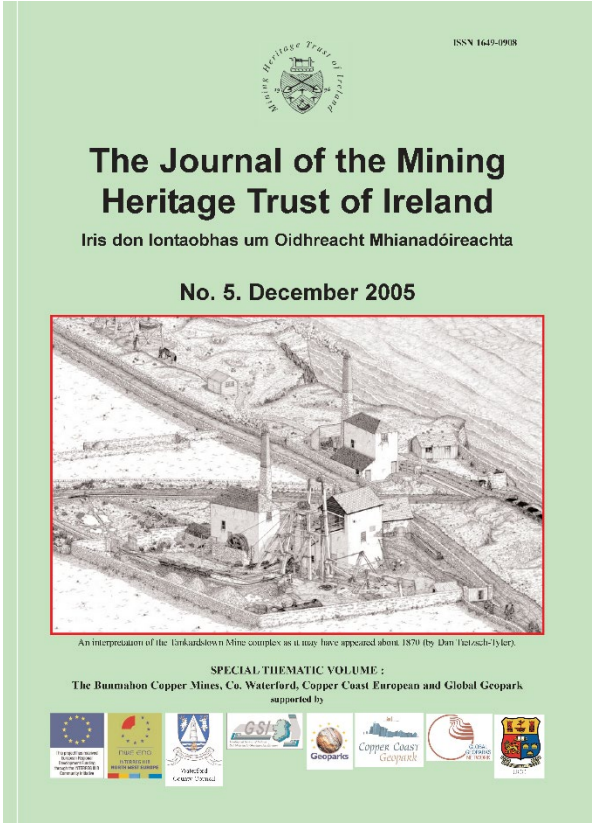

Tietzsch-Tyler, D. (2005) 'Historical Reconstruction Drawings of the Copper Coast Mines, Co. Waterford' *Journal of the Mining Heritage Trust of Ireland,* **5**, pp.29-46

HISTORICAL RECONSTRUCTION DRAWINGS OF THE COPPER COAST MINES, CO. WATERFORD

By Dr Daniel Tietzsch-Tyler

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Abstract: For the half-century between 1828 and 1878, the Co. Waterford coast east of the village of Bunmahon was the site of intense mining activity and the export of significant volumes of copper ore. As part of the development of the *Copper Coast Global and European Geopark*, two drawings were commissioned to interpret how the principal sites of mining operations might have appeared at the height of this activity. The first drawing attempts to reconstruct the site at Tankardstown where the copper ore was brought to the surface after 1850 as it might have appeared in about 1870. The second drawing attempts to reconstruct the site of the ore dressing floors beside Knockmahon village as it might have appeared in about 1860. The main mine buildings at Tankardstown have recently been partially restored, but almost nothing now remains of the formerly extensive dressing floors. This article presents an illustrated commentary to facilitate an exploration of the mine sites as reconstructed. *Journal of the Mining Heritage Trust of Ireland*, **5,** 2005, 29-46.

1. INTRODUCTION

The coast of Co. Waterford west of Tramore is an area of great scenic beauty, characterised by small bays between stretches of high cliffs below which a multitude of small rocky islands pockmark the sea. Travelling west on the R675 coast-road, after you pass Dunabrattin Head and Kilmurrin Cove, your horizon is interrupted by the 19th century pumping engine-house and chimney of Tankardstown copper mines, which you pass on the landward side of the road (Figure 1). Less than a kilometre further on you pass on your left the wall of the old copper yard that tops the cliff above where copper ore was shipped to, and coal imported from South Wales.

Figure 1. Tankardstown pumping engine-house (right), winding engine-house and chimney (looking towards the sea).

Figure 2. The mine manager's house.

Finally you come down to Knockmahon, where you pass the junction with the R681 Waterford road. Above a rock cutting on the left side of the road stands the fine 19th century three-storey house built for the mine managers (Figure 2). Across the stream on the other side of the road are the remains of the dressing floors where the copper was concentrated by a small army of men, women and boys (Figure 3). Today, the only substantial evidence of these dressing operations is the walled yard of the mine count-house on the slope above the valley floor, a cobbled dressing floor and a stone façade beside the course of the old mineral tramway.

Figure 3. Dressing floors at Knockmahon, with the mine count-house at the centre.

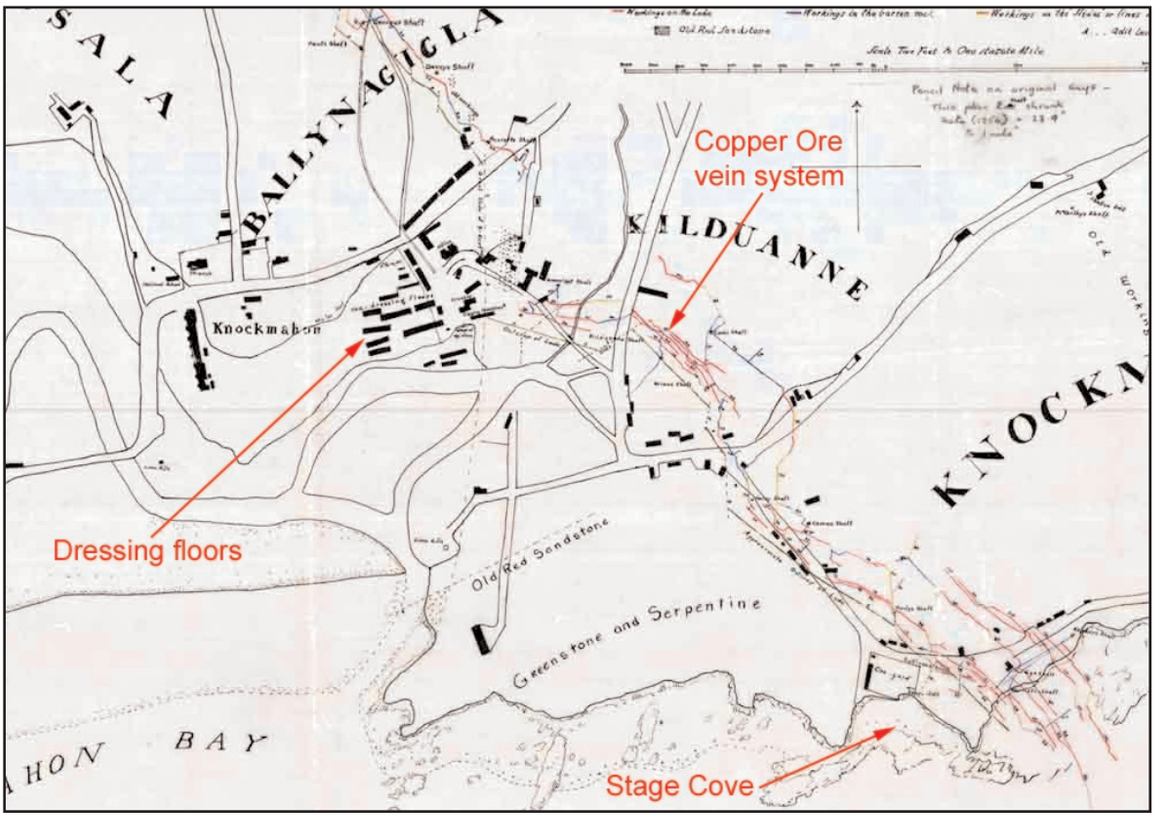


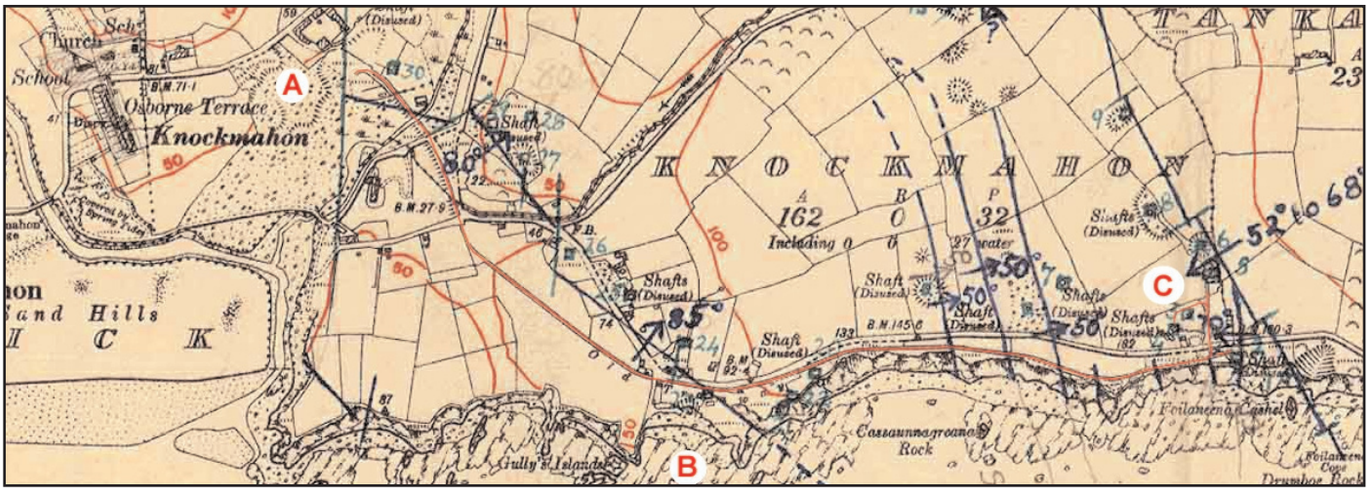
Figure 4. The copper veins between Stage Cove and Knockmahon (from W.W. Smyth's map, drawn in 1845).

As part of the development of the INTERREG IIIB (NW Europe Region) funded *Copper Coast Global and European Geopark*, two drawings were commissioned to interpret how the principal sites of mine-related operations may have appeared in their heyday. This commentary is intended to provide an explanation to accompany an exploration of those drawings: of the mines at Tankardstown as they might have appeared in about 1870 (Figure 6), and of the dressing floors beside Knockmahon village as they might have appeared in about 1860 (Figure 7). Both drawings are based on various combinations of extant remains, old Ordnance Survey and mine maps (some illustrated with sketches of the mines), some archaeology at Tankardstown, reference to a rich treasure of late 19th and early 20th century photographs of very similar Cornish mines, and general research on 19th century mining methods. This article explains some of the reasoning and assumptions that went into their making.

1.1. A BRIEF HISTORY

The mines reconstructed in these drawings were operated in the 19th century by the Mining Company of Ireland (MCI), which was established by Act of Parliament in 1824. After four years of exploration on lands they had leased east of the River Mahon, MCI was able to announce on July 12th 1828 the eco-

Figure 5. The extended MCI area of operations including the Tankardstown mines. The former dressing floors were just below the road east of Osborne Terrace (A). Stage Cove is at the bottom in the centre (B). The mineral tramway that formerly served the mines is highlighted in red. Tankardstown is near the right edge of the map, where the tramway turns north (C). (Geological Survey of Ireland field sheet showing the principal ore veins, based on the 1922 edition of the Ordnance Survey 6" scale map.)



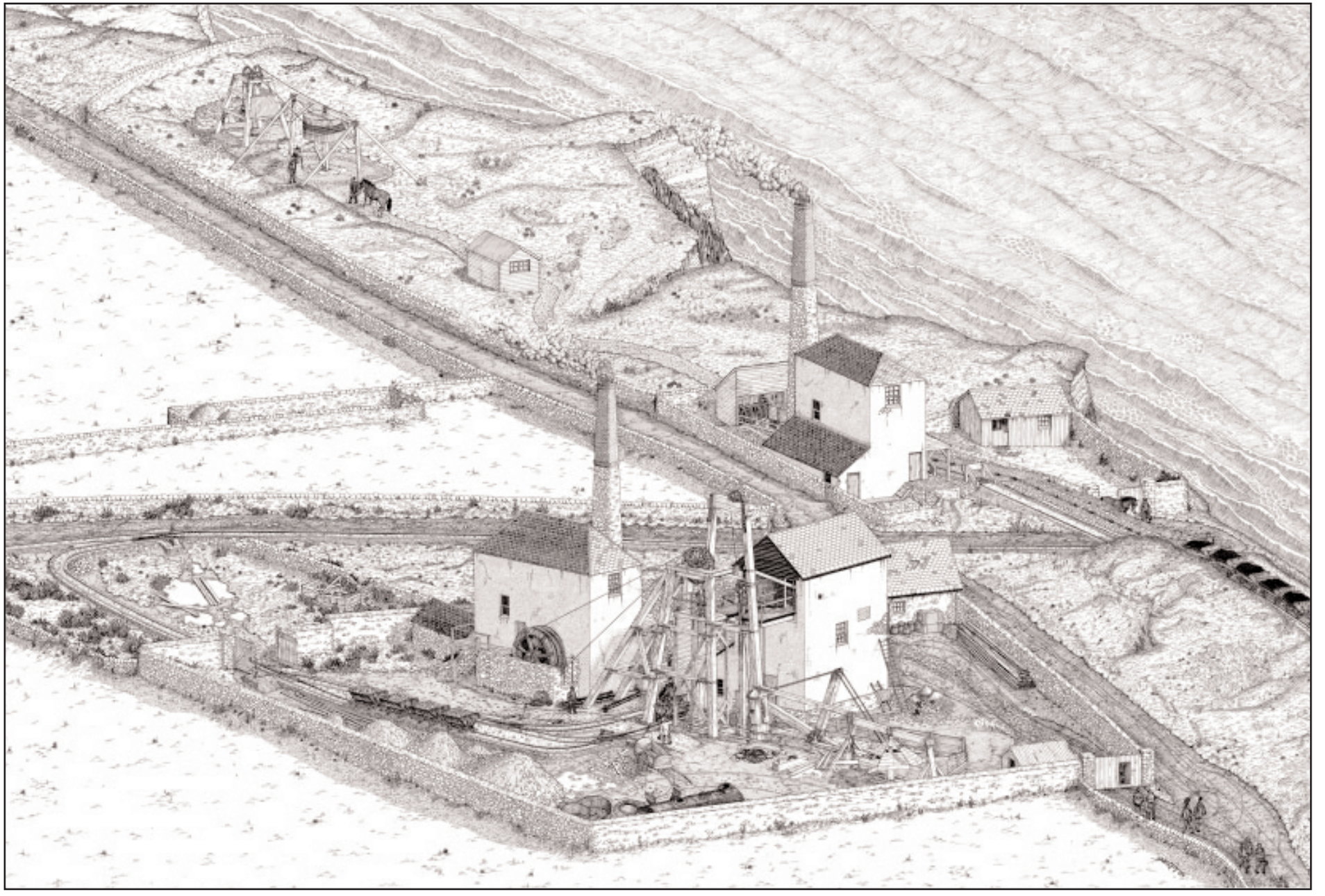


Figure 6. The mines at Tankardstown as they might have appeared in about 1870. (© Daniel Tietzsch-Tyler, February 2006)

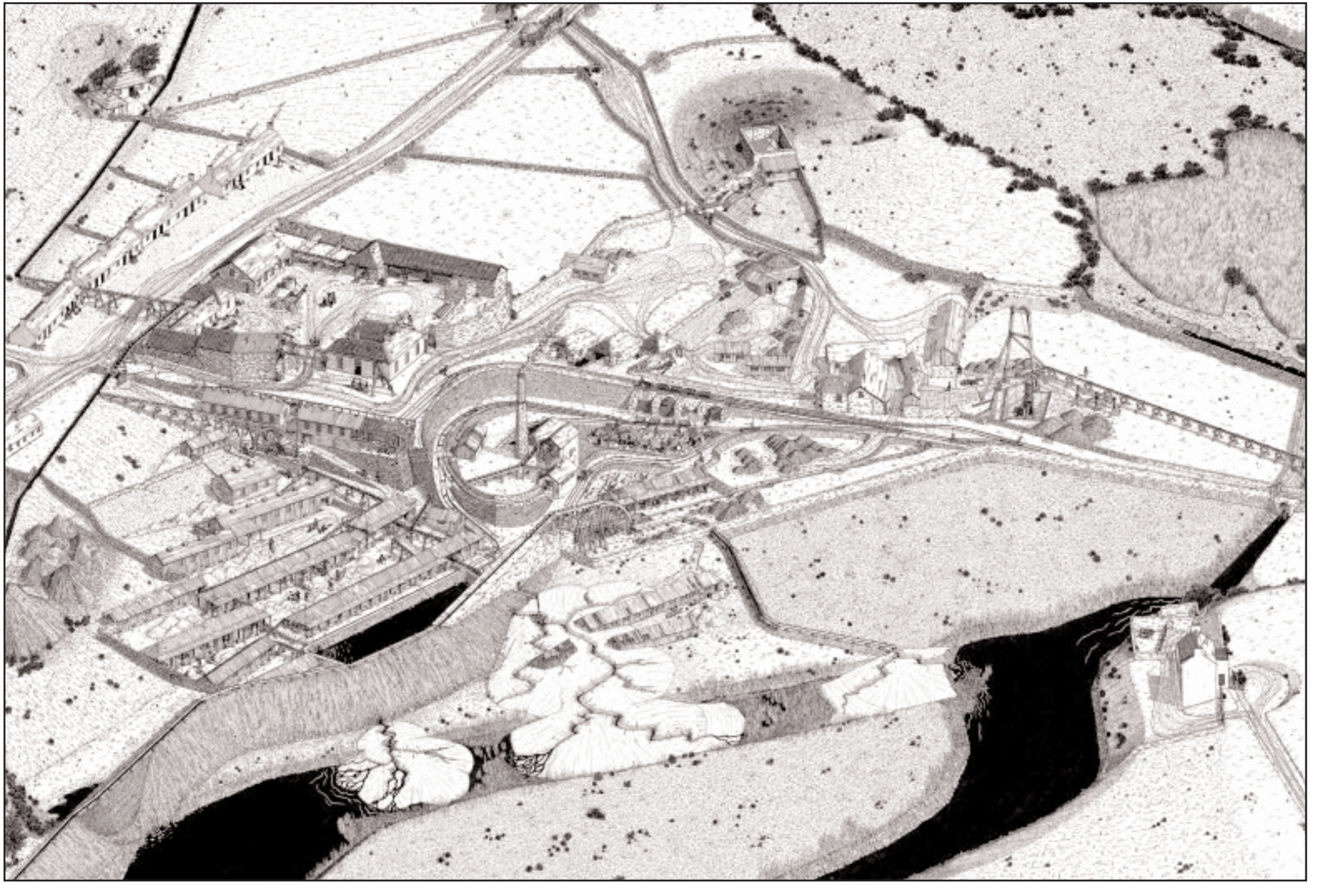


Figure 7. The dressing floors beside Knockmahon village as they might have appeared in about 1860. (© Daniel Tietzsch-Tyler, February 2006)

nomic viability of a mineral vein system extending north-west from the cliffs at Stage Cove, past Knockmahon village (Figure 4). Mining by MCI continued from this date until 1878 - 50 years later - when the mines were finally abandoned.

The rocks here are hard Ordovician volcanic and sedimentary rocks (about 460 million years old) - seen in the prominent cliffs at Stage Cove - and, locally inland, a thin cap of slightly younger Old Red Sandstone. The veins of interest to the mining company comprise mainly copper ore with subsidiary lead ore in veins chiefly of quartz (Cole 1998). In profitable years (1834-46 and 1851-68) annual output reached as high as 7000 tons of 10-13% copper ore. In unprofitable years (1828-33, 1847-50 and 1869-78) production fell as low as 100-270 tons of 4-5% copper ore each year. Total profits from the good years were £331,126 (averaging £11,000 per annum), far exceeding total losses of £47,757 from the bad years (averaging £1,447 per annum).

Mining operations began on the valley floor beside the dressing floors, with water-powered pumping and ore dressing. Four waterwheels with diameters ranging from 12 feet (3.7 metres) to 40 feet (12.2 metres) had been erected by 1831 for these operations. During the 1830s and 1840s the focus of mining moved to the cliff top above Stage Cove, where five steam engines were erected for pumping and winding. Mine workings extended under the sea from there but began to flood with seawater, causing the abandonment of these mines in 1852.

However, already by this time the focus of attention had shifted again, this time 0.8 kilometres east to Tankardstown where a good copper vein system had been discovered and was being worked by 1850 (Figure 5). With the closure of the mines at Knockmahon, the engine-houses there fell into disuse. Their steam engines were dismantled and moved to Tankardstown where they were re-erected in three new engine-houses, one to pump water from the mines, another for winding - both from Heron's Shaft, and a third to operate a mineral tramway that was used to haul ore and coal between Tankardstown, Stage Cove and the dressing floors at Knockmahon (Figure 5; see also Morris *et al*., 2005, for a detailed description and interpretation of the tramway system).

1.2. TANKARDSTOWN REMAINS

The most impressive mining remains are at Tankardstown (Figure 8). Still standing in a walled yard are a partially restored pumping engine-house (Figure 1), the ruins of a winding engine-house and a restored chimney (Figure 16). The foundations of the boiler-houses serving both engine-houses also survive. The main shaft, Heron's Shaft, was still open until 1970, when it was blocked and partially filled in during the making of the film The McKenzie Break. You can see the shaft in the film when a group of escaped prisoners-of-war roll a truck into the shaft, where it explodes!

A small quarry northeast of the engine-houses was the site of another shaft, Pope's Shaft. There was also a trial shaft between Heron's Shaft and Pope's Shaft that was sunk too close to the

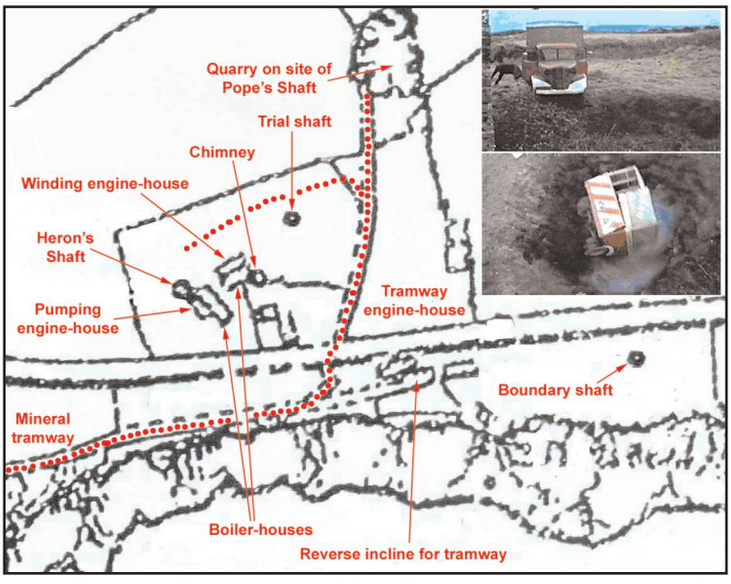


Figure 8. Tankardstown Mine Remains (based on the 1905 edition of the Ordnance Survey 6" scale map). Inset: two stills from the film The McKenzie Break (1970), showing a truck being driven into Heron's shaft, then still open, where it subsequently exploded.

vein of ore and was abandoned. A fourth shaft, Boundary Shaft, is still open close to the edge of the cliff about 175 metres west of the engine-houses. Almost nothing now remains of the engine-house, boiler-house and winding apparatus that also stood on the cliff-top to operate the mineral tramway. All that remains is a wall on one side of a reverse incline that was used to counterbalance the wagons carrying coal and copper ore to and from the mines here.

1.3. STAGE COVE REMAINS

The walled copper yard on the cliff-top above the cove is only one of several remains at Stage Cove. The copper yard itself was extended at some point after 1840 and consequently has evidence of cobbled surfaces at two different levels - that in the extended area being about a metre above that in the original yard (Figure 9). East of the copper yard, also on the seaward side of the road, are sections of wall and the shell of a small building corresponding to another ramp on the mineral tramway.

Figure 9. The cobbled copper yard.

Between the tramway and the cliff-top are several open shafts and the vague outlines on the ground of an engine-house complex that was dismantled when the mines here were abandoned in 1852. The ruins of one engine-house still stand on the landward side of the road (Figure 10). Two inclined grooves in the roadside wall of the tramway ramp probably accommodated support timbers for an elevated gantry that crossed over the road and tramway between the surviving engine-house on the landward side of the road and the shafts on the cliff-top. An 1845 drawing of installations at this location shows a horizontal winding cable system, supported on a gantry, connecting this engine-house and haulage gear over the cliff-top shaft (Figure 11). The tramway, constructed between 1854 and 1856 (Morris *et al*. 2005), passed below this gantry alongside the road.

Figure 10. Ruined engine-house, Stage Cove.

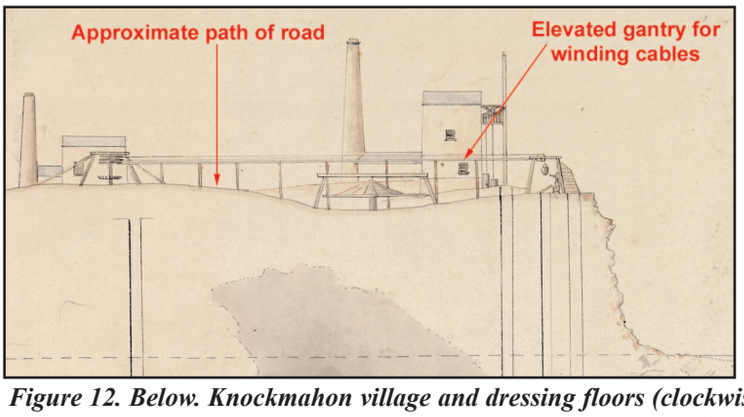


Figure 11. Left. Mine buildings above Stage Cove in 1845 (as drawn by H.W. Smyth on a cross-section across the Stage Cove mines).

1.4. DRESSING FLOOR REMAINS

The mine dressing floors were located beside Knockmahon village (Figure 4). The core of the 19th century village exists to this day, including the church (disused and ivy-covered), and the school-house, the mine management's houses of Osborne Terrace and the house built to lodge the MCI Director(s) - all still occupied to this day (Figure 12). Terraced miners' cottages shown alongside the road out of the village on 19th century maps have long been demolished and part of that area has been re-developed as the National School (Figures 19:G and 21).

The mine dressing floors were located just east of the village, extending down from the road and across the marshy valley bottom towards a small south-flowing stream (Figure 4). A second stream joins this one just north of the mine manager's house. In 1840 these flowed into the River Mahon through two broad channels. By 1905 the western channel had vanished beneath mine waste to leave the single narrow channel we see today (Figure 5).

Very little remains of the buildings shown on the dressing floors in Figure 13. The most substantial remains are the mine count-house that stands at the south corner of a large yard enclosed by stone sheds and high walls (Figure 13:B). The house and the buildings forming the west corner of the yard were in existence by 1845 (see Figure 21: the building along the roadside probably an old cottage), and the rest of the yard was built between then and the end of the 19th century. For the reconstruction drawing of the dressing floors, it is assumed that the whole complex had been built by 1860.

Nothing remains of the long narrow buildings on the slope down to the valley beside the count-house and by the river channel beyond. By comparison with late 19th and early 20th century photographs of Cornish dressing floors, these building were almost certainly made of wood.

Figure 12. Below. Knockmahon village and dressing floors (clockwise from top left): the church; the school-house; Osborne Terrace; the company directors' house; the count-house and walled yard; the ruined facades of stone buildings on the valley floor.

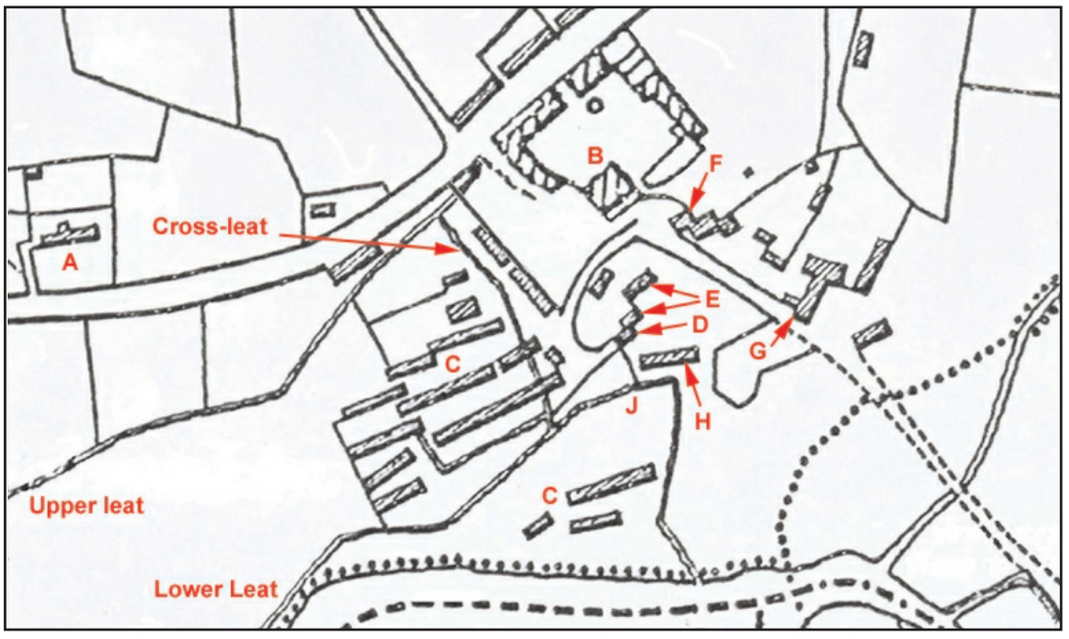


Figure 13. Composite map showing the mine dressing floors sometime after 1840 (based on the 1840 and 1922 Ordnance Survey maps). The MCI directors' house in the village is on the extreme left (A) and the count-house is in the upper centre (B: the counthouse yard is the only element of the 1922 edition of the Ordnance Survey map to be superimposed here onto the 1840 edition). Timber buildings would have dominated west and southwest of the count-house (C), but a few stone buildings were dotted around the remainder of the dressing floors: the crusher (D) and probable engine-house and boiler-house complex (E); part of the foundation of a stone building preserved in a small quarry (F); a surviving stone façade (G). Also shown are the shed for the jigging machines (H) and the site on the lower leat of the forty-foot water wheel (J). (For an explanation of leats, see text.)

The rest of the dressing floor buildings were probably a mix of timber and stone-built structures. Certainly the Crusher identified on the Smyth's map of 1845 would have been built in stone and any engine-house powering the crusher would also have been stone-built. A stone façade still survives alongside the path of the mineral tramway - still clearly visible (Figures 12 and 13:G) - and the foundation for a stone building is also preserved in the wall of a small, more modern quarry beneath the count-house yard (Figure 13: F).

2. TANKARDSTOWN MINES IN ABOUT 1870

The reconstruction drawing of the mines at Tankardstown attempts to show the complex of buildings and associated mining paraphernalia as they might have appeared in about 1870, just before ore production began to fall away irrevocably. Three main elements of the mine are illustrated in the drawing (Figure 14):

- Heron's Shaft and associated engine-houses and boiler-houses (Figure 14:A)
- the Tankardstown terminus of the mineral tramway and its engine-house (Figure 14:B)
- the minor Boundary Shaft and its associated winding gear (Figure 14:C)

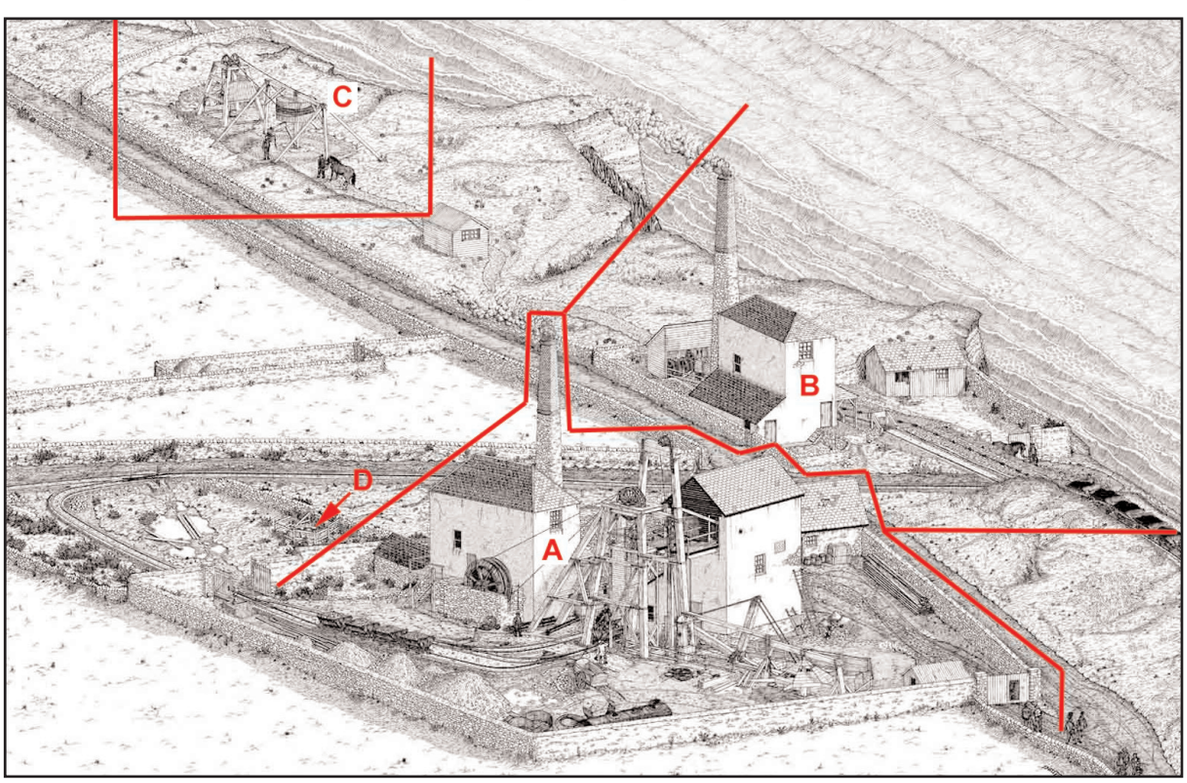


Figure 14. The mines at Tankardstown as they might have appeared in about 1870: Heron's Shaft and engine-house complex (A); Tankardstown tramway terminus (B); Boundary Shaft workings (C); trial shaft (D).

2.1. Heron's Shaft and Engine-Houses Complex

Heron's Shaft lay just north of the coast road through Tankardstown (Figure 8). In 1870 it was at the centre of mining operations and would have stood within a walled yard. The shaft appears to have been very broad in the 1970 film *The McKenzie Break* (Figure 8:inset). This is because it served three purposes: for the miners to descend to and ascend from the underground workings, to raise ore to the surface and to pump water out of the mines. A timber partition probably divided the shaft into two unequal parts, the larger one for pumping. The smaller section would have been fitted with ladders for the miners (the uppermost ladder can be seen emerging from the shaft in the drawing) and provided the space for raising the ore.

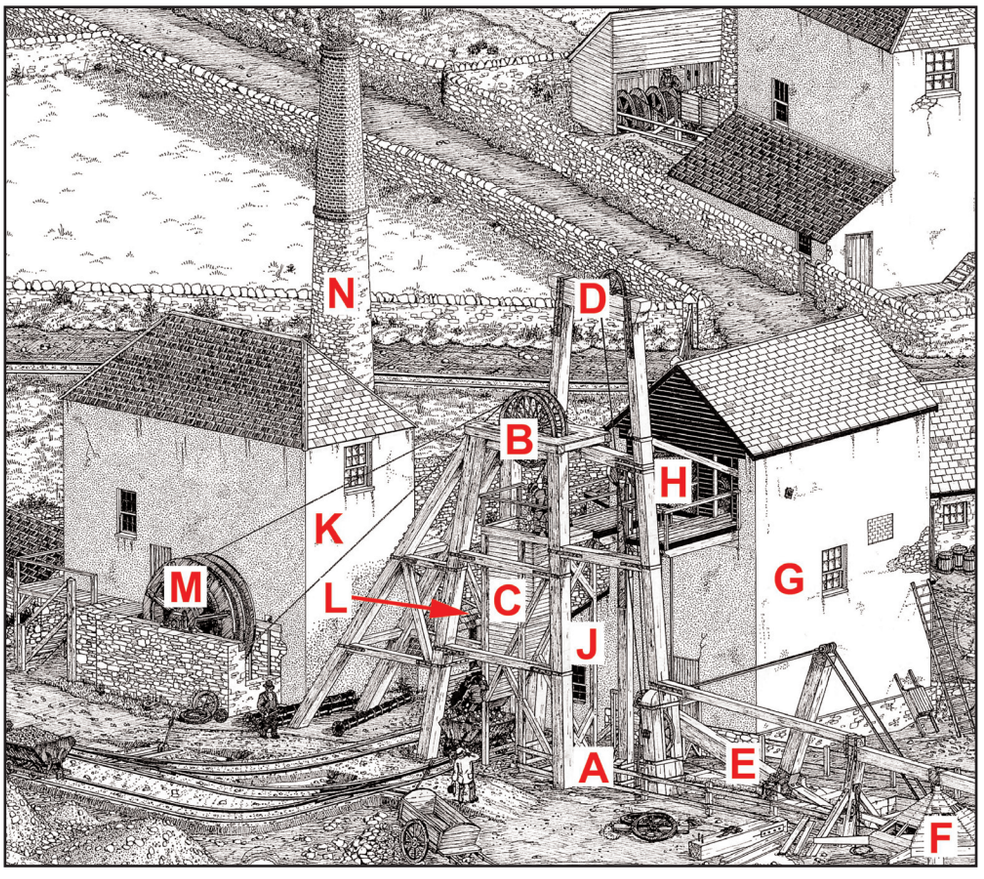


Figure 15. Heron's Shaft (A) with winding head-frame (B), ore-bins (C), shear legs (D), balance bob (E) and windlass (F); the pumping engine-house (G) with its iron beam (H) and adjacent boiler-house (J); the winding engine-house (K), adjacent boiler-house (L), external winding drum and plinth (M) and the chimney shared by both boiler-houses (N).

An earlier trial shaft excavated nearby was probably abandoned when it was found to intersect the ore-body too close to the surface (Des Cowman, personal communication). It is shown fenced off outside the walled enclosure in the drawing (Figure 14:D). Just off the left side of the drawing, beyond the puddles and at the end of a branch of the tramway, was Pope's Shaft - now the site of a small quarry (Figure 8).

To pump the mines dry, a large rectangular engine-house was built beside the shaft (Figures 1 and 15:G). The engine-house stands almost complete today, with the damage seen in *The McKenzie Break* now restored. The building has an entrance in both of its shorter walls. One overlooks Heron's Shaft and the other, which has a fine restored semi-circular brick arch, faces the road below windows on two levels. Several windows punctuate the longer walls to light the three floors inside that were reached by stairs - the lines of which are still visible on the inside walls.

The wall overlooking the shaft stops at the second level to support a massive iron beam, called the main beam or bob (Figure 15:H), which oscillated up and down to work an underground pump (Drew and Connell 1993). Half the beam was inside the engine-house and the other half extended out over the shaft below. A steam engine bolted to the ground floor of the building drove the stroke of the bob by pushing and pulling a piston rod attached to the indoor end of the bob. A heavy timber beam, the 'main girder', spanned the width of the building just below the inside end of the bob. This acted as a buffer and shock absorber should the indoor end of the bob drop too low, with potentially catastrophic results. Its location is seen in the bricked-up rectangular openings just over half way up the longer walls of the engine-house (Figure 15:G).

A long timber beam called the pump rod (actually several beams held together by iron bands and bolts) hung from the outer end of the bob and extended down to a pump at the bottom of the shaft. The stroke of the bob moved the pump rod up and down to work the pump. No pipes or wooden troughs (launders) are shown expelling water from the shaft in the reconstruction drawing because it was probably expelled through adits (horizontal mine-workings) emerging in the cliff face below here. To reduce the strain on the steam engine of the pump rod's weight, it was finely counter-balanced by a timber construction called a balance bob (Figure 15:E). A steel rod connected one end of the balance bob to the pump rod so that it oscillated about an axle with each stroke of the pump rod. This lifted a large box filled with rocks at the opposite end of the balance bob, the weight of which more-or-less equalled and thus cancelled out the weight of the pump rod (Drew and Connell 1993).

To emplace and maintain the pump rod, a tall timber frame - the shear legs (Figure 15:D) - was erected over the shaft and connected to a windlass. To lift the pump rod, a cable connected it

to the windlass via a pulley-wheel at the top of the shear legs and a second pulley near the bottom of one of the legs (Figure 15:F). When maintenance was required, mining came to a temporary stop, as all miners were required to work the windlass (Drew and Connell 1993). Commonly, shear legs were erected parallel to the engine-house, but here it appears they had to be erected at a slightly oblique angle to make room for the winding gear (Figure 15:B) that had also to be positioned over the shaft. This arrangement closely resembles that of the famous Levant Mine in Cornwall (Corin 1992).

The house for the coal-fired boiler that fed steam to the pumping-engine was a stone lean-to structure on the side of the engine-house (Figure 15:J). This arrangement was typical and can again be seen at Levant Mine (Corin 1992).

The location of the winding gear is dictated by the orientation of the winding drum (Figure 15:M) on the side of the winding engine-house (Figure 15:K). The winding drum is shown partitioned to wind two cables, one winding over the drum and the other under it. These extended over two pulley wheels on the winding gear so that as the drum turned, one cable dropped an empty kibble (ore-bucket) down the shaft while the other hauled up a full kibble. Once a kibble reached the surface it was emptied into a timber ore-bin erected beneath the winding gear (Figure 15:C). The rotation of the drum was then reversed to send the empty kibble back down again while hauling up another full one. The ore in the bin was unloaded into wagons and transported on the mineral tramway to Knockmahon.

Figure 16. The winding engine-house at Tankardstown. The vertical grooves in the wall in the foreground are for the long retaining bolts that secured the winding drum. The higher wall between the engine-house and the chimney beyond it is the long wall of the adjoining boiler-house.

One end wall of the winding engine-house (Figure 15:K) still stands close to its full height (Figure 16). Only the lower levels of the rest of the building's walls remain. Vertical grooves for the long bolts that secured the timber mounting for the winding drum can seen in the outer face of one wall (Figure 16). Most of the long wall of the lean-to boiler-house (Figure 15:L) also survives to its full height. A cobbled yard has also been exposed between the two boiler-houses and was probably the coal yard for both.

The winding engine-house was smaller - both narrower and lower - than the pumping engine-house because it housed a smaller steam engine. It also differed from the pumping engine-house in that a smaller bob was enclosed entirely within the engine-house. The winding engine-house at Tankardstown is very similar to the winding engine-house at Levant Mine (Corin 1992).

Several men are shown working in the yard around the engine-houses in the reconstruction drawing. One stands on a platform on top of the ore-bin, emptying a kibble. Another is emptying ore from the bin into a wagon on the tramlines. The 'surface captain' in his white coat stands at the foot of the winding gear, shouting up to the man emptying the kibble. Finally, a shift of miners can be seen walking home on the road to Knockmahon, Bunmahon and beyond. Scattered around the yard in the drawing are the typical paraphernalia of 19th century mining operations. Much of it is waste (or perhaps spare parts), for example: old cogwheels (leaning against the winding plinth); spare pumping pipes (in front of the winding-house); pulley-wheels and pieces of timber (in front of the fence around the balance bob pit); spare tramway rails (inside the rear gate of the yard); and an old, partially dismembered Cornish boiler (in the near-corner of the yard).

Also seen in the yard are: wagons filled with ore waiting on the tramlines to travel down to the dressing floors at Knockmahon; the branching tramlines extending to Pope's Shaft and across the road to the cliff top; an unhitched horse cart; materials for patching up the rendering on the pumping engine-house; barrels, crates and timber stacked against one wall of the yard and one of the stone sheds that are preserved only in foundation on the site; and a night-watchman's hut inside the main gate.

2.2. Tankardstown Tramway Terminus

Coal for the boilers was brought up to the mines on a single-track tramway from the copper yard at Stage Cove. By return, copper ore was taken from the mines down to the dressing floors, passing the copper yard at the halfway point. The tram wagons were pulled up to Tankardstown by a cable that wound on and off one end of a partitioned winding drum (Figure 17:G) situated a little distance away from an engine-house, at the foot of a short ramp inclined in reverse to the tramline (Figure 17:H). The cable ran on rollers set between the tramway tracks (Figure 17:D).

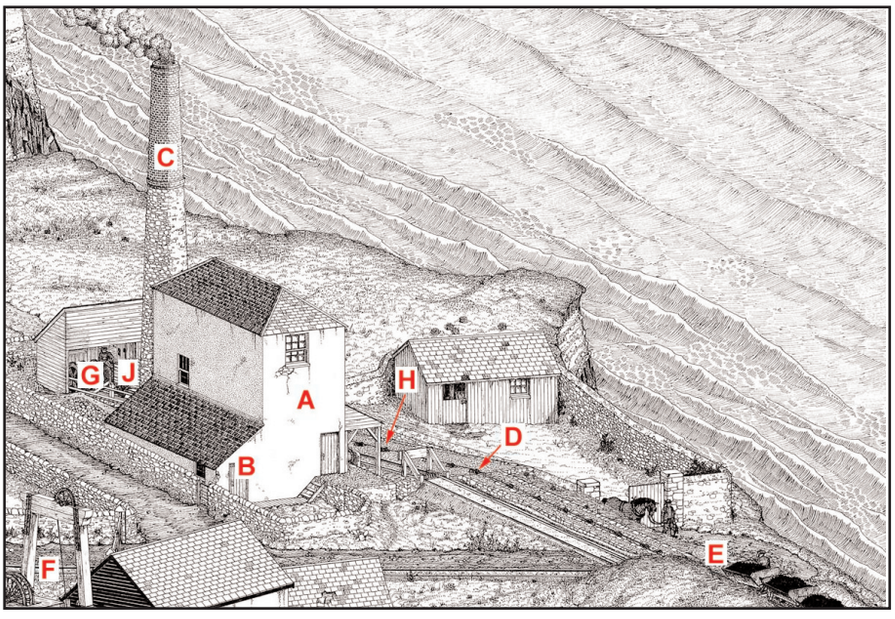


Figure 17. The winding engine-house (A) on the cliffs at the Tankardstown tramway terminus, its lean-to boiler-house (B) and chimney (C). Wagons were pulled up the tramway by a cable running on pulleys (D), but were disconnected from the cable at the top of the incline (E) and pulled by horse into the yard across the road (F). The cable wound onto a winding drum (G) situated at the foot of a reverse incline (H), on which a heavily-laden wagon (J) moved up and down to counter-balance the weight of the ore or coal-laden wagons on the tramway.

The other end of the winding drum wound a cable that pulled a rock-filled wagon (Figure 17:J) up the reverse-ramp. This cable used a system of multiple-pulleys at each end of the ramp to enable the wagon, in one length of the ramp, to counter-balance the laden wagons being pulled up all the way from Stage Cove. The winding drum was probably housed in a shed of some sort to protect it from bad weather, as shown in the drawing (Morris *et al.* 2005).

Because nothing now remains of the engine-house, boiler-house or chimney (Figure 17:A, B and C) that powered the winding drum, it would be reasonable to assume that horse-power pulled the wagons up from Stage Cove - either directly or using a horse-whim (see below) to turn the winding drum. However, the footprint of a building on several 19th century maps (e.g. Figure 8) - actually described as a "whim" (winding) engine on one - confirms that an engine-house existed here, as shown in the reconstruction drawing. From the shape of the footprint and the space available between the ramp and the road it appears that this was a small engine-house, perhaps similar to or smaller than the winding engine-house across the road. Like that engine-house, this one is depicted enclosing fully its bob. Because of the distance between the engine-house and the winding drum, a drive-belt (shown in the drawing) or a sweep rod must have connected the winding drum to a flywheel inside the engine-house that turned with the sweep of the beam (Morris *et al.* 2005).

When coal-filled wagons reached the junction at the top of the inclined tramway (Figure 17:E), it is presumed that they were disconnected from the cable and then drawn by horse the rest of the way to Heron's Shaft or Pope's Shaft. In the drawing, a man is shown leading a horse from a paddock and shed between the engine-house and the edge of the cliff towards a waiting train of coal-filled wagons.

2.3. Boundary Shaft Workings

The third feature of interest in the reconstruction drawing is the Boundary Shaft, excavated in the cliff-top a couple of hundred metres east of the tramway terminus. Both this shaft and Pope's Shaft were relatively shallow shafts, which didn't require the power of a steam engine to lift ore or equipment. Consequently they were most probably worked using a horse-whim, a wooden winding drum that was turned on a vertical axis by a horse (Figure 18). In the early days of mining operations, this type of equipment would have been used throughout the mines.

As with the larger winding gear at Heron's Shaft, cables extended from either side of the winding drum to two pulley-wheels on top of a low head-frame over the shaft. A horse was harnessed to a horizontal beam that extended out on either side of the drum. As the horse turned the drum, one of the ropes wound onto the drum, pulling a bucketful of ore up the shaft, while the other unwound from the drum, allowing an emptied bucket to descend again.

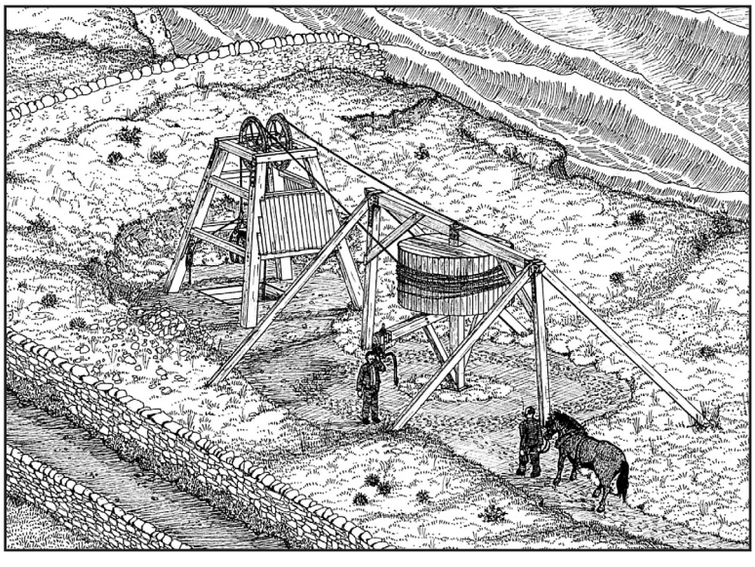


Figure 18. Boundary Shaft with small winding head-frame and a horse-whim used to wind the kibbles up and down the shaft.

3. THE MINE DRESSING FLOORS AT KNOCKMAHON IN ABOUT 1860

Because so little remains of what once stood on the dressing floors at Knockmahon, re-imagining the site depends to a great extent on mid-19th to early-20th century photographs of comparable mines in Cornwall (Trounsen and Bullen 1999). The second reconstruction drawing aims to bring back to life what is now virtually an empty valley. At the time represented in the drawing, about 1860, a large workforce of people of both sexes and all ages was employed here to dress the ore coming from the mines. A close look at the drawing will identify 93 people engaged in different activities across the area (Figure 19). The work was mostly carried out in sheds as shown on Smyth's mine map of 1845 (Figures 4 and 21). Most of these buildings would have been timber-built, but some were stone-built - we can either see the remains of some of the latter or infer stone-building from their functions (e.g. the engine and boiler-houses).

In the following discussion, the dressing floors are divided into five areas (Figure 19):

- the count-house yard (Figure 19:A)
- the breaking, crushing and jigging area (Figure 19:B)
- the main dressing floor, where the ore was concentrated (Figure 19:C)
- the gunpowder magazine, and the yards and sheds it over looks (Figure 19:D)
- Downright (or Engine) Shaft (Figure 19:E)

The reconstruction drawing also shows the mine manager's house (Figure 19:F) - which, together with the count-house, provides a present-day anchor point for locating the other elements of the site - and former terraced miners' cottages beside the road from Knockmahon village (Figure 19:G).

3.1. Count-house Yard

The high-walled yard beside the road out of Knockmahon village, with the count-house at one corner, is the only substantial survivor of the 19th century dressing floors (Figure 20). The count-house, once the office for the day-to-day running of the mines, is occupied today as a private house (Figures 3, 12 and 20:A). The other buildings ranged about the yard walls are now roofless shells. Although it is not possible now to say exactly

Figure 19. The ore dressing floors at Knockmahon as they might have appeared in about 1860: count-house yard (A); breaking, crushing and jigging area, including engine-house and boiler-house (B); main dressing floor (C) including several sheds housing circular buddles (some sheds are shown ruined and disused on the valley floor, partially covered with mine waste: C1); gunpowder overlooking yards and sheds on different levels (D); Downright Shaft (E); mine manager's house (F); miners' cottages (G and G1). The red spots mark the locations of all the 93 people included in the reconstruction drawing.

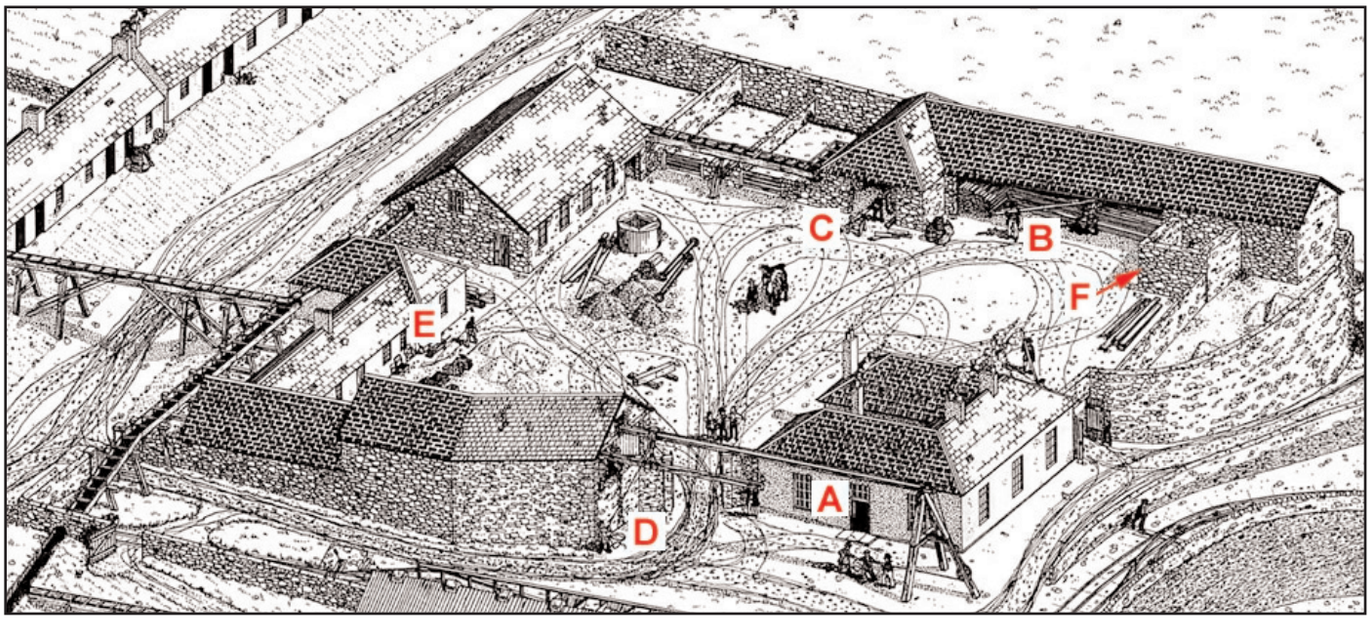


Figure 20. The count-house yard with the count-house at one corner (A). Selected buildings have been interpreted as: a long, open-fronted timber store (B); a combined cart-maker's, cooper's and wheelwright's workshop (C); a long saw-house (D); an assay office (E); and an open-roofed outside privy (F).

what these buildings were used for, it is possible to make some inferences based on 1846 valuations for the townland of Ballinagigla (Des Cowman, personal communication). These state that areas of human activity here at that time included offices, two stables, two tool houses, a forge (perhaps the one a few hundred metres further along the road past the count-house yard), an open-fronted timber store measuring 19.2 metres by 4.42 metres (including a cart-maker's, wheelwright's and cooper's workshop), a large carpenter's shop measuring 15.24 metres by 8.53 metres, a 34.4 metre-long saw-house, a tar and rope-house, a powder and candle-house (presumably the magazine discussed below) and two privies (toilets).

A number of these buildings were obviously outside the count-house yard, for example the magazine. Others were also probably outside the yard, corresponding perhaps to buildings in the yards below the magazine that are not identified on Smyth's map (Figure 21). Some of the very long buildings described above, measuring between 15 and 35 metres long, perhaps could correspond to the longer sheds on the main dressing floor, except that Smyth labels these as ore-dressing [sheds] and stamps, not workshops. Also, workshops, offices and stores needed to be secure from pilfering. Consequently, many of the buildings described in the account are taken to correspond to the - often very long - buildings ranged around the count-house yard. In the drawing, these include: the long timber store (Figure 20:B) and, adjacent to it, the (combined) cart-maker's, cooper's and wheelwright's shop (Figure 20:C); the long saw-house, which had a 'five-foot (1.53 metres) deep by five-foot wide pit along its full length' (Figure 20:D); the assay office where ore samples were valued (Figure 20:E); an open-topped privy (Figure 20:F).

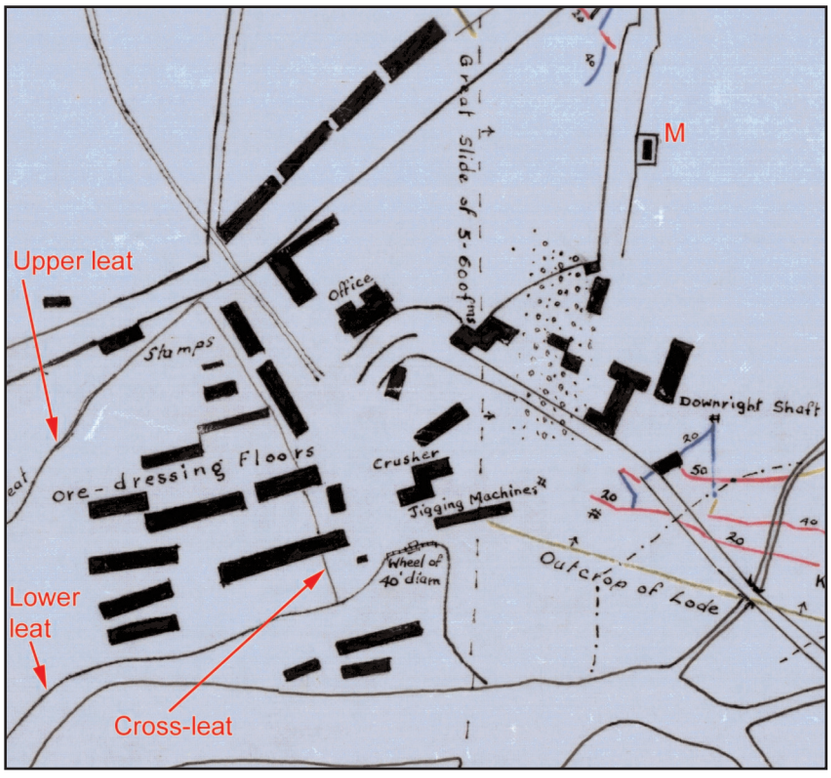


Figure 21. Detail from W.W. Smyth's 1845 map showing the mine dressing floors. The labels on selected features are: office (the count-house); stamps (probably the two north-south orientated buildings west of the office); ore-dressing floors (the long east-west orientated sheds generally); crusher; jigging machines; wheel of 40' [12.2-metre] diam[eter]; Downright Shaft. The rectangular black building in the rectangular frame in the top left corner of the map is the magazine (M).

A number of activities are depicted in the yard, including a man sawing at the entrance of the cart-maker's shop and two pairs of men moving timber planks from the store to the side gate of the yard. At the front entrance of the yard, a timber gantry is being used to lift a large timber beam into the saw-house - while three managers look on! The head of a man can also be seen in the privy! Note also the elevated wooden launder that carries the upper leat (a Cornish term for a channel excavated to supply water to mine workings) across the road in front of the count-house yard.

3.2. Breaking, Crushing and Jigging Area

Hand-drilling, picking and hammering, and also gunpowder were used to extract copper ore from the mines. The ore was raised to the surface, deposited in wagons and sent to the dressing floors at Knockmahon. On arrival the ore was dumped from the wagons into large ore-hoppers (Figure 22:A) below the tramline (implying the presence of a ramp bringing the tramline up above the hoppers - see below). From there it was shovelled into barrows and dumped on a coarsely cobbled dressing floor (Figure 22:B) for the first in a series of dressing and separation operations. Dressing removed as much waste as possible to maximise the percentage of copper that was transported to South Wales for refining. The range of dressing operations that the ore went through is illustrated in Figure 23.

In the reconstruction drawing, women called 'bal maidens' or 'bal girls' (Cornish terms) do the ragging, spalling and cobbing of the ore using large hammers and smaller picks (Figure 22:B). Contemporary accounts state that these women worked in the open (Des Cowman, personal communication). The broken ore was taken to the crusher (Figure 22:C) to be reduced mechanically to about pea-size. The crushed ore then went on to the jiggers beside the crusher (Figure 22:F).

Jigging involved vigorously shaking the crushed ore in mesh-bottomed boxes suspended in water. Light waste accumulating at the top of the water was skimmed off and discarded. The finest ore passed through the mesh to be collected and sent to the main dressing floor for buddling (see below). The richest of the remaining ore settled on the mesh at the bottom of the box, from where it was removed for valuing and shipping. The mixed ore above it was sent up to the stamps beside the count-house for further crushing. The first MCI shareholders' report of 1847 states that a ramp and an extra waterwheel had been erected in the previous six months to move this ore up to the stamps (Des Cowman, *personal communication*). In the reconstruction drawing, it is assumed that the ramp is the one that climbs from the cobbled yard over the ore-hoppers and past the count-house. The 30-foot (9.3-metre) waterwheel driving the stamps (Figure 25:B) may also have been used to wind the wagons of ore up to the stamps.

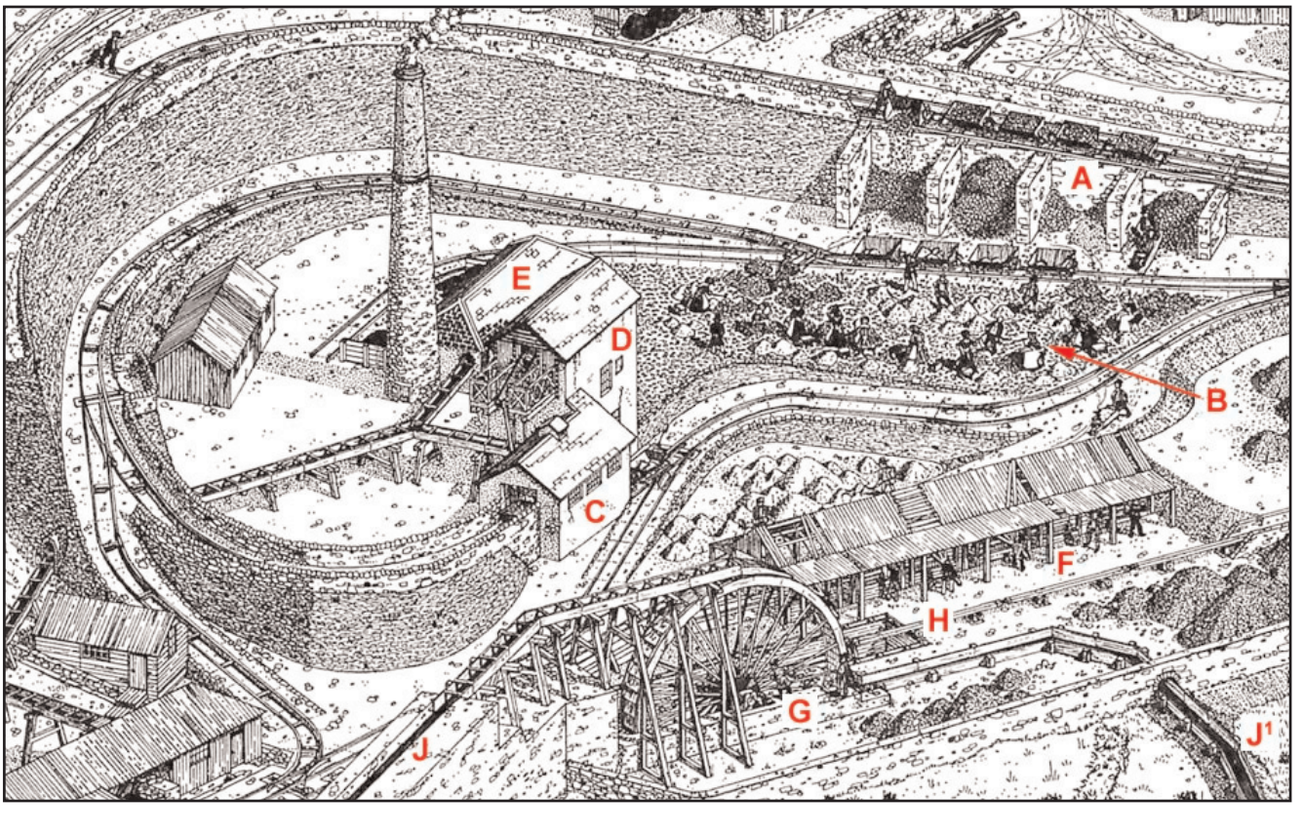


Figure 22. Breaking, crushing and jigging area. Ore from the mines was emptied into large ore-hoppers below the tramway (A). The ore was moved to the cobbled breaking floor (B), where it was hand-broken by women. The broken ore was then taken to the crusher (C) close beside a steam-powered engine-house (D) and boiler-house (E). From the crusher, the ore went to the jigging sheds (F) for separation. The separated ore then went either to the stamps for further crushing or to the buddles (in the lower left corner) for concentration - both on the main dressing floors (Figure 25). Note here also the 40-foot (12.2-metre) waterwheel (G) that drives pumping in Downright Shaft (see Figure 28) via a system of flat-rods (H), and the lower leat that carries water to and from the wheel (J and J[1]).

In the drawing, the crusher is shown powered by a steam engine and boiler similar to those described at Tankardstown (Figure 22:D and E). Though none of the old maps identifies an engine-house, a sketch from the 1840s shows smoke spewing from a chimney on the dressing floors. Only two groups of buildings on Smyth's map (Figure 21) could be an engine-house and boiler-house grouping. One was near the top of the ramp from the cobbled dressing floor (Figure 13:F) and the other was beside the crusher (Figure 13:E). Contemporary accounts state that pumping of the mines was water-powered so the engine-house probably powered crushing, making the latter location most likely.

3.3. Main Dressing Floor

On maps from about 1840 and 1845 (Figures 13 and 21), the main dressing floor is shown cluttered with long narrow buildings. Nothing remains of these and it is hard to imagine them today on the scrubby slope below the road. They were certainly no more than simple timber sheds to provide some shelter for dressing operations, as seen in contemporary photographs of Cornish mines (Trounsen and Bullen 1999).

Of the buildings on the main dressing floor, only the stamps are labelled on Smyth's map (Figure 21). The functions of the other buildings are not identified. In comparison with the size and layout of stamps at many Cornish mines - in two long sheds aligned on either side of a driving mechanism - it is probable that the two long north-south aligned sheds west of the count-house were for the stamps. In the reconstruction drawing, the southern shed is shown still under construction even though the stamps are in use - a frequent sight in photographs of Cornish mines (Trounsen and Bullen 1999).

Dressing operations at Knockmahon were water-powered from the beginning, with a 40-foot waterwheel erected and operational by 1829 (Figure 22:G). The location of this wheel, used for pumping the nearby Downright Shaft (Figure 28), is known from Smyth's map (Figure 21). Another three waterwheels were operational by 1831: a 30-foot (9.3-metre) wheel, a 15-foot (4.6-metre) wheel and a 12-foot (3.7-metre) wheel. They are not shown on Smyth's map, but are interpreted to lie in line along a cross-leat connecting the upper leat and the lower leat on Smyth's map (Figure 21; see also Figure 25:H and J respectively) and on the 1840 O.S. map (Figure 13). The ground drops

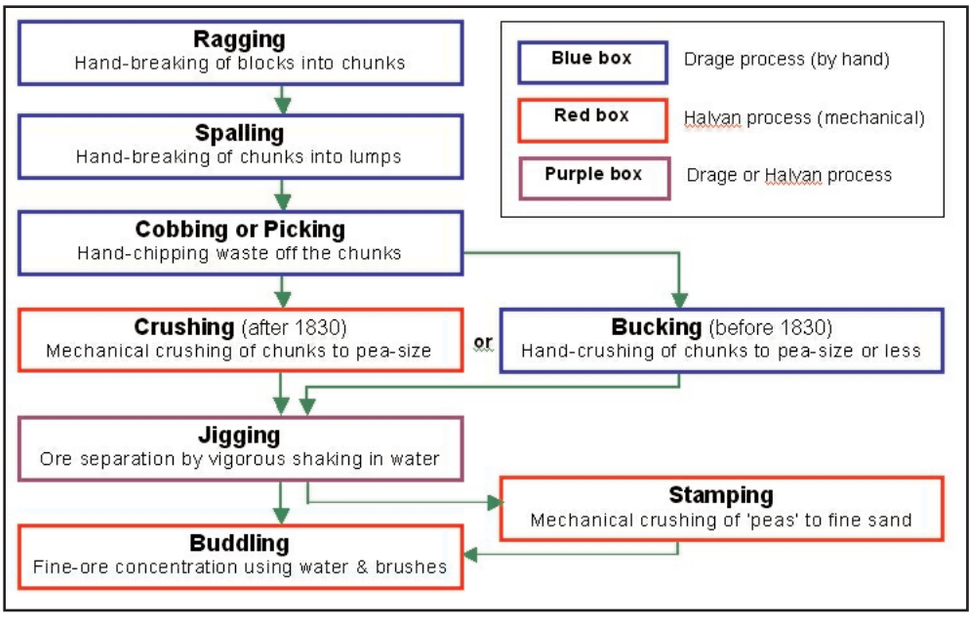


Figure 23. The sequence of operations commonly used to dress and separate copper ore in the 19th century.

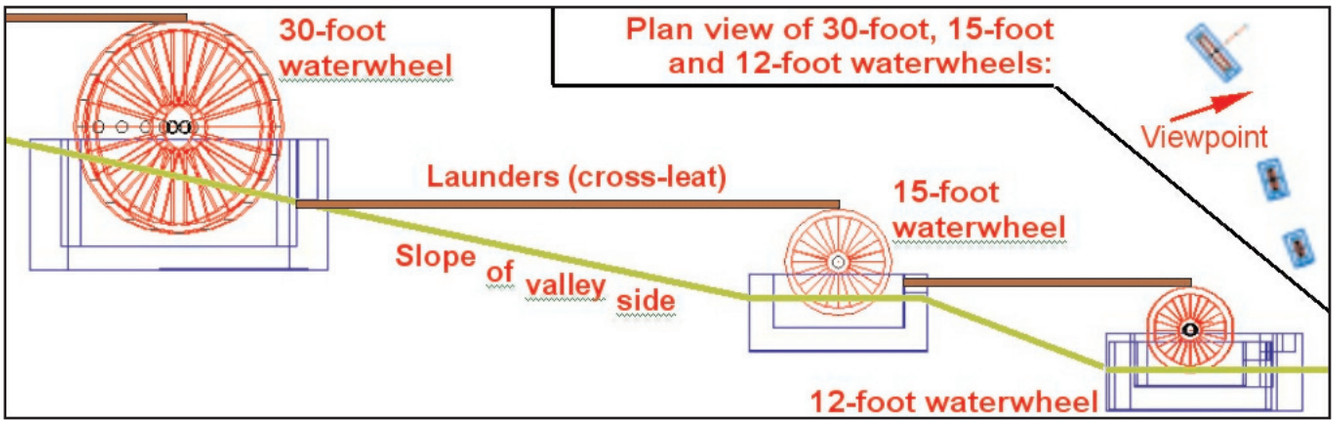


Figure 24. The relative elevations of the 30-foot (9.3-metre), 15-foot (4.6-metre) and 12-foot (3.7-metre) waterwheels as interpreted for the reconstruction drawing. Ground level (green) rises from the valley floor on the right and continues up to the level of the upper leat, which was at the same elevation as the top of the 30-foot wheel. (Modified from a 3-dimensional planning drawing of the dressing floors.)

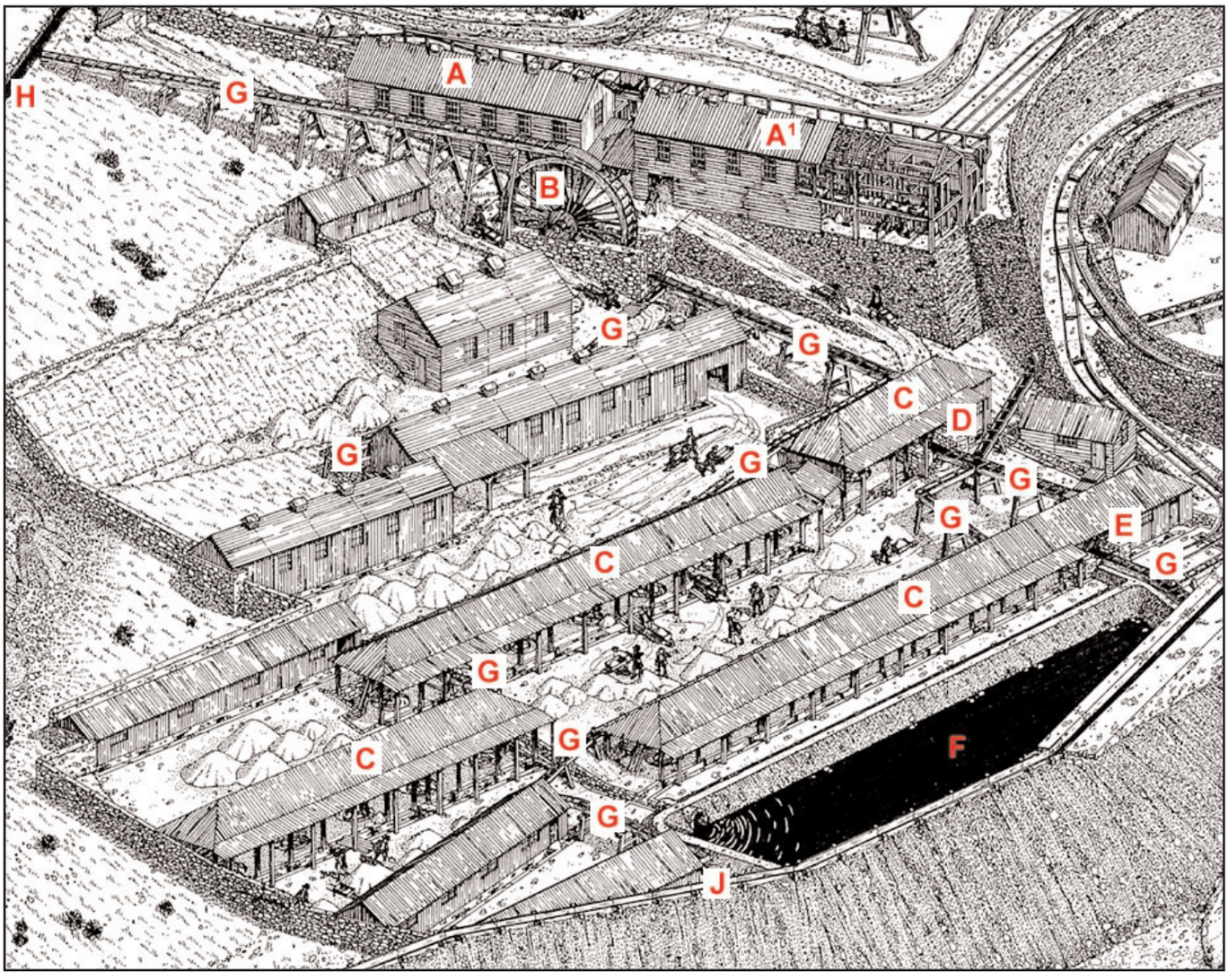


Figure 25. The main dressing floor. The layout of these timber sheds is taken from mine-maps dating from about 1845. The functions of several sheds are interpreted (partly based on the same maps) as: unfinished but fully operational stamp sheds (A and A1) powered by a 30-foot waterwheel (B); sheds extended by awnings (C) to provide shelter for circular buddles powered by enclosed 15-foot (4.6-metre) and 12-foot (3.7-metre) waterwheels (D and E respectively); and a tailings pond for waste (F). Water is supplied to the different dressing operations by elevated wooden launders (G), which are themselves supplied from an upper leat or canal (H). Note also a lower leat (J) that supplies water to power the 40-foot (12.2-metre) waterwheel (Figure 22).

about 15 metres from the road to the valley floor along this line, so the leat shown on the maps must in fact have been a stepped series of launders (wooden troughs) that supplied water to each waterwheel in turn (Figure 24). These launders probably also supplied water to the ore-dressing sheds on the main dressing floor via a series of subsidiary launders (Figure 25:G).

While we cannot say with certainty what occurred in the long ore-dressing sheds, buddling was probably the main operation here. A buddle was a circular pit with its floor sloping gently away from the centre to the edge. Brushes suspended from a frame over the pit rotated about the pit's axis to sweep the floor. Fine-grained ore was fed by water into the centre of the pit and gravity concentrated the copper near the inlet. The rotating brushes smoothed the ore to prevent channels forming in the sediment. The copper was then removed from the centre of the pit for valuing and shipping, and the waste was shovelled out from a slightly deeper trough just inside the edge of the pit. This waste was either reprocessed back through the dressing cycle, or discarded if it was the final residue at the end of such a cycle.

Four sheds have been interpreted as housing buddles in the reconstruction drawing. Because the sheds are quite narrow and buddles usually have a diameter of up to 4 metres, the sheds are shown as being open-sided with awnings extending their roofs (Figure 25:C) (cf. Trounsen and Bullen 1999). The buddles lie more-or-less in two lines and it is inferred that they were powered by the 15-foot (4.6-metre) and 12-foot (3.7-metre) waterwheels (Figure 25:D and E), enclosed at the eastern end of the easternmost shed in each row. (Mostly hidden in the drawing by the shed roofs, the wheels can be located by the launders entering the sheds above them and exiting below them). Mine workers with barrows can be seen dumping the waste in piles between the sheds and close scrutiny of the drawing reveals the feet of several men shovelling waste from the buddles.

Two other features are of interest in Figure 25. The lower leat is shown elevated on a steep embankment (Figure 25:J) to enable it to supply water to drive the overshot 40-foot (12.2-metre) wheel (overshot means the water was supplied to the top of the wheel to turn it). In the extreme lower left corner of the reconstruction drawing, this embankment merges into higher ground. An 1831 section sketched across the Knockmahon dressing floors (Figure 26) shows the top of the 40-foot (12.2-metre) wheel standing about eight metres above the valley floor, with a stepped (presumably stone-built) platform supporting the launder, on wooden trestles, that supplied water to the wheel. Moving west from the wheel (not included in Figure 26), the ground appears to rise to meet the lower leat - to become the embankment in Figure 25. (The stepped stone platform and 40-foot wheel can be seen in Figure 22.)

The final feature of interest is the suggestion of a tailings pond for waste from the dressing process (Figure 25:F). In the reconstruction drawing the pond is the first stage in waste dispersal, draining through the embankment supporting the lower leat and the 40-foot (12.2-metre) wheel platform to form two deltas of mine waste. These are depicted gradually covering derelict sheds on the valley floor (Figure 19:C1). The evidence for this comes from a comparison of Smyth's mine map and the 1840 and 1905 O.S. maps. In 1840 the stream flows into the River Mahon through two broad channels and three sheds stand close to the western channel. By 1905 the western channel had completely disappeared beneath a blanket of mine waste and today appears as the level, bulldozed area between the Bunmahon 'Geological Garden' and the visible remnants of the dressing floors further up the valley.

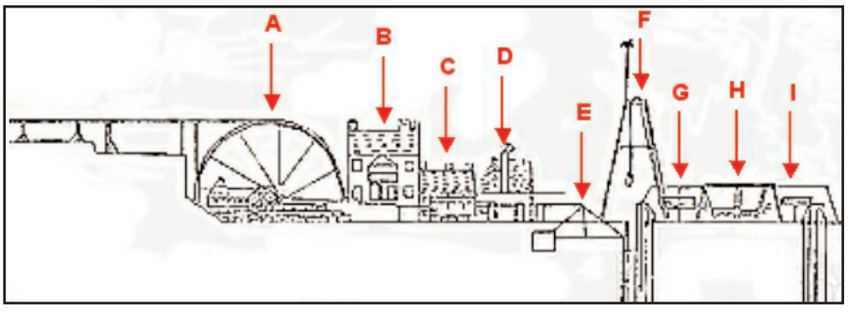


Figure 26. Sketch taken from an 1831 mine section, which is annotated to show: the 40-foot waterwheel (A); the count-house (B); a pitman's house (C); a smith's shop (D); the main beam (E) for pumping from Engine Shaft (Downright Shaft?); shear legs standing over Engine Shaft (F); horse whims (G, I); and a capstan (H). (The shaft on the extreme right is Highbarrow Shaft.)

3.4. Gunpowder Magazine and adjacent Yards and Sheds

The gunpowder magazine for the mines was sited on top of a small hill that projects onto the valley floor above the dressing floors (Figure 27:A). All that remains of it today is one corner of high windowless wall with two shallow buttresses on its inner side. Looking at Smyth's map (Figure 21), this appears to be part of a rectangular wall enclosing a small building. This is a classic example of magazine architecture, in which explosives and related material were secured in a small roofed building inside a strong wall. The outer wall provided additional security and would also direct the force of any accidental explosion upwards rather than outwards. The high wall extending from the magazine down the hill towards the dressing floors today is interpreted as the surviving stretch of the wall that once enclosed the whole site. In the reconstruction drawing, a couple of workers are shown gingerly carrying a box of gunpowder down the steps from the magazine to a cart waiting below.

The dressing floors below the magazine were on different levels, presumably with low ramps connecting them (Figure 27). A number of wooden sheds are shown scattered about them, but there is evidence also for stone buildings at two locations. Nothing survives of a group of buildings that existed below the count-house (Figure 27:B) except for a fragment of wall built onto the rock below in a small modern quarry. This was part of the westernmost of three connected buildings shown on the 1840 O.S. map (Figure 13:F) and on Smyth's map (Figure 21). In the reconstruction drawing they are all interpreted to be stone-built.

The second group of stone buildings survives as a façade beside the former tramway, halfway between the stream and the count-house (Figure 27:C). Facing it from the tramway track, the façade comprises a high gabled end-wall in the centre with an integrated lean-to extension to the right and a flat-topped wall extending to the left. The latter wall turns twice through 45° into a short left-facing end-wall, with brickwork defining the bevel corners. On Smyth's and the 1840 O.S. maps, the gable end appears to belong to a long building extending back from the tramway, with a small extension parallel to the tramway.

3.5. Downright Shaft

Of the shafts sunk in the 1830s and 1840s between Knockmahon and Stage Cove, most had been abandoned by the early 1850s. Only one shaft is shown on the dressing floors on Smyth's map (Figure 21). Called Downright Shaft, this probably corresponds to Engine Shaft on the 1831 sketch (Figure 26:F), though a second shaft appears there too, called Highbarrow Shaft. The name 'Downright Shaft' is used here because it is the more evocative name.

The 1831 sketch shows a counter-balanced main beam (or bob) pumping water from Downright Shaft. It is shown positioned mostly below ground (Figure 26:E) and this is recaptured in the reconstruction drawing, where the bob (Figure 28:B) is sunk into a timber-lined pit, from which the shaft (Figure 28:A) is sunk. A man is shown carrying a plank down the ramp from the ground surface to the floor of the pit.

The bob oscillated about its axle to work a pump rod attached to one end, while a weighted box at the other end balanced the weight of the pump rod - just like the balance bob at Tankardstown (Figure 15:E). As reported in 1835 (Des

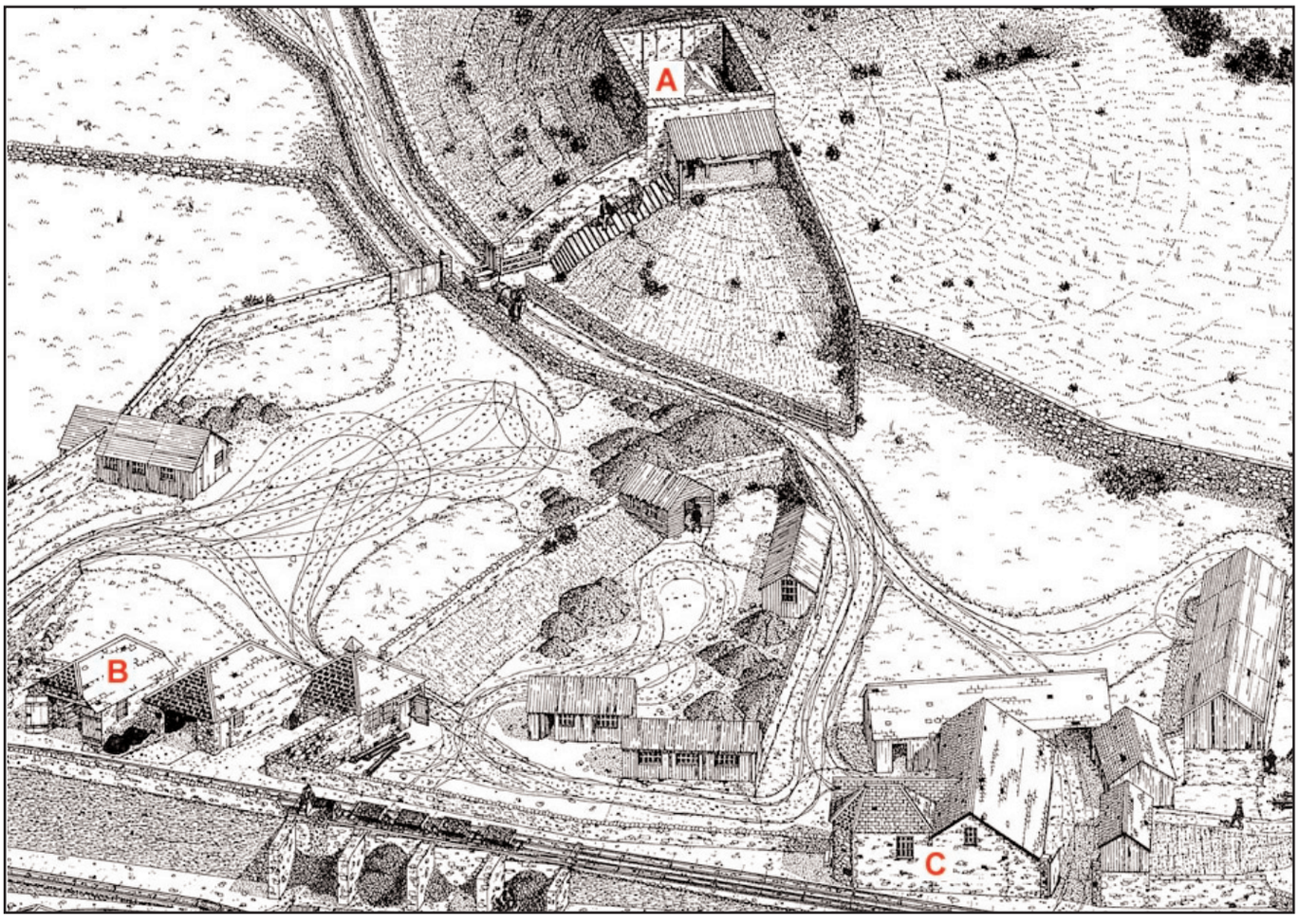


Figure 27. The gunpowder magazine overlooking various yards and sheds. The magazine, a small stone building surrounded by a strong outer wall (A) stands isolated on a hill in the valley. Below it are several yards with sheds scattered about them on different levels. The stone foundation of one of a group of three connected buildings (B), shown on the 1845 maps, can still be seen in a small modern quarry, and the stone façade of another group also survives alongside the former tramway (C).

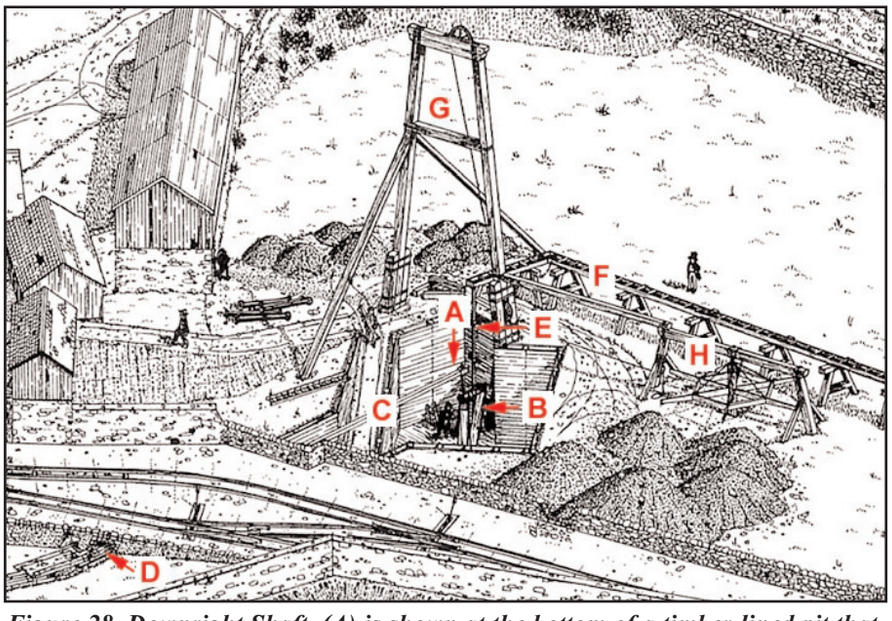


Figure 28. Downright Shaft (A) is shown at the bottom of a timber-lined pit that also accommodates the main beam or bob (B) attached to a pump rod in the shaft. The 40-foot waterwheel drives the bob via flat-rods (C) that pass under the tramway at (D). A metal pipe (E) brings pumped water from underground to a wooden launder (F), which discharges into the nearby stream. The usual arrangement of shear legs (G) and windlass (H) is also depicted.

Cowman, personal communication), the beam is shown driven by flat-rods (Figures 22:H and 28:C) - linked timber beams that pushed a vertical post projecting up from the bob (Figure 28:B) forward and back. The flat-rods ran on rollers through a culvert beneath the tramway (Figure 28:D) and across the dressing floors (Figure 22:H) to a crankshaft attached to the 40-foot waterwheel (Figure 22:G). In the reconstruction drawing, the water is shown being pumped up a pipe into an elevated wooden launder (Figure 28:E and F) and discharging into the nearby stream (Figures 7 and 19). Spare pipe segments can be seen lying nearby. As at Heron's Shaft in Tankardstown, shear legs were erected over the shaft (Figure 28:G; compare with 26:F), attached to a nearby windlass (Figure 28:H).

3.6. Mine Manager's House

In the reconstruction drawing, the mine manager's house, known locally as 'Petherick's House' after one of its occupants, is depicted just as it appears today (Figure 29; compare with Figure 2), but with an open-topped carriage waiting at the front door. The road that now runs alongside the stream below the house was constructed since the date of the drawing. From his elevated vantage point, the mine manager was kept aware of all the activity on the dressing floors across the valley, not least from the rhythmic din of noise that emanated from there day and night - from the background squelch of the waterwheels to the thump and rending of the stamps, as recorded in an 1840s report (Des Cowman, personal communication).

Figure 29. The mine manager's house stood above the river with no road between them in the mid-19th century.

Presumably the mine manager was able to access the complex either via a combined tramway and access bridge over the stream, as shown near the extreme left hand edge of Figures 7 and 19, or by travelling the short loop of road inland that crossed the stream north of the magazine and past the front of the count-house yard on its way into Knockmahon village.

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5. ACKNOWLEDGEMENTS

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