flat rope, which suggests that this might have replaced the chains referred to as in use on the incline by Draper in 1860. Wire flat ropes were introduced in about 1841 for winding purposes with many collieries in the North of England introducing them. Black splatters and drips on the rocks below and to the side of the tramway indicate that the chain/flat rope used on the tramway was heavily greased. A recommended mid-nineteenth century mixture by R.S. Newall Ltd. of England was 'tar six parts, linseed oil two parts and tallow two parts, the whole part melted together and applied while hot' (The Penny Cyclopaedia 1841, 156). The tubs probably also had crude bearings that needed to be greased regularly and the sheave wheel was possibly used to guide the chain/flat rope and prevent it from hitting the ground where it would be subject to wear.

Close to the top of a zig-zag mine road **(GL-2)** leading up from a row of eight cottages **(GL-1)** close to the main mine road **(GL-17)** towards the Second Adit is the tramway drum-house marked by a rectangular structure of randomly coursed moorstone and mica schist built into the slope of the mountain. The gable ends have eroded away and the structure had a slate roof (evidenced by fragments in the vicinity). It held the horizontal winding drum secured within a strong wooden framework for the tramway cable. A similar structure is extant at the top of the second section of tramway at First Adit.

***'Bouse team' (ore bin*) (GL-6A)**

This solidly built granite structure built into the slope of the hillside served as an ore storage bin fed by a tramway from above that led from Third (White Rock) Adit and possibly also a rail coming in from the base of the inclined tramway **(GL-5H)**. The bouse team measures 6 metres wide by 5.5 metres in

Figure 25. The cobbled 'bouse team' or ore bin used to store ore prior to it being ragged and washed. This is the best preserved structure of its type in Ireland

length and is lined with sloping granite cobbles to a depth of 1.5 metres; a wall at the front has an opening through which the ore was raked (Figure 25). Keystones projecting from both sides of the front wall of the building suggest that further structures might have been planned but not erected. An identical bouse team was erected at Van Diemen's Land Mine in the late 1860s, but it is in a less well preserved condition. The Glendalough bouse team is constructed in a style quite different to those common on contemporaneous British lead mines. Most Welsh examples are built into banks and found in pairs with steeply sloping semicircular cobbled interiors with an opening at the very bottom of the walling forming the front of the bin (such as at Bryn Dyfi and Bronfloyd); a similar design may be seen at the Beevor Mine Grassington, Yorkshire and at Tankerville in Shropshire, but these are constructed in rows with much steeper sloping semicircular interiors.

In the Pennines, bouse teams are more commonly open fronted structures with cobbled, non-sloping interiors built in a line with masonry dividing walls (such as at Scordale; Gunnerside Gill, Swaledale; Beldi Mines; Slitt Mines, Mohopehead; Nenthead and Killhope) where each team of miners stored their ore prior to it being dressed. Bouse teams of this type were not found on Cornish mines; Sir Henry de la Beche's 1837 map of Fowey Consols Mine depicts a series of wooden hutches that served as 'places for storing the ore prior to being dressed' (Lewis 1997, 63). The Glendalough bouse team is not a design recognisable in Britain. It, and the example at Van Diemen's Land Mine, are unique within an Irish context and of considerable heritage value.

The vertical iron pipe **(GL-6B)**, a piece of rising main (used to pump water from underground) might have formed part of an apparatus used to convey water in a launder to the bouse team to wash the ore on a picking grate that would have been located below the front aperture. At Rheidol United near Aberystwyth in Wales, are two extant ore hoppers used as wash kilns along with the leat carrying water to them (Palmer and Neaverson 1992, 263). Indeed, many others have been located in Wales by Palmer and Neaverson and they suggest that this practice might have been more common in other mining areas too (except the Pennines where the bouse teams

Figure. 26. Inclined box launder (centre) emerging through a damaged section of the revetment walling of the primary dressing floor. A set of posts for a tramway to the crusher can be seen centre left and the bouse team far left

were not steeply inclined and where the ore was washed outside on picking grates), but that archaeologists have often failed to look for a water supply to them (Palmer and Neaverson 1989, 23).

Primary dressing floor **(GL-7)**
A rectangular cobbled terrace delineated by granite boulders **(GL-7A)** and partially covered by finely crushed spoil is contained by a revetment wall about two metres high constructed of large blocks of moorstone. This was the primary ore dressing area where the washed ore was manually reduced. This raised platform was probably deliberately created by dumping layers of mine waste from the nearby workings, as the ground beneath the rounded granite cobbles (taken from the nearby river) consists of broken fragments of quartz and granite. The floor is badly eroded on its eastern side by water action and footfall and the central part of the revetment wall has collapsed, spilling granite blocks and loose gravel from the floor above. Two buildings are shown on this dressing floor on old mine plans and were probably open-sided wooden sheds offering some shelter to the ore dressers.

A wooden box launder **(GL-7D)** has been uncovered by water action close to a boulder at the back of the dressing floor and probably conveyed water from Third Adit for dressing purposes. Another much larger gently inclining 'plumbed-in' box launder (**GL-7C)** about 18cm (7 inches) wide on its interior seems to have conveyed slimes from the primary dressing floor, presumably to a settling pit (Figure 26). The end of it may be seen emerging through the remains of the revetment wall. As the Luganure ore could be separated relatively easily and cheaply from its gangue, this cobbled area would have remained in use throughout the life of the MCI operations. A rectangular feature 60 cms (2 feet) wide running east west **(GL-7B)** is marked by a distinctive line of cobbles. A wooden plank containing two square headed iron bolts crosses the centre and, judging by the indentation marks and fragments of wood, this feature appears to have been lined at the sides with wooden boards. It might therefore represent the site of an early picking grate where the ore was washed and sorted. This nineteenth century dressing floor is the most extensive and best preserved example of its kind in Ireland.

Dressing Floor Tramway.
An above ground tramway conveyed ore to be crushed by the Cornish rolls from an area between the bouse team and the primary dressing floor towards the crusher **(GL-8A)** sited about 60 metres away. Three sets of inclined wooden posts **(GL-7E)** that supported this tramway with pegs at the top to fit into a socket on the rail sleeper have survived just above ground level on the cobbled dressing floor, before the two metre drop beyond the revetment wall (see Figure 26). The archaeology is backed up by the 1860 etching (see Figure 12) that portrays this tramway supported by the inclined posts leading to an area **(GL-10)** in front of the Cornish rolls crusher house.

Glendalough-Van Diemen's Land tramway and road
Just over one kilometre in length, this tramway **(GL-16)** ran up the mountainside from a grassy area on the south side of the Glenealo River where the ore wagons were uncoupled (Figure 27). The ore to be crushed was trammed across to the top storey of the crusher house (Figure 28). The gradient at the top of the incline (1:6) was greater than the gradient at the bottom (1:25) and it was not a gravity assisted inclined tramway like those working the First and Second Adits. Materials also needed to be hauled up and it was thus worked by a waterwheel set alongside the drumhouse at the top of the incline. The steepest section was in the middle third which was 1:3 and entailed crossing a small ravine, probably by means of a trestle bridge. The lowest third of the route traversed a boulder field and instead of clearing this by blasting to make way for the track, it was simply built above it. Notches cut into the granite to take the base of the wooden trusses for the track as well as numerous drill holes for bolts and cable stays can still be seen.

In order to facilitate the haulage of materials needed as the tramway was being built, a roadway **(GL-19)** was constructed to bring materials to its base. Above the ravine, the tramway entered a small stone lined cutting to pass under a wooden bridge carrying the mine road from Glendalough to Van Diemen's Land. This beautifully engineered road **(GL-17)** complete with stone culverts diverting streams and storm waters beneath it now forms part of the popular walking route from the Upper Lake Car Park to the Spinc. It appears to have formerly bypassed the boulder field by a bridge over the river just above where the service route **(GL-19)** ran toward the tramway, crossing it again higher up by another bridge to begin the ascent up the ravine. Probably due to flooding events that damaged the bridges, the MCI was forced to create a route through the boulder field. The place where the old road joined the route of the present road may be seen at the first hairpin bend. The road then zig-zagged up the side of the ravine and crossed over the Glenealo River by means of a bridge in line with the tramway cutting that was spanned by another bridge. It then turned sharply west to run uphill almost parallel with the tramway.

Cornish rolls crusher house **(GL-8A)**
This two storey building of randomly coursed granite and

Figure 27. Early morning light illuminates the zig-zag mine road from Glendalough dressing floor up to Van Diemen's Land Mine (marked by the conical white spoil heap in the centre) as seen from the Second Adit. The faint scar of the former route of the inclined tramway track to Van Diemen's Land Mine can be seen to the left of the Glenealo River. The front wall of the reservoir is visible bottom left

Figure 28. The Cornish rolls crusher house still dominates the site today as it did 150 years ago. Its conservation is a matter of urgency

mica schist contained a set of Cornish rolls and although truncated, it still dominates the site today as it would have done 150 years ago (Figure 28). It was powered by an overshot waterwheel, probably in the region of 30 feet in diameter and was built in 1855. The NW wall had two windows in its upper storey and a doorway in the top right of the NE wall, as depicted in the 1860 etching. Another doorway in the top storey of the SW wall probably received ore from the Van Diemen's Land tramway. Two doorways at ground level in the NE and SW ends of the building gave access to the lower storey. The hole for the drive shaft of the waterwheel in the SE wall is no longer very evident as the surrounding masonry has gone, but grease marks can be seen on the exterior of extant walling beneath where it would have been. The waterwheel pit **(GL-8B)** is ill defined and this might be because the 1860 etching appears to depict it as built into a wooden frame. The tailrace was conducted into a wooden launder and mixed with crushed material from the Cornish rolls then fed into a series of tyes sited in front of the crusher house **(GL-10)**.

A deliberately engineered rectangular opening in the SW wall of the crusher at floor height and to the left of the doorway (looking from the outside) could be an opening for a drive shaft of some description, possibly to power jigging hutches. Another small opening in the SE wall probably served the waterwheel in some capacity, maybe as a braking or clutch mechanism. The line of the flooring and numerous joist holes can be seen inside the building which was rendered with lime plaster and painted white. Two large holes indicate where strong baulks of wood traversed the interior of the building, to support the rolls crusher. The exterior of the building was rendered with lime plaster and painted white and it had a pitched slated roof. The area at the rear of the crusher (SW end) is strewn with fragments of iron and this might have been where the scrap metal for the blacksmiths' forge (just about opposite) was stored.

Launder to the crusher waterwheel **(GL-8C)**

Evidence of the route of the wooden launder that conveyed water from the reservoir at the NW end of the site to the crusher's waterwheel is visible. Close to the crusher house is a wrought iron stay attached to a circular iron pin embedded into a granite boulder which would have carried a cable to stabilise the launder, which was at this point quite high. Another similar stay can be seen close to the western wall of building **GL-14G**. Circular wrought iron pins can be found along the course of the launder and also drill holes in the nearby rocks, some of which have been deliberately blasted away to accommodate the passage of the launder.

Reservoir **(GL-9)**

This is a double walled moorstone enclosure probably with an infill of impermeable clay covering approximately a quarter of a hectare to impound water carefully diverted from the Glenealo River at the NW end of the site (see Figure 27). The feed for the crusher's waterwheel **(GL-11F)** came off at the NE end of the reservoir and that for the stamps' waterwheel **(GL-8C)** from the SE end.

Tye and jigging area(s) **(GL-10)**

In front of the crusher is a flat area that appears to have been extensively cobbled (but is now covered with fine sand and grass) and which formed part of an area where the ore was classified and concentrated. A well preserved fragment of this cobbled surface has survived between the blacksmith's forge **(GL-14D)** and the NW wall of the crusher **(GL-8A)**. Having the area cobbled made it easier to barrow materials round the site and to provide a firm working surface that was easy to cleanse of mud and sand. Draper's description informs us that this area formerly contained several tyes which are now not visible. Three rectangular buildings are depicted on a MCI map dated 1868 in the area in front of the crusher house and probably covered the tyes and/or jigging hutches. The lines of masonry at ground level **(GL-10A** and **GL-10B)** are perhaps associated with these buildings that are also indicated in the 1860 etching. Sub surface archaeology undoubtedly exists in this part of the site.

Mechanised jigging hutches would have been sited close to the crusher, run by a drive shaft from its waterwheel. A square masonry base in mica schist roughly 2m square **(GL-10C)** might be the remains of a platform for a manual jigging hutch. Any fine slimes resulting from the classification in the tyes and jiggers would have been collected in pits for further processing. Two exposed wooden launders **(GL-10D)** set in purposely built stone lined channels about a 30cm (1 foot) in width and that had wooden covers can be seen running away from the area in front of the crusher towards the east of the site (Figure 29). One launder running at an angle towards the other has been carefully directed over the top of it. Both are heading off to slightly different areas of the dressing floors and would appear to have carried slimes, perhaps from various jigging hutches to be processed in buddles. At the far end of the grassy area are two settling pits **(GL-10F)** the first cobbled and seeming to gently incline towards the lower pit. These appear to be connected to operations in front of the crusher rather than with the stamps. A long bank of spoil **(GL-11A)** heading towards the river has been built up between the grassy area and the first settling pit, and seems to be of much later derivation as it partially covers earlier archaeology and dates perhaps from the Wynne period. It might even represent a

Figure 29. Two wooden launders that conveyed slimes from the tyes and jigging area in front of the crusher house once crossed over each other

more recent attempt to prevent storm water from flowing unhindered across the site.

The water from the Third Adit and from a spring that is situated behind the mine yard were formerly carefully diverted below the site not far from the bouse team and emerged from a culvert to join the Glenealo river. It is clearly depicted on the OS map of 1911. This has long since been washed out by flash flooding and is now denoted by a stream that flows unhindered between the revetment wall of the primary cobbled dressing floor and the grassy area in front of the crusher house. Sections of cobbled flooring are extant beneath the water.

Cornish stamps **(GL-11)**
Heidkamp incorrectly interprets this as the base of the inclined tramway from First and Second Adits. It is in fact the site of the Cornish stamps, marked by four square rusted concretions **(GL-11D)**, the base of the stamps on which the mortar boxes sat, which indicates that there were two batteries side by side on site (probably containing about 16 head of stamps). These were erected in about 1855 when the dressing floor was built and were utilised to crush batches of jigged smalls (chats) and halvans (poorer ores). There is excellent survival of the substantive base of the timber framing for the stamps and a single cam has been discovered, its position recorded at the site, then removed for conservation. Fragments of the stamps' screens have also been found here through which the pulp passed from the mortar box (Figure 30). The screen is made of punched iron sheeting as described by Moissenet (1858, 83-84), the holes of which are approximately an eighth of an inch in diameter (3 mm). Directly behind the iron concretions of the stamps is a 2m high masonry wall of granite and mica schist. The wing wall of this structure **(GL-11B)** nearest the Glenealo river has been destroyed by flooding. This seems to have functioned as the base for a wooden ore bin into which material to be stamped was trammed to be dropped down behind the stamps via a wooden slide and fed into the mortar boxes. Adjoining the base wall of the ore hopper is a small building **(GL-11E)** containing a fireplace in its western wall and a small alcove to the right and above the fireplace (Figure 31). This possibly served as the stamp watchman's hut, a retreat from the wind, rain and bitter cold that afflicted the valley in the long winters for the man who had the responsibility for maintaining the stamps, including greasing the bearing and guides, changing the screens, replacing the stamp heads, making any necessary repairs as well as probably watching other nearby dressing equipment.

The waterwheel powering the Cornish stamps was sited to the south of the stamps **(GL-11C)**. Four square headed bolts that held the wooden frame of the waterwheel in place are extant. The wheel is estimated to have been in the region of 24 feet in diameter and about 4 feet in width and was most likely overshot, the water conveyed by a wooden launder **(GL-11F)** from a take off point on the SE side of the reservoir (shown in Figure 13). The tailrace **(GL-11G)** from the wheel pit is well preserved and ran towards a channel that emerged from a culvert passing under the site towards the Glenealo river. Any decking that might have been placed along the front of the stamps down which the pulp ran has not survived as the area

Figure 30. A fragment of stamp screen manufactured from punched iron sheeting, with holes approximately 3 mm (one eighth of an inch) in diameter

has been subjected to considerable scouring by flood water. This suite of features is at high risk of further damage and attempts must be made to study and understand the site's fluvial geomorphology in order to protect the archaeology from being erased during flooding events. The Glendalough stamps contain the remnants of a suite of important features which, taken together, add up to be more than the sum of their parts. This site is unique in the island of Ireland and is unrivalled on many British mine sites. It is of therefore of considerable heritage value.

Sands and slimes concentration
With space at a premium at Glendalough due to the terrain, it seems likely that the area in which the concentration of fine sands and slimes would have been located is in the extreme south eastern section of the site, between the primary cobbled dressing floor's revetment wall and the area to the east of the stamps, below the large spoil heaps. Unfortunately, this area has also been subjected to considerable water erosion. Directly in front of the two rectangular settling pits is a raised fragment of ground **(GL-12A)**, the cobbles of which are laid directly on top of peat which gives some indication of the former height of the ground. Immediately in front of this area is a rectangular tye or strake with a partially exposed wooden board across it which was undoubtedly used for upgrading sands. There is documentary evidence for at least one round frame, a free standing wooden construction, which would have been mechanised by a drive shaft run off the stamps waterwheel. A 'L'-shaped structure in front of the stamps is shown on the 1868 mine map that possibly accommodated the round frame and possibly even some mechanised kieves. Further evidence of this area being the probable site of the final treatment of sand and slimes are the two box launders running towards it, as well as another section of exposed box launder **(GL-12B)** running towards the Glenealo River which seems to have been conveying run off that originated in the area below the stamps, and probably predates the construction of the tailings dam.

Figure 31. The site of the Cornish stamps, erected in about 1855, contains a unique suite of features which makes this the most important site of its type in Ireland. It is of significant heritage value

Piles of sand and slimes were impounded below the large heaps of spoil and contained with wooden stakes and boards in a manner similar to those at Glendasan.

***Halvans stockpile* (GL-13)**

South of the site across the Glenealo River and not far from the Cornish stamps **(GL-11)** is a highly visible area of rocks that have not vegetated (see Figure 23), although moss and lichen growth indicate that they have been there some time. The fist sized fragments of rock lie directly on top of peat on one of the areas that now forms an island in the Glenealo River and date from the MCI period. This dump contains remnants of the lodestone rejected from the primary picking floor as 'halvans', poor ores that were then not worth the cost of processing, or containing minerals of little or no commercial value like sphalerite ((Zn,Fe)S): zinc sulphide. It is possible that the MCI was stockpiling halvans with a view to reprocessing them (by passing them through the Cornish stamps nearby) at periods when the lead price fell and the company wished to maximise profits. It is not hard to find good specimens containing 10-20 per cent lead here, which gives some indication as to why this and other nineteenth dumps were reworked by the Wynnes in the twentieth century.

***Mine yard and buildings* (GL-14)**

This complex has been dubbed the 'Cornish Miners' Village', but this is a misnomer as no one ever lived here on a permanent basis (Figure 32). It most certainly was not a 'small village of miners' houses' as described in the field trip notes of the Industrial Heritage Association of Ireland newsletter (Anon 2011) but rather a walled industrial complex comprising the stores and workshops for the mines and the dressing floor. The yard, enclosed by a coarsely constructed wall of mica schist about 2 metres (6ft) high now choked with bog and grass, was probably used to store the same types of materials as described at Glendasan. The series of buildings clustered around the mine yard are in various states of preservation and show clear signs of multi-phase development, backed up by historic mapping. A map dated 1864 by Captain Frederick Richards shows a three sided yard seemingly open at the northern end but that possibly incorporated buildings fronting onto and running parallel to the mine road **(GL-14E)**, as these can be seen in the 1860 etching (Figure 33). A detached rectangular building **(GL-14A)** is shown to the east of the yard.

An 1868 map of the mines by Captain G. J. Bailey (see Figure 13) depicts the yard that was shown as enclosed and entered via an opening between buildings constructed onto the front of the yard wall facing the mine road and a new row of buildings that has been built onto the wall of the yard to run parallel to the mine road **(GL-14F** and **GL-14G)**. The detached rectangular building **(GL-14A)** is still depicted. A map of 1873 shows that some development within the yard had taken place with a rectangular building **GL-14I)** running north south and built onto the north west wall of the yard, and a building (**GL-14H)** set into the NW corner of the yard. A small square structure is also depicted in the SE corner of the yard of which no trace now remains; it might have functioned as a privy. The detached building **(GL-14A)** is still shown. The 1911 OS map, published over two decades after the mines had been sold by the MCI, shows one minor change had occurred, and that was an extension to the rear of building **(GL-14G)**.

Field study has shown that the existing entrance to the yard is via a gateway in the southern wall facing onto the mine road **(GL-17)** running east west between the yard and the crusher

Figure 32. The first rays of the morning sun catch the stonework of the 'Miners' Village', something of a misnomer, as it was not residential, but an industrial complex comprising office, stores, forge and workshops for the mines and the dressing floor. The truncated remains of the Cornish rolls crusher house can be seen in the centre

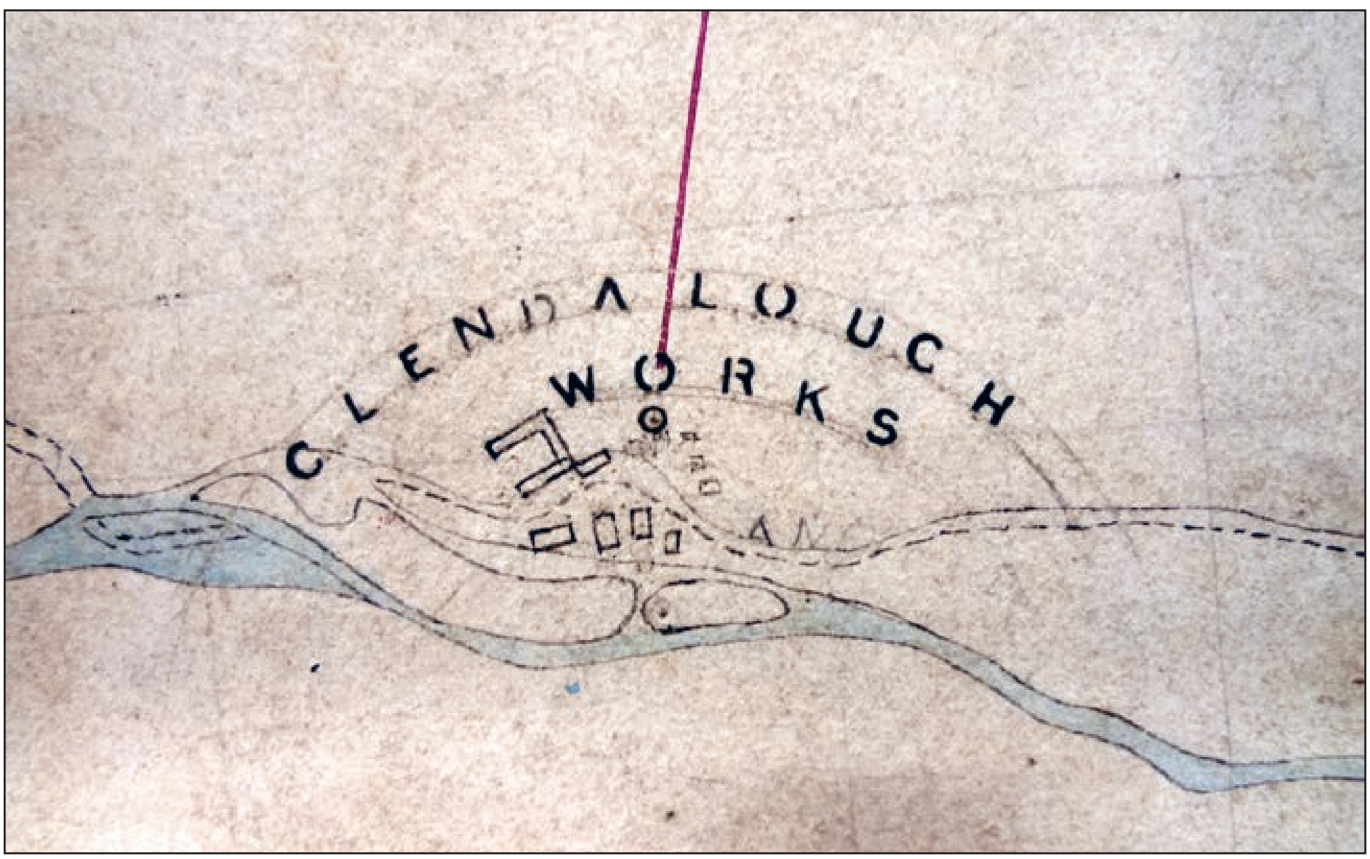


Figure 33. A section of Captain Frederick Richards' 1860 MCI mine plan, depicting the layout of the Glendalough dressing floor. The mine yard can be seen as a three sided enclosure

building **(GL-8A)**. The exact purpose of most of these buildings is largely speculative and subjective, as their function is not marked on any maps, but based on evidence gleaned from mines elsewhere, an attempt has nevertheless been made to explain what they might have been used for. To the west of the yard entrance was the blacksmith's forge **(GL-14D)** with a broad doorway and two forges built of granite blocks diagonally opposite with an anvil between (the granite anvil base bearing four holding down bolt holes with cut off iron bolts is extant). The forges were probably blown by a pair of two-chambered forge bellows to deliver air and may have been constructed at different times as one is more poorly defined than the other. The blacksmiths would have been kept continually busy, undertaking all the metal repair work on the mine, sharpening the miners' drills, re-shoeing the mules and manufacturing a wide variety of items required.

To the east of the entrance gateway is a two roomed building **(GL-14C)** built into the corner of the yard and accessed via a doorway in its eastern end. There was no access to the yard from inside these buildings which were probably storehouses which had slated pitched roofs. Inside the yard and built into the NW corner is a building **(GL-14H)** accessed via a doorway from the yard with a sloping slated roof and a single window facing into the yard. It had a low ceiling and a loft space with a small vertical rectangular slit leading to the exterior of the building, which appears to have been for ventilation of some sort. It shows no signs of ever being plastered or containing a fire place but it does resemble the mine office at the Glendasan yard and might therefore have functioned as an early office. Immediately to the west and contiguous to this building with which it shares a wall, is a long rectangular building **(GL-14I)** accessible from the yard and also the open grassy area to the west. The building has a window at the northern rear wall with a dressed granite cill and appears to have had a slated pitched roof. Another window looked out onto the yard. This building was plastered and might have served as a dinner room for the ore dressers. There are no obvious signs of a fireplace in this building, but a stove might have been used instead to warm up the workers' victuals. Its western wall almost abuts a large granite boulder and a fragment of walling built between this and a boulder suggests it might have been used as a small makeshift storage space.

The area behind the blacksmith's forge and the southern wall of this building is occupied by another large granite boulder, illustrating how the buildings are cleverly built around these obstacles. Two single storey buildings **(GL-14E)** and **(GL-14F)** next to the blacksmith's forge on the SW side have entrance doors facing the cobbled mine road. These might have served as stables for the managements' horses as they are depicted on the 1860s etching accompanying Draper's description as having pitched slated roofs with long narrow doorways and high set windows on either side.

Beyond these is a rectangular building **(GL-14G)** running NW-SE which is split into two rooms. A doorway fronting onto the cobbled mine road leads into the first room, the walls of which are very badly damaged. Fragments of plaster can be seen on the surviving masonry. Beyond this and reached via an internal doorway is a room that was clearly added on later.

Figure 34. This building (GL-14A), shown on all historic mapping, might have functioned as an ore store, where the lead concentrate was safely secured prior to being weighed, bagged and transported to the Ballycorus Smelting Works

It contained a fireplace in the west wall; plaster marks suggest that it had an ornamental surround of some description with a mantelpiece above. The interior walls were plastered and lime-washed and it was weather proofed in lime plaster on the exterior and roofed in slate. It had a window by the door in the northern wall that led out into the grassy area near **(GL-14I)**. This two roomed building was clearly of higher status than the others and quite possibly functioned as a later office.

Beyond the yard to the east is a single storey detached rectangular building **(GL-14A)** that had a slated roof with two windows set into the southern wall facing the dressing floor and a door at either end, one just under three metres wide, large enough to admit passage of a cart straight from the mine road. At the opposite end, the smaller of the two doors lay inside a porch. This building is depicted on all historic mapping, underlining its relative importance (Figure 34). It has been suggested by Heidkamp (2003) that this was a barracks for miners, but the MCI had a deliberate policy of building good quality cottages for their employees in Glendasan and Glendalough in order to incentivise them to settle with their families in such a remote and isolated spot. There is no mention to miners' barracks in any documentary records and those mineworkers who were not accommodated in MCI cottages walked in from Laragh, Brockagh, Seven Churches and surrounding townlands as noted by Draper in 1860. This settlement pattern is further confirmed by the St Kevin's School Admission Register (private MSS). This building is unlikely to have been a miners' dry, as the men entered the workings via adit portals high up in the cliff face for much of the nineteenth century and where there were rudimentary buildings close to the adit entrances serving this purpose. It is more likely to have functioned as an ore store, where the lead concentrate was safely secured prior to being weighed, bagged and transported to the Ballycorus Smelting Works.

The lower walling (about half a metre in height) of two rectangular structures **(GL-14J)** and **(GL-14K)** crudely built of moorstone roughly at right angles to each other close to a large boulder can be seen behind building **(GL-14G)**. Their function is indeterminable, but it could be that they predate mining activities and were a kind of booley as people were certainly living in the valley and impacting its geomorphology long before the MCI arrived; or maybe they were rudimentary shelters built for the workforce that was constructing the dressing floor. A similar feature **(GL-15)** can be seen near the reservoir **(GL-9)**.

CHALLENGING PERCEPTIONS OF INDUSTRIAL HERITAGE

This paper has demonstrated that the dressing floors at Glendasan and Glendalough represent the best preserved nineteenth century lead processing sites in the whole of Ireland and are on a par, in terms of their heritage value, with many contemporaneous lead mines in similar uplands regions of Britain. Both are in the ownership of the Wicklow Mountains National Park (WMNP) which is not just responsible for protecting and conserving the natural environment, but also the historic environment, the physical legacy of thousands of years of human activity, in the form of buildings, monuments, sites and landscapes. Certain parts of the historic environment are valued because of their historical, archaeological, architectural or artistic interest and are seen as 'heritage assets', representing a unique source of information about the lives of our ancestors and how they adapted to, and changed, their environment. Moreover, such heritage assets inform and influence our perceptions of identity and sense of place and are vital for research, education, tourism, leisure and recreational activities. Crucially, they are a finite, irreplaceable and fragile resource that is vulnerable to a wide range of human activities and natural processes and for that reason merit statutory protection through designation.

Glendalough valley is rich in historic monuments, in particular the famous 6th century Monastic City of Glendalough that is owned by the state and managed by the Office of Public Works (OPW). It has been included in the Record of Monuments and Places (RMP), the highest state heritage designation, and is comprehensively detailed within the Sites and Monuments Record (SMR). The SMR is a list of monuments issued on a county basis between 1984 and 1992 that evolved out of an inventory compiled by the Archaeological Survey of Ireland (ASI). This took place prior to, and during the time of the 1987 Amendment to the National Monuments Act, which required the establishment of the Register of Historic Monuments (RHM). The RHM was a logistical nightmare as it prescribed that the landowner be notified in writing of the presence of a monument on the RHM within their lands. It proved impossible to trace all the landowners and the RMP was consequently revived in 1994.[23]

The SMR, revised in the light of further research and fieldwork, formed the basis for the statutory RMP established under Section 12 of the National Monuments (Amendment) Act (1994)[24]. Similar in format to the SMR, this was issued for each county in Ireland between 1995 and 1998 but it also includes a selection of monuments from the post-AD 1700 period.[25] In 2011, considerable alarm was caused when the Department of the Arts, Heritage and the Gaeltacht (DAHG) announced a proposal to de-list post-1700 AD monuments that had been added to the RMP, thus removing their statutory protection. The DAHG, by its own admission, recognises the inconsistency in listing procedures, stating for instance that SMR's are '… indicative of ASI record holdings and reflect the incremental and organic manner in which material has been added to the archive over many years, especially for monuments dating from the post-1700 AD period' (NMS website). Following a public outcry about the proposed de-listing, the national listing regimen is currently under review.

The SMR contains numerous entries related to pre-1700 AD industrial activity in Glendalough valley, including 83 charcoal burning platforms thought to date from the 13th-18th centuries, and also a site of iron founding discovered during excavation for the OPW Visitor Centre dating to the thirteenth or fourteenth century (Manning 1983-4, 342-7). Additionally, numerous other monuments dating from prehistory to the medieval period in the Glendalough valley have been added, demonstrating that this area has witnessed human settlement and activity that has shaped its geomorphology for a considerable time. Inexplicably, despite their high visibility, the mines and dressing floors in the Glendalough and Glendasan valleys do not appear in the SMR, yet 83 largely invisible charcoal burning platforms and a buried medieval metal working site do. The omission of the mines and dressing floors from the SMR truncates the timeline of industrial activity in the area and squanders the opportunity to present a complete narrative of its rich industrial heritage.

The dressing floors of Glendasan and Glendalough offer the finest example of nineteenth century ore dressing technology in all of Ireland. Yet, despite the fact that they are unique heritage assets within the historic environment, they are also omitted from the National Inventory of Architectural Heritage (NIAH), even though partial entries for some of the mines in nearby Avoca have been included. The NIAH is a section within the DAHG and its work involves identifying and

23 The legislation contained within the RHM is still legally binding.

24 RMP's are protected under the National Monuments Acts 1930-2004.

25 The post-1700 AD monuments were included mainly for counties Cork, Dublin and Galway.

Figure 35. The dressing floors of Glendalough (shown here in 2005) and Glendasan at the heart of Ireland's most important nineteenth century lead mining centre, offer exceptional preservation of a wide range of features, all in relatively close proximity to each other, thus making the relationship of one feature to another clearly comprehendible. Mining activity in the two valleys has bequeathed to us a relict rural-industrial landscape of considerable heritage value which should be conferred the very highest level of state protection

recording the architectural heritage of Ireland from 1700 AD to the present day. The NIAH does not currently record many of the smaller scale or more industrial monuments that are integral to the development of Irish history and society during this period and although 1700 is used as a cut-off point, there is no basis in legislation in defining whether a monument is, or is not, archaeological (IA 2011). Indeed, according to the *Frameworks and Principles for the Protection of Archaeological Heritage*, 'date is not in itself a determinant of archaeological significance or interest. Any material remains which can contribute to understanding past societies may be considered to have an element of archaeological significance' (Dúchas 1999). As Hamond and McMahon (2002, 12) noted a decade ago, none of the national inventories currently purport 'to deal with all types of industrial heritage in a systematic and comprehensive way'. The fact that the lead mines of Glendasan and Glendalough do not appear in the NIAH database is therefore a startling oversight and a strong case for their future inclusion must surely be made.

Wicklow County Council is the only public body that currently recognises their importance. In accordance with Section 12 of the National Monuments (Amendment) Act (1994), it has recorded a number of Protected Structures: buildings that are considered to be of special interest from an architectural, historical, archaeological, artistic, cultural, scientific, social, and/or technical point of view. These are listed in the Council's Record of Protected Structures (RPS), the provision for which is set out in Part IV of the Planning Development Act 2000 and are thus afforded some protection in statutory law.[26] The lead mines of Glendalough, Glendasan and Glenmalure appear in Wicklow's RPS, due solely to the prescience of the County Heritage Officer. But it is the nature of their listing that is to be commended, for this goes beyond the mere inclusion of single structures or discrete features and adopts a holistic approach to the historic environment by incorporating a suite of elements which, taken together, have far greater significance than if viewed on their own. This begs the question of why the dressing floors and other local mining features have not been included in the SMR or the NIAH?

26 The decision to include buildings on the RPS is made by the elected members and there are obligations on owners and occupiers to ensure the preservation of Protected Structures; assistance is offered by the Council in the form of annual conservation grants.

Arguably, the omission of many nineteenth and twentieth century industrial features has to do with the overall perception of industrial heritage in Ireland, which, it is fair to say, has a fairly low profile. Industrial heritage is defined by the Industrial Committee for the Conservation of Industrial Heritage (TICCIH) as consisting of:

> … the remains of industrial culture which are of historical, technological, social, architectural or scientific value. These remains consist of buildings and machinery, workshops, mills and factories, mines and sites for processing and refining, warehouses and stores, places where energy is generated, transmitted and used, transport and all its infrastructure, as well as places used for social activities related to industry such as housing, religious worship or education' (Nizhny Tagil Charter 2003).

Industrial heritage worldwide had, until the 1970s, been a rather neglected aspect of the historic environment (Schwartz and Lorenc 2011) and the Nizhny Tagil Charter (TICCIH 2003) was published to highlight the fact that the buildings and structures constructed for industrial activities, the processes and tools used within them and the towns and landscapes in which they are located, along with all their other tangible and intangible manifestations, are of fundamental importance. Moreover, the Charter stated categorically that these should be studied, their history taught, their meaning and their significance probed and made clear for everyone. The Charter also stressed that the 'most significant and characteristic examples should be identified, recorded, protected and maintained, in accordance with the spirit of the ICOMOS (International Council on Monuments and Sites) Venice Charter (1964) for all to enjoy in the present and future'.

Of particular relevance to the issue of the relative neglect of Ireland's industrial heritage is the fact that post-independence Ireland has had a particularly ambivalent attitude towards its industrial past, the De Valera government of the 1930s deliberately distancing itself from the British economy, evincing a policy of economic self-sufficiency. De Valera's promotion of Ireland as a bucolic haven, encapsulated in his 1943 St Patrick's day broadcast, was rooted in an opposition to industrial Britain and the identity associated with it. Ireland as a rural idyll, free from the corrupting influences of industrialism, was not a new idea and de Valera's nationalism had a firm basis in earlier, nineteenth-century, nationalist philosophies (Dowling 2009). This perception of Ireland was arguably responsible for school textbooks of the 1950s categorically stating that there was no mining in Ireland.

Ireland was, however, not alone in manifesting an ambivalence about its industrial past, for the same backlash against 'British' industrial imperialism was demonstrated in Cornwall that lay at the very epicentre of Britain's metalliferous mining industry. Here, paralleling the decline of tin mining in the early twentieth century, was an increased salience of Cornwall's Celtic past, the so-called 'Celtic Revival' that gathered momentum in the decades after WW1. This socio-cultural watershed represented an opportunity for Cornwall and the Cornish to look back beyond the crumbling engine houses of a failing mining industry to a perceived golden Celtic era. Crucially, affiliation with its Celtic past thus allowed the Cornish to opt out of the monocultural and static identity of a domineering industrial England/Britain and to seek commonality with her Celtic neighbours within a vibrant north-western European Celtic arc (Schwartz forthcoming, 454).

Today, however, Cornwall takes immense pride in her industrial heritage, epitomised by the Cornish Mining World Heritage Site, added to the World Heritage List in 2006, celebrating a period in time when Cornwall led the world in metalliferous mining. This remarkable turn around has come about partly because the perception of industrial heritage has changed and it is now regarded as being something worthy of valorisation. But also because the Cornish people's perception of the industrial revolution has shifted. A sense of ownership of the industrial process now prevails, a recognition of the Cornish mining industry as being 'home grown', rather than something imposed on it from outside, exemplified by the Cornish Mining World Heritage Site strap line, 'our mining culture shaped your world', and the Cornish-type engine house that has become an global icon of regional pride (Schwartz 2008). A similar process might be argued for Wales, dominant throughout the nineteenth century in metalliferous and non-metalliferous mining and in smelting. Wales now prides itself on its industrial past, heritage and identity, as distinct from England or Britain, encapsulated in its claim to be 'the world's first industrial nation' (CADW 2011).

Although Ireland has arguably some of the finest industrial landscapes in Europe (many of which are mining related), due largely to the fact that it did not witness the large scale development of the late nineteenth- early twentieth century-period that destroyed many similar sites elsewhere (Rynne 2011), it has yet to fully acknowledge and capitalise on its industrial heritage as other European nations have done.[27] Indeed, it is telling that Ireland does not have a national mining museum and currently has just five mining heritage attractions (Critchley 2012). This paper has outlined the relative importance of the Glendasan and Glendalough dressing floors at a national level and we argue that there is a strong case for improved state recognition and protection of these and similar industrial sites. Northern Ireland is currently embracing its industrial heritage with the Northern Ireland Environment Agency's Industrial Heritage Record listing more than 16,000 features. In Wales, Scheduled Ancient Monument status, the highest national designation comparable to our RMP, is conferred on many nineteenth century lead mines and dressing floors comparable to ours, for example, Ystrad Einion and Bronfloyd (there are a total of 23 lead mine sites with this listing in Wales). However, in Ireland, metalliferous mining is currently only represented on the RMP by the Bronze Age copper mines of Mount Gabriel in County Cork.

27 It is, perhaps, no coincidence that the industrial buildings so far consolidated in Ireland have been the Cornish-type engine houses at Allihies, Tankardstown and Silvermines.

Ireland's nineteenth century mine sites are testament to a period in which the country underwent great change, witnessing one of the most remarkable population movements in recent history. The mining industry, the labour force of which was highly mobile, played a role in the Irish Diaspora of the nineteenth century (see Emmons 1989, MacRaild 1998; Kenny 1998; O'Neill 2003; Haughey 2004; Mulligan 2004-06; Walsh 2009). The mines of Ireland are therefore also the archaeology of the Diaspora and of the immediate ancestors of the Irish people and are worthy of protection. However, the state's arbitrary and inconsistent listing procedure, whereby most post-1700 structures, including almost all mining features, are only listed in the incomplete and somewhat *ad hoc* NIAH, currently militates against important sites like Glendalough and Glendasan being conferred a higher national designation. 'Given the vulnerability of our industrial heritage, a record of all surviving sites and those which formerly existed is urgently required', concluded Hamond and McMahon a decade ago, noting that a variety of surveys undertaken by statutory and non statutory organisations and volunteer groups have previously identified and recorded in the field less than five per cent of Ireland's industrial sites (Hamond and McMahon 2002, 12-13).

It seems that their plea has so far fallen on deaf ears and a form of national standardisation and consistency where industrial buildings and features are concerned, is urgently required. Crucially, acknowledgement of the importance of Irish industrial heritage, as set out in the Nizhny Tagil Charter, is vital to ensure the future protection, consolidation, conservation and valorisation of the extant remains of our metalliferous mining industry, which constitutes an extremely valuable and irreplaceable part of our historic environment.

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