

Rookhope Old Smelt Mill, Rookhope, County Durham: results of the 1995 survey

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ABSTRACT: Rookhope Old Smelt Mill (Scheduled Ancient Monument No 29010) was abandoned some time after the construction of Rookhope Smelt Mill 1km to the E by the Blackett company between 1730 and 1740. In 1995, the authors carried out a survey of the site and were able to confirm its use for smelting lead ores. There were one and possibly two smelting mills on the site together with evidence of slag crushing and ore dressing operations. There is a system of leats to supply water to the various operations. The site is overlain to the W by the dam of the newer Rookhope Smelt Mill and the shafts and outlet from the Tailrace Level to the E. In August 1999, the Environment Agency commenced work to build a lagoon to intercept silt carried by water overflowing from the nearby Fraser's Grove mine further up the valley. This work has destroyed much of the old smelt mill site

Introduction

Rookhope Old Smelt Mill (Scheduled Ancient Monument No 29010, NY 915428) is situated on the south side of Rookhope Burn (Fig 1) on an area of level ground approximately 1km W of the later Rookhope Smelt Mill (NY 925429). The Old Smeltmill site consists of a series of leats and earthworks, most of which are less than 0.3m above ground level. The only appreciable masonry remains are the foundations of a two-roomed building at the SW corner, which almost certainly housed an ore hearth. In August 1999, the Environment Agency commenced work to build a lagoon to intercept silt carried by water overflowing from the nearby Fraser's Grove mine further up the valley. This work has destroyed or overlain much of the E part of the old smelt mill site.

The SE corner had previously been surveyed by Alan Blackburn and Tom Gledhill some time before 1995. It was decided to carry out a survey of the whole site in early 1995 and this was completed by Blackburn and Smith during July and August 1995. The site was protected as a Scheduled Ancient Monument in 1997.

History

The lead veins in the Rookhope Valley run approximately NE to SW. The line of the East Scarsike

Vein is marked by a series of shafts (Fig 2) and the emergence of the Tailrace Level at the NE, just above Rookhope Burn at the foot of the steeply-sloping fell side. Although the mouth of the level has collapsed, a very strong stream of water issues from it. The Tailrace Level is driven in the Little Limestone and after approximately 300m, turns NW to cut the parallel West Scarsike Vein and further on, the parallel Rispey Vein at Rispey Shaft. Tailrace Level also drains the more

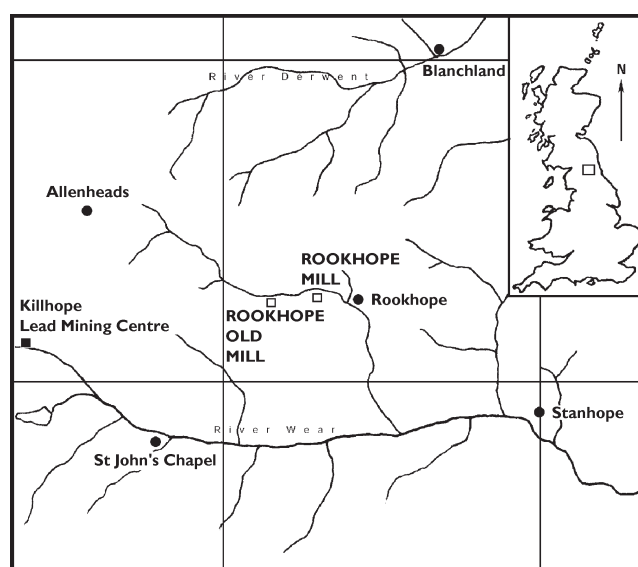


Figure 1: Location map

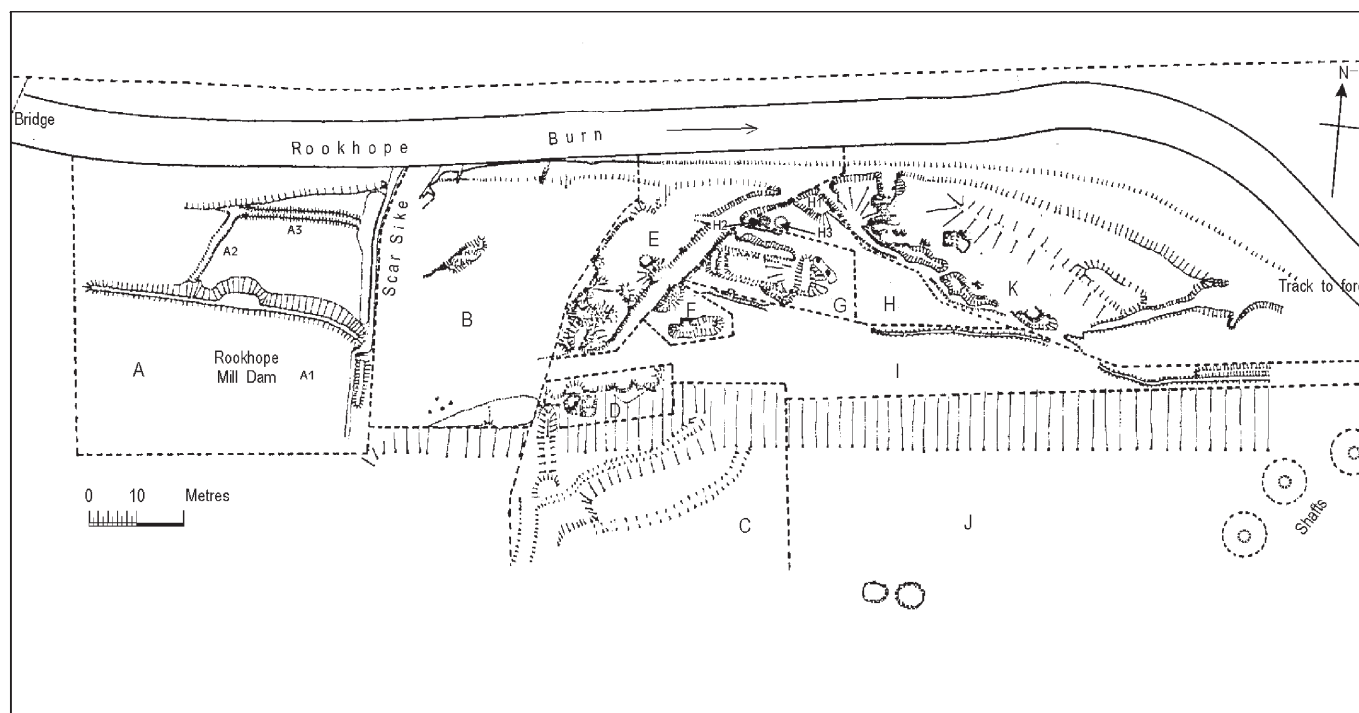


Figure 2: Plan of the site of Rookhope Old Smelt Mill as surveyed by the authors in 1995.

distant Wolfcleugh and Groverake Veins. Rispey Vein has also been worked from the Rispey Sike Level, driven NW approximately 150m N of the Tailrace Level mouth on the opposite side of the valley. Fairbairn (1996) described the area in detail.

Very little is known about the history of the site (Fairbairn 1996). The mill pre-dates the Rookhope (or Lintzgarth) Smelt Mill which was built by the Blacketts in 1737. It has been assumed that the Rookhope Old Mill closed about 1750. The East Scarsike, West Scarsike and Rispey Veins were leased to William Errington, George Baker, William Soppith and John Bell in 1751. The Errington Company owned or leased Feldom Mill (NZ 000487) at this time and it is not known if they used Feldom for Rookhope ores or if they had access to Rookhope Old Mill.

The 1995 survey

The survey was carried out using tapes and offsets relative to datum points which were related to National Grid references by theodolite and to features which could be located on the 1:25,000 OS map. The features shown in Figure 2 were plotted at 1:200 and later scanned into a CAD/overlay system which allowed variable format outputs and working diagrams to be made.

The ends of each hatch line in Figures 2 to 5 represent two positional measurements. Because of the level

terrain and low height of the features, there will be little difference between the measured and projected plottings. The exceptions to this were the measurements of the fell side on the S side of the site. However this feature does not have clear boundaries and for this reason cannot be defined precisely.

The line of the leat from Rookhope Mill dam was established by probing with a 10mm-diameter rod. The very dry conditions of the 1995 summer allowed penetration on most of the site to a depth of 25-50mm with some difficulty, whereas, along the course of the leat, the penetration was usually greater than 300mm. The method was established on defined parts of the leat and then progressed into areas covered by high sedge grass where the course was indistinct. A possible earlier course along the foot of the fell side was explored but with negative results.

Area A

This area (Fig 2) is mainly covered by the dam, A1, constructed to serve the later Rookhope Smelt Mill and believed to date from early in the 19th century. The interior is dry and silted up to within 0.5m of the top. Water was supplied from Scar Sike, which approaches from the S, and also from the Rookhope Burn, further upstream. The wall is breached, but some remains of a wooden sluice exist at the SE corner. The exit is recent and cuts through the dam wall and earlier

features; it was cut in 1995 by the farmer to overcome flooding of Area B.

Two gullies, A2 and A3, appear to be water leats. A3, running E to W, has been cut by the new course of Scar Sike at the E end and by the flood plain of the Rookhope Burn to the W. A3 appears to run in the general direction of the leat to Rookhope New Mill, which is visible in areas I and F. It may also have been an earlier direct feed to this leat from the Rookhope Burn. Gulley A2 runs N and is overlain by the dam wall. There is no indication of a sluice at this point, suggesting that A2 predates the dam and was possibly associated with a smaller earlier dam also built to serve the new mill.

The main trackway to the west is has large pieces of brown slag which are believed to have been brought in from outside the area during the 20th century.

Area B

This area had been subject to flooding from Scar Sike before 1995, when a new watercourse was dug out. It is level and covered with sedge grass c 0.7m high, which obscured any features. Apart from a small hillock, this area was not surveyed. In addition, flooding has resulted in considerable deposition of silt which may cover site features.

Area B has been unaffected by the Environment Agency operations and is one of the few parts of the site which may respond to geophysical techniques. One might expect to find the line of the leat to Rookhope Mill running from E to W through the area, together with more features connected with the smelt mill in Area D. This latter may be complete, but its W boundary is abruptly cut by Area B. Finally, there is a raised feature in the middle which deserves further examination.

Area C

There is a series of watercourses, C1-C4, on the higher parts of the fell side to the S of the site (Fig 3). The wide depression C1 cannot be interpreted easily. It is in a direct line with the channel, E5, running through the centre of the site between areas E and F. If it is a continuation of the channel it might be an old course of Scar Sike. In which case, the location of the site immediately adjacent would have been logical, as would the present absence of water or dams in this area. Scar Sike is known to provide a good source of running water, even in dry periods.

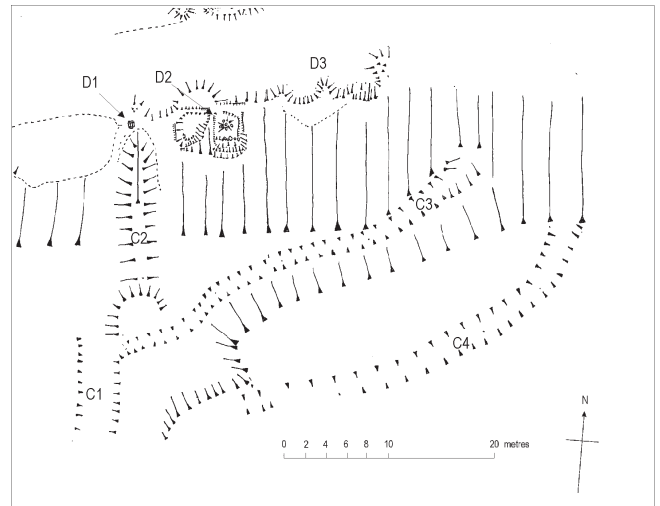


Figure 3: Areas C and D, showing possible smelt mill building, D2, bingsteads D3 and watercourses C1, C2, C3 and C4.

C2 is a ridge, almost certainly artificial and which probably carried a channel or leat supplying water to the building D2. C3 and C4 appear to be leats leading to the main part of the site or spillways diverting water from leat C2. The abrupt ending of C3 and C4 strongly suggests that water was carried by wooden launder from here onwards to provide the required head for the operations below.

Area D

Area D is occupied by the foundations of a two-roomed building, D2, infilled with a tumble of stones (Fig 3). Fragments of lead, lead ore (galena), partially-smelted galena and slag were found here. There is a hole in the wall dividing the two rooms, consistent with a tuyere hole found in simple lead mills. The ground around was either very hard or covered with stones from the building and it was not possible to define the position of a wheelpit or tailrace. Given the height of ridge C2, it is possible that the wheel could have been situated above ground or over a wooden box.

A stone-lined post-hole D1 is situated at the foot of the ridge C2. At its base is a flat square stone, surrounded on three sides by short vertical stones. It is possible that this is one of the pads on which the launder supports rested. Searches were made for similar features but no others could be found.

At least two depressions have been scooped out of the fell side immediately E of building D2. Their purpose is unknown and they may have been the positions of ore or fuel bins. Similar features were observed in a

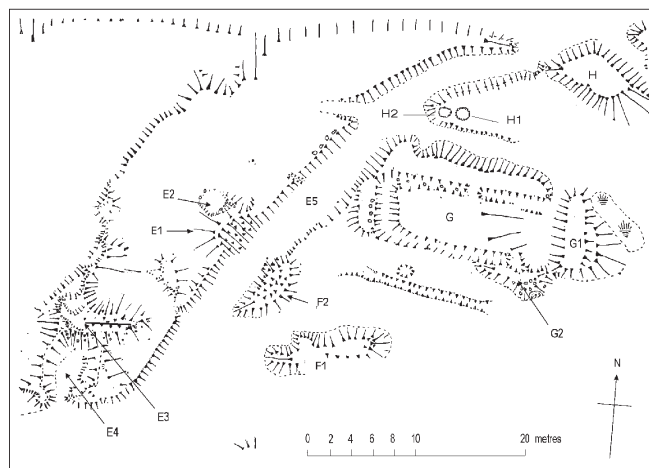


Figure 4: Areas E, F, G and H showing robbed-out building foundations G and locations of finds of metal, G1, and of slag, G2.

recent survey at Knock Smelt Mill on the W slopes of the Pennines (Murphy and Smith 1999).

Excavation to remove the tumble of stones within building D2 and immediately outside its north wall may give more information on its purpose. The superficial indications strongly suggest that this was a smelt mill or a house for a slag hearth.

Area E

This is an area of level ground, separated from D by flood silt and with a channel, E5, running from SW to NE (Fig 4).

E1 is a low heap of slag, of 5-50mm pieces together with occasional 75mm pieces. There are also pieces of coal up to 25mm and cinders or coke. Channel E5 appears to cut through E1 and its possible continuation on the W side at F2.

E2 is a hollow abutting E1. There are occasional bits of slag under the grass but this feature seems to be a compacted floor surface which could not be pierced by the probe. There were some large stones around the edge.

E3 is a large heap, the highest artificial feature on the level part of the site. A fragment of wall runs from E to W through it; some lime mortar was found in a rabbit burrow on the S side but there were no slags. Pieces of slag c 100mm were found on the N side of the wall; some is semi-fused material and therefore indicative of ore-hearth or bale smelting rather than coming from a slag hearth. A rabbit burrow exposed a bed of concreted

grey-coloured slag in a layer at least 100-150mm thick. This was very different from the slags which were scattered over the site.

E4 is a grassed area, immediately S of the wall in E3, and may hide a feature associated with the wall. Probing showed that it had 25-75mm of soil over a uniform compacted surface.

E5 is a large gulley, which appears to be a continuation of the channel C1 and was possibly an old course of Scar Sike. It cuts through features E1 and F2.

Area F

This consists of two heaps containing slag (Fig 4). F1 was exposed by rabbits, leaving large and small pieces of slag in profusion. The westernmost extremity of the heap appears to be entirely stone. The northernmost heap, F2, is cut through by channel E5 and appears to be a continuation of E1.

Area G

The main feature (Fig 4) is an outline of a building, G1, having the typical appearance of robbed-out walls, with interior fill and mortar being turned to either side. A small piece of lead was found under the grass at the E end of G1. The trench is absent at the NE and SE corners, which might be the positions of doorways. A heap, G2, outside the SE corner doorway had been part-demolished by rabbits and consisted of soil and fines with a profusion of 50-100mm slag pieces. From experience at other smelt mill sites, a true slag heap would be expected to consist almost entirely of slag with little or no dilution by soil; nevertheless this might be the case at depth. The finds suggest that this was a second smelt mill, served by water leats C3 or C4. Probing revealed no area corresponding to a wheelpit or tailrace.

Area G has since been substantially obliterated by a lagoon constructed by the Environment Agency.

Area H

Level area H is grassed and has few obvious features. A large heap H1 (Fig 4) on the bank leading down to Rookhope Burn consisted of stones with large pieces of slaggy material on top. These were heavy and part smelted. H2 is a bare patch with no vegetation, showing small pieces of broken slag, 5-25mm across, on the surface, with a large quantity of sandy material

containing spar of the same size. H3 lies immediately E of H2 and consists of a flat patch with slag continuing underneath the grass.

Area H has since been substantially obliterated by a lagoon constructed by the Environment Agency.

Area I

Area I (Fig 5) is predominantly occupied by leat I1, leading to Rookhope Mill, c 200-300mm wide in those places which were probed.

Area I has since been substantially obliterated by a lagoon constructed by the Environment Agency.

Area J

This is an area of mine shafts on the fell side, not included in the survey.

Area K

The features here are (Fig 5):

K1 is a hollow. Large stones and outlines of possible wall foundations suggest that K2 may have been a building or enclosure. Finds comprised a few pieces of slag on the surface and one piece of weathered ore.

K3 is a gulley leading down to Rookhope Burn with large (100-150mm) pieces of slag c 40mm thick under a surface of grass at the W end. Some part-smelted material was also found.

K4 is a long heap consisting of 25-75mm slag pieces and many 5-15mm pieces of spar, which are widespread on the level part of this area and on the bank sides. K5 is a long heap similar to K4, but with more grass.

K6 is a long heap with 5-15mm pieces of spar under grass, some small bits of slag and some ore. Unlike K4 this was almost completely grassed over. Features K4, K5 and K6 may have been the remnants of larger heaps which had been removed, or overspill from wooden decking.

K7 is a gulley separating Areas H and K, leading to the Rookhope Burn.

K8 is a major track, possibly the main access road to the site and now disused. It crosses the Rookhope Burn

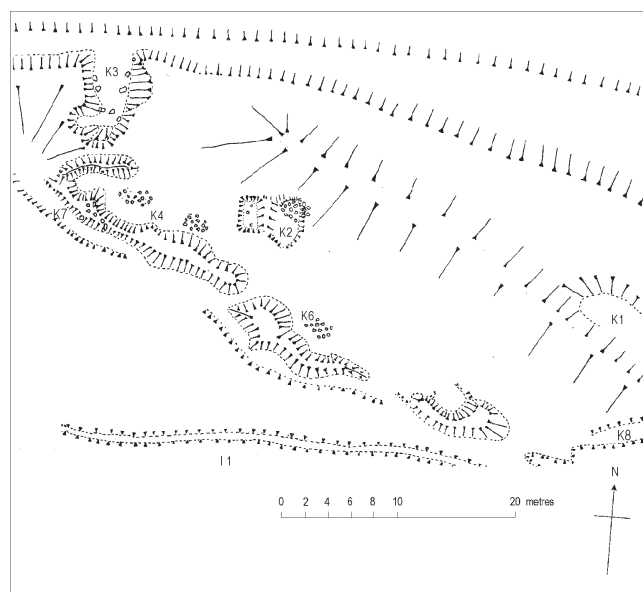


Figure 5: Areas K and I.

at about the only point on the site where there are no steep banks and where the burn might be forded.

Area K has since been partially obliterated by a lagoon constructed by the Environment Agency.

Microscopy and analysis of slags

Slag samples were examined using a scanning electron microscope (SEM) fitted with an energy-dispersive X-ray microanalyser (EDX). The SEM/EDX examinations were much more extensive than can be described here. We have sought to give an accurate report of the main types of slag found on the site and to illustrate these by examples.

Mid-grey slags

The main slags found throughout the site occur as flattened pieces, generally up to 100mm diameter by up to 50mm thick and occasionally larger. The rough nodular appearance and flow marks indicate that they had been produced as a viscous or semi-solid melt which flowed with difficulty. When sampled in 1995 our opinion was that these were high-lime lead smelting slags—this view has since been confirmed by the analytical work. The term ‘grey slag’ is used throughout this paper to describe the colour of the slag. There is no implication that the slags found on this site were produced by a single pass in an ore hearth.

Many of the specimens cut and prepared for examination in the SEM had occasional spherical

inclusions of lead (up to 1mm diameter and in rare cases larger); large gas vesicles were generally absent although nearly all had small vesicles of <1mm diameter. The overall visual appearance of the cut surfaces was of a compact, solid mass with few features or inclusions.

SEM/EDX showed the slags to be consistently high in calcium (Ca) with lower amounts of iron (Fe) and silicon (Si). Semi-quantitative analysis on large areas (typically 3mm square) showed 50-70% Ca, 5-20% Si and 5-20% Fe with 0-5% aluminium (Al) and 0-5% fluorine (F). This is the range obtained on slags of this type from various locations throughout the site. There did not appear to be any significant variation between locations.

Examination at magnifications of x200 to x10,000 showed the presence of high-Ca-Si phases which had solidified first in a matrix of Fe-Ca-Si with smaller amounts of Al (Fig 6). The Fe-Ca-Si phases also contained trace metals particularly manganese (Mn) and zinc (Zn). Although there is a spectral overlap of the sulphur (S)-K α and lead (Pb)-M peaks and distinction between these elements is normally difficult, it was possible to confirm S-rich inclusions in the Fe-Ca-Si phase, as other Pb peaks were absent. Examination at high magnifications showed that these were patches of iron sulphide (matte). The high-Ca phase varied

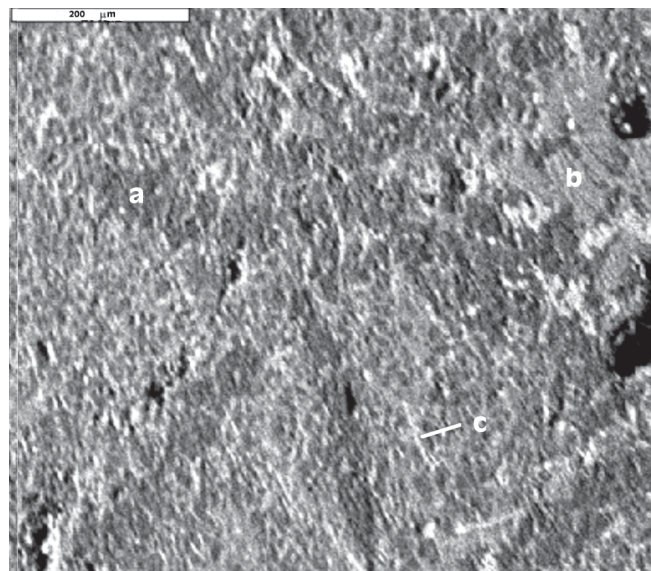


Figure 6: Back-scattered electron image of typical mid-grey slag sample from building D2 at x200. The dark grey star-shaped phase (a) is high-Ca with some Si and probably a high-melting calcium silicate. The mid-grey phase (b) which surrounds it is Fe/Ca/Si-rich. The very light grey streaks (c) were examined at higher magnification and were principally Fe with some S. This is very similar to the phase relationships in Fig 7.

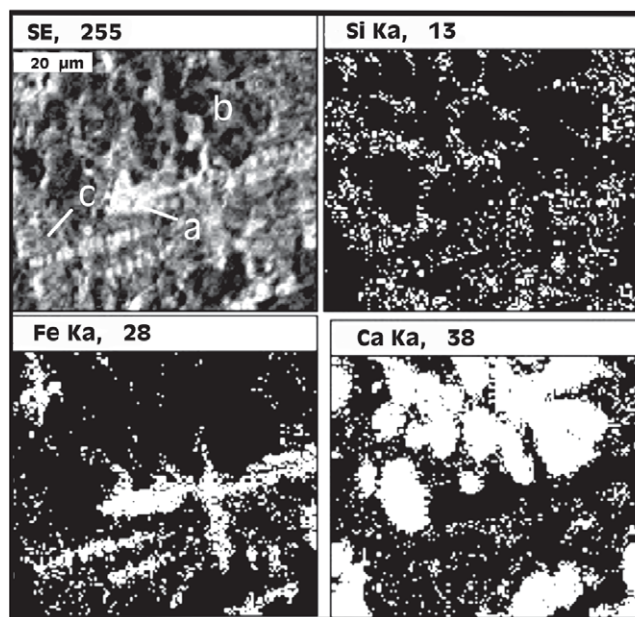


Figure 7: Back-scattered electron image and element maps of typical mid-grey slag from building D2 at x1600. Upper left: back-scattered electron image; upper right: silicon; lower left: iron; lower right: calcium. The field of view is 70μm wide x 50μm high. Note the light-grey high-Fe phase which is not associated with other elements (sulphur was not detectable) and so is probably wustite or metallic iron. The darkest phase is coincident with the high-Ca areas which has no other elements with the possible exception of F which appeared at low levels throughout this sample. Si is associated with a mid-grey phase which is difficult to discern. This phase has some Ca and Fe and appears to be a silicate matrix having the lowest melting point of the phases seen here.

between samples. In some, it was accompanied by F and in others small amounts of Si (up to 10%) were present, while others showed Ca only.

Samples were scanned across the field of view for specific elements (elemental mapping). This showed very clearly the presence of high-Ca regions surrounded by a matrix of Fe-Ca-Si (Fig 7). The rounded edges of the high-Ca regions suggest that the slag was initially fully molten and that the phase had solidified from the melt. There was no evidence either with secondary electron imaging or in back-scattered mode that the high-Ca domains were unreacted inclusions.

These slags are clearly derived from ores containing Fe-Si-Al together with a source of calcium such as calcite, fluorspar and possibly limestone.

Figure 8 shows an interesting sample of slag with some partly-smelted material and some secondary weathering of lead minerals (probably sulphate or carbonate).

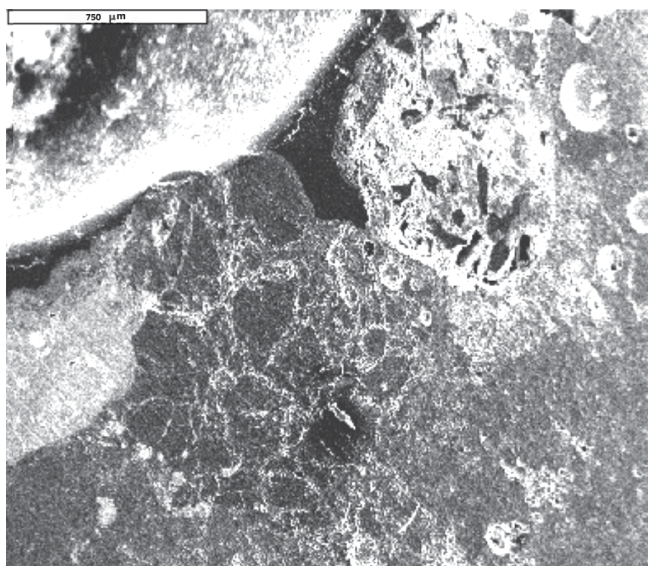


Figure 8: Secondary electron image of slag sample from K4 (x60). This is a mid-grey slag similar to those found elsewhere on the site, but with partly reacted and altered components. The sample had a 1mm diameter sphere of lead in the centre (not shown on this image). The mid-grey phase at the lower right and bottom is slag, showing small gas vesicles c 50 μm diameter (cf Fig 6). The light grey patch to the left is a piece of Pb or PbS. Within it are smaller areas, also of Pb with possible S present. The central area is composed of fragments of material containing Si only, probably unreacted silica. The honeycomb area to the right is Pb with possible S, together with a surrounding halo of Ca/Si containing a trace of Fe. The three areas suggest that this is a piece of incompletely reacted slag, or slag which has come into contact with fragments of ore after tapping.

Crushed slags (Area E)

The heap of crushed slag (E3) appeared at first sight to consist of the ubiquitous mid-grey slags cemented together by weathered fine material (Fig 9). The cemented bond was very strong and did not allow the sample taken to be crushed further for a reliable sieve analysis. The bond appears to have been formed by dissolution of sparingly-soluble calcium salts and their subsequent conversion to calcium carbonate by reaction with atmospheric carbon dioxide. The source of the calcium is almost certainly the slag itself as most of the pieces encountered on or near the surface show signs of superficial weathering; some of the others buried in moist ground show more substantial disintegration.

On SEM/EDX examination important differences from the mid-grey slags were noted:

- Pb or PbS inclusions were irregular in shape rather than the spherical form found in most of the mid-grey slags.
- Several cases of Pb or PbS attached to, or part

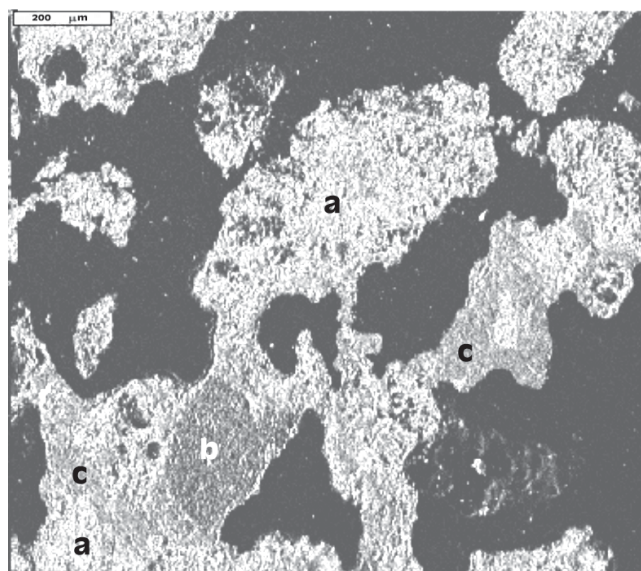


Figure 9: Back-scattered electron image of cemented, crushed slag sample from E3 (x100). It consists of mid-grey slags, but with discrete patches of other material. The majority appears as a very light grey matrix (a) containing Si, Al, Pb, Ca and F. At x240, Ba and Zn could also be detected in parts of this matrix. The darkest grey patch in the lower left quadrant (b) appears to be an unreacted piece of silica. The mid-grey phase evident in several places in the lower half of the image (c) contained Ca only. The resin mount appears black.

of pieces of slag were noted, showing that smelting was incomplete.

- Although many of the pieces had the Fe-Ca-Si matrix found in the mid-grey slags, there were also discrete pieces having only calcium or silicon detectable.
- Some of the Fe-Ca-Si areas were complex and contained Pb, Ba, K, F and Zn. Some of these trace elements would normally be diluted beyond the limit of detection after melting; these appeared to have undergone little or no mixing in the melted phase.
- Where cemented junctions could be defined the agent appeared to be Ca with other detectable elements absent.

Brown slags

The track which runs approximately N-S from the bridge over Rookhope Burn at the W end of the site, has many pieces of dark brown slag on it. The pieces are 50-250mm in diameter and have many gas vesicles. They are only found on the track and form a significant part of the track material. SEM/EDX examination showed the presence of small spherical inclusions of metallic iron. The slags contained Al, Si and Fe with no other elements detectable. In all relevant respects they were very different from the other slags found on

the site and are believed to be iron-working slags, brought in to make the track.

Discussion

Although there is little historical evidence relating to the site, there is a unanimous local tradition that this was the precursor of Rookhope Smelt Mill, situated to the E, down the valley. The presence of ore, part-smelted material, slags and metallic lead, when taken with the site features, confirm the tradition.

One of the more obvious conclusions from the survey has been the change in access arrangements. At present this is by a bridge at the W end of the site, constructed over the Rookhope Burn, although this is constantly endangered by river flooding. In the absence of a bridge it would be virtually impossible to cross at this point. This bridge leads to a track containing a high proportion of iron slag and which continues in a S-E direction across the fell. An alternative and probably older access point is at the ford at the E end of the site where there is a track (Fig 2) and a convenient crossing.

Area K (Figs 2 and 5) is nearest to the ford and would have been the place where raw materials entered the site, assuming that they were brought from across the burn. Not surprisingly this is the area where mining waste was found. Almost all of this material had been removed, leaving only fragments of the heaps, and a profusion of pieces lying around the barren flat areas where the heaps appear to have been. The nature of the debris, angular broken stone and pieces of spar, suggests that some form of ore dressing or sorting took place here. However, it is not possible to show if this activity was contemporaneous with smelting or the result of later mining on the nearby veins. It is the only place on the site where there is convenient access to the Rookhope Burn; elsewhere there are short but steep banks. There are also traces of a small stone structure in this area.

Building G (Figs 2 and 4), in the centre of the site, may have been a smelt mill; there is slag and lead nearby. However, more evidence based on internal structure, wheelpit etc would be desirable. This feature has been partly destroyed by the Environment Agency works.

There is more evidence of Building D2 (Fig 3) being used as a smelt mill. The internal wall structure, with its tuyere hole, arrangement of leats, and the finds, confirms this fairly conclusively. It is also situated in the most obvious location, near the higher ground,

where a good head of water can be obtained, needing only a short launder to supply a waterwheel. This, together with its smaller size, suggests that it would have pre-dated any mill at G and it is also possible that it could have been retained as a slag hearth after the main operations were transferred to Rookhope Smelt Mill. However, none of the slag from D2 is a typical slag-hearth product (see below).

The area of crushed slags at E3 (Fig 4) is conveniently close to both possible smelt mill locations, at G and D2. These slags are more heterogeneous than those found elsewhere and contain small amounts of lead, suggesting that they have been obtained from a first run in an ore hearth. The fragment of wall in the middle of E3 suggests that this was an area devoted to slag treatment, rather than merely a stockpile. If so, leat C3 could have been for bringing water for washing and possibly for crushing.

Explaining the occurrence of slag on many parts of the site remote from the two buildings at D2 and G (Table 1) is a difficulty which cannot easily be solved. Some slag may be the result of moving stockpiles, either during the transfer to Rookhope Smelt Mill or from other sites such as bales or early mills.

Lead smelting processes

Turning to the smelting processes which might have been employed, the slag finds and features give an indication of what might have been present. It is reasonable to discount the presence of reverberatory smelting or roasting, on the grounds that although the technology was available at the beginning of the 18th century, both furnaces would require a large building to house them and provide adequate clearance for working. There is no evidence of suitably large buildings at Rookhope. Roasting hearths were not common in the north of England until early in the 19th century.

The most likely technology for this situation and period is the ore hearth. It was popular throughout northern England from the last quarter of the 16th century until the 20th century, and was well-suited to intermittent operation with wood, peat, coal or mixtures of these as fuels. The two small buildings at G and D2 are large enough to accommodate the hearth and bellows, and both have traces of leats which would have supplied water to the wheels driving the bellows. Furthermore, building D2 has a tuyere hole in the central wall between the bellows room and the furnace room.

Table 1: List of features and associated metallurgical finds

Area/feature code:description	metallic lead	crushed slag	slag	part-melted residue	lead ore	fluorspar	coal, coke or cinders
A: track			✓				
D2: hut	✓*		✓	✓*	✓		✓
D3: bingsteads			✓				
E1: heap			✓				✓
E2: hollow			✓*				
E3: heap		✓					
F1: heap			✓				
F2: heap			✓†				
G1: heap at building	✓*						
G2: heap at building			✓				
H1: heap			✓	✓*			
H3: bare patch			✓			✓	
K2: building			✓*		✓*		
K3: gully			✓	✓*			
K4: heap			✓			✓	
K5: heap			✓			✓	
K6: heap			✓			✓	

Note: * rare occurrence; † probably contains slag but not established

The ‘grey slags’ produced by the ore hearth were typically high in lead; levels of 20-35% Pb were normal for a first run slag. Contemporary accounts (Mulcaster 1971, Pattinson 1831) give the reason. Ore was roasted on the surface of the fuel and later smelted in the reducing parts beneath. Low-melting components of the ore (mainly lead sulphide), litharge (lead oxide) produced in roasting, and slag of some compositions, could all melt and bring a halt to any further reaction, by preventing oxygen or carbon monoxide from reaching the part-smelted mass, which was known as ‘brouse’. To make matters worse, the ore hearth became hotter as the shift progressed; the brouse became ‘pasty’ and eventually the furnace had to be stopped and allowed to cool. This fitted in well with local practices of working one or two shifts. The lead content of the slag could be present as metal, silicate, sulphate, oxide or sulphide, as well as mixed species such as basic sulphates. It was a complex mixture and, as some of these species had low melting points, the smelters mixed lime with pasty slags to make them more manageable. We do not know if deliberate additions of lime were made at Rookhope Old Mill but calcite and fluorspar are commonly present in the vein mineralization and would have provided a source of calcium.

Ore hearth slags were often crushed and washed to remove prills of metallic lead, before re-smelting in the ore hearth or in a slag hearth. The latter was a short blast furnace having a shaft 0.5-1.0m in height and a single tuyere. The slag hearth was a direct descendent of the ‘blackwork oven’ used in medieval times to treat bale slags, and of the later German blast furnace used for smelting roasted lead or copper ores. It was used from the start of the 17th century; in most instances it was built after an ore hearth had been running for some time. The slag hearth produced a ‘black slag’ and was tapped intermittently—it could routinely produce slags with less than 0.5% Pb and had the capability of performing better than this under favourable conditions. Crushing and washing was normally carried out to remove prills of lead, and visitors to the smelt mill sites in the Yorkshire Dales mills will see large heaps of finely-ground slag, nearly always cemented together to a hard mass by the action of weather. Confusingly, the cementitious deposit usually gives the slags a grey appearance. There are no similar heaps on this site, although the crushed slag at E3 is bonded by a cemented deposit.

The important question here at Rookhope Old Mill is how slag cleaning was carried out. Was there a slag hearth or were slags cleaned by repeated ore-hearth

smelting, crushing and washing? There are arguments for both routes. The slags have very high calcium contents and this has two major effects. Firstly it will displace elements of lower electronegativity, such as lead, from a silicate; secondly, it will produce a slag with a high melting point. This favours the argument that the ores here could have been worked successfully with an ore hearth alone. Repeated smelting would have been necessary to eliminate sulphur and hence losses of lead as sulphide or sulphate. The main disadvantage with this approach would be the long time taken for ore hearth smelting and hence high wage and fuel costs.

A much cheaper approach would have been to install a slag hearth. This would operate much faster, and one slag hearth could typically treat the slags from four to six ore hearths. The main drawback to the installation of a slag hearth at a simple site such as this would be the relatively high capital cost, for a piece of equipment which would stand idle for most of the time.

One solution used at some of the early Yorkshire smelt mills (for example at Beldi Hill, Grovebeck/New Mills and the early Surrender Mill) was to build an ore hearth and introduce a slag hearth once a stockpile of valuable material had been accumulated. A second approach has been suggested (Murphy 1992) for some single-hearth mills (such as Buckden High Mill, Lumb Clough and Hoggett Gill in Cumbria). The appearance and low lead contents of the slags from these sites are not consistent with ore hearth production and it has been proposed that the ore hearth could have been converted to a slag hearth for a short period simply by building up the sides *eg* with firebricks, heat-resistant stone or cast iron blocks.

The slags at Rookhope Old Mill support the interpretation that only ore hearths operated there. They are flattish plates of up to about 100mm in diameter and 50mm thickness. They have very pronounced run marks, and for the most part have been fully molten but do not have the appearance of a free-running slag. They are more consistent with the use of an ore hearth, where small shovel-fulls of slag would be placed on the workstone for lead to separate, rather than with a slag hearth. With the latter, one would expect to have large pieces of slag—the result of a single tapping. These would have been broken before disposal, and would have many fractured edges. However, if the Rookhope Old Mill slags came from a slag hearth, they must have been tapped out with considerable difficulty. Further experimental work might resolve this problem, *eg* by running some of the slag in a small furnace, or

determining the melting range by differential thermal analysis or a related laboratory technique.

Figure 10 shows a reconstruction of the smelt mill in Area D, based on the foundations of the two-roomed building, the watercourse leading to it, and the lined post hole at the foot of the ridge, which appears to have carried a launder to supply the wheel with water. There was no evidence for a wheelpit, and as this would have been one of the more enduring features of the site, it is suggested that the wheel would have been supported on a wooden framework, running in a trough from which the tailrace would have issued. The chimney has been shown as supported by a lintel which formed the ore-hearth arch. This is similar to that shown in a drawing, dated 1735, of a smelting mill in Yorkshire, probably at Spout Gill (Clough). The older ore hearth mills (*eg* Hoggett Gill, Buckden High Mill, Knock and Lumb Clough) appear to have been built with a lintel like this, whereas masonry ore hearth arches such as those at Surrender, Old Gang and Marrick leave clear traces, particularly at the main longitudinal wall of the building.

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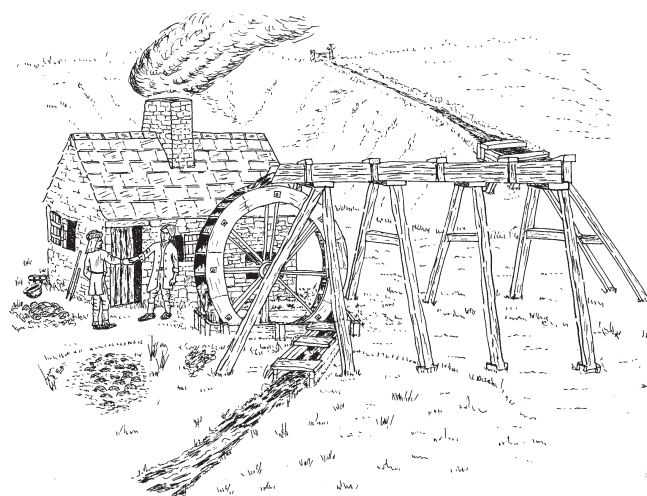


Figure 10: Reconstruction of the smelt mill in Area D.

References

- Fairbairn R A 1996, 'Weardale Mines', *British Mining* 56.
- Mulcaster J 1971, 'An account of the smelting of lead ore as it is practised in the northern part of England in c 1795' *Bull Hist Met Group* 5 (2), 45-62.
- Murphy S 1992, 'Smelting residues from boles and simple smeltermills' in L Willies and D Cranstone (eds) *Boles and Smeltermills* (Matlock Bath) 15-8.
- Murphy S and Smith R 1999, 'Smelting Mills of the West Pennines—Knock Smelt Mill', *British Mining* 63, 104-17.
- Pattinson H L, 1831, 'An account of the methods of smelting lead ore and refining lead practised in the mining districts of Northumberland, Cumberland and Durham in the year 1831', *Trans Nat Hist Soc Northumberland and Durham* 2, 152-77.
- Clough R T, 1962 *The Lead Smelting Mills of the Yorkshire Dales*, 40 (Keighley).

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