Dale Mine: Archaeological Excavations and Consolidation at and around the Settling Tanks

August-September 2019

John Barnatt

SOUTH WEST PEAK
LANDSCAPE AT A CROSSROADS

HERITAGE FUND

Cover: The settling tanks at Dale Mine after excavation and consolidation in 2019.

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Summary

Excavations were carried out at the unusual stone-walled bank of six tanks at Dale Mine that lies close to the site of the main engine shaft, placed between small upper and lower dressing floors. This work was done in conjunction with consolidation of the stonework here, with both tasks undertaken by supervised volunteers from the South West Peak Landscape Partnership Scheme supported by the National Lottery Heritage Fund. An archaeological watching brief was undertaken as collapse material was removed from adjacent to the downslope wall of the structure. Also four of the openings through this wall were dug and two of the tanks were carefully excavated to gain a better understanding of these. A second small trench was dug at the site of one of the Cornish-type engine houses that once stood next to the main shaft, to gain information on the state of preservation of its buried basal wall courses; the bob wall investigated was shown to have been fully removed except for a small lower part of its footings.

Excavation of the stone-walled tanks, which we can show from historical documentation to have been at least partially built in the second half of the 1850s, revealed that they were vertical-sided with near-flat paved floors. These were suitable for use as settling tanks for sludge from ore processing, placed here in advance of further processing on a lower dressing floor to remove residual ores not recovered on the upper dressing floor above. The six tanks comprise four identical ones to the south-east, and two larger ones to the north-west that may well have been built in a separate phase of construction. All the tanks had small openings through the *c.* 3m high downslope wall; those to the north-west have surrounding iron plates with bolts and were clearly for bulkhead doors that were bolted on. Excavations showed that the four openings to the south-east, which are designed differently from the other two, each with a wooden doorframe surrounding the inner part of the opening, also had bulkhead doors fastened to bolts that were originally set in the now-rotted wooden side timbers. Outside these frames, the arched openings in the downslope wall has stone-built sills with paving between these and the outer edge of the wall; there was also paving between the wooden frame and the tank interiors, placed on the floors of small flat-topped openings with wooden lintels at their roofs.

There were other important but unanticipated outcomes of the excavations. We now know the downslope wall for the six tanks was more than doubled in width along its full length after it was initially built, perhaps done when the mine's ore dressing plant was mechanised in 1859 at the time when the 1854-55 steam engine was converted to be used for winding and

ore crushing after a new pumping engine was installed. A slot between the old and new walls in their upper halves was incorporated in the modification, which was filled with clay to act as a waterproofing barrier. The tank sides were also rendered after they were first built, at an uncertain date, to make them more waterproof. We also now know the two excavated tanks, and at least two of the others, were later converted for use as filter beds. Each of the two excavated tanks had carefully laid layers of small stones, clinker and larger stones placed above their original paved floors. This conversion perhaps took place in 1873 shortly before the mine closed; these filter beds were probably never used.

Introduction

Background

All the surface remains at Dale Mine were surveyed and analysed in August 2018 (Barnatt 2018; in prep.) and description and interpretation of this mine have been published previously (Porter and Robey 1972; 1973; 1874, 2000). One structure here has always stood out as both very unusual and in need of consolidation; this comprised a bank of six stone-walled tanks with small openings through the *c.* 3m high downslope wall; its facing stones had been robbed many years ago and it was slowing deteriorating.

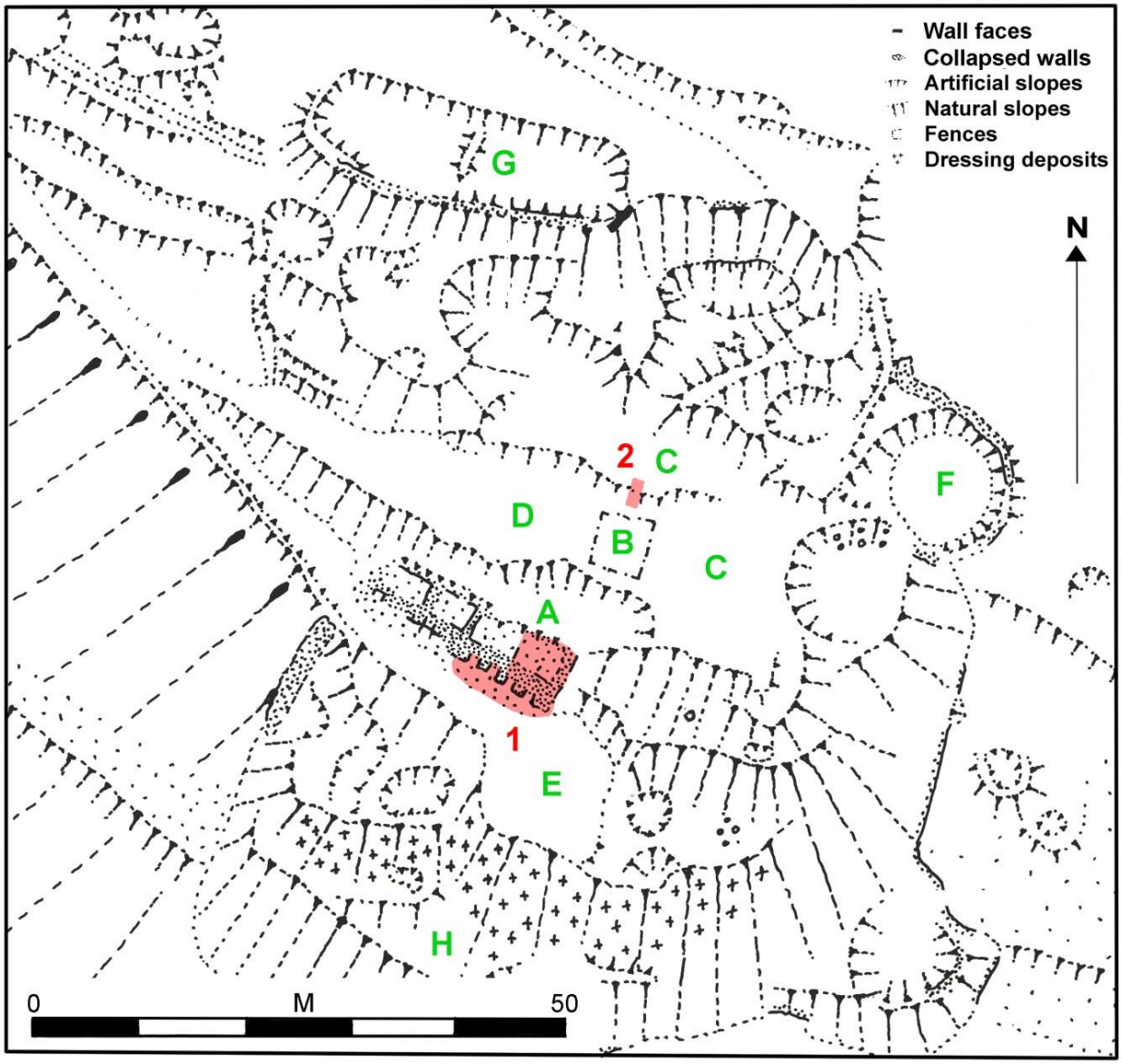

Figure 1: The central area of the Dale Mine surface features, showing the location of Trenches 1 and 2 (A: Settling tanks, B: Site of main engine shaft, C: Sites of engine houses, D: Upper dressing floor, E: Lower dressing floor, F: Gin circle, G: Reservoirs, H: Main hillock).

Plate 1: The downslope wall of the bank of settling tanks at Dale Mine, photographed at the end of consolidation work and archaeological excavations in 2019 at the south-eastern tank openings (1-4); the north-western tank walls and openings (5-6) not worked on lie to the far left, with Opening 5 visible, while the wooden fence posts above to the right surround the site of the main engine shaft.

Plate 2: The two excavated settling tanks (1-2) at Dale Mine, looking downslope, photographed at the end of consolidation work and archaeological excavations here in 2019.

Plate 3: Opening 4 at Dale Mine at the end of consolidation work and archaeological excavation of its floor in 2019.

The bank of walled tanks is sited just downslope of the now-buried collar of Dale Mine's main engine shaft, with small flat dressing floors adjacent to and below this. It has long seemed likely that the tanks were built in conjunction with ore processing, although before excavation it was unclear whether they were bins for ore-storage and washing, or were built as settling tanks; in the past their purpose has been the subject of great confusion with some interpretations subsequently rejected (Barnatt 2004; 2018; Barnatt et al. 2003; 2006; Kirkham 2006).

We knew prior to excavation that the tanks and the adjacent lower dressing floor lie on a terrace created when the top of the mine's main hillock was dug away in 1854-56 to recover previously discarded zinc ore, hence they cannot have been built earlier than this; historical documentation showed that at least part of the bank existed by 1859 at latest. The focus of

ore processing at the mine moved away from the dressing floors adjacent to the engine shaft in 1862-63, after a new shaft was sunk well to the north-west and new ore processing floors were built here. It was not known whether the tanks lay abandoned from 1862-63 to 1873 when the mine closed, or had been used for other purposes. Similarly, their history from 1873 was obscure.

There had been two large Cornish-type engine houses adjacent to the shaft collar, used for ore-winding and water-pumping, one built in 1854-55 the other in 1858-59; the first one was taken down in 1861-62 and the other demolished after the mine closed in 1873. It was not known whether the lowermost wall-courses and their footings still lay buried or had been removed.

Inevitably, any text on a mine site includes the use of specialist mining terms and there is a glossary at the end of the report to explain these.

The 2019 Work

In August to September 2019 funds were made available, via Catherine Parker Heath the South West Peak Landscape Partnership Scheme's Cultural Heritage Officer, to start to put what remained of the bank of six tanks back in good order. This was done as part of the Small Heritage Adoption Project one of the projects being delivered by South West Peak Landscape Partnership supported by the National Lottery Heritage Fund. In the limited time available, due to funding constraints and the availability of the project supervisors, only the south-eastern half of the tanks was worked upon (Trench 1); here the downslope wall was at its highest and in the most need of consolidation. It may be possible to return in 2020 to work on the other half.

Plate 4: Before: The downslope wall of the bank of settling tanks at Dale Mine photographed before the start of consolidation work and archaeological excavations at Tanks 1-4 in 2019.

The stabilisation work at the bank of tanks was done by South West Peak Landscape Partnership Scheme volunteers, under the supervision of Mark Womersley, who specialises in rebuilding with lime mortar and training others to use this. John Barnatt carried out an archaeological watching brief and directed further excavations.

Plate 5: After: The downslope wall of the bank of settling tanks at Dale Mine photographed at the end of consolidation work and archaeological excavations at Tanks 1-4 in 2019.

Plate 6: Volunteers preparing the downslope wall of the bank of settling tanks wall for repointing at an early stage in the work.

The outer side of the downslope wall and parts of two of the tanks behind were repointed using lime mortar, with the mix determined by prior analysis of samples taken of the original mortar. In parts the wall faces and other places at the exposed wall core were partially rebuilt to stabilise original stonework. The consolidation work undertaken is illustrated in Plates 4-12.

Plate 7: Volunteers repointing the downslope wall of the bank of settling tanks at a more advanced stage in the consolidation; the working tower allowed the upper half of the wall to be accessed safely.

Plate 8: Settling tanks 1-4, looking downslope, photographed before the start of archaeological excavations and consolidation work to the left in 2019.

Plate 9: Tank 1, looking downslope to its end wall, showing the stonework found intact during excavation, photographed shortly before the start of consolidation work here in 2019; this needed doing before digging proceeded further, while the upper wall was still in easy reach.

Plate 10: Tank 2, looking downslope to its end wall, showing the stonework found intact, photographed shortly before the start of consolidation work here in 2019 (note the one stone at the wall top behind that is higher than the rest had been placed here during the work to save it falling on someone and it was later placed back in the inner wall).

Plate 11: Tanks 1 and 2, looking downslope to their end walls after the 2019 consolidation work was finished here, with the inner walls partially rebuilt to give support to the *in-situ* outer part of the downslope wall, which here was to too narrow for sustained survival. The photograph was taken when the upper filter bed layers in the tanks had started to be removed.

Plate 12: Tanks 1 and 2, looking upslope to their end walls, showing the stonework found intact, photographed before the start of consolidation work here in 2019; the wall in Tank 1 (right) was later heightened to the same level as the top of *in-situ* walling in Tank 2 (left), added to give support to the wall core material behind; the core material left exposed was repointed where necessary.

The watching brief was undertaken to ensure that no *in-situ* archaeology was inadvertently damaged in the process of removing the rubble that had accumulated during face-robbing and subsequent deterioration at the downslope side of the structure. In addition to this, two of the tanks behind the wall at the south-eastern end of the structure were fully excavated, not only because further wall consolidation was needed here but also to acquire more information that would help the understanding of why these tanks were built and how they were used. Similarly, the floors of the four south-eastern openings through the downslope wall were excavated to reveal details of what was there and further our knowledge of how the openings were used.

Plate 13: Removing the collapse material at the base of the downslope wall was done under archaeological supervision to ensure work stopped when the pre-collapse soils were left *in-situ*; this photograph was taken towards the end of the first day of work.

At the end of the excavation both tanks were left open, with safety fencing placed around them, so that future visitors can better appreciate the structure. The two openings from these running through the downslope wall were each sealed with a drystone wall to prevent visitors crawling to the inside under the rotted timber lintels.

Shortly before excavations commenced, resistivity surveys were undertaken at the sites of the two engine houses next to the main engine shaft (Area C), and also at the lower dressing floor (Area E), to better place the bank of tanks and surrounding features in context by supplementing the detailed survey of surface features undertaken in 2018. These remote-sensing surveys were undertaken by South West Peak Landscape Partnership Scheme volunteers under the supervision of Richard and Angela Knisely-Marpole. The volunteers also cleared the site of shrubs and brambles prior to the excavation work starting.

Plate 14: The investigative archaeological work in the two settling tanks involved forming bucket chains to take material out, photographed when we had started to remove the upper filter bed layers in Tank 2.

Plate 15: We had pondered for days over why roofing slabs had been placed against the dividing wall between Tanks 1 and 2; it was an exciting moment when the first set was moved and the reason became clear.

Plate 16: Tanks 1 and 2 photographed just as excavations were completed; with increasing depth bucket removal had become harder work.

A second small trench was dug at the postulated site of one of the Cornish-type engine houses (Trench 2). This trial excavation, which measured only 1m by 3m, was undertaken to test this interpretation. It was positioned at the likely site of the bob wall, where there is a distinct change of slope between the shaft collar area and a flat terrace above. The aim was to see what, if anything, remained of the structure, and to determine if there was potential for large-scale excavations from 2020 onwards to expose wall bases, consolidate these and leave them open for people to see in the future and thus allow enhanced appreciation of the site.

In both trenches all digging was by hand, using usual archaeological digging techniques. Context sheets for all features were created on site to document what was found, supplemented by photographs and detailed drawings at 1:20. The spoil from Trench 1 was placed in an adjacent hollow on the downslope side that dated to when the hillocks were robbed in 1854-56; Trench 2 was backfilled. It should be noted that in the excavation records made during the fieldwork, for simplicity of recording sake, 'site north' was designated as at right angles to the bank of tanks; throughout this report orientations are quoted in relation to true north as 'site north' was actually oriented north-west.

Excavations at the Tanks (Trench 1)

Introduction

As noted above, the structure where excavations were carried out comprises six tanks with stone walls, in a long rectangular bank set into a steep slope below the mine's main engine shaft and an adjacent small upper dressing floor. Prior to excavation all six tanks had been largely filled with rubble and soil, and the facing stones of the outer face of the downslope wall has been robbed, while excavations showed that the internal walls defining each of the tanks had also been robbed but to a lesser degree; there were visible traces of render on the exposed *in-situ* upper pasts of the walls of Tanks 1, 5 and 6.

The two tanks to the north-west, with one larger than the other, contrast with the four to the south-east that are significantly smaller and have their long axes at right angles to the other two. All six have low openings in the high wall on the downslope side that lie next to the site of a mine roadway to an adjacent lower dressing floor. The openings in the four south-eastern tanks are differently designed to the two north-westerly ones, but we now know that all six originally contained small bulkhead doors fastened to support frames with bolts. Excavation has shown that the original downslope wall was strengthened by adding an outer wall and a waterproofing barrier comprising a clay-filled slot placed in the upper half of the structures; this barrier was sited between the two walls over much of the length of the downslope side of the tanks. Evidence of water management also included metal pipes, one revealed by excavation in the south-easternmost tank, the other above the bulkhead door-support in one of the north-western tank openings. Excavation has also shown that there were ceramic pipes running through the wall between the two south-easternmost tanks.

These six tanks, the design of which appear to be un-paralleled elsewhere, have been the cause of much confusion in the past; they, for example, have been interpreted as limekilns or zinc calcining kilns but this cannot be the case as they have wooden roof beams in their downslope openings (Barnatt 2004, Barnatt et al 2003; 2006; Kirkham 2006). Immediately before the excavations started two likely interpretations for the tanks were being considered - settling tanks for sludges from initial ore dressing (Porter and Robey 2000) - or bins for washing and storing crushed ore (Barnatt 2018).

The two south-easternmost tanks, which were the only two excavated in 2019, were found to have been later converted to filter beds, each with layers of small stones above layers of clinker that in turn lay above larger stone placed on the original paved floors of the tanks. When these were added the downslope openings were blocked off with crude drystone walls and the four ceramic pipes in the dividing wall between the two tanks were covered by reused sandstone roofing tiles. At this time, or previously, the tanks had been rendered using Portland Cement in an attempt to make them more watertight.

The Walled Structure

In advance of carrying out the excavations a 1:20 survey of the whole bank of six tanks was undertaken. This shows that the structure was originally about 21m long from the south-east end to the north-west end, with the latter now poorly defined; it had a width of 6.4m at the former end and 5.4m at the latter. The two north-western tanks have a wall that is inset to the downslope side when compared with the south-eastern tanks. The north-western tanks, each with long axes aligned north-west/south east, have interiors that are approximately 5.0-5.5m x 2.9m (Tank 6) and 3.7m x 2.9m (Tank 5) in plan, as indicated by parts of the inner faces of

the vertical walls that are still visible as they rise above the part-backfilled interiors of the two tanks.

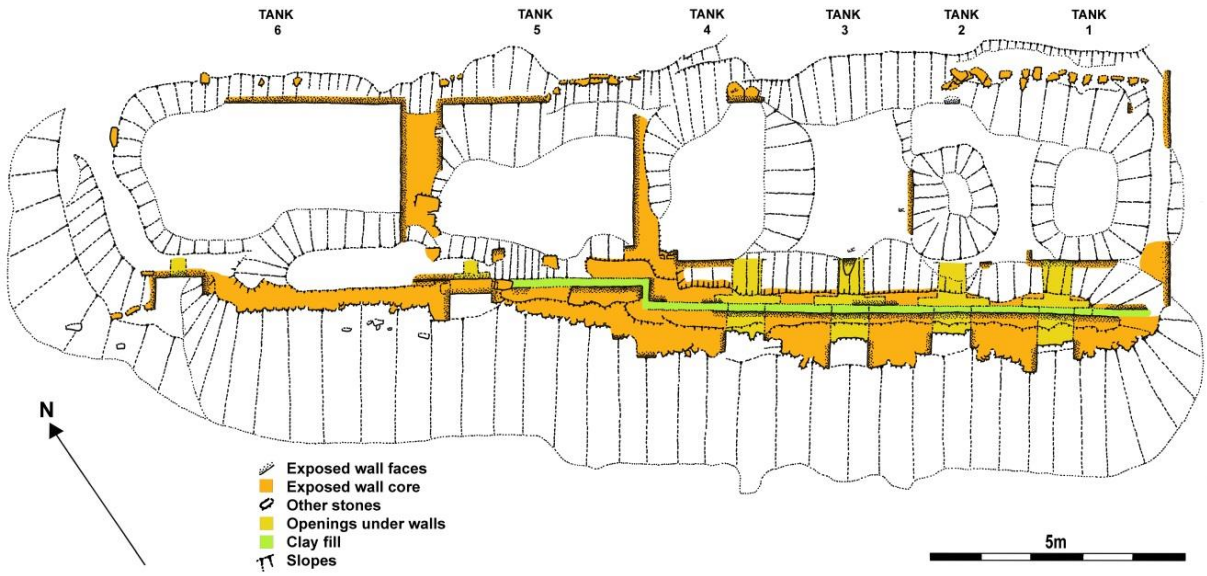

Figure 2: Trench 1 before excavation, showing the visible wall faces and stones in the wall cores, and also the clay-filled slot. The tanks and lower part of the downslope wall are partially buried by discarded robbing and collapse material, and also by later tipping in the tanks.

Plate 17: Part of the face of the upslope wall in Tank 6 was still visible, which together with another exposed face, allowed its dimensions to be assessed.

The four tanks to the south-east have their long axes oriented at right angles to the other two and are significantly smaller. Excavation of two of these tanks has allowed precise measurement of their sizes, with that to the far south-east (Tank 1) being 3.1m x 1.9m in plan and the next along originally 3.1m x 1.8m (Tank 2) before a brick wall was later added along one side. The other two tanks were of a similar size but not enough remains above their backfill to be precise (Tanks 3/4).

Plate 18: Tanks 1 and 2 looking downslope, photographed after excavations and consolidation were completed and their exact dimensions were known. The two openings through the downslope wall were walled up to support the rotting timber lintels and prevent visitors crawling in and risking collapse of these in the process.

The four south-eastern tanks have three dividing walls between them; in one case this is 0.50m wide, while the others were probably similar but they cannot be measured as they were not excavated. The dividing wall between the two north-western tanks is wider at 0.80m. A similar dividing wall, at 0.9m wide, lies between the two sets of tanks where the insetting of the downslope wall's outer face aligns to a point about half way across the line of this dividing wall.

Turning now to the outer walls of the bank of tanks, the one to the south-east end, at 0.8m wide, is wider than the nearby tank dividing wall but is similar to that dividing the two sets of tanks. To the north-east side the wall defining all six tanks was probably similar in width and has up to 0.7m thick of visible stonework but this wall almost certainly has no outside face as here it is set into the slope. The downslope wall of the tanks, which is significantly more massive than all the other walls, has an overall width at ground level of 2.6m to the south-east

and 2.1m to the north-west; this wall is returned to below as excavation showed it has been significantly widened part way through the life of the tanks. The original wall here was 0.8-0.9m wide to the south-east, matching those at the two end walls of Tanks 1-4, but the original downslope wall to the north-west, for reasons that are not understood, was narrower at only about 0.6m.

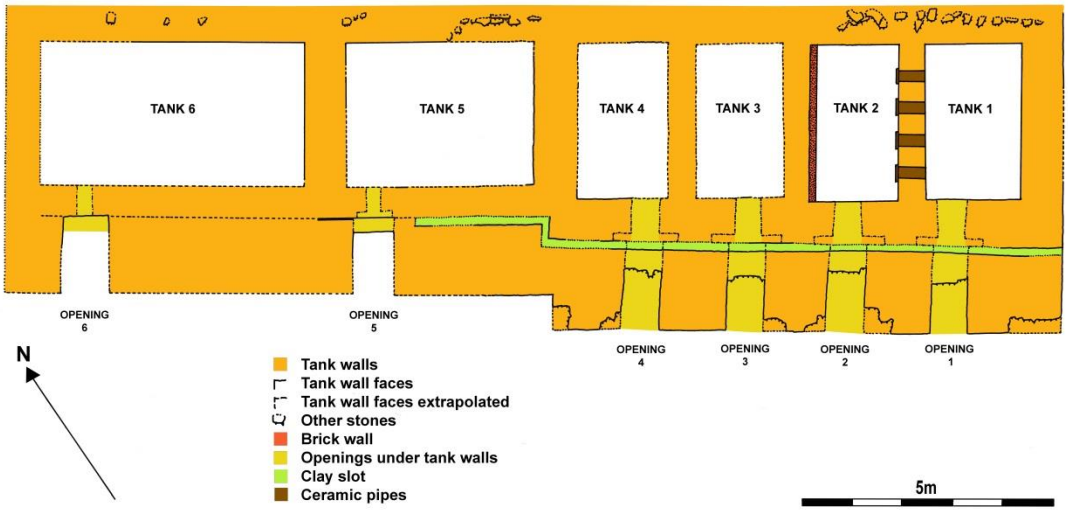

Figure 3: Trench 1 after excavation, showing the positions of the tank walls, the clay slot, the openings through the downslope wall and the original face of this at ground level (how far the Openings 1-4 extended outwards is not known).

Plate 19: The dividing wall between Tanks 4 and 5, with render visible on the Tank 5 side, is significantly wider than the dividing walls between Tanks 1 and 4 but matches the dividing wall between Tanks 5 and 6, with the wall photographed interpreted as an original end wall of the structure before Tanks 1-4 were added.

At the south-east half of the bank of tanks, the height of the structure today is 2.8m at the present robbed outer face and originally, given that the floor slopes gently down from here to where the original outer face was, this is more like a true height of 2.9m. The top of the wall today for the most part does not appear to have lost any significant height and the original wall height must have been somewhere in the region of 3.0m or perhaps a little more. In the north-west half of the bank, the tops of the walls are at a similar level as the others, but, as the ground level slowly rises here, the floors of the tanks may well be set at somewhat higher level than those to the south-east, as indicated by the level at which the two downslope openings are set. There is no sign that the structure was ever roofed and this seems highly unlikely, as settling tanks elsewhere were not, as a roof would serve no purpose.

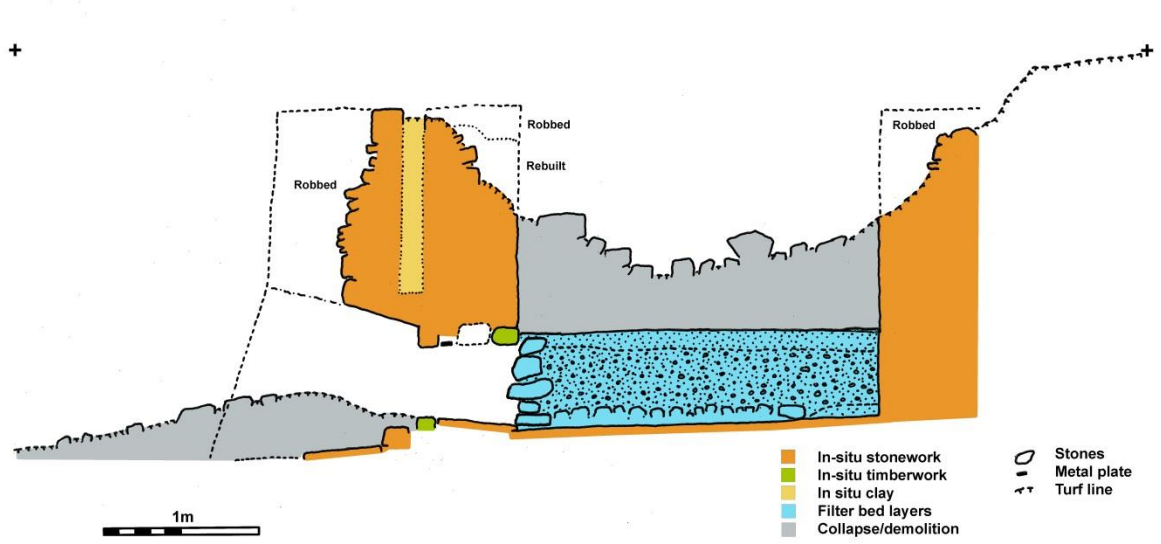

Figure 4: A north-east/south-west elevation through Tank 2 and Opening 2, showing the walls, clay slot, floors, filter bed layers and demolition layers.

All the wall faces of the structure were built with limestone blocks and slabs bonded with lime mortar, with these carefully chosen to create an 'ashlar-like' finish; in the wall cores smaller and less regularly shaped stones were used. With the exception of the outer face to the downslope side of the tanks, they have vertical sides. When the heap of rubble and soil that had accumulated against the base of the downslope wall of the tanks was removed, parts of the basal facing courses of carefully-shaped limestone slabs and blocks were found. Here the downslope wall in its lower part was battered back by 16-18 degrees, while a small remaining area of upper face at the south-eastern end of the two larger north-western tanks, which elsewhere had been removed, shows that the upper wall was still battered but was significantly closer to vertical. The wall's facing stones revealed during the excavation are illustrated in Plates 20-25.

The outer face of the structure on the downslope side, and some core material behind this, was extensively robbed after it fell out of use, and subsequent deterioration led to more of the core stonework and associated lime mortar also falling, debris from which accumulated in the low continuous linear heap at its base. This mound was 0.6-0.8m high at its crest and contained more rotted-mortar forming a loose sandy soil of pale-brown colour than it did stones. The latter were of small to medium size and randomly placed, with more present to the south-eastern end compared with between Openings 1 and 4. The preponderance of

mortar based soil may well suggest this includes much mortar that was discarded during the initial robbing. The upper parts of the internal walls of the tanks were also robbed and these are returned to below when the two excavated tanks are discussed.

Plate 20: A small vertical slither of surviving nearly-complete outer facing of the downslope wall, located immediately north-west of where the wall stepped outwards between Tank 5 (left) and Tank 4 (right); the exposed wall cores were built of smaller and less regular stones. This stonework was photographed just after work removing the soil and rubble heap at the base had started but before consolidation of the battered face was undertaken.

Plate 21: Three *in-situ* facing stones of the downslope wall in its final form remained between one corner of the structure (right) and Opening 1 (left); two of these were at the basal course and had no footings stonework below. The three facings stones had an outer face that was battered back from vertical, matching the more intact area of intact facing illustrated in Plate 20.

Plate 22: Two *in-situ* facing stones at the basal course of the downslope wall between Opening 1 (right) and Opening 2 (left).

Plate 23: Only one *in-situ* facing stone at the basal course of the downslope wall remained between Opening 2 (right) and Opening 3 (left), with two thin course-levelling slabs above.

Plate 24: The *in-situ* facing stones at the basal course of the downslope wall were intact between Opening 3 (right) and Opening 4 (left).

Plate 25: The *in-situ* facing stones at the basal course of the downslope wall were intact between the Opening 3 (right) and the corner (left) where the wall steps back; when photographed the base of the battered wall beyond the step-back that supports Tank 5 had already had new stonework added to stabilise the remaining original walling.

In the rubble derived from the bank of tanks several examples were seen of stones which must have come ultimately from within the mine as they had shot hole scars on one of their faces.

The Four South-Eastern Downslope Wall Openings (1-4)

As described in the survey report catalogue and expanded upon here, the four south-eastern openings each have an outer and inner section, with a now-rotted wooden structure between the two.

Plate 26: Opening 4 before excavation, showing the outer arched roof, behind which is the vertical wall above and to the sides of where the timber frame for the bulkhead door had been located, with the smaller inner opening beyond; a crude later drystone wall blocks its inner end.

The outer sections each have vertical side walls and an arched top; the surfaces are not rendered; in all four openings, their side walls have courses that slope gently downwards towards the interior. These outer openings are 0.70-0.75m wide and have tops that taper downwards towards the interior. After excavation at the floors, their original heights at their inner end were 0.83-0.90m; stone floor sills a little further out are 0.15-0.24m high, so just beyond these there is an additional height of this much. The paved floors here slope gently down to the outside but the original height of the openings at the outer face of the wall cannot be measured because of the wall robbing here; it must have been in the region of 1.30m; however, we do not know whether the openings came to a point flush with the outer wall or were recessed into this by a short distance.

At the interface between the outer and inner parts of the four openings there are shallow recesses to the sides that originally contained the vertical parts of timber frames; rotted traces of these remained in parts; the timber sills at the base remain intact and these are returned to below when their excavation is described. At the top of each frame there was a now rotted-away timber beam set horizontally that formed the top of the rectangular timber structure. At each of these, today there are holes where these now-gone timbers extended into the side walls by 0.24-0.34m; this bonding into the wall would have given the frame added strength. The openings defined by the frames were 0.55-0.60m wide and after excavation at the floors we now know they were about 0.50-0.55m high.

Plate 27: One of the two shallow side recesses in Opening 1 that once contained the timber frame for its bulkhead door, with imprints of rotted wood from the side timber in the mortar. Above is the hole left after the top timber rotted where it was set within the main wall.

Plate 28: The other of the two holes at Opening 1, where the now-rotted top timber for its bulkhead door was built into the stonework of the main wall.

Beyond the timber frame, going inwards, the openings are 0.55-0.60m wide near the wooden frame and after excavation at the floors it was seen that here these were 0.60-0.68m high; the openings continue through the wall to its inner face. Measurements taken during the excavation showed that only Opening 4 had parallel sides, while Openings 3 and 2 became slightly wider as they went in and Opening 1 got narrower. These inner 'passages' are 0.70-0.75m long and all of the vertical walls are built of stone but with render covering the stonework surviving in parts. Careful inspection during excavation, made possible because the openings had been cleared to give better access compared with the previous inspection during survey in 2018, showed that the roofs comprised a variety of timber beams used as lintels. These have often now fully rotted away but here, in parts, the mortar between them and render below them still remains. Above the timber doorframe there was a narrow stone wall to the outer side of the timber lintels in every opening, extending for the height of these adjacent beams. The number of beams between here and the tanks varied: at Opening 1 there were two main beams with a much smaller timber filling the gap between them, the inner beam remains *in-situ*; at Opening 2 there were three beams, with a small metal plate, now bowing, set horizontally between these and the wall over the doorframe, the innermost beam remains partially *in-situ*; at Opening 3 the rendered roof is intact and the arrangement of beams cannot be seen; at Opening 4 there were again two beams and a small timber filling the gap between them, the outer beam remains partially *in-situ*. Variation in beam dimensions and resulting infilling of gaps suggests that the timbers used were what were available on site and these may well have been previously used elsewhere. At Openings 2

and 4, rotted timbers here had what appeared upon casual inspection to be small *in-situ* metal pipes that ran vertically through the beams, which were covered in stalagmitic deposits from the lime mortar; this proved not to be the case, the 'pipes' turned out to fully comprise lime mortar and are interpreted as fills within pre-existing drilled holes in the timbers, where wet mortar ran to fill them as the wall directly above the timbers was being built.

Plate 29: One of the side walls of the inner part of Opening 2, with a largely-intact render-covering remaining in place.

Plate 30: The roof of the inner part of Opening 4, with an in intact roof lintel, a smaller space-filling timber behind and the site of a now largely-rotted second lintel beyond. The dimensions of the last can be determined from the surrounding *in-situ* mortar, with traces of the render covering also remaining. The pale coloured pipe-like protrusion here is where a pre-existing hole in the now rotted lintel had filled with mortar during the laying of the wall course above.

Plate 31: The intact rendered roof at the inner part of Opening 3.

Plate 32: The two cylindrical pipe-like objects coming through the rotting inner lintel at Opening 2 are the result of pre-existing holes in the beam that had filled with mortar during the laying of the wall course above; the lower part of the beam has dropped breaking these lime-tubes in the process.

The 2019 excavations revealed more details of the opening's floors and the timber frames, which are now known to have supported bulkhead doors; these are described in the section below on their excavation. We also now know that the outer faces of the timber frames were set flush with the outer face of the original downslope wall for the tanks and both are integral parts of the initial build; the outer parts of the openings were constructed when a strengthening wall was later added.

The Two North-Western Downslope Wall Openings (5-6)

As also described in the survey report catalogue, the two north-western openings are of different design to those to the south-west but again have outer and inner parts. The outer sections of the openings are each 0.80-0.90m wide and to the inside were more than 0.80m high, with the bases now buried by soil and rubble. They have vertical sides and Opening 5 has a horizontally-placed timber lintel above, set against the outer face of the inner wall, with an outer stretch of faced stonework above this; a lintel at Opening 6 has now rotted away or has been removed but its stone supports at the side walls remain. These openings in the outer part of the downslope wall appear to have been recessed into this rather than being roofed in their outer section but robbing here makes this uncertain. Behind the outer parts of the two openings there are vertical walls that we now know are parts of the face of the original tank wall; below this there is a small inner opening going to the interior of the tanks. Each of these upper walls was built of stone at the top, with two to three courses of brick visible below with faces that are slightly inset from the stones above. At Opening 5 the bricks are covered in lime mortar, with Portland Cement render to the opening sides. Near the top, about half way down the stonework, there is a metal pipe of 65mm external diameter protruding from this wall to the right-hand side. Below the upper visible part of the wall just described at Opening 5, there is an iron plate affixed to the front of the lower parts of the wall

that flank the small inner opening. This plate has a 130mm deep horizontal top and 80-95mm wide vertical sides; the bottom is buried by collapse rubble so cannot be assessed. There are four protruding bolts, all 60-65mm long, two at the top and one in the upper part of each of the vertical sides; these may well have fastened a bulkhead door in place that was taken off when the tanks were to be emptied. To the sides, where the outer edges of this door would have been, the stonework is rendered so that this would have fitted neatly. The 'opening' that the metal plate defines is just over 0.60m wide and at least 0.15m deep but with the lower part buried. The actual opening through the inner wall to the tank behind is of the same height but is only *c.* 0.30m wide; perhaps the design of these was changed after the plates were made as erection of the tanks proceeded, or the plate was added as a later modification to the opening. The lower half of Opening 6 is buried but a small part of a comparable iron plate with inner opening below is visible.

Plate 33: At Opening 5 the timber lintel in the outer wall has faced stonework above, while below the lintel the earlier face of the original wall behind has a shallow recess with brickwork and an iron plate for a bulkhead door, with a small inner opening behind leading to the now partially backfilled tank.

Plate 34: At Opening 6 the timber lintel in the outer wall has gone, exposing the earlier face of the inner wall. Below there is a shallow recess with brickwork and an iron plate for a bulkhead door in its lower part, the latter largely hidden behind grass and a fallen stone.

Plate 35: The iron plate at Opening 5, where there are four protruding bolts for the bulkhead door, with a small inner opening behind.

Opening Positions

The position of the openings in relation to their tanks varies. At the four south-eastern tanks Openings 2 and 3 are roughly at the centre of their tanks, while Opening 1 is to the north-west of centre and Opening 4 was south-east of centre. This allowed the four openings to be placed as close together as possible, presumably to make them more efficient to use in terms of the distance that needed to be travelled when moving from one to the other. Openings 5 and 6, at the two north-western tanks, were both placed near the north-western ends of their respective tanks.

Tank Phasing

Given the different designs of the two sets of tanks and their openings (Tanks 1-4 and Tanks 5-6), it may well be that these were built in two phases; at present more excavation is needed to confirm this. It is tentatively suggested below that the two north-western tanks were built before the other four (see The Tanks: Phases of Build and Use).

What was shown by excavation was that the downslope wall for both sets of tanks was built in two phases. The original wall was vertical-sided, but this was later substantially strengthened by adding an outer wall with a battered face. To the south-east this addition was 1.7-1.8m wide at the base and originally about 1.2m near the top; to the north-west this wall was probably of very similar dimensions. The openings to the south-east were extended outwards when the strengthening wall was added and given tapering arched roofs; the two north-western openings were each surmounted by a new timber lintel with walling above, with both placed adjacent to the outer face of the original wall, while the parts outside here were probably not roofed.

Plate 36: The downslope wall at Tanks 1-4 after consolidation, where the four arched parts of the openings are in a thick wall added to the original wall, with the outer face of the latter hidden in the gloom above the sites of the four bulkhead doorframes within the openings.

Between the two walls in their upper parts, which were butted directly against each other in their lower parts, there was a slot left between them that was fully filled with still-sticky plastic clay of a mottled mid-tone orange-brown to grey-brown colour. To the south-east this slot was 0.17m wide and about 1.6m deep; thus its base was about 0.20-0.35m above the top of bulkhead doorframe that lay offset from the slot within the original inner wall. To the north-west the slot was about 0.20m wide but its depth has not been investigated. Here, for reasons that are not currently understood, the clay-filled slot only extends to just short of the near end of Opening 5; in contrast, just beyond the opening it can be seen in exposed stonework that the two walls are abutted directly against each other; perhaps the original tank walls here did not leak. The obvious explanation for the clay-filled slot as a whole is that it was designed as a waterproofing barrier to prevent water leaking through the new downslope wall at Tanks 1-5; the implication of its presence is that the tanks regularly held water that came up to near their tops.

Plate 37: The south-eastern end of the clay-filled slot between the inner and outer parts of the downslope wall; the original floor of this is at the base of the ranging pole. The slot was not excavated beyond the point shown as this would have jeopardised the long-term stability of the structure.

The Two Excavated Tanks (1-2)

The two most south-easterly tanks were fully excavated. These proved to originally have had vertical stone walls, were about 3m deep, had rendered inner faces and near-horizontal floors paved with slabs; each had an opening leading through the downslope wall. Both tanks later had their lower parts filled with layers of stones and clinker and were used as filter beds. Later still their walls were partially robbed.

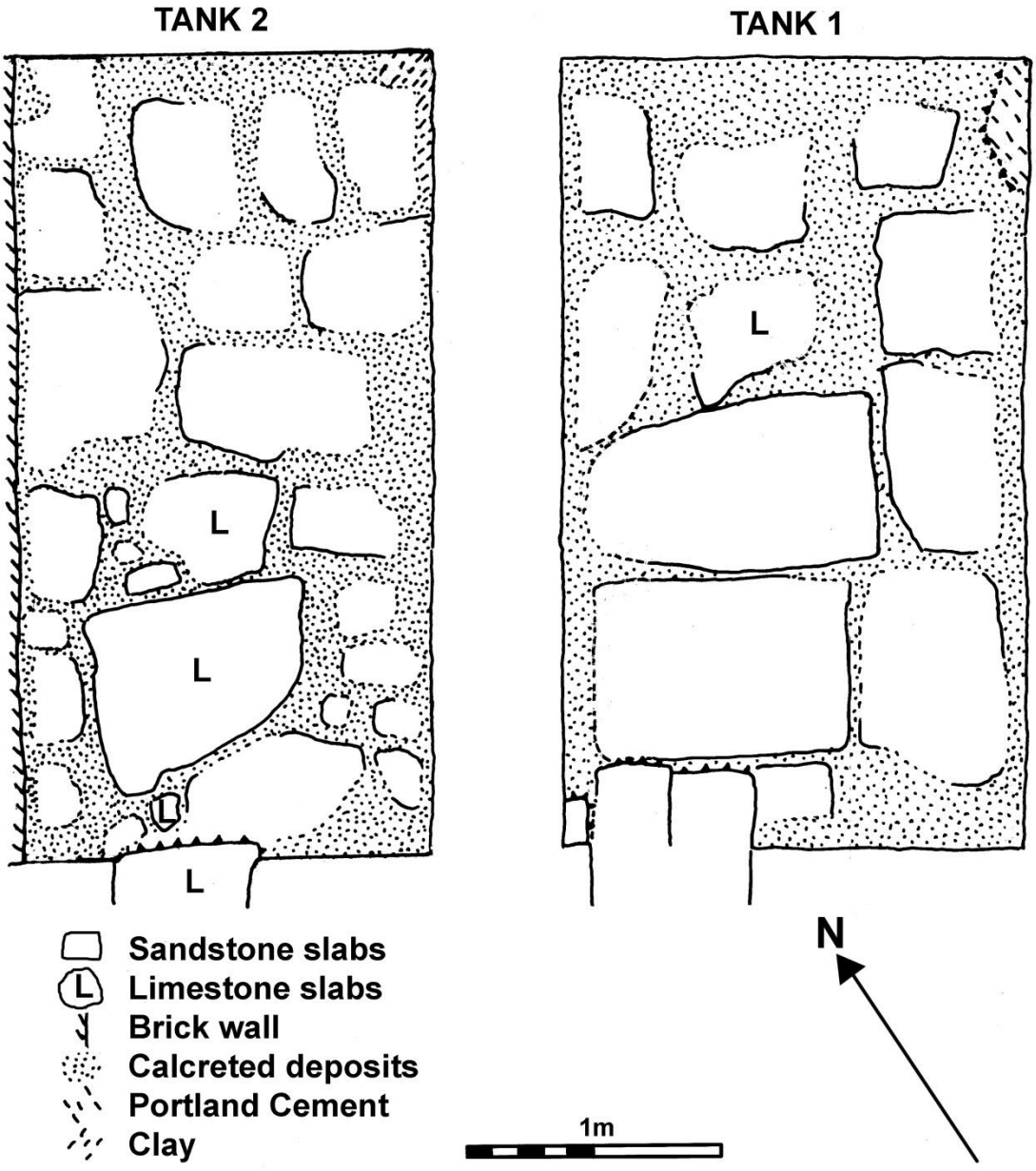

Figure 5: The paved original floors in Tanks 1 and 2.

Tank 1: This measured 3.08m x 1.87-1.92m in plan and in the lower parts had surviving facings to its walls; the opening through the downslope wall was placed near the west corner of the end wall of the tank. The north-western side wall had a 0.08-0.09m wide ledge along its length, rising to 0.7-0.8m above the original floor, with a somewhat irregular render-covered top. That it was built of limestone, unlike the brick wall on the comparable side wall

in Tank 2, suggests it was an original feature; it may have been built to give additional support to four ceramic pipes that pass through the partition wall between Tank 1 and Tank 2 (described below). In the north corner of this wall, at 0.34m above the ledge top there was a small, irregular, limestone slab protruding from the walls; the reason why this was left standing proud is unknown. The outer face of the timber lintel for Opening 1 was visible and was 1.28m long, with this extending beyond the opening further to the right, when viewed from within the tank, than it did to the left. To the right side of the opening, between this and the ledge along this side of the tank, the bottom of its wall extended into the tank for 0.18m to form a 0.12m wide, round-topped, 'buttress' that was 0.3m high.

Plate 38: Tank 1 emptied of its fill to expose the original paved floor, with the ledge and buttress at the side-wall to the right and Opening 1 at the far end.

The walls of Tank 1, the outer face of the timber lintel at Opening 1, and the roof and walls of inner part of this opening, were all covered in a Portland Cement render, often about 15-20mm thick. The lower parts of this survived in reasonable condition, with only a few parts where it had subsequently fallen away, while above this it, where it was sometimes thinner, had often flaked off. The render on the south-western end wall survived in good condition in its upper half and here it could be seen that it had been applied quickly and little attempt had been made to create a smooth finish, in contrast with the lower parts of both tanks where the

render was well finished. The thickness of the render at the end wall was not sufficient to create a watertight seal (Mark Womersley pers. comm.); the way it was applied suggests the render here was a hurried addition in response to water leakage rather than being part of the original tank design; there was no evidence to suggest it was added after the well-finished render was applied elsewhere in the tanks. On the floor of the tank at its north-eastern end, in the eastern corner, there was a small deposit of Portland Cement render that had spilled here when the wall above was sealed.

At the south-western end wall of the tank there was an iron pipe passing through the wall, placed 0.03m above the timber lintel of Opening 1 near the centre of the tank's end. This pipe had an external diameter of 55mm; it was probed, which revealed that it passed horizontally through the original tank wall and then something like 10-15cm beyond, where it was partially choked by yellow-brown clay; its end was sealed by the stonework of the outer wall added after the initial tank construction, indicating the pipe was made redundant when this was built. No matching pipe existed in Tank 2.

The original floor of Tank 1 sloped gently downwards from the upslope end to the north-east to the other end with its opening, with an overall increase in depth of only *c.* 0.10m. It comprised ten medium- to large-sized, flat-topped, slabs of fine-grained sandstone, and one of limestone; two of the former had ripple marks of geological origin. The interstices between these slabs were often obscured by a thin layer of calcreted small stones from the deposit above, which had been cemented together by stalagmitic secretions from the lime mortar in the tank, while around the edges of the tank slabs their interstices were often obscured by a somewhat thicker layer of the same material. At Opening 1 two of the thin sandstone slabs that made up its floor protruded by 0.32m into the tank, with their end forming a 0.02m high lip where they rested on the paved floor.

Plate 39: The paved floor of Tank 1, photographed at the end of excavation; Opening 1 (far left) had been walled off for health and safety reasons, and the roofing slabs (right), originally placed over the four ceramic pipes in the wall, had been stacked for safe keeping.

Plate 40: The paving in the inner part of Opening 1, comprising three thin sandstone slabs, which slope gently upwards towards the timber sill beam for the bulkhead door.

Tank 1 had no original settling deposits on its paved floor, except for a thin skim of yellow-brown clay over the slabs in parts, indicating it had been swept clean after it was last used as a settling tank.

Tank 2: This measured 3.10m x 1.78m in plan and thus it was slightly narrower than Tank 1 even before a brick wall was later added down one side; its walls and their character were identical to Tank 1, but the opening through the downslope wall was placed near its centre; the outer face of the timber lintel for Opening 2 was initially partially visible but largely covered in render and its full length of *c.* 1.2m was only determined after some of the render was later removed. The original north-western stone-built side wall had been covered by a wall of bricks extending from the base to the current top; there were further bricks in the demolition rubble suggesting it once extended to the original top of the tank. The brick wall was only 0.10m wide and it was of single brick thickness; these were poor-quality, hand-made bricks of an orange-brown colour. They were laid using a Portland Cement mortar, suggesting this wall was an addition, built after the tank was first made; the primary walls had lime-mortar. As with Tank 1, the walls of Tank 2, the outer face of the timber lintel at Opening 2 and the roof and walls of inner part of this opening, all had all been covered in Portland Cement render; the lower parts survived in reasonable condition, with only a few areas missing, while above much had flaked off.

Plate 41: Tank 2 emptied of its fill down to the original paved floor (the stone block to the bottom right was positioned here to support the base of the access ladder). Opening 2 lies to the back; the brick wall to the right side was added later.

The original floor of Tank 2 sloped gently downwards from the upslope end to the other with its opening, with an overall increase in depth of only *c.* 0.10m. It comprised large- and medium-sized, flat-topped, slabs, 19 of fine-grained sandstone and two of limestone; one of the former had ripple marks of geological origin. The interstices between these slabs were often obscured by a layer of calcreted small stones from the deposit above that had been cemented together by stalagmitic secretions from the lime mortar in the tank walls. At

Opening 2 a thin limestone paving stone protruded by up to 0.08m into the tank, with its end forming a *c.* 0.015m high lip where it rested on the paved floor.

Plate 42: The brick wall added to the side of Tank 2, photographed before the filter bed layers were removed; the wall extends down to the original paved floor of the tank.

Plate 43: The paved floor of Tank 2, photographed at the end of excavation; Opening 2 (right) had been walled off for health and safety reasons.

Plate 44: The limestone paving slab in the inner part of Opening 1 slopes gently upwards to the timber sill beam for the bulkhead door.

Tank 2 had virtually no original settling deposits on its paved floor except for a thin skim of yellow-brown clay over the stones, indicating it had been swept clean after it was last used as a settling tank. The exception was at the north-east end of the tank, at its eastern corner, where there was small patch of clay that had been missed. Also near this end of the tank, a small angular fragment of galena and calcite was found in the interstices between the floor slabs.

Dividing Wall: This wall between the two excavated tanks had four factory-made ceramic drainage pipes, with glossy mid-brown glaze, passing through it horizontally from one tank to the other, with their bases set 14-16cm above the floor. While they were relatively regularly spaced along the wall, with measurements between the pipes varying from 0.37m to 0.40m, they were set 0.43m from the north-east end and 0.51m from the south-west end. These pipes had an internal diameter of 17cm and at the Tank 1 side these had straight ends that were flush with the render on the wall. On the Tank 2 side there were the moulded ends to the pipes, of a type where the protruding lip was designed to link one pipe with another; these lips stood proud of the render on the wall side by 2.5cm. Within the pipes there was a coating of yellow-brown clay, thickest towards the base where it was up to 3mm, indicating that water mixed with settling deposits had passed this way. The pipes were either placed here when the wall was first built or later when the render was added. The stone wall between Tank 2 and Tank 3 had a brick wall added to the side, so it is not known whether pipes also exist here.

Plate 45: The four ceramic pipes going the through the wall between Tanks 1 and 2, with their protruding lips at their ends seen here in Tank 2.

Plate 46: One of the protruding lips in Tank 2 at the ceramic pipes running through the dividing wall between Tank 2 and Tank 1.

The Filter Beds within the Tanks (1-4)

There is clear evidence that the two excavated tanks were employed for a different purpose after they ceased being used as settling tanks; the layers of fill in the bottom third of the tanks, and other features associated with these, are interpreted as filter beds. Each tank had a flat horizontal floor of small stones and gravel about 70-80cm above the original gently sloping paved floors. Below this upper layer there was a middle one of clinker, while beneath this was a lower layer of larger stones. Each of the inner ends of the two tank openings had a crude drystone wall built across it and all of the four ceramic pipes in the central wall between the two tanks had reused sandstone roofing slabs placed across them at both sides of the wall; the drystone walls and slabs were added to allow water to flow but to prevent the small stones and clinker being flushed through.

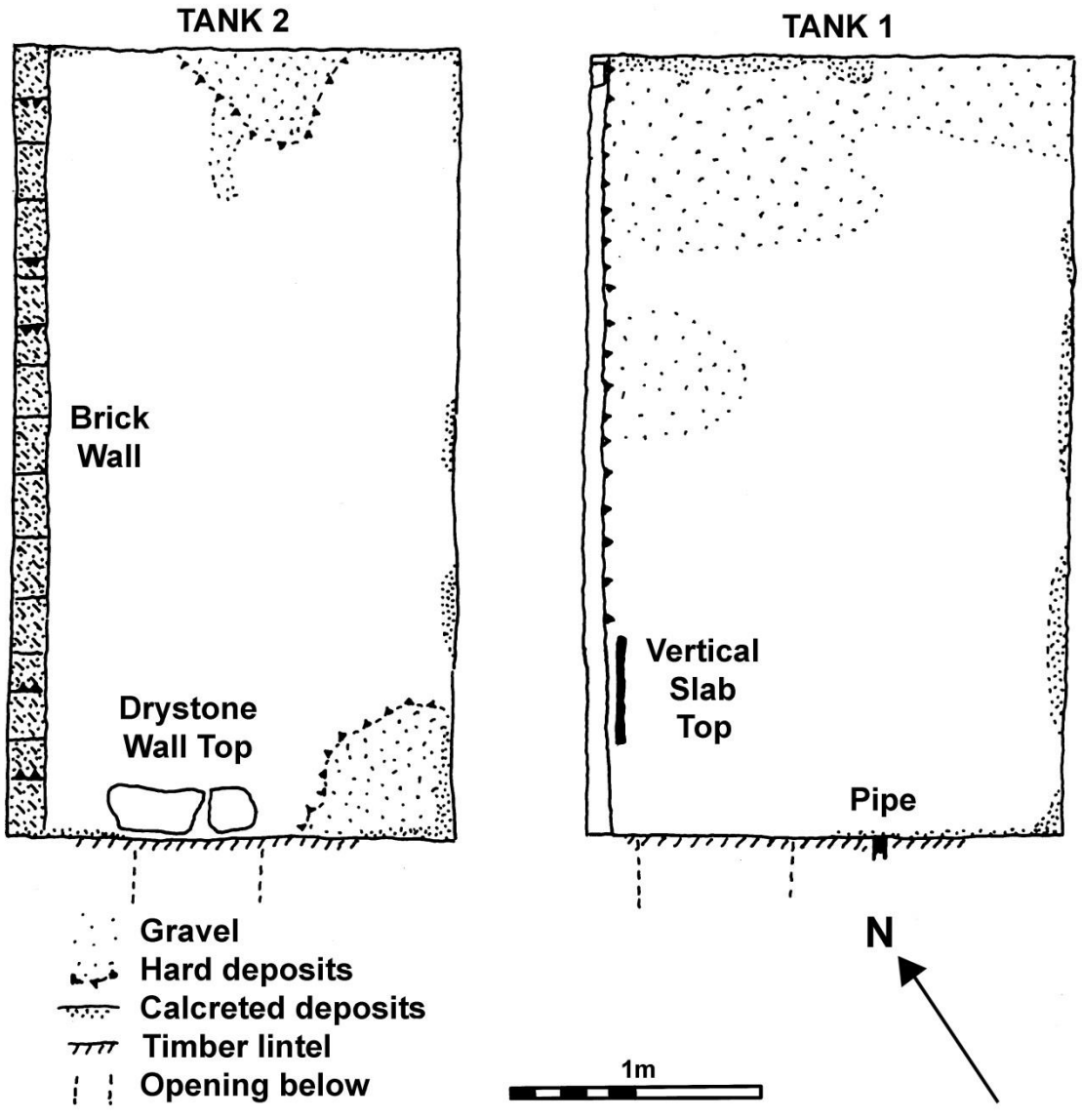

Figure 6: Tanks 1 and 2 at the top of the filter bed layers.

Tank 1: this has a main top layer that was consistently 0.13-0.14m thick, comprised small angular limestone chips in a loose mid-brown gravel/coarse sand, with the stones forming 70-80% of the deposit. Above this layer, in patches in the north-eastern half of the tank, there

was a 0.01-0.03m thick layer of gravel comprising mostly small pieces of limestone but also occasional calcite; no other minerals were present as would be the case if this material was derived from crushing ores and associated waste from within the mine. Around the edges of the tank there are patches of the small-stone layer that had been calcreted into a hard deposit by stalagmitic deposition of lime mortar washed from the tank walls.

Plate 47: The level top of the filter bed layers at the upslope end of Tank 1; these extended across the whole tank.

The middle layer was mostly 0.40m thick and comprised clinker of orange-brown to black colour in a very loose deposit with voids between all the pieces of this imported material. The depth was less to either end of the tank where the clinker overlay heaps of finer material to be described below, measuring 0.22-0.28m deep to the north-eastern end and 0.34m to the south-west. The clinker, as with other deposits of this material found during the excavations in Trenches 1 and 2, is likely to be derived from previously discarded heaps outside the steam engine boiler houses.

The bottom deposit, of larger stones compared with the top layer, was *c.* 0.10-0.15m thick and was found to cover much of tank's original paved floor; there were also heaps of finer material at either end (see below). The main deposit comprised randomly placed stones of small- to medium-sized in an evenly spread layer. Between these stones there was a loose, dark grey-brown, gritty soil but there were also some voids in the interstices.

Set against the north-western wall of the tank there were four groups of slabs that match the positions of the four ceramic pipes through the wall; these slabs were placed at the same time as the bottom layer of stone in the tank, with their tops protruding upwards into the other filter bed deposits above; one was visible at the top of the these. The slabs are all reused roofing slates of fine-grained sandstone; four of them were complete and had perforation holes at their top ends created for fastening the slabs on a roof. All were near-vertically

placed, but leaned slightly to the wall, to cover the ceramic pipes but still let water through. Describing each grouping in turn, starting at the south-west end, the first comprised a single large slab, with a top corner missing, resting on the paved floor. The second was a complete but somewhat smaller slab resting on the stones of the bottom layer, with a large broken rectangular piece from a second slab behind. The third was a large complete slab resting on the paved floor with three broken pieces of one or more further slabs behind. The fourth had two complete slabs, except for one broken corner, both resting on the paved floor, with the outer one overlapping the other. The stones of groups three and four had a low mound of stones of the bottom layer placed against their lower parts.

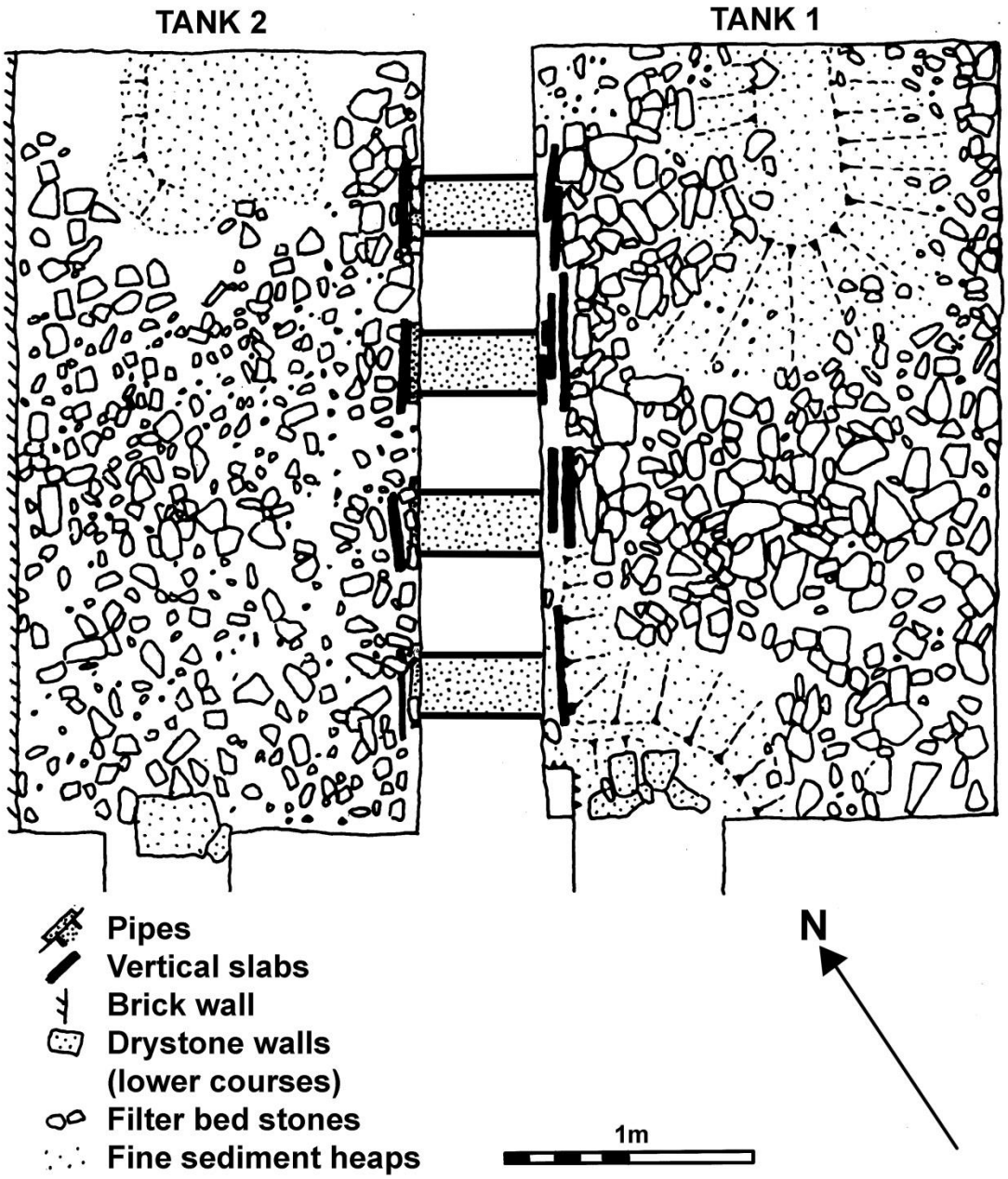

Figure 7: The stony lower filter bed layers, mounds of finer material, reused roofing slabs and ceramic pipes in Tanks 1 and 2.

Plate 48: The bottom stony layer of the filter bed in Tank 1 runs across much of the tank, but there is also two heaps of finer material, one to either end of the tank. That to the right has larger stone above its edges but none under the mound core. The other mound, to the left, abuts the bottom courses of the crude drystone wall across the opening and had the stones of the bottom layer running under it. The roofing slabs placed against the side wall cover the ceramic pipes coming through this wall.

Plate 49: The reused roofing slabs placed against the side wall of Tank 1 set within the lower deposits of the filter beds; those to the right have a low mound of stones resting against them, while the that to the far left has a heap of finer material abutting it.

Plate 50: Three of the reused roofing slabs against the side wall of Tank 1, each with perforations for fasten them on a roof, photographed after the abutting mound of stones had been removed, with their bases resting on the original paved floor coated with a skim of yellow-brown clay.

Immediately in front of Opening 1 there was a crudely-built drystone wall of single-stone thickness, built of irregular and rectangular limestones, rising from the paved floor and probably originally reaching the top of the opening. However, the upper stones were removed during excavation before the feature was recognised; these may have been partially collapsed before the excavation started. Only one to two courses of stones remained after the upper stones were inadvertently removed.

There were two mounds of finer material between the clinker layer and the paved tank floor. To the north-east end there was a 0.25m high heap of compacted mid-grey-brown sand/gravel that extended 1.3m laterally into the tank on its centre line; at its edges it was overlain in places by the stones of the main bottom layer on the tank floor; these stones did not run under the heap. Given that a similar mound exists in Tank 2, these are interpreted as the positions where stones mixed with the finer material were tipped into the tank for use in the construction of the filter beds; this is the only direction from where this would have been sensible. Once tipped, the stones were extracted from the heap and spread across the tank floor leaving much of the sand and gravel where it was.

At the other end of the tank, in front of Opening 1, there was 0.24m high small heap of identical material, abutted against the drystone wall here, with this soil also filling the interstices between the wall stones. In contrast with the north-eastern heap, the stones of the main bottom layer run beneath the south-western heap. This heap is interpreted as added here to support the wall, with the material taken from the heap at the other end of the tank.

Plate 51: The remaining lower part of Tank 1's drystone wall placed across Opening 1.

Tank 2: This had a main top layer that was 0.17-018m thick, except at the south-western end of the tank where it approached the blocking wall with it reducing here to 0.09m. It comprised small angular limestone chips with occasional pieces of calcite of the same size in a loose mid-brown gravel/coarse sand, with the stones forming 70-80% of the deposit. Around the edges of the tank there were patches of this layer that had been calcreted into a hard deposit by stalagmitic deposition of lime mortar washed from the tank walls. At the north-east end of the tank, and at the corner at the other end of this, there were to small slightly raised areas of the same material protruding into the tank, but these were compacted. These again may well have been affected by calcreted stalagmitic deposition.

The middle layer was mostly 0.45m thick and comprised clinker of identical character to that in Tank 1, except that there was some dark soil as well as voids. To the north-eastern end of the tank the depth was somewhat less, at 0.42m, where the clinker overlay a heap of finer material to be described below.

The bottom deposit, of larger stones compared with the top layer, was *c.* 0.10-0.20m thick and covered much of tank's paved floor, except for a small area in the north corner where it was missing and also nearby at the centre of the tank end where there was a heap of finer material. The main deposit comprised randomly placed stones, of mostly relatively small size compared with those in Tank 1, in an evenly spread layer. Between these stones there was a loose, dark grey-brown, gritty soil.

Plate 52: The level top of the filter bed layers at the upslope end of Tank 2; these extended across the whole tank. The brick wall to the left side was added at the same time as the render in the tanks, probably several years before the filter bed layers were introduced.

Set against the north-western wall of the tank there were four slabs that match the positions of the four ceramic pipes coming through the wall; these were placed at the same time as the bottom layer of stone in the tank, with each slab set on a small mound of stones that also came up the lower parts of the slabs, with the slabs protruding upwards into the other filter bed deposits above. These slabs were somewhat smaller on average compared with those in Tank1 and thus the mounds were created to bring them to the correct height. The slabs are all reused roofing slates of fine-grained sandstone; two of them had perforation holes at their top ends created for fastening the slabs on a roof. All were near-vertically placed, but leaned slightly towards the wall at their tops at or above the tops of the ceramic pipes, to cover these but still let water through. Describing each slab in turn, starting at the south-west end: the first comprised a slab with broken top; the second was significantly shorter and was also broken, with its top coming *c*. 1cm short of the pipe top and had stones identical to those in the main bottom deposit wedged between the slab and the wall to its sides and top, the third was virtually complete but with a top corner missing; the fourth was complete and again had stones identical to those in the main bottom deposit wedged between the slab and the wall to its sides and top.

Plate 53: The bottom stony layer of the filter bed in Tank 2, with a heap of finer material to the upslope end (left). When photographed the basal course of the drystone wall across Opening 2 was still in place (right). The roofing slabs placed against the side wall cover the ceramic pipes coming through this wall.

Plate 54: The reused roofing slabs placed against the side wall of Tank 2 within the stony lower deposit of the filter bed, with each slab set within a low pile of stones.

Plate 55: Two of the reused roofing slabs placed against the side wall of Tank 2, each in a low mound of stones; at the one to the left, with stones placed above and to the sides of the slab, the top of the ceramic pipe in the wall is just visible.

Immediately in front of Opening 2 there was a crudely-built drystone wall of single-stone thickness rising from the paved floor to the top of the opening. This was mostly built of irregular limestones but with one rectangular limestone slab at the bottom. Unlike that in Tank 1, the wall was abutted directly by the clinker layer.

Plate 56: Another of the reused roofing slabs placed against the side wall of Tank 2 in a low mound of stones, with these also placed above and to the sides of the slab.

Plate 57: The crude drystone wall in Tank 2 built across the entrance to Opening 2, erected to hold back the upper filter bed layers. Some of these layers were still *in-situ* to the left when the photograph was taken, with the top small-stone layer abutting the render over the Opening 2 timber lintel; further to the right this render had flaked off as excavations here started.

There was a mound of finer material resting of the paved tank floor to the north-east end. This was 0.10m high, extended 0.7m laterally into the tank on its centre line and comprised a compacted mid-grey-brown sand/gravel identical to that in Tank 1. Given that a similar mound also exists in Tank 1, as discussed above, the mounds are interpreted as the positions where stones mixed with the finer material were tipped into the tank for use in the construction of the filter beds.

Tanks 3 and 4: These have blocking walls that are visible through their openings, indicating they were also designed to be used as filter beds, but the brick wall in Tank 2 shows that the water flows in the Tanks 3 and 4 were intended to be independent of those in Tanks 1 and 2. The brick wall would have been a necessary addition if there were ceramic pipes through the original dividing wall.

Using the Filter Beds

Both excavated tanks have a configuration of layers that is consistent with the design of filter beds created in the 19th and early 20th century. There were no clear signs that the filter beds at Dale Mine were ever used; the clinker deposit in particular was largely clean with no fine sediments having accumulated around the pieces of clinker, and similarly there were none within the sediments around the lower stones. While a short period of use cannot be discounted, it seems more likely the beds were never used and indeed may not have been finished given that no sign of drains to take the water away from the openings in the downslope wall were found.

The Afterlife of the Excavated Tanks (1-2)

As the tanks deteriorated after they were abandoned some the render above the level of the filter bed layers started to flake off; as the render that covered the brick wall in Tank 2 came away, parts of the bricks came with it because the mortar-mix used was too strong for such badly made bricks. In other areas some of the render remained until 2019 but in parts it was already loose and flaked off immediately as excavations proceeded.

The stone facing blocks and slabs in the upper parts of the tanks were extensively robbed, presumably at the same time as the outer face of the downslope wall was taken down. These stones were removed from site selectively and many awkwardly-large or poorly-shaped blocks were left and these remained above and within the upper tank backfills. That the lower parts of the tank walls visible at that time above the filter bed deposits were left intact may suggest the person doing the robbing had sufficient stone for their needs and thus left those parts of the walls.

The infill of the tanks found in 2019 above the filter beds layers was about 1.1m thick, but with irregular hollows at the centres of both tanks where the fill was only about 0.5m deep; no well-defined topsoil existed above the filter bed layers although the basal soils in the upper fill were in parts darker than above. In Tank 2 the fill in its south-western half had fewer stone than found elsewhere, where stone sometimes predominated; many of those in this particular area were irregular wall-core stones rather than the discarded face stones mentioned above. The fills of both tanks included stones of all sizes and much rotted mortar within grey-brown soils; however, in the lower parts something like 20% of the interstices between the stones were voids with no fill. In the upper 0.20-0.30m of the fills there was also much limestone chatter between the large demolition stones and this material is very unlikely to have come from the walls; thus, the chatter must have been imported from elsewhere, the part-filled tanks being a convenient dumping ground. Throughout the tanks fills above the filter bed layers there were many broken and discarded artefacts that undoubtedly came with the imported stones; most were in the upper parts with the chatter, while those found below had presumably trickled down voids between stones.

Amongst the artefacts there were:

- Mould-made, blue-green, glass bottles and ink containers, mostly broken but with one intact rectangular bottle that was embossed ‘GARTONS HP SAUCE’; this product was made from 1905 onwards.
- Sherds of white glass with pink exterior, probably from a small crenelated light-shade.
- A ‘rubber’, screw-thread, bottle-stopper inscribed ‘L&D’ and ‘LORD & DENBIGH DERBY’.
- A number of sherds of stoneware with cream-coloured glaze and vertical incised lines, from ‘marmalade-type’ jars of different designs, one inscribed on it base ‘NOT GENUINE UNLESS BEARING W^{m} P HARTLEY’S LABEL’.
- Several sherds of a broken stoneware jug with a glossy white glaze, the exterior with a dark-blue floral transfer print.
- Two small stoneware bottles, one with a glossy cream-coloured glaze, the other, of ‘ink-bottle’ type, with a brown glaze.
- Many other sherds, a few of china; some of stoneware with transfer prints; others of red-brown earthenware, including two from a puncheon with an interior glossy cream-coloured glaze.

Metal objects included:

- A damaged domed motorbike headlight, in alloy, with small embossed circular logo on the side inscribed 'KING OF THE ROAD' surrounding a lion.
- A large piece of cast-iron 'bowl-shaped' perforated ironwork with spiralling leaf designs.
- Two heel irons.
- A rectangular tin can.
- A corroded small sheet-iron bottle that was vertical-sided and circular in shape with a small neck.
- A small, narrow, circular metal flask with flat faces and an alloy screw cap.
- Pieces of a large enamelled tin bowl.

There were also amorphous and undiagnostic rusty iron objects, rotted piece of timber and undiagnostic glass and ceramic sherds that were not retained.

Taken together the artefacts from Tanks 1 and 2 are a typical rubbish-dump assemblage, in this case brought to the site sometime in the first half of the 20th century.

In Tank 1, a small dog had been buried relatively recently near the surface, placed under a stone block; as well as bones from the full skeleton, parts of the skin at ears and one paw remained. In Tank 2 several sheep bones were found in a cluster and had presumably filtered down into the infill deposit.

The Excavated Floors at the South-Eastern Openings (1-4)

The design of the six openings in the downslope wall is described above; this section concentrates on the excavation of the floors of the south-eastern openings. All four of the floors of these near-identical 'tank-openings' were excavated. Each has an outer part under the inward-sloping arched roof, where there is a stone sill on the floor, with paving outside this that sloped gently downwards to the outside that were presumably added to facilitate shovelling and/or to help prevent erosion as water passed this way. In Openings 1-3 the archaeological excavations stopped at the line of the original outer edge of the downslope wall, but at Opening 4 the trench was extended for a further 1.0m. The inner parts of the openings, which are smaller and have flat-topped roofs, have floors that were again paved, with these sloping gently upwards in an outwardly direction. Between the two halves of the openings these all once had a rectangular timber doorframe, the sill beams of which survive at floor level. To the opening sides the floor was often covered with stalagmitic deposits from the lime mortar in the walls.

It is not clear whether the opening doors were last used when the filter bed activity ceased or, less probably, whether they were used again when the filter beds were put in place.

Inner Openings: The floors of Openings 1 and 2 comprised paving that sloped gently upwards from the bottom of the tanks to the top of the sill beam of the timber doorframe. That at Opening 2 sloped at an angle of between seven and ten degrees and that Opening 1 was somewhat less. In Opening 1 there were three fine-grained sandstone slabs, the two innermost ones protruding into the tank with a lip of 2cm where they rest on the paving here (See Plate 40). All three slabs are of the same stone-type and thickness as the roofing slabs used in Tanks 1 and 2. This invites speculation as to whether or not these slabs were part of

the original build or were later 'replacements'. However, the type of mortar used here to set them within the opening was unclear as this had largely rotted, this in itself suggesting it was lime mortar. While there was probable Portland Cement mortar near the sill beam, this may have been spilt here later when the inner opening was being rendered. In Opening 2 there was one main limestone slab with two smaller limestones partially infilling the gaps left towards the sill beam end; they all appeared slightly worn (See Plate 44). In the interstices between the slabs there was a lime mortar containing small pieces of limestone and calcite consistent with being derived from crushed mine waste. In contrast with the floor slabs in Opening 1, those in Opening 2 are certainly original features. In both openings the paving slabs were covered in a dark soil indistinguishable from the material that had spilled into the openings when the outer face of the downslope wall was robbed; two small limestone slabs lying next to the timber sill of Opening 2, placed parallel to this, appeared to be coincidentally placed as they rested on the dark soil.

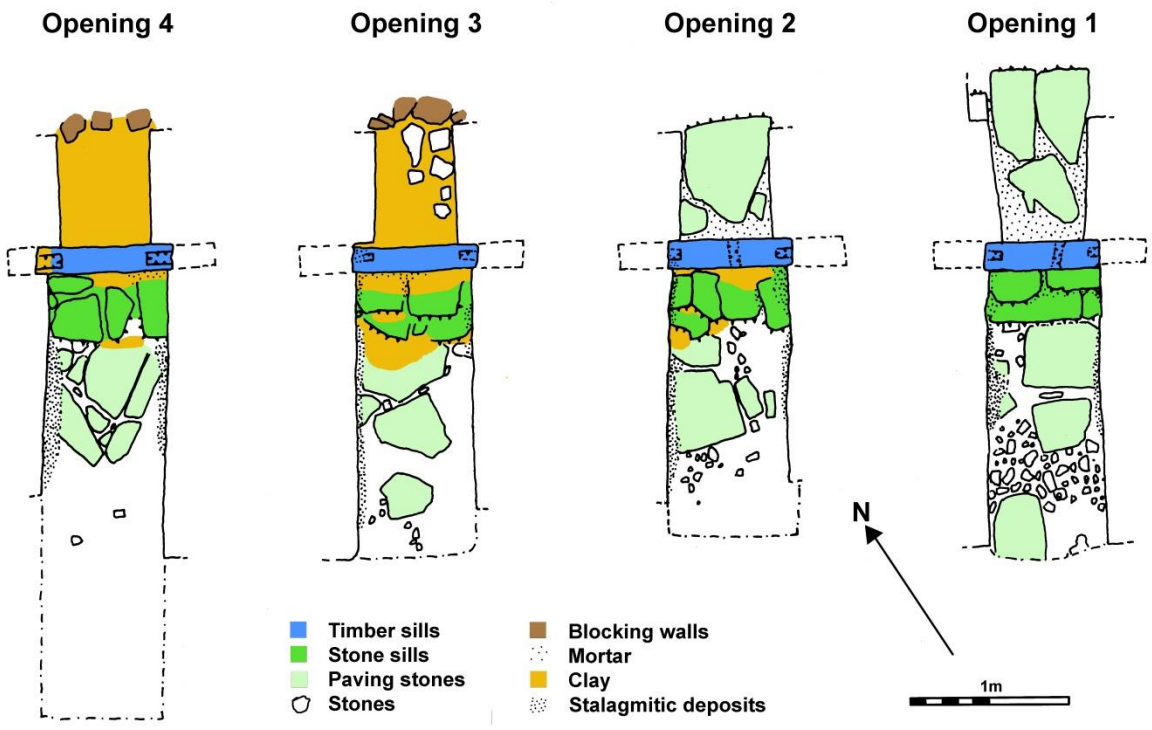

Figure 8: The excavated floors at Openings 1-4, showing the timber doorframe sills, the sites of the upper rotted timbers here where they extended into the wall, the stone sills, paving stones, blocking walls (already removed in Openings 1-2) and clay deposits (those in Opening 3 extended further outwards than shown but had been removed before the plan was drawn).

The inner parts of Opening 3 and 4 could not be properly excavated, for as soon as digging started they filled with water from the unexcavated tanks behind; hard surfaces could be felt at the base that presumably comprised paving as in Openings 1 and 2. What was clear is that this 'paving' did not come up to the same level as the tops of the timber sill beams but only came to points part-way down the timbers sides. At Opening 3 this was at 0.09m down, while at Opening 4 it was 0.07m. Above the floors in both openings there were clay deposits that are returned to below.

Outer Openings: Placed immediately outside the timber doorframe sills in all four openings there were limestone sills built with lime mortar. Their tops, in two or possibly three cases, were originally coincident with the top of the sill beams; however,the stone sills at Opening 3 and possibly Opening 4 appear to have their stone sill tops lower than the beam tops. All the stone sills are rather damaged but originally were probably built of two courses of limestone slabs and blocks; this heavy damage may well have happened during the use of the openings rather than being subsequent, as indicated by clay deposits over the damaged areas in Openings 2, 3 and possibly 4.

At Opening 1 the sill was 30-33cm wide and 22cm high, made of well-shaped rectangular slabs; the outer parts of the upper course were missing. At Opening 2 the stone sill was also damaged but originally was 39-41cm wide and 19-20cm high, made from limestone slabs and blocks, some of which were rather irregular in shape, with a shallow upper course presumably missing at the centre and possibly to the left. At Opening 3 the sill was 41cm wide and 21cm high, made of well-shaped rectangular slabs; the outer parts of the upper course were again missing. The top of the upper course is 6cm lower than the top of the timber sill beam. At Opening 4 the damaged sill was again 41cm wide but was only 16cm high and comprised one course of stones; however, it may be that thin slabs above, up to 8cm thick, have gone, assuming their tops were coincident with top of the wooded sill (but see Opening 3). There are three relatively regularly-shaped stone blocks surviving here, but in the centre there is a very irregular piece of unbroken stone; presumably there was mortar here that has now rotted away.

Outside the stone sills the original floor levels comprised paving stones and compacted mid-grey-brown soils, in parts contained small limestone cobbles. These floors sloped gently downwards towards the outside at approximately five degrees. The paving stones appear to be slightly worn and these outermost parts of the openings had all appearances of being shovelling floors.

Plate 58: The stone sill in Opening 1, with the timber sill beam of the bulkhead doorframe immediately behind.

Plate 59: The stone sill in Opening 2, with the timber sill beam of the bulkhead doorframe immediately behind, where its outer side as well as its top are visible.

Plate 60: The stone sill in Opening 3, with the blackened timber sill beam of the bulkhead doorframe immediately behind, where its outer side as well as its top are visible. Above the stone sill is the one surviving iron bulkhead fastening bar, whilst there is an iron nut from one of the fastening bolts in the now-decomposed side timber resting on the paving in front of the stone sill. Both are located where they were found.

Plate 61: The stone sill in Opening 4, with the timber sill beam of the bulkhead doorframe immediately behind, where its outer side as well as its top are visible. Beyond here the clay deposit was still to be removed at the time the photograph was taken.

At Opening 1 there were three or four limestone paving slabs, with all but one of these close to the stone sill; the possible example was small and largely covered in stalagmitic deposits. That nearest the sill had a large piece of very-rotted cloth resting on it; this had been folded several times and had a close weave and appeared to be cotton or a similar fabric. The paving stones were covered with a 5cm thick compacted soil identical to that between the paving slabs and it may be that this had accumulated during the use of the opening; at Openings 2 and 3 a similar soil may have also existed but was not obviously distinguishable from what lay above. At Opening 2 there were one large and three small limestone paving slabs. At Opening 3 there were four limestone paving slabs, with three of these close to the stone sill; these were mostly covered with yellow-brown clay that is returned to below. In the soil to the south-east side of the opening, where there was no clay above the compacted soil at the slab horizon, there was a broken piece of a handmade brick that was only 6cm thick with a pale-red-brown fabric; this is unlike any other bricks found in the two trenches. Nearby, but further north-west, there was a corroded iron bar resting on the clay deposit. This is 305mm long and had a probably square cross-section measuring 10mm across each side; its function is unknown. At Opening 4 the whole first 0.70m of the opening beyond the stone sill was paved. Here there are two large limestone slabs and at least four smaller infilling stones. A further two relatively small pieces are either further examples of infilling or are parts of the largest paving slab if this has cracked. Whilst it is tempting to see this whole paved area as comprising an area of worn and fissured bedrock, the two main slabs have natural linear hollows at different orientations.

Plate 62: Opening 1 after excavation, with paving and cobbles in front of the stone sill.

Plate 63: Opening 2 after excavation, with paving in front of the stone sill.

Plate 64: Opening 3 after excavation, with clay-coated paving in front of the stone sill.

Plate 65: Opening 4 after excavation, with paving in front of the stone sill.

At Opening 4 the trench was extended beyond the line of the original outer face of the downslope wall and here, under a 1-2cm thick turf line below the demolition and collapse layer, there was a gently sloping compacted floor level comprising a mottled grey-brown soil; both this and the topsoil above contained 1-3mm flecks of crushed minerals including calcite and barytes.

The Timber Doorframes: The *in-situ* sill beams in Openings 1-4 comprised blackened timbers that were somewhat rotted with slightly spongy outer surfaces. These beams had flat tops and sides, which were rounded at the corners due to wear and/or rotting. They extended the full width of the openings and at the ends were set in shallow recesses in the walls, designed so that the inner faces of the vertical side timbers of the wooden frames were flush with the walls of the inner openings. As noted above, the top timbers of the wooden frames were longer than the sills and set into the walls to either side, thus giving added strength against lateral pressure.

All four surviving beams had remains of mortice slots at both rotted ends, where the vertical side timbers were attached using mortice and tenon joints. In every case rectangular mortices remained in the sill beams and in three out of eight cases there were still rotting tenons from the side timbers within the mortices. In every case the inner ends of the mortices were aligned with the walls of the inner openings and the outer ends were at the timber ends flush with the walled recesses here.

At Opening 1 the beam was 68cm long and 16 cm wide. The mortice slots were originally 6-7cm wide and 8-9cm long but the outer ends had rotted away; both contained rotted *in-situ* fragments of the tenons. At Opening 2 the beam was 73cm long and 16 cm wide. The mortice slots were well preserved and were originally 7cm wide and 12cm long. At Opening 3 the beam was 78cm long and 14cm wide. The mortice slots were originally 7cm wide and 14cm long but the outer ends of the timbers had rotted away; that to the south-east contained the rotted *in-situ* stub of its tenon. At Opening 4 the beam was 84cm long, 17-18cm wide and 12cm deep. The mortice slots here were relatively well preserved and were originally 9cm wide and 18-19cm long, and thus significantly larger than those in Openings 1-3. That to the north-west end went right through the timber, although the lower part of the wood here may have rotted away, while the slot to the south-east end had a timber bottom and was 8.5cm deep.

At Openings 1 and 2 the tops of the sill beams had shallow ‘grooves’ located near their centres, running across them from inside to outside, that are of unknown interpretation; these were not present at the beams in Openings 3 and 4. At Opening 1 the groove was south-east of the centre line and was at a slight diagonal angle. It had a shallow U-shaped profile and was 8cm wide and 2cm deep. At Opening 2 the groove was again south-east of the centre line, but not by as much, and ran across the beam at approximate right-angles to its sides. It again had a shallow U-shaped profile and was 7cm wide and 1.5cm deep.

Plate 66: The timber sill beam in Opening 1, abutted by the later stone sill in front.

Plate 67: The timber sill beam in Opening 4, abutted by the later stone sill in front, with the clay deposit still *in-situ* behind.

Plate 68: The mortice slot at the south-east end of the timber sill beam of Opening 4, which is not cut right through the timber but has wood at its base.

The Bulkhead Door Fittings: One important discovery made during the excavations is that the timber frames did not support hinged doors but held bolts for bulkhead doors, with one iron fastening bar and several displaced corroded bolts remaining. These hand-made wrought iron artefacts were found in Openings 1-3.

At Opening 1 there was a corroded and slightly bent iron bolt to the north-west side, resting on the sill beam with a little soil beneath it, with its head in the inner opening direction; it presumably had fallen directly from above when the side timber rotted. This bolt was *c.* 190mm long and of *c.* 13mm diameter, with a probable circular cross-section, a threaded end and a domed circular head at the other end that was *c.* 30mm across. Traces of rotted timber adhered in its central part with the grain at right angles to bolt. A second corroded iron bolt, almost identical to the first, was found displaced in soil above the beam and stone sill. This again was *c.* 190mm long and of *c.* 13mm diameter, with a circular cross-section, a threaded end and a large domed circular head that was *c.* 30mm across. Traces of rotted timber again adhered in its central part with the grain at right angles to bolt.

At Opening 2 a corroded iron bolt was found to the south-east of the centre line of the stone sill with a little soil beneath it. This was *c.* 190mm long and of *c.* 13mm diameter, with a domed circular head that was *c.* 28mm across and uncertain cross-section; it was presumably threaded at the other end but this part of the bolt was badly rotted. A second corroded iron bolt was found nearby resting directly on the stone sill, which comprised a broken and slightly bent corroded bolt, now *c.* 100mm long, with at attached nut at one end. The bolt has a square cross-section that was *c.* 15mm per side, except close to the nut where it is circular.

The nut is square and measures *c.* 40mm per side and is *c.* 15mm deep. Resting on the stone sill top to the north-west of centre, with a little soil underneath, was a third corroded bolt that was 198mm long, with a square cross-section of *c.* 12mm and domed circular head that was *c.* 28mm across; it again was presumably threaded at the other end but this part of the bolt was badly rotted.

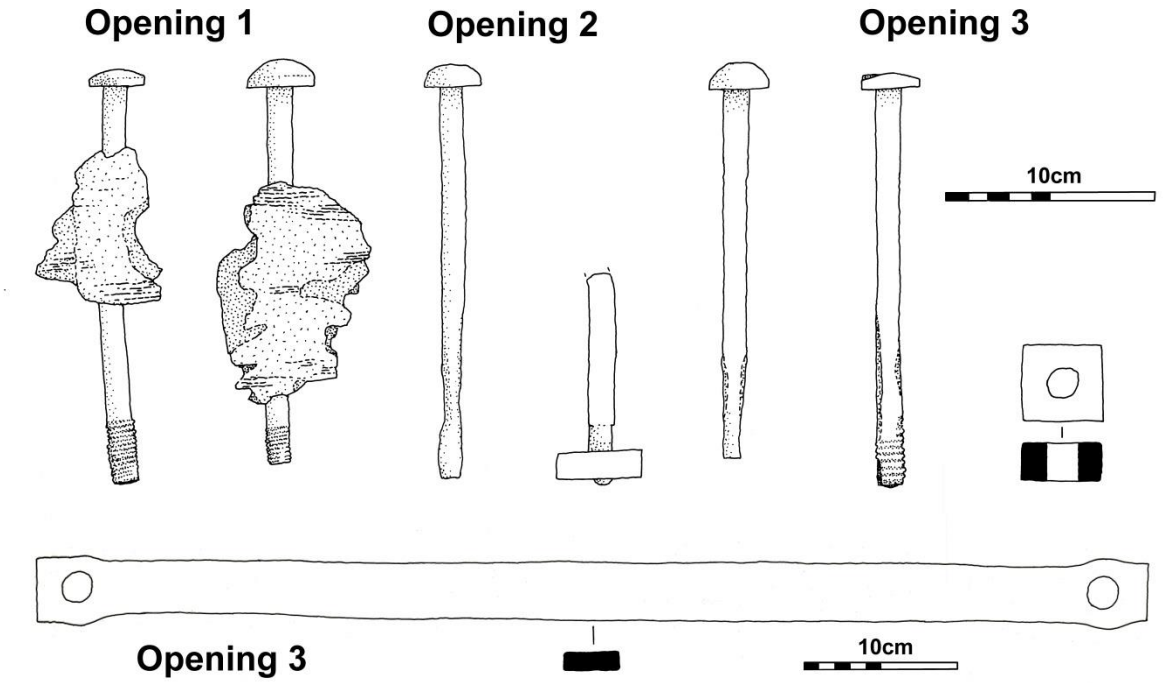

Figure 9: The iron bolts and the bulkhead door fastening bar found in Openings 1-3 (the rust calcretions are not shown and the bolts are shown from left to right in the order in which they are described in the text).

At Opening 3 a corroded iron bolt was found in loose material over the stone sill. This was *c.* 200mm long, with a square cross-section that was 14mm across each side, except for a circular threaded end; there was a domed square head at the other end that was 27-28mm across. A large rusted iron nut was found resting directly on the first paving slab south-west of the stone sill to the north-west side. It is square, *c.* 13mm thick, with each side measuring *c.* 35mm across; a corroded central circular hole had an original diameter of *c.* 13mm. The most important find was an iron bar found *c.* 10cm in front of the timber sill beam, placed parallel to this above the stone sill, with *c.* 2cm of yellow-brown clay beneath it. This bar is 720mm long, has a rectangular cross-section of 36mm x 12mm, and has two circular bolt holes through its long face, each of *c.* 17-18mm diameter, one near each end at 28mm from these to the centre of the holes; the bar here had bulging outer sides. This object is interpreted as a holding bar for the bulkhead door attached to the wooden frame in Opening 3.

From these details it can be seen that the hand-made bolts, with two in each side timber, protruded towards the outside of the opening by only *c.* 30-40mm. Here they held the bulkhead door, which from the length of the bolts must have been a metal plate rather than a wider construction of wood. Each bulkhead plate was secured by two iron bars outside the plate that would have been placed on the bolts before the fastening nuts were screwed on.

Plate 69: The iron bulkhead fastening bar resting on the stone sill of Opening 3; the holes near the two ends fitted on iron bolts in the now-decomposed doorframe side timbers, with this fastened in place using nuts. One of these nuts was found resting on the paving in front of the stone sill.

The Clay Deposits: In the inner parts of Openings 3 and 4 there were thick deposits of yellow-brown plastic clay above the 'paved' floors. At Opening 3 the top of the layer was roughly coincident with an horizon about 1-2cm above the top of the sill beam and was a little higher at the back near the tank; to the east side there were several large irregular limestone blocks within the clay; these may derive from the filter bed blocking wall behind as this appears to be in a state of semi-collapse. Below the clay to the west side of the opening where it was investigated was a *c.* 1cm thick dark soil resting on the hard 'paved' surface below. In Opening 4 the clay was thicker and its top was *c.* 10cm above the sill beam horizon at the back of the inner opening, with this decreasing towards the sill.

At Opening 3 the clay deposit continued forward of the timber sill beam onto the stone sill, including its upper damaged part, and extended over the paving slabs. Against the stone sill's outer face it was 6cm thick but soon reduced outwards to 3cm and towards the outer end of the opening became more patchy and mixed with the soil above the hard floor. At Opening 4 there were only patches of clay in the outer parts, including: one over the north-west end of the sill beam that may have slumped here after the side timber rotted; a patch between the wooden sill beam and the remaining sill stones; another on the paving at the base of the sill; and others on the surface of the compacted soil floor adjacent to the downslope wall's outer face.

At the inner parts of Openings 1 and 2 there were no recorded clay deposits identified over the inner paving slabs nor for the most part on the sill beams, stone sills and paved areas of the openings, although in the outer areas thin lenses of this material may have been unwittingly trowelled away without record before the significance of the clay deposits was

recognised. The exception is in Opening 2 where there were coherent patches of yellow-brown clay in the small gap between the timber sill beam and the stone sill and at the base of the latter. The clay was also found on the tops of the surviving sill stones where stones above were missing.

Plate 70: Opening 4 after excavation of its outer part, with the clay deposit behind the wooden sill beam still in-situ.

These clays in three out of four of the openings may well derive from deposits that settled in the tanks, but they clearly flowed out into the outer openings when these were in use and perhaps afterwards. When the bulkhead door was removed for the last time in Opening 3, the securing bar was placed on the ground in front of this when there was 2cm of clay on the stone sill. It is not clear whether the openings and their doors were last used at the time when the tanks ceased being used for settling, or whether they were used again when the filter beds were put in place. However, at the north-west ends of the sill beams in Openings 2 and 3,

under where the side timbers originally were, the sill beams were overlain by small patches of mortar; if this mortar dates to when the settling tanks were being prepared for reuse it could suggest the bulkhead doors were already dilapidated and unusable when the filter beds were created.

Plate 71: The clay deposit in Opening 2 between the timber sill beam and stone sill, with this also overlying the damaged stone sill, photographed before the clay was removed.

The different amounts of clay associated with Openings 3/4 and Opening 1/2 could indicate that the settling tanks were used for different ore deposits from within the mine, each with variable amounts of associated clay, or alternatively it may be that the two sets were cleaned differently after they were last used.

Exploratory Work at the Sites of the Engine Houses and the Lower Dressing Floor

Remote Sensing

Shortly before the excavations started resistivity surveys were undertaken, supervised by Richard and Angela Knisely-Marpole, at the two platforms adjacent to the main engine shaft where it is known engine houses once stood, and also at the lower dressing floor immediately to the south-east of the bank of settling tanks.

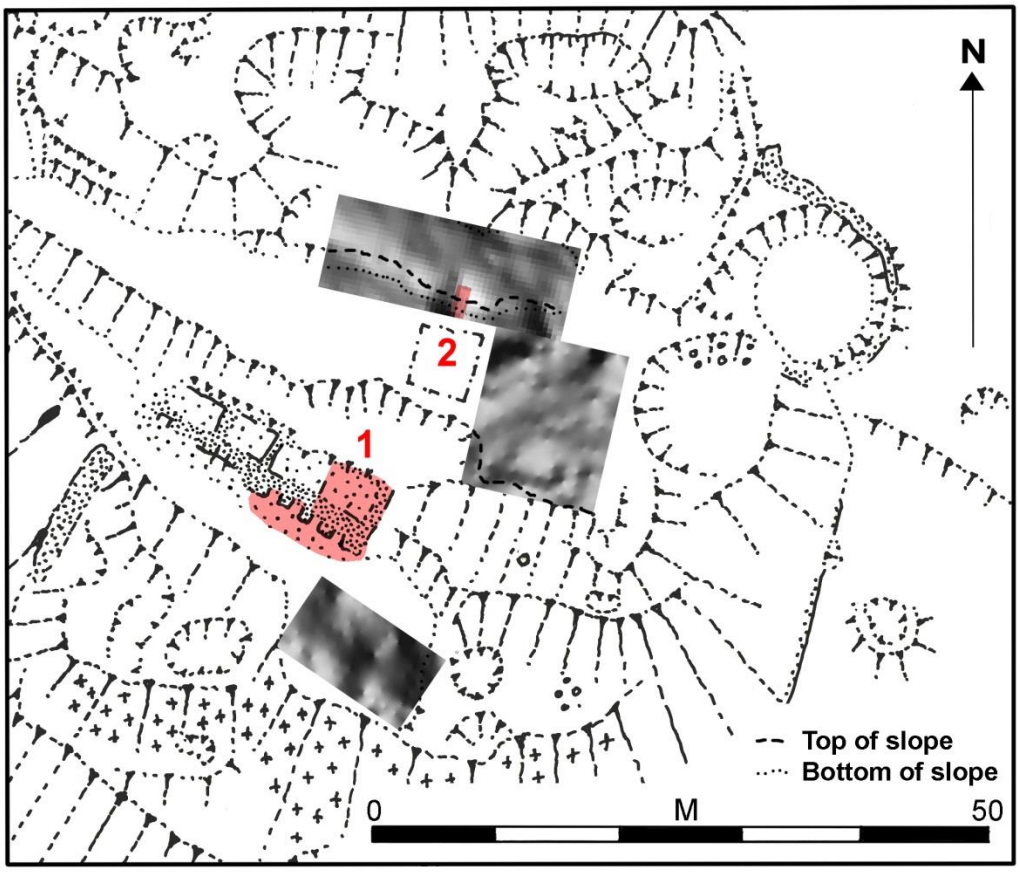

Figure 10: The remote sensing results around the site of the Dale Mine engine shaft and lower dressing floor in relation to the two trenches, the settling tanks and other surface features.

The remote sensing of the lower dressing floor, while having areas of high and low resistivity, gave no results that identified interpretable features. However, in contrast, in the area to the north and east of the engine shaft there are sub-rectangular features on the plots that can be interpreted as the sites of parts of two buildings. Each has pale linear lines of high resistance on the postulated lines of walls, flanked by dark patches of low resistance that may be foundation or robber trenches beyond wall footings. One of these 'buildings', to the south-east of the shaft, measures *c.* 7.5m externally along its southern side and the two side walls that meet the first at right-angles were at least 3.5m long. The other identified 'building', to the north-east of the shaft, again measures *c.* 7.5m externally along its south-eastern side and the potential north-eastern wall was at least 4.5m long. The presence of the features here was unanticipated and it came as a surprise that a possible building is orientated at a diagonal angle to the known position of an 1854-55 engine house with attached boiler

house, with the geophysical anomalies partially overlapping its site; the orientation is also at odds with what we know from documentation of other buildings that stood near the shaft in the mid-19th century.

Historical sources indicate the former presence of 1850s buildings around the main engine shaft, while low platforms that are visible today may well relate to these (Barnatt 2018; in prep.). To the north of the shaft the 2018 surface survey identified a flat topped area between the main part of the working platform around the shaft that includes the upper dressing floor to the west, and quarry pits with spoil heaps beyond to the north; this platform has a 0.5m high break of slope to its south side. The platform may well mark the sites of an 1854-55 engine house, boiler house, ore crusher and possibly a coal yard, with the slightly protruding part of the southern lynchet marking the position of the bob wall of the engine house that faced the engine shaft.

A mine plan of *c.* 1860 shows details of the shaft top area in the *c.* 1857-59 period (Porter and Robey 1973, p. 172); this is clearly schematic with the shaft and building shown too far away from each other and thus it cannot be directly superimposed on the modern survey. Here the 1854-55 engine house is shown standing to the north of the shaft on the platform visible today, with its boiler house attached to the east side.

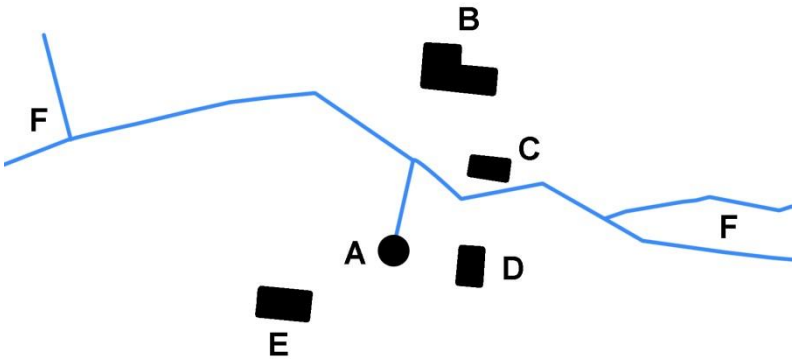

Figure 11: The documented *c.* 1857-59 buildings around the main engine shaft at Dale Mine, taken from a *c.* 1860 plan (A; Shaft, B: Old Engine, C: Wood Shop, D: Smith Shop, E: Dressing Floors, F: Passages at river level and above).

This engine was at first used for pumping from the main engine shaft. The distance between the shaft and the excavated wall footings at the break of slope, postulated to be the bob wall of the 1854-55 engine house, is not usual for a pumping engine. The engine house is normally erected immediately next to the shaft so that its pumping beam could be connected directly to the pump rods going down the shaft. However, this distance is explained by two 1850-60s drawn mine sections of Dale Mine, both showing a short length of flat rods running between the 1854-55 engine house and the pump rods in the shaft (Porter and Robey 2000, pp. 122, 126).

From 1859 the engine here was converted to be used for winding and to power ore crushing. As the attached boiler house lay to the east side, the crusher, which may have been free-standing rather than within a building, would have been placed in a convenient place in relation to the dressing floor that lay to the west of the shaft.

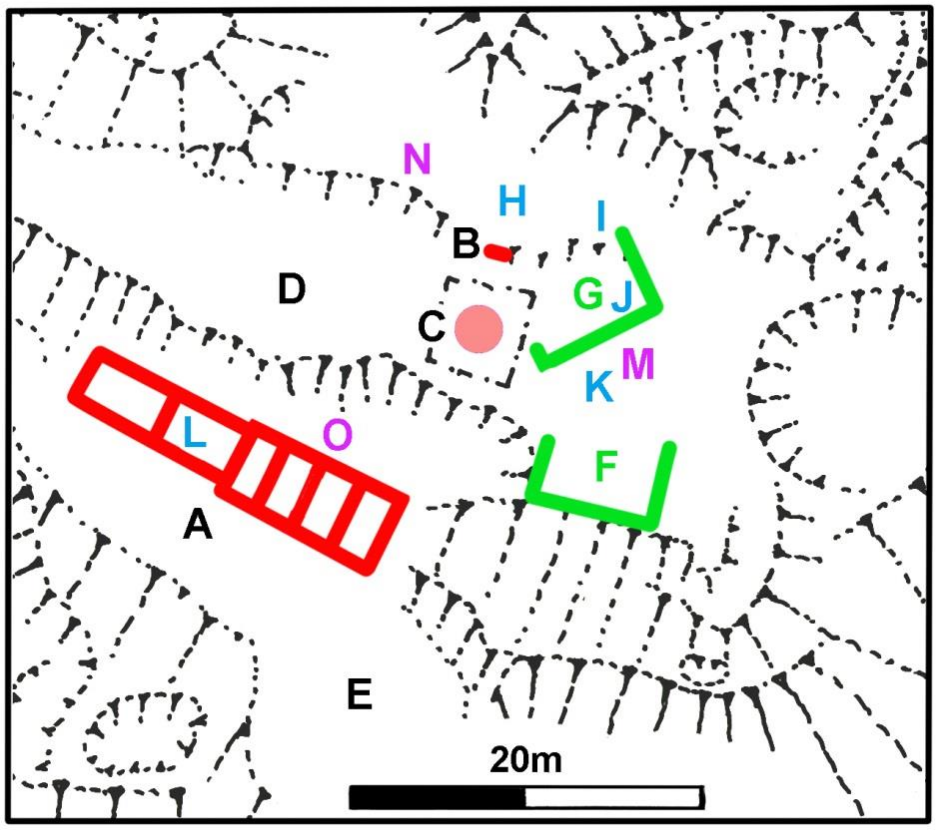

Figure 12: The Dale Mine settling tanks, the excavated bob wall, the engine shaft and the dressing floors (BLACK - A; settling tanks, B: excavated bob wall, C: engine shaft, D: upper dressing floor, E: lower dressing floor), shown in relation to the postulated buildings found by remote sensing (GREEN - F: south-eastern building, G: north-eastern building). Also shown are the approximate positions of documented sites of buildings (BLUE - on 1857-59 Plan – H: 1854-55 engine house, I: 1854-55 boiler house, J: carpenters shop, K: smithy, L; north-western settling tanks. MAUVE - later than 1857-59 Plan – M: 1858-59 pumping engine house, N: crusher, O: south-eastern settling tanks).

To the east of the shaft, there is a second flat topped area, with a slight break of slope that is up to 0.50m high at its south-eastern corner. We know that two engine houses at the shaft top were in work in the 1859-1861 period; as just discussed, that used for winding and crushing lay to the north, so the relatively large engine used for pumping erected in 1858-59 is likely to have stood to the east. The *c.* 1860 mine plan showing details of the *c.* 1857-59 period indicates that at this date to the east of the main shaft prior to the erection of this engine house there was a smithy and carpenters shop, respectively east and north-east of the shaft (Porter and Robey 1973, p. 172). The smithy was at the approximate presumed site of the 1859 steam engine house, hence it must have been demolished to make way for the new pumping engine; a new smithy would thus have been needed but its location is undocumented.

At an earlier date a Newcomen-type engine house of probable late-18th century date, converted to an ore-house in the early 19th century, is documented as having been built next to the main engine shaft; its exact site is not known but this is likely to have been to the north or east side, while there would have been a dressing floor to the west.

That the buildings present in the mid-19th century do not appear on the remote sensing plots can be partially explained by their documented history. The 1854-55 engine house with boiler house is recorded as having been blown up in 1861-62 and the stone used to build new buildings at a new engine shaft well to the north-west of the main mine complex; we know from Trench 2 dug in 2019 (see below) that the bob wall and most of its footings were removed and the robber trench then backfilled. The 1859 engine house stood on site until after the mine closed in 1873 but was demolished soon afterwards; perhaps the removal was just as thorough as at the 1854-55 buildings, hence the lack of appearance as resistivity anomalies.

The resistivity plots show two different potential buildings to the south-east and north-east of the shaft, but their date and interpretation is open to question; the plots of linear features are sufficiently clear to indicate they cannot be easily dismissed as being coincidental.

The south-eastern 'building' is not the smithy present in *c.* 1857-59, which is likely to have stood a little further north and was oriented at right-angles to what the resistivity plot shows. Three possible interpretations may apply: that it is the boiler house for the 1859 engine, but if this was sited here it would have made suppling its coal awkward; that it is a smithy built in 1859 to replace the one demolished in that year to make room for the new pumping engine house; or that it is an earlier building not mentioned in the surviving partial documentation provided by the historical records, which before the 1850s are far from detailed.

The north-eastern 'building' is even more problematic to interpret. Again it certainly is not matched with what was present in *c.* 1857-59; similarly it is unlikely to be the 1858-59 engine house as its footprint overlaps with the 1854-55 engine house and boiler house and these were still in use from 1959 onwards. Hence it may well be that we are looking at a substantial pre-1850s building. Perhaps it is the late 18th century Newcomen-type pumping engine house, but there are problems with this interpretation; if it stood here then it would have blocked the line of the winding ropes from the horse engine used to wind ore up the shaft that is thought to have been positioned at the gin circle a short distance further ENE (Barnatt 2018; in prep.).

Clearly there is still much to learn and this could only be achieved by large archaeological excavations in the areas around the engine shaft.

The Trial Excavation (Trench 2)

A small excavation trench was dug close to the main engine shaft to its north-eastern side. This trial was dug to investigate the state of preservation of the buried base of the bob wall of one of the engine houses in the hope that archaeological excavations in the 2020s could uncover the surviving parts of the walls of the documented engine houses so that future visitors could better appreciate the site. However, the excavation showed that the wall had been almost fully removed, leaving only a basal part of its footings.

These footings as excavated in 2019 comprised mostly *in-situ* hard lime mortar with a number randomly placed limestones within it, mostly of irregular shape, in a layer that was only about 0.10-0.20m high. The original width of the footings is not known as it extended beyond the south-western end of the trench; this could not be excavated as permission had not been sought from the National Park Authority, who own the land, to dig under the informal footpath here.

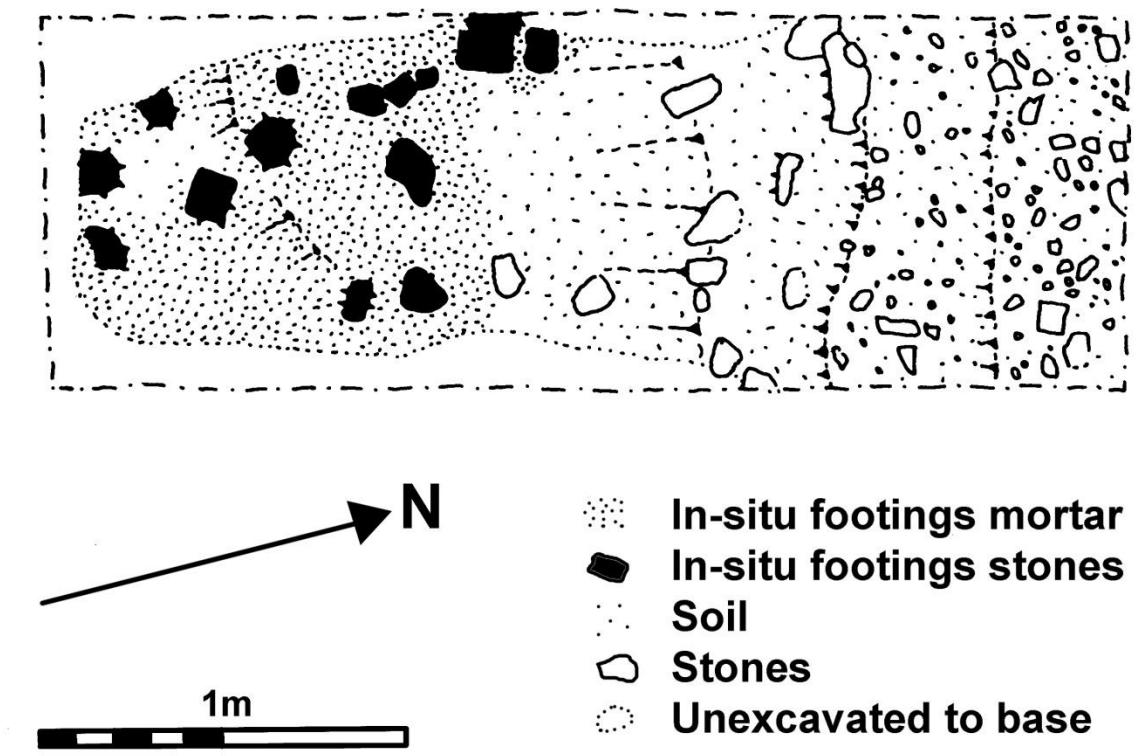

Figure 13: Trench 2 plan, showing the remaining basal layers of the bob wall footings and the north-eastern robber trench side.

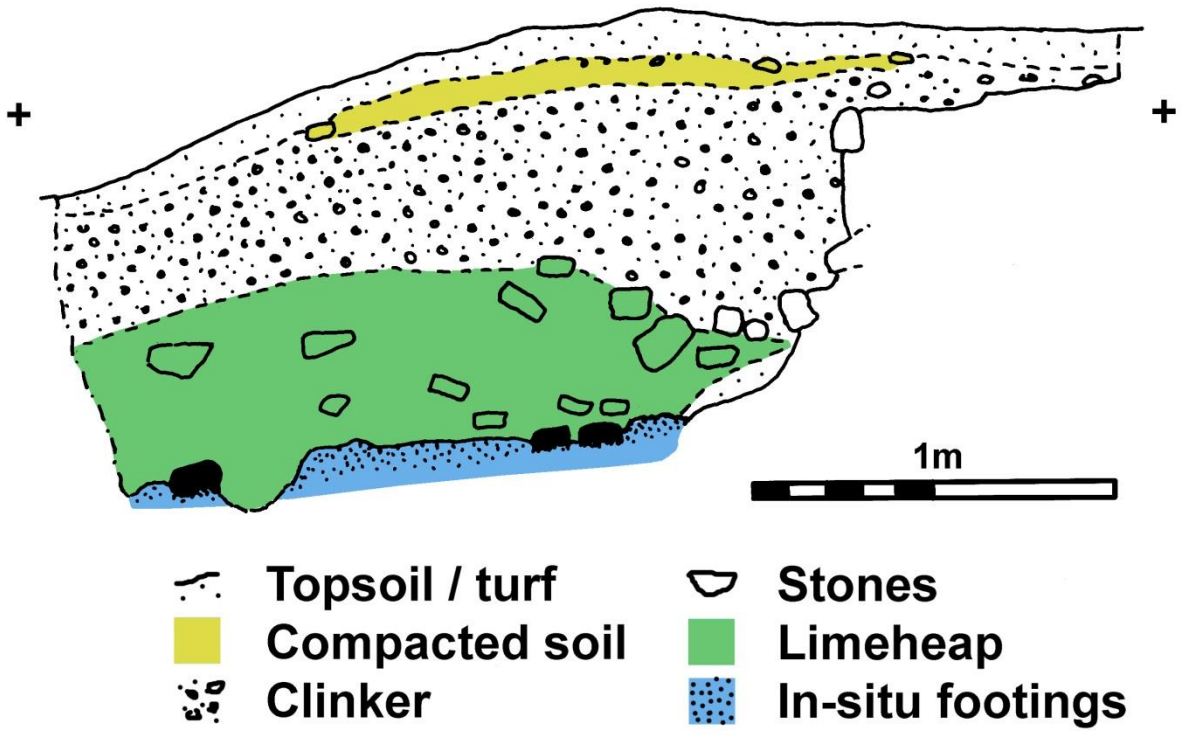

Figure 14: Elevation through Trench 2 at its north-western side, showing the bob-wall footings and the robber trench and its fills.

Plate 72: The north-western side of Trench 2, showing the various fills of the robber cut dug for removing the bob wall of the engine house. A heap of redeposited lime mortar and discarded stones is surmounted by an infill of boiler clinker. A compacted paler soil above at the centre was placed to create a hard standing at the disturbed edge of the flat terrace here to the right of the break of slope between here and the engine shaft that lies out of shot to the left.

Plate 73: Detail of the north-western side of Trench 2, showing the *in-situ* randomly placed stones set in line mortar at the base of the trench to the left, located below the lime heap and layers above seen here in the section.

Above the *in-situ* footings there was a heap of soft, rotted, lime mortar with a few mostly-small limestones at all angles, which was up to 0.45m high. Near the bottom of the deposit there was a base sherd of a large stoneware vessel. This mortar is interpreted as a heap of material that was knocked off the stones of the lowermost part of the bob wall as they were being removed for reuse; it is documented that the above-surface parts of the building were blown up. The edge of the robber trench dug to remove the lowermost parts of the bob wall was 0.80m deep and comprised an upper 0.70m irregular semi-vertical cut; below here within the robber trench the floor shelved down gently to where the *in-situ* footings remained. The width of the bob-wall footings within Trench 2 is 1.2m and, given the position of the apex of the lime heap above it, they are unlikely to have originally been more than about 2.0m wide; the wall above is likely to have been significantly narrower than its footings.

Plate 74: Trench 2 looking towards the site of the engine shaft, showing the lime heap over the site of the bob wall before it was removed.

At the north-eastern end of the trench there was *in-situ* soil within the demolished engine house. This comprised a relatively compacted mid-grey-brown sandy soil with some intermixed clay, with a few randomly placed limestones of small- to medium-size, some are angular and others are naturally-worn with semi-rounded edges. This soil with stones is tentatively interpreted as made-up ground, placed here when the engine house was built.

Shortly after the bob wall had been removed, the robber trench was purposefully backfilled with loose clinker originating from one of the steam engine boilers; this presumably was available in significant quantities, having been previously placed in a heap or heaps outside the boiler houses. Within this layer there were two handmade bricks and five sherds of flat ceramic roof tiles that are of the same fabric and type as each other; all were presumably from previously demolished buildings somewhere nearby. Above the clinker a layer of compacted mid- to pale-brown soil with occasional small pieces of limestone had been introduced, which was up to 0.10m thick; this is interpreted as a hard standing made so that the site of the engine house robber trench could be used as part of a useful working floor after the building had been demolished.

Trench 2 targeted the bob wall of the 1854-55 engine house, which would have been more substantial than other walls of the building and thus the most likely to have substantive remains. The 2019 excavation showed that this had been thoroughly removed, with even its footings largely robbed, and this may well go a long way to explaining why it was not visible on the remote sensing results.

The Tanks: Phases of Build and Use

Historic Sources and Dating

The tanks are known to have been built sometime in the second half of the 1850s, one of the two sets probably erected in 1856-57 at a time when significant output of lead ore, together with some zinc and possibly copper ores, was anticipated; the mine workings were re-opened below river level in late 1855 after a small steam engine for pumping was installed at the shaft top in 1854-55. The tanks are on an upper part of the main Dale Mine hillock affected by its reworking for previously discarded zinc ore by Melville Attwood from Ecton between 1854 and 1856. Thus the tanks must have been built after this, but part of the bank at least already existed before a new larger Cornish-type pumping engine house erected in 1858-59; only some of the tanks appear to be depicted on a schematic mine plan showing the surface structure in the *c.* 1857-59 period, which does not show this new engine house (Porter and Robey 1973, p. 172). The second set of tanks was added after this plan was drawn sometime in the 1857-59 period.

In 1859 the old engine was converted to winding and ore crushing; power taken from this engine would have allowed the dressing floors to be mechanised using belt drives, although nothing is documented to confirm this happened; the tanks may have been added to, or strengthened, at this date.

Later, the winding engine, together with rubble taken from its old house after this was blown up, was moved in 1861-62 to a new shaft located over 200m to the north-west; the rubble was used to build the new engine house and new dressing plant is documented as also erected here. From this time onwards it is likely the old dressing floors and the bank of tanks fell out of use. However, the pumping engine continued to be used at the old shaft until the mine closed due to declining output in 1873, but with closure also precipitated by a dispute with the owners of Swainsley Hall regarding polluting the River Manifold below the mine and thus spoiling the trout fishing. The conversion of the tanks to filter beds may have happened at this time. The pumping engine house was demolished soon after the mine closed. The facing stones at the walls of the bank of tanks were robbed, probably sometime in first half of the 20th century.

Phasing and Function

The discussion of the tanks given below is based on what was found in 2019, with certain aspects not yet clearly understood, and it may be subject to change if further work is done at the tanks to the north-west.

What is clear is that they are settling tanks and not ore bins, as the floors were nearly horizontal rather than being more steeply sloping as would be expected at the latter. Also, two main phases of use can be demonstrated, the first of which relates to the construction and modifications of the settling tanks in three stages and the second comprising their reuse as filter beds.

The text below starts with these phases for the main structural elements, while three sets of specific details are given afterwards, as these are not confidently ascribed to the specific constructional episodes and periods of use.

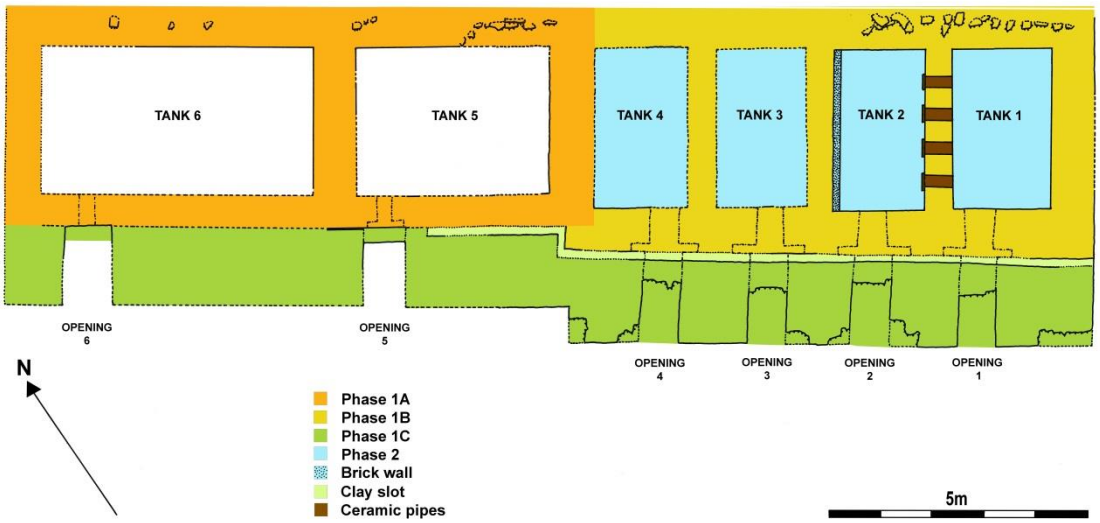

Figure 15: Interpretative plan of Trench 1, showing the different phases of construction at the settling tanks and their later reuse as filter beds (how far the Openings 1-4 extended outwards is not known).

Phase 1 (A-C) Settling Tanks

The six tanks are interpreted as initially used for settling the discarded sludge from buddles or hotches on the upper dressing floor that was located to the west side of the shaft. It may well be that jigs were installed on this dressing floor in 1859 when the power for mechanisation of the dressing process became available; these also similarly produced discarded sludge. The height of the tanks and the waterproofing barrier in their upper halves strongly suggests that large amounts of water were mixed with rejected sands and clays from the dressing equipment above. The liquid sludge would have been transported over the narrow area of rough ground above the tanks via launders (pre 1859) or pipes (post 1859 as was normal with jigs). After the sludge settled in the tanks, the water would be let off before the sand and clay were taken out of the tanks to be reprocessed on the adjacent lower dressing floor.

As noted above, the initial creation of the settling tanks is likely to have been in 1856-57, built shortly after the first 1850s engine house; the tanks are shown schematically on a plan showing the mine buildings in the *c.* 1857-59 period (Porter and Robey 1973, p. 172). Taken at face value, given the location and size of the structure shown, this appears to be the bank of two tanks to the north-west rather than all six tanks; however, while the plan is unlikely to show all six tanks, it is so schematic that the possibility it depicts the four south-eastern tanks cannot be discounted. The later phases of modification to add the rest of the tanks and to strengthen the downslope wall date to the 1857-63 period, with 1859 being a critical year as the dressing floor is likely to have been mechanised in this year.

Phase 1A: This comprises the building of the two north-western tanks (5-6) with their very small inner openings behind bulkhead doors to the downslope side. In Tank 5 there is an overflow pipe just above the bulkhead plate that is part of the original build (also see Concluding Remarks below).

Plate 75: Tank 5, built in Phase 1A, has a downslope opening that is differently designed from those in Tanks 1-4 of Phase 1B. Opening 5 has an iron plate for securing the bulkhead door placed in front of a significantly smaller opening than to those at the south-eastern tanks. The wooden lintel and wall above and to the sides of this were added in Phase 1C.

Plate 76: Tank 1, one of the four small but deep tanks built in Phase 1B, photographed after excavation and the subsequent walling up of Opening 1. The iron pipe is just visible above the opening lintel towards its left end.

Plate 77: A mortice slot in the end of the timber sill beam of Opening 2, which was part of the Phase 1B frame for the bulkhead doors that were placed in Tanks 1-4.

Tanks 5 and 6 are larger than the other four to the south-east and their openings are designed differently, which strongly suggests that they were built at a different date to the south-eastern settling tanks and possibly functioned differently. This said, any suggestion that they were built to store fully processed ore that was ready for sale is untenable as both openings have bulkhead doors and Opening 5 has the associated iron water pipe. Thus, Tanks 5-6 were probably settling tanks as with those in Tanks 1-4 where excavation has shown this is certainly the case. However, the small opening sizes of the north-western tanks suggest that, while they let out water, their sediments were emptied from their tops (see Concluding Remarks below); this stands in contrast to those in the south-eastern tanks.

The chronological relationship between the north-western and the south-eastern tanks is not fully clear. As noted above it seems very unlikely that they are contemporary with each other. The north-western tanks may well be earlier than the other set, as suggested by the relationship between the dividing wall between the two sets in comparison with the outer face of the downslope wall where it steps out for Tanks 1-4. If the south-eastern tanks were the earlier set then the step out indicates their north-western end wall would be significantly narrower than their south-eastern end wall; this seems unlikely. Therefore, it is probable that the four north-western tanks date to 1856-57 and were the first to be built on site.

Phase 1B: This comprises the erection of the four small but deep south-east settling tanks (1-4), including their inner downslope wall with small flat-topped openings and bulkhead doors. In Tank 1 there is a water pipe going through the downslope wall just above the opening that must predate Phase 1C as it is blocked by the addition of a new wall to the outside of the original wall (see Concluding Remarks below).

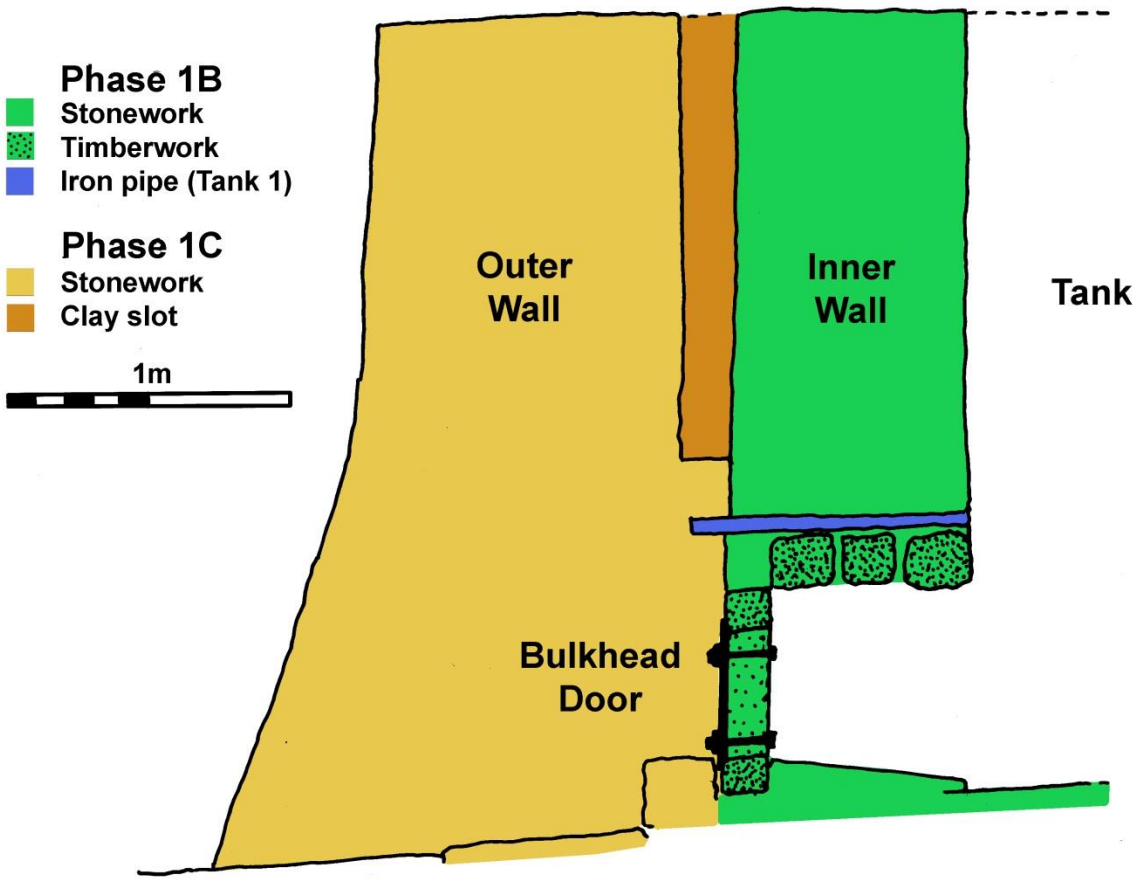

Figure 16: Schematic interpretative section through the downslope wall of the south-eastern settling tanks (1-4), showing the structural elements and phases of build.

As discussed above, there is a strong possibility that the south-eastern tanks (1-4) were added to supplement the 1856-57 north-western tanks (5-6), built either shortly afterwards, or in 1859 when the mechanised crusher was installed next to the engine house above. If built in 1859 the new tanks would have increased the capacity of the settling tanks at a time when greater throughput was anticipated with a new pumping engine installed to allow pumping to a greater depth. This said, why smaller tanks were wanted is not currently understood; one possibility, that this is because of space restrictions at the site in combination with the number of tanks needed, is explored below (see The Tanks: Interpretation and Debate). The addition of Tanks 1-4 to Tanks 5-6 may have allowed the two sets to be used in different ways and thus made production more effective; varying grades of material may have been better processed separately and/or differences in the nature of ores the sludges contained, with varying amounts of lead and zinc ores, may have been better treated separately.

Phase 1C: Both sets of tanks were strengthened with the addition of an outer wall abutted to the original downslope wall, with a clay waterproofing barrier between the two walls in their upper half except at the far north-western end. The four original south-eastern openings were given arched outer parts beyond the bulkhead doors, while the two north-western openings appear not to have been roofed beyond timber lintels set against the outside of the original bulkhead doors.

Plate 78: The clay-filled slot between the Phase 1B and Phase 1C walls, photographed at the south-eastern end of the tanks; the butt joint between the two wall builds is visible extending downwards below the base of the slot. The two phases of wall face at the south-east end of the tanks can also be seen above the turf line.

This new wall is likely to have either been built in 1859 when the dressing floor was mechanised in the anticipation of greater throughput that would result in more wear and tear, or alternatively it may have been added somewhat later in the 1859-63 period in response to worries about the structural stability of the tanks once they were in use. It should be noted that an 1859 interpretation can only apply if the south-eastern tanks (1-4) predate the conversion of the 1854-55 engine to winding and crushing in this year as these were built earlier than the Phase 1C wall. That the clay-filled channel goes through only part of the north-western tanks downslope wall, but that the butt joint continues between the two walls, indicates that waterproofing is not the only function of the new construction, but there must also have been concern about the structural stability of the tank walls due to their relative thinness and this must have been the primary reason for building the strengthening wall.

Temporary Abandonment: All six tanks almost certainly fell out of use in 1862-63 when an ore dressing plant was installed at the new shaft to the north-west; there is no record of ore being brought up the old shaft after this happened and this seems highly unlikely as the steam-powered winding engine here had been removed and there is no documentation of a horse-powered engine being employed in this period.

Phase 2 Filter Beds

This phase comprises the introduction of filter beds into the disused south-eastern tanks (1-4), with crude blocking walls placed across the inner ends of the bulkhead door openings at the downslope wall, and with reused roofing slabs placed over the ceramic pipes in the wall between the excavated Tanks 1 and 2. The last two measures seem to have been put in place to prevent water flows disturbing the three filtering layers; whether or not the bulkhead door remained in use is not known, on balance their use in conjunction with the filter beds seems the less likely option. These filter beds seem either to have had little use as there was no sign of trapped sediments here, or they were never finished as related infrastructure, such as a restriction valve or drains to take the water away, has not been found.

Plate 79: The re-used roofing slabs that were placed over the ceramic pipes in the side wall of Tank 1 at the time the settling tanks of Phase 1B were converted to filter beds in Phase 2; the unremoved top of these beds is visible in the foreground.

Whether Tanks 5 and 6 were also used as filter beds is not known; currently there is no evidence to suggest they were.

Several interpretations of the conversion of the four south-eastern settling tanks to filter beds need consideration, all of which are fraught with problems and/or uncertainties.

The conversion may have been undertaken in response to the 1871-73 court case with the owner of Swainsley Hall, who sued the New Dale Mine Company because they were polluting the River Manifold and spoiling the trout fishing. 'Catch pits' were documented as built in 1873 somewhere at Dale Mine in response to the court case but it seems likely that those for cleaning the ore-processing water were at the new shaft to the north-west as all ore concentration had taken place here from 1863. It is unlikely that the dirty water from ore processing at the other shaft would be brought the long distance to the old ore-processing site at the earlier engine shaft and put into the tanks investigated in 2019. There is a fundamental problem with this suggestion, for if sludge-rich water was introduced into the filter beds then they would have soon clogged up with sediments and the filtering layers would have needed regular replacement; it would have made for more sense to keep using the excavated structures as settling tanks and then discard the collected sludges onto the waste hillock. In neither of the tanks excavated were there any clay sediments within the filter bed layers, with the distinctively-coloured clays always overlain by these.

The same objection regarding ore processing sludge and filter beds applies to a postulation that the New Dale Mine Company were planning to rework the hillocks at the old shaft in the 1870s but then they went out of business before this happened. In addition, as can be seen today, there are only relatively small amounts of discarded material containing ores on the main hillock that post-date the wholesale removal of ore rich deposits from here by Melville Atwood in 1854-56, so hillock reworking seems unlikely in the context of a large if admittedly struggling mine company. An alternative postulation, which has the same problem regarding the use of filter beds, is that a small operation with no high overheads was planned by persons unknown after 1873 to rework the tips for a meagre profit; such operations at large mines after they had closed were common and often went undocumented in the absence of Barmaster records, which, if they were ever kept, do not survive for Staffordshire. However, looking at the profiles of the tips of post-1856 deads at Dale Mine, there is no indication that they were disturbed later.

Returning to the potential use of the filter beds by the New Dale Mine Company in 1873, one legitimate interpretation, given the problems with sludge just discussed that allows the rejection of the alternative explanations given above, is that the filter beds at the excavated structure were designed to be used for the mine water pumped up the old engine shaft in 1873, as the pumping engine here was still used until the mine closed later in that year. Most of the water pumped from depth had long been let out of the mine along the pumpway at river level (Barnatt 2018 and in press; Feature R), but perhaps they planned to bring all to surface to help combat the pollution problem. Previously the mine has been working in the main pipe deposit that comprised ancient cave passages filled with ore-rich clay sediments and thus the water would have been very 'dirty'; however, in the second half of the 1860s they ceased following the pipe north-westwards and concentrated on reworking and extending higher workings further to the south-east. It seems likely that this work was at solid ore deposits within the limestone bedrock rather that clay-rich deposits. Thus, the water from this date is likely to have been relatively 'clean' and in this circumstance filter beds may well have worked well.

This said, it is not known how well the bank of tanks would cope with all the water that was being regularly pumped from the mine to the pumpway, which is documented from 1869 as on average being a little under 85,000 gallons every 12 hours (Porter and Robey 2000, p. 212); thus, average throughput would have been about 7,100 gallons per hour. This is 32.28 cubic metres and the capacity of each of the four tanks was approximately 16.5 cubic metres

and thus it would take only half an hour to fill one tank. If they cycled through each of the four tanks in turn, each tank would have to be filled, drained down and be ready for refilling once every two hours.

Alternatively, the filter beds may have been created at an unknown date after the mine closed; the only such possibility that is apparent is that the filter beds were for sewage from the village of Warslow. However, this seems unlikely, as closer and more favourable places are available and the current sewage treatment plant is just south of the village and much better sited.

Given all these problems and uncertainties, and based mainly on the documentation of 'catch pits' built at Dale Mine in 1873 to counter pollution problems, it is very tentatively suggested here that the filter beds were created in that year to cleanse the water pumped from the mine, but that these were never put into operation as the New Dale Mine Company went out of business before this happened. However, this interpretation begs the question – why were new filtration tanks not placed at the entrance to the pumpway near the river (Barnatt 2018; in press - Feature R) instead of reusing the settling tanks above? These would have been more expensive to build but would have kept the cost of running the pumping engine down, for if water was to be taken up above river level the engine would have had to work significantly harder. We badly need archaeological investigation of the unexcavated tanks in the hope that this will throw further light on the filter bed interpretation.

The Phasing of Specific Details

Three sets of details found during excavation are hard to phase with confidence and these are now discussed in turn.

The Ceramic Pipes: These four ceramic pipes in the dividing wall between Tanks 1 and 2 are uncertainly dated; potentially they could be part of the initial build (Phase 1B) or they may have been inserted into the pre-existing wall at a later date (Phases 1C or 2). The problem here is that the wall faces are rendered and thus it is impossible to see whether the pipes were insertions or not. The render is flush with the pipe ends to the south-east side of the wall making it tempting to see them as going together (and thus Phases 1C or 2), but this may not be the case; if the pipe belong to the initial construction phase then they may have been designed to protrude slightly However, it seems very unlikely that the pipes date to Phase 2 as they were covered by the roofing slabs as the filter beds were created and if water-flow arrangements were being inserted at this time then they would have been designed differently so that they were more suitable for purpose. Also, and more significantly, the pipes contain the clay sediments discussed below and these are interpreted as being derived from the settling tank process and thus the ceramic pipes are most likely to date to Phases 1B or 1C; that Tank 1 has a ledge part way up its north-western side, with the wall above being narrower, may well suggest the pipes belong to Phase 1B, for no explanation for the ledge is apparent other than that the thicker lower wall was designed for strength around the pipes; the ledge is too narrow to be easily explained as an addition to a pre-existing wall. This thicker wall contrasts with the brick wall in Tank 2 that is certainly an addition, in that the lower part of the wall of Tank 1 is built of limestone.

Why these pipes were needed is far from clear, one possibility is that they allowed water to flow to Tank 1 where the iron 'outlet pipe' was, but this seems unlikely as they are set so low that flow between the two tanks would have been impeded by ore-rich sludge once this had settled. Alternatively, and more probably, they may have been designed to help flush clean

the bottoms of the tanks after they had been emptied by the introduction of water pumped up the shaft, presumably coming to the tanks via the reservoir above the upper dressing floor. If this is true there are implications for how the tanks were used in sequence. Rather than one tank being filled as a second was settling, while a third was being emptied and a fourth being prepared for reuse, it seems likely that while they may have been filled and emptied of settled sediments in sequence, they were cleaned together. What we currently cannot know without further excavations is whether Tanks 1 / 2, Tanks 3 / 4 and Tanks 5 / 6 were cleaned separately or together. This explanation is not convincing but no better one is apparent.

Plate 80: The four ceramic pipes passing through the dividing wall between Tanks 1 and 2, photographed in Tank 1, where there is a ledge at the top of the lower wall that may well have been built thicker to provide additional support for the pipes; the render in the tank has been carefully added to be flush with the ends of the pipes.

The Clay Deposits: The yellow-brown clay found in the ceramic pipes, in the corner of Tank 2 on top of the paved floor, as a thin skim on the original paving stones of both tanks, and in the bottoms of Openings 2-4. The clay deposits are almost certainly residual remnants of sediments from the last uses of the tanks for settling ore-processing sludges; this is supported by this clay pre-dating the filter bed layers in Tank 2, with remnants overlain by lower filter bed stones only in one corner, rather than the clay being found surrounding the basal filter bed stones across the tank as whole. The clay certainly continued to 'flow' through the four south-eastern openings until the point in time when they were abandoned as settling tanks, leading to significant deposition over the structures here, including the timber sills, the damaged stone sills and the inner and outer shovelling floors. This clay also lay directly under the removed bulkhead door fastening bar in Opening 3, so the clay was here and not covered in later soil when the bulkhead door was removed for the last time. An important question is - was the bar removed before the conversion of the tanks to filter beds or at a later date? It may be that the filter beds were left unfinished and the downslope openings not touched in Phase 2; if they were finished then the builders would have presumably put in a drain to take the water away. In addition, it seems very unlikely that using the filter beds would have led to the deposition of the clays in the way they were found in the openings and in the ceramic pipes. This said, the possibility that clays, left below the filter bed layers when

these were added, continued to accumulate in the openings in Phase 2 after the settling tanks ceased being used for their original purpose cannot be discounted. While the four south-eastern settling tanks would have accumulated clays from the outset (Phase 1B), these would have been periodically cleaned away, therefore it seems most likely that the clay found in 2019 dates to when the settling tanks were last used (Phase 1C).

Plate 81: The clay deposit in the inner part of Opening 3; the stones within it to the right-hand side may well have fallen to here and sunk into the sticky clay when the drystone wall behind partially collapsed.

The Render: This was found in Tanks 1-4 and the inner parts of their openings as far as the bulkhead doors were lined with Portland Cement render. A new brick wall in Tank 2 was also added using this cement in its mortar, and new floor slabs were possibly put in the inner part of Opening 1. There is also Portland Cement render on the visible sides of the walls of Tanks 5 and 6, as well as a small amount of this at the Tank 5 opening. Looking at all the options, the use of Portland Cement could have taken place in Phases 1A/B immediately after initial construction, or in Phase 1C when the downslope wall was strengthened, or in Phase 2 as a preliminary to the introduction of the filter bed layers. While much of the render is carefully applied as an even and relatively thick layer, but becoming thinner on the downslope wall of Tank 1 the upper parts have had the render applied in casual fashion as an uneven skim with no attempt to finish this neatly as if it was applied in a hurry. This militates against the render belonging to the Phase 1B build here. Similarly, the visible render on the upper faces of Tanks 5 and 6 is applied thinly.

Plate 82: The brick wall at the side of Tank 2, photographed part way through excavations, was added outside the original wall face and was constructed using Portland Cement in the mortar; it was then rendered using the same mix. In this upper part of the wall much of this render has subsequently weathered-off, taking parts of the poorly made bricks with it because the mix was too strong for sustaining their faces in the long term.

Plate 83: The now-flaking render on the downslope end wall of Tank 1, where remaining, can be seen to have been added in casual fashion and not given a smooth finish (the uppermost 2-3 wall courses in this photograph were repointed or in places added during consolidation of the structure).

If the ceramic pipes running between Tanks 1 and 2 and the render applied around them go together, with the pipe ends coming flush with render at south-east side and given the neatness of the render finish here, then this makes Phase 1C for the render the most likely interpretation given the presence of clay in the pipes. However, as noted above, the neatness of the render around the pipes may be coincidental and thus Phase 2 for the render, as a preliminary to inserting filter beds, also needs full consideration. This said, currently there are no other indicators at Tanks 5 and 6 that these were used as filter beds and one priority for future excavations would be to establish if this is the case or not.

One important factor in assessing the phasing of the render is to assess at what date Portland Cement is likely to have been first available for use. This was only used commonly for 'ordinary' building purposes from the late 19th century onwards and while modern-type Portland Cement was first developed in the 1840s, initially it was significantly more expensive than using lime mortar and did not produce mortar mixes that were as strong as later in the century (Mark Womersley pers. comm.). While Portland Cement could have been used because of its improved waterproofing properties in either Phases 1C or 2, given that it was expensive to purchase, a strong argument can be made for its use when the filter beds were installed in Phase 2. In 1873 the circumstances were unusual, and this expensive option may have been adopted in response to the New Dale Mine Company being threatened to be taken to Chancery Court in London on appeal because they were said to be polluting the river; they may have imported Portland Cement to help solve their problem, or at least to show willing, and thus hopefully satisfy the owner of Swainsley Hall.

Afterlife

After the tanks were abandoned, perhaps several decades after the 1870s, many of their limestone facing stones were robbed, presumably for use in a building elsewhere. Domestic rubbish was later tipped into them; most of the discarded artefacts date to the first half of the 20th century and earlier items may well have been already old when they were discarded.

The Tanks: Interpretation and Debate

During the 2019 excavations we learnt much about the bank of tanks. We now know they were erected as settling tanks rather than ore bins and that the downslope openings had bulkhead doors. Unanticipated finds included identification of the strengthening of the downslope wall by more than doubling its width and adding an upper waterproofing clay barrier, and also that the four south-eastern tanks were later converted for use as filter beds.

Plate 84: The Phase 1C outer part of the downslope wall of the settling tanks, now heavily robbed but conserved, was added after the original wall behind was first built in Phase 1B to give added strength to the structure.

Plate 85: Tanks 1 and 2 built in Phase 1B, with the flat-topped filter bed layers inside that had been added in Phase 2 after the tanks ceased to be used as settling tanks; these were photographed when their removal had started.

There is a lot we still don't fully understand where there are interpretative uncertainties, including:

- Whether the two north-western tanks were built before or after the other four.
- The reason why the two north-western tanks were larger than the four smaller south-eastern tanks.
- Whether or not the two sets of tanks were used for different types of ore processing residues.
- Why the inner openings of Tanks 5-6 are smaller than those in Tanks 1-4 and whether they were used in a different way.
- The function and date of the ceramic pipes between Tanks 1 and 2, and whether there are further pipes in the dividing walls between the unexcavated tanks.
- Why two of the six tanks have iron 'outlet' pipes while at least two of the others do not.
- Why the inner paving in the openings in Tanks 1-4 slopes up towards the bulkhead door sill.
- Why a brick wall was added to the north-western side of Tank 2.
- Whether or not the bulkhead doors in Tanks 1-4 were reused when the filter beds were added.
- The date at which the tanks were lined with render.
- When and why the filter beds were installed.
- Whether the filter beds were ever finished or not.
- Whether or not Tanks 5 and 6 were later converted to hold filter beds.

All this said, a series of phases of construction and use of the main structural elements has been proposed above and this is summarised in Table 1.

Features	*Phasing*			
North-western settling tanks and inner openings	1A?			
South-eastern settling tanks and inner openings		1B		
Outer wall at all six settling tanks and outer openings			1C	
Reuse of south-eastern tanks as filter beds				2
Ceramic pipes in the wall between Tanks 1 and 2		1B?	(1C?)	
Yellow-brown clay deposition in the settling tanks and downslope openings		(1B?)	1C?	(2?)
Render lining within Tanks 1-4 and their inner openings, and a brick wall in Tank 2	(1A?)	(1B?)	1C?	2?

Table 1: The postulated phasing for the construction and modification of the stone-built bank of tanks at Dale Mine (with those entries placed in brackets less likely than those without).

Why the stone-built structure includes six separate tanks is not fully understood. It is possible that this was to allow materials to be processed that were produced underground by different work-gangs of miners on tribute or bargain, each of which needed to be paid their share of the price the processed ores fetched. However, while ore bins were commonly used in this way in places like the Northern Pennines this was not the norm in the Peak District. More generally it is not clear if and how residual ores put in settling tanks were subdivided. In the case of the Dale Mine tanks it seems more likely that multiple tanks were used to facilitate the efficiency of the ore recovery process, with tanks being filled in sequence, so

that one could always be being filled while others were settling and emptied. An added complication, that may help explain the presence of two sets of tanks of different sizes, is that some ores may have been recovered from 'cave' sediments in the pipe workings and thus have large quantities of clay mixed with them, while others were mined from ore deposits in the bedrock where clay was absent. Also, ores of lead and zinc were being won at Dale Mine and these two types of ore needed smelting differently. Separation could have been done with crushed ore when it was processed in hotches and jigs by using them differently; it could also have been beneficial to also keep the residues separate so that these could be processed differently.

In Tanks 1 and 5 there are iron water pipes in the downslope wall, the interpretation of which is uncertain. That in Tank 1 goes through the original downslope wall of Phase 1B just above the opening here and this must predate Phase 1C as this addition to the wall blocks its outer end. This pipe could be tenuously interpreted as an 'overflow pipe' that could be used once material in the tank had settled to let off the water above.

Plate 86: The iron pipe in Tank 1, which passes through the original Phase 1B tank wall just above the lintel of the flat-topped inner opening.

Plate 87: The iron pipe in Tank 5, which passes through the original Phase 1A tank wall at a point above one end of the iron plate for the bulkhead door.

However, it is far from clear why Tank 2 did not have a matching pipe and there are problems with seeing the one pipe serving both tanks during the normal settling process; the ceramic pipes through the dividing wall between the two tanks are set so low that these would have ceased to work once the settling process was advanced as they would be choked. Also, it may well be that water was let out through the downslope openings rather than the postulated 'overflow pipe', with the bulkhead doors being loosened once the settling was well advanced to allow water to pass around their sides; this was common practice with bulkhead doors. Thus, it may be that the iron pipe was placed as an emergency outlet in case for whatever reason the tanks were overflowing because the bulkhead doors were not letting out enough water; given that there is only one pipe for the two tanks. However, this interpretation of the iron pipe only works if the dividing wall between the tanks was somewhat lower than those to the exterior and thus water could flow over its top; this said, this postulation does not explain why the pipe was dispensed with when the Phase 1C wall was added.

Without further excavation, the interpretation of the iron pipe in Tank 1 remains uncertain; currently it is not known whether similar pipes existed or not in Tanks 3 and/or 4. In Tank 5 there is a similar 'overflow pipe' above the bulkhead plate that is part of the original Phase 1A build; it is tenuously interpreted in the same way as that in Tank 1, but in this case it was not blocked by the Phase 1C wall and hence the absence of a comparable pipe in Tank 6 seems real, as such a pipe would still be visible today.

The most fundamental question at the Dale Mine tanks is - why were Tanks 1-4 built so high with inconveniently small 'emptying' doors? The small size of the openings may well have been dictated by the need for strength at the bulkhead doors because of the weight of water behind. The height may well be explained by large amounts of water being mixed with the solid residues. The height of Tanks 5 and 6 may well have been less and the observations about to follow may not apply. On a mine site where there was plenty of available space then it would make sense to have larger but shallower tanks, but this was not an option at Dale Mine after Tanks 5 and 6 were built, as there was very restrictive space close to the dressing floors. The solution adopted had the disadvantage that, with the tanks being about 3m high, it would have been far from easy and probably wholly impractical to empty them of settled material by shovelling this out over the top of the walls as was usually the case at lower tanks. While the downslope openings are small and the bulkhead door could have primarily been designed to hold back but also let out water, at Tanks 1-4 the openings also have evidence that can be interpreted to indicate solids were also taken out via these. The paved slabs in the inner and outer parts of the openings are best explained as shovelling surfaces and probable wear on the slabs in the outer openings supports this; the inclined-arched openings here also appear to be designed to facilitate this, giving the person shovelling material from the outside more space to work. This said, the openings at Tanks 1-4 are relatively small and they may well only have been usable with long handled shovels and rakes and even then there would need to be at least one person inside any one tank to bring material from the back towards the opening. In contrast, the inner openings in Tanks 5 and 6 are so narrow that shovelling through them may well have been wholly impracticable; these may have been used solely to let water out. What we don't know is how deep these two tanks were but it is probable that they were shallower and thus it may have been practicable to remove solids over the wall tops. Another awkward uncertainly is why in Tanks 1-4 the inner paving in the openings slopes up towards the bulkhead door sill, and in two cases the latter rises higher that the paving; this would have meant that water in the bottom of the tanks could not drain away and no advantage for this arrangement is apparent

Plate 88: The settling tanks of Phase 1B were originally c. 3m high structures, as shown by the excavations at Tanks 1 and 2. The downslope end wall (right) has been rebuilt close to its original height, while the others are largely as found, with their upper parts collapsed but not rebuilt.

Plate 89: The paving in the outer part of Opening 1 that may well have been designed as a shovelling floor, with the stone and timber sills behind.

Plate 90: The original Phase 1A openings through the downslope wall, as here at Opening 5, are so narrow that shovelling through them may well have been impossible and the bulkhead door here was probably installed to purely hold back the water in the settling tank behind.

Given the above discussion, one possibility is that the settling tanks were badly designed, built at a time when larger mines were starting to concentrate heavily on maximising ore output by reprocessing residual material coming from the primary dressing equipment, and also starting to mechanise the dressing process, and thus the Dale Mine design not replicated elsewhere.

Postscript: Future Research

A final question is - what happens next at Dale Mine? Given that there is still much we don't understand about the settling tanks, it would be ideal for further excavations to be undertaken, which should include emptying Tanks 3, 4 and 5; emptying Tank 6 would be impracticable because of the large ash tree here. Similarly, exposing the downslope wall in the north-western half of the settling tanks would be useful, not only to allow consolidation, but also because it would allow investigation as to why the waterproofing slot does not continue to the north-western end of the bank.

While the trial excavation at Trench 2 has illustrated that little engine house stonework may survive and thus long term presentation to the public is likely to be unviable, there is still great potential for large research excavations to elucidate the sequence of buildings around the engine shaft and to investigate the unanticipated potential structures revealed by the geophysical work.

Glossary

Bargain: A miners' term for a short-term contract between specific miners and the mine management, where ore extraction work was paid for by an agreed percentage of the sale price of the ore (also see Tribute Bargain), or when non-ore producing work was undertaken, for example at levels or shafts that were being created, where this was done for an agreed price per fathom (6 feet).

Barmaster: The miners term for the chief official at the traditional lead miners courts in the Derbyshire orefield. These courts primarily were concerned with settling miners' disputes, recording changes in ownership of mine titles and quantifying lead ore outputs from each mine so that duty could be charged; it was beyond their jurisdiction to monitor extraction of ores of other metals or outputs of minerals such as fluorspar, barytes or calcite.

Bob Wall: The wall of a steam engine house which supported the large rocking beam that was connected to a vertically-placed cylinder within the building at one end and at the other end either to the pump rods going down the shaft if the engine was used for dewatering workings, or a winding drum if it was used for bringing ore out of the mine. Because of the weight put on a bob wall, this was usually significantly thicker than the other walls of the engine house.

Boiler house: A building designed to hold a boiler or boilers, used in conjunction with steam engines and installed in a separate or conjoined building.

Buddle: A miners' term for wood- or stone-lined troughs of various designs used to concentrate ore, where water was mixed with finely crushed ore and waste. Lead and other metal ores were heavier than the non-metallic minerals with which they occurred and thus by mixing the crushed material with water and carefully pouring this into the buddle, the lead ore settled on its sloping floor while lighter material was flushed away.

Catch pit: A miners' term for a pit or tank that sludge from ore dressing was fed into. This allowed the fine sediments in the water, which often contained residual ore, to settle here rather than entering the local water system.

Collar: A miners' term for the top of a shaft; this was often strengthened with stonework or timber, which made access and haulage easier. Sometimes platforms across the shaft top were added to make it easier to reach kibbles; often these included trapdoors that helped prevent accidental falls down the shaft.

Cornish-type steam engine: A type of engine introduced in the 19th century that was used for pumping, or for winding or crushing ore, which had a vertical cylinder operated by steam under pressure.

Crusher: Mechanised ore crushers in the mid-19th century often comprised two revolving circular stones with flat sides and outer edges, with ore fed between their ends.

Dressing floor: Dressing is a miners' term for the processing of mined ores to remove all unwanted material attached to the ores, such as rock or non-metallic minerals, so that the ore could be concentrated before sale and removal to smelters. Larger mines usually had a built working floor at surface adjacent to the engine shaft top or level entrance where the ore was processed. With some ores a preliminary task was to wash what came out of the mine to remove clay and other easily separated contaminants. After washing where necessary, two basic operations took place on the dressing floor in order to prepare the ore concentrate. Firstly, crushing the lumps of ore and non-metallic minerals brought from the mine, either by hand or with a mechanised crusher. Secondly, separating out the crushed ore from the waste by sieving and buddling.

EDM: A survey instrument that, like a theodolite, accurately measures horizontal and vertical angles, but also contains a laser that measures distance; hence Electronic Distance Measurer.

Engine house: The building erected to contain an engine, usually powered by steam. In 18th and 19th century examples these were often impressive buildings built of stone and had an attached or nearby boiler house.

Engine shaft: A shaft that normally came to surface, used in conjunction with an engine (horse-, water- or steam-powered) for haulage and/or pumping. Such shafts are typically of relatively large diameter and deeper than shafts used to climb in and out of a mine; they were usually designed to bring ore and water in one vertical lift from the sole of the mine to surface. In some instances large engine shafts were partitioned and had sections for haulage, pump rods and pump pipes, and access ladders.

Flat rods: A miners' term for a series of timber beams or metal rods placed horizontally or on slopes, linked together and used at surface or underground along levels. These were designed to connect steam engines or waterwheels, which were often but not always sited at surface, to shafts tops, where the flat rods were connected to vertical pump rods that led down to pumps. They were also used underground, leading from pump rods to reach pumps in irregular and often sloping pipe workings, as found for instance at Dale Mine.

Gin circle: A horizontal circular platform, either on built-up ground or levelled into a natural slope, where a horse-drawn winding whim stood; 'gin' is a miners' term for an 'engine'. Near the gin circle's outer edge there was a circular bed where the horse walked when operating the engine. At the centre there was bearing-stone for the vertical timber axle for the winding drum above.

Hillock: A miners' term for a heap of waste material at surface, usually comprising non-metallic mineral and/or stone, either placed here as it came out of the working or dumped after it had been crushed and dressed.

Horse-drawn winding whim: A whim is a miners' term for a type of horse-drawn engine used for bringing ore, and sometimes barrels of water, up a shaft; this was placed to the side of the shaft top (see the section on 'Horse-drawn winding whims' above for a detailed description).

Hotch: A miners' term for a sieve for ore processing on a frame within a rectangular tank, with a pole to hand-operate it. Mechanised versions were referred to as jigs.

Jig: A miners' term for a hotch that was operated by an engine rather than by hand.

Launder: A miners' term for an open-topped artificial water channel, usually made of wood, and common on dressing floors and also underground where water needed to be carefully channelled to prevent flooding below, or to bring water to where it was to be used or disposed of.

Newcomen-type steam engine: An early type of steam engine, named after Thomas Newcomen one of the main inventors of these in the early 18th century. At mines, they were often placed in tall engine houses that contained the main cylinder, which was operated only by the weight of the cylinder piston top under atmospheric pressure. All early Newcomen-type engines at mines were used for pumping but in the last three decades of the 18th century Newcomen-type engines used for winding were also introduced.

Ore bin: A miners' term for a wooden tank or stone-lined container used for holding part-processed or processed ore.

Ore-house: A miners' term for a small building used to store ore, often after it had been dressed and was ready for sale; these helped protect the ore from theft.

Pipe: A miners' term for an ore deposit that often lies roughly horizontally or runs irregularly rather than being vertical and following a fault. In some cases what miners called pipes comprised ancient cave passages that had been filled or part-filled by mineralised deposits, either at the time of mineralisation, or by the re-deposition of eroded alluvial sediments that contain ore in caves that post-date the mineralisation.

Pipe working: Mined cavities in a pipe deposit.

Pumping beam: A substantial rocking beam of timber or iron with a central pivot, placed on the bob wall of an engine house, which was connected at one end to a pumping engine cylinder and at the other to pump rods.

Pumping engine: An engine, powered by steam or water, which was used to pump water out of a mine in order that workings did not flood.

Pumpway: A miners' term for a horizontal level, usually just above the water table, where water could be removed from the working in the same way as a sough, but where water had first been pumped from deeper in the workings.

Settling Tank: A raised tank or a lined pit where fine sediments rejected from buddles, hotches and jigs were placed to allow the water they were mixed with to be separated and let off.

Shot hole: A distinctive drilled hole made by miners into which gunpowder (or later high explosives) was placed in order to remove rock and mineral by blasting.

Tribute Bargain: A miners' term for a short-term contract between specific miners and the mine management, where ore was extracted, raised and dressed in return for an agreed percentage of the value of the ore.

Winding engine: An engine that was steam-, water- or horse-powered, which usually was used for bringing ore and/or waste stone up a shaft; sometimes water was brought up in barrels.

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