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HILTON MINE, SCORDALE, CUMBRIA
IDENTIFICATION OF MINERAL SAMPLES

TECHNOLOGY REPORT

Sarah Paynter

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Scordale,
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SUMMARY

Archaeological remains at the site of the former Hilton and Murton mines in Scordale, Cumbria, a Scheduled Monument, are being severely eroded. A programme of survey and excavation was initiated to investigate and record the features, which were associated with the extraction of lead ore and the barium minerals barytes ($BaSO_4$) and witherite ($BaCO_3$) at different periods over the last 200 years. Numerous samples were taken during the excavation to help link the surviving features with these different mining and mineral dressing activities. Much of the area investigated was covered by gravel-like waste from lead ore dressing. Evidence for barytes processing was found in Trench 1. The function of the building in Trench 2 is unknown. The buddles in Trench 4 were used for lead ore processing, but the samples from these areas comprised re-deposited waste. The function of the mill in Trench 5 is unclear, although no evidence for the processing of barytes was found in this area. None of the samples from the site contained witherite.

CONTRIBUTORS

Sarah Paynter

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INTRODUCTION

North Pennines Archaeology Ltd undertook an archaeological field evaluation at the site of the former Hilton and Murton mines at Scordale, Cumbria, on behalf of the Defence Estates (Giecco 2007). The site is a Scheduled Ancient Monument (27842) centred on grid reference NY 7612 2254, extending for several kilometres along both sides of a steep-sided valley.

The Hilton and Murton Mines are documented as producing lead concentrates under the London Lead Company from 1824. Production ceased in 1876 but the mines were reopened in 1896 by the Scordale Mining Company and worked for witherite ($BaCO_3$) and latterly barytes ($BaSO_4$) by various companies until the 1920s, including the Brough Barytes Company from 1906 and Scordale Barytes Limited from 1912 until at least 1921 (Carruthers *et al.* 1916; Giecco 2007; Hunt and Ainsworth 2007; Wilson *et al.* 1922).

Many areas of the valley are being rapidly eroded by water. A survey programme identified features of particular significance that were suffering damage (Hunt and Ainsworth 2007) and these were evaluated archaeologically by North Pennines Archaeology Ltd by means of five trenches, listed in Table 1 (Giecco 2007). The trenches were numbered 1 to 5 and also assigned letters A to E; however only the numbers have been referred to here to avoid confusion with the letters previously attributed to areas of the Scordale valley in the survey report by Hunt and Ainsworth (2007). Trenches 1 to 5 were sited in an area corresponding to Area B of that survey. Hunt and Ainsworth (2007) also attributed unique numbers to features, which were recorded on a GIS database, and these numbers are used in this report as well (eg. dressing-mill 27) (Figure 1).

Table 1: Features and samples from each trench at Scordale (not all of the samples were examined in detail)

Trench	Features	Mineralogical samples
1	Waste tip south east of large crushing plant with series of timber-built drains	2, 3, 4, 6, 7, 19, 20, 21, 22, 23, 24, 25, 26, 36, 37
2	North west corner of a small stone building	None. Environmental samples 3 and 4 examined.
3	Bridge abutment	None
4	Group of three buddles (A to C)	A: 17 (2 monoliths) B: 8 (2 monoliths), 27, 30, 31, 32, 34, 35 C: 28, 33
5	Small building adjacent to wheel pit	9, 10, 11, 13, 14, 16

AIMS

The primary aim of analysing samples from Scordale was to identify the minerals present, and thus determine the function of the associated features. A secondary aim was to evaluate different approaches to sampling and analysis, so that the most appropriate techniques can be adopted for similar work in future, for example the North Pennines Miner-Farmer Project (Ainsworth 2008).

GEOLOGY

Forbes *et al.* (2003) and Bulman (2004) provide comprehensive summaries of the North Pennines geology and how this relates to the mining industry of the area. In the Scordale valley the Carboniferous rocks of the North Pennines are exposed, composed almost entirely of layers of limestones, sandstones and shales. The Melmerby Scar Limestone is especially prominent, above which the Whin Sill is intruded; the latter made up of sheets of hard, black dolerite rock, forming dark grey crags in the valley landscape. Several mineral-rich veins cut these rocks in the valley sides and, in the Melmerby Scar limestone, well developed flats are associated with most of the veins. Veins are sheet-like bodies of minerals filling roughly vertical cracks in the surrounding rocks whereas flats are approximately horizontal and may extend for many metres from the side of a vein. In some flats much of the limestone was replaced by iron minerals. Flats were important mineral sources at the Hilton and Murton mines in Scordale (Bulman 2004; Forbes *et al.* 2003).

Dunham (1990) plotted the distribution of veins and mineral zones in the North Pennines and mapped out a central zone containing abundant fluorspar, whereas fluorspar was absent outside this zone, with barytes and associated minerals being found instead; both minerals were found in small intermediary areas between these zones. Scordale is shown as a small, isolated, fluorspar zone within the barium region; the Scordale mines are well known for deep amber fluorspar crystals as well as large, white, platey crystals of barytes (Forbes *et al.* 2003).

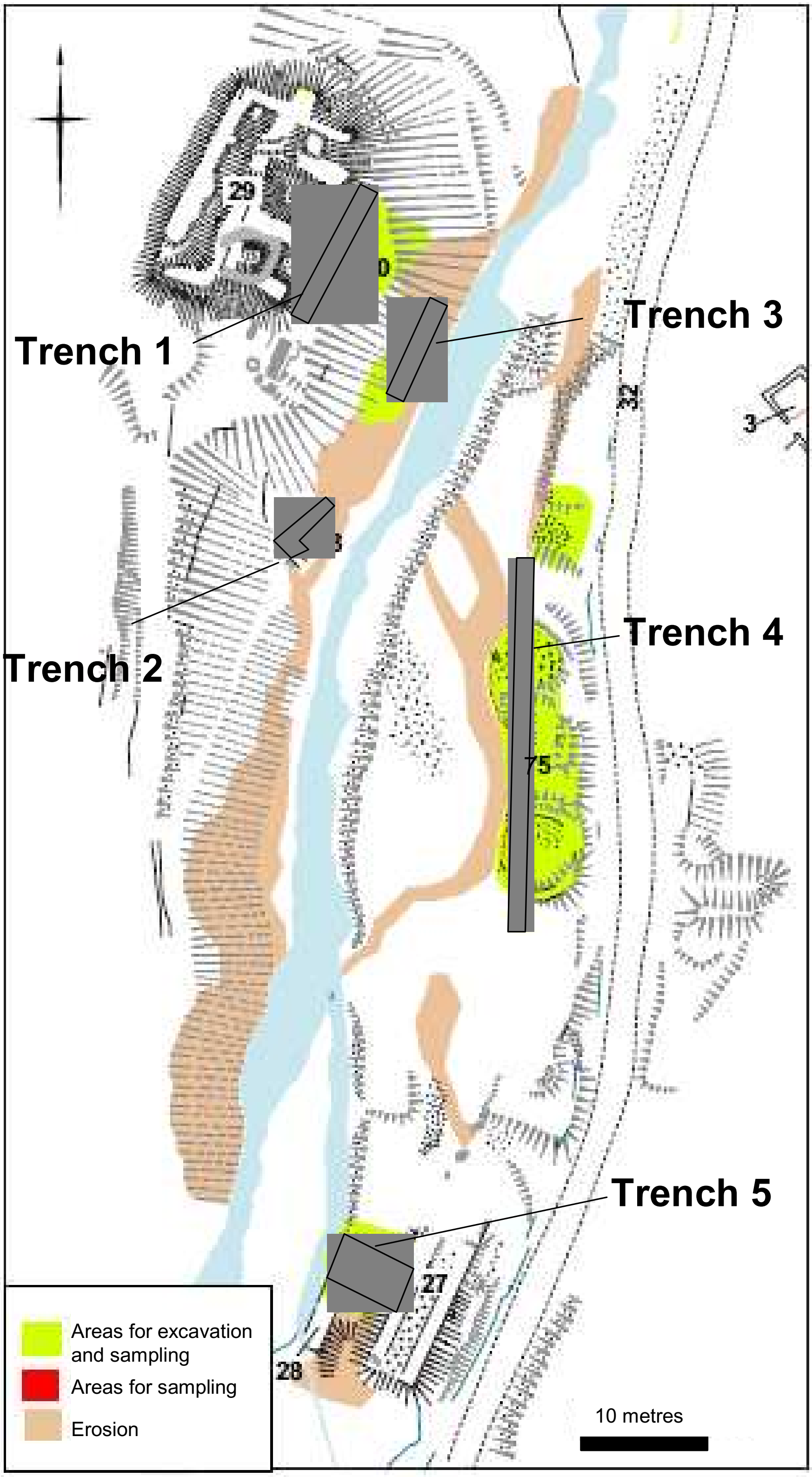

Figure 1: Location of trenches 1 to 5 superimposed onto a plan of survey Area B from Hunt and Ainsworth (2007), showing the position of the mills (27 and 29), the circular buddles (75) and the small stone building (28).

METHODS

The samples were all examined and described in terms of the different material present. The types of stone and mineral were differentiated initially by appearance (for example colour, lustre, shape and type of fracture), although some of the minerals are difficult to distinguish by eye. Low power microscopes were also used.

Other techniques were then employed as necessary to identify the material, including X-ray fluorescence (XRF) spectrometry. XRF is a rapid technique that could be used to spot-check the identification of minerals. The XRF is an EDAX Eagle, which targets an area of approximately 0.5mm across, using a tube voltage of 40kV and a variable current. This XRF can detect elements such as calcium, lead, silicon, zinc, sulphur and barium, but cannot detect light elements, such as fluorine or carbon. For example it is not possible to distinguish between limestone ($CaCO_3$) and fluorspar (CaF_2) using XRF; only calcium will be detected in each case. Another limitation of the equipment for this particular application is that it targets a small area for analysis. Most of the samples from Scordale contained numerous fragments of rock and mineral, from gravel-sized (fragments of around 5mm or less) to large boulders. In these cases it is not possible to obtain a representative analysis of the complete sample without processing it, for example by powdering.

Dilute hydrochloric (HCl) acid was used to test for the presence of carbonates. X-ray diffraction (XRD) was also used for certain samples. XRD identifies minerals based on their structure, rather than their composition, and is therefore able to distinguish compounds even when they are differentiated only by elements that are difficult to detect by other techniques, for example fluorspar (CaF_2) and calcite ($CaCO_3$) or different forms of iron oxide.

The samples were sieved through different mesh sizes to determine the proportions of fragments of different sizes present in each sample and the separated fractions were then weighed (Appendix 1, Table 2). Varying proportions of particular minerals in each size fraction influence the results when presented as wt%, as some of the minerals present have vastly different densities from each other, for example galena (PbS) relative to quartz (SiO_2). In practice, however, only samples with broadly similar mineral assemblages were compared.

RESULTS

In general, the samples fall into two categories, indicative of the type of activity taking place. Certain samples from Trench 1 (see later) were dominated by barytes ($BaSO_4$) and fluorspar (CaF_2) indicating barytes processing. The majority of other samples contained little barytes or fluorspar, but a significant amount of angular calcite, and are likely to be by-products from the mining and processing of lead ore.

The first category of assemblage is dominated by barytes, which is a white to transparent mineral with a slight sheen (Figure 2). The more transparent fragments also contain a substantial amount of strontium, which can substitute for barium in this mineral series (Deer *et al.* 1992). These samples also contain varying amounts of dark- or orange-coloured stone, which is iron-rich (Figure 3). XRD analysis identified these iron minerals as goethite (FeO.OH) and some siderite ($FeCO_3$), with patches of galena (PbS), cerrusite ($PbCO_3$) and quartz sometimes present. In addition, opaque, grey limestone (Figure 4) and large, transparent, amber crystals of fluorspar (Figure 5) are present.

Figure 2: Barytes fragments

Figure 3: Dark iron-rich stone, banded with orange; the lower piece has quartz crystals on its upper surface.

Figure 4: Pale grey limestone

Figure 5: Fluorspar crystals

The second category of mineral assemblage also contains white and translucent minerals, but in this case these are mainly angular fragments of calcite (Figure 6), with some quartz (Figure 7). Again, fragments of opaque grey limestone and dark or orange-coloured, iron-rich stone are present, plus occasional barytes.

Figure 6: Calcite

Figure 7: Quartz crystals with differing appearance

Trench 1

This trench was sited to the south-east of mill 29, a large crushing plant, which was being actively eroded (Hunt and Ainsworth, 2007). The mill was shown on mapping from 1861, but was expanded significantly or replaced by a larger mill during the period 1861 to 1899. Photographs of the mill when it was still operating, probably in the early 20th century, show a number of timber or corrugated iron structures between the mill and Scordale Beck. The mineral products were fed by timber chutes to loading areas below the mill (Hunt and Ainsworth 2007).

The trench was sited over a substantial waste tip of fairly homogenous material (198, sample 26), which spread in all directions (Giecco 2007). This was sealed by a slightly coarser gravel (197) from which sample 22 was taken. Samples 26 and 22 are similar, both containing some calcite, a large proportion of dark, orange-tinged stone, some limestone and some barytes. Occasional large fragments of fluorspar and barytes are present in sample 22, but these appear to be contamination from the material within the timber conduits above (see later). Otherwise, the mineral fragments are generally less than 5mm in size. The size and type of minerals present suggests that these waste tips are probably a by-product from lead ore processing during earlier phases of the crushing plant's use.

This trench also contained a number of timber conduits (Figure 8), with distinctive fills (see Hunt and Ainsworth 2007, feature 47). A variety of size fractions, from sand to gravel-sized, are recorded but the processed samples from these fills are dominated by barytes. Barytes processing clearly took place during the final phase of mill use.

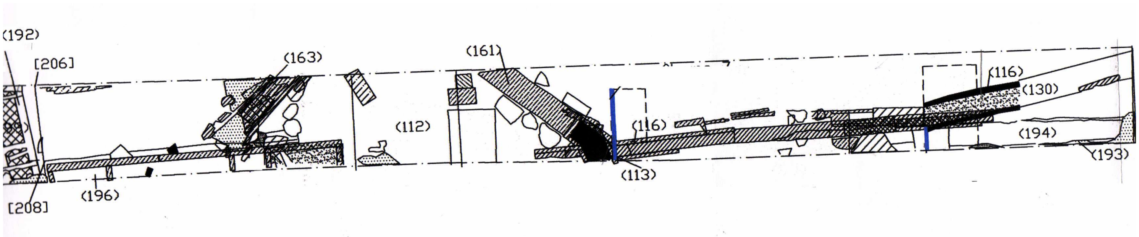

Figure 8: Plan of Trench 1, from Giecco (2007), showing the timber shutes near crushing mill 29 used in barytes processing. The trench is aligned north-east (left) to south-west (right).

Further examination of the samples provides more information about the different stages involved. Sample 37 is from the fill of a conduit (192) at the far north end of the trench (Figure 8), which was constructed differently to the others in this area and more robust. This sample is distinctive because, although dominated by barytes, there is a large proportion of gangue (waste rock), including dark stone and significant amounts of fluorspar (Figure 9). Large fragments are also present, with about 40wt% of the processed sample over 5mm in size. This conduit appears to be carrying relatively unprocessed material into the mill area for subsequent separation of the barytes. The more robust construction of this conduit, relative to the other chutes in the area, may have been necessary because it was part of a system carrying material over a greater distance and / or because it carried a larger volume of material, however it is probably contemporary with the other chutes because it contains a similar suite of minerals.

Figure 9: The 5mm to 16mm fraction of sample 36 (left) and sample 37 on the right at the same scale; sample 36 is predominantly barytes, with very little gangue, whereas sample 37 contains a considerable amount of gangue, including fluorspar (amber), limestone (grey) and iron-rich stone (dark brown / orange).

The remaining conduits shared a similar construction to each other. Sample 23 was taken from fill 167 of conduit 163, also towards the more northern end of the trench. This contained many small wood chips from the timber construction, and the results must be interpreted with caution as the lid to this chute had collapsed, contaminating the contents. Although this sample was again dominated by barytes it also contained an intermediate proportion of gangue material, including some dark, orange-coloured stone and fluorspar and a small amount of grey limestone, but nearly all fragments in this sample were less than 5mm in size (Figure 10). This material has therefore been crushed or passed through a sieve and possibly some of the gangue removed relative to sample 37.

In the more southerly end of the trench, sample 3 was taken from the primary fill of chute 113, which discharged into chute 116. This small sample contained a good proportion of fragments in excess of 5mm and very little gangue, although sample 4, from the secondary fill of this chute, contained a larger proportion of gangue. Sample 36 was taken from the fill (203) of chute 116 and contained very little gangue and a fairly large size range with about 64wt% of the processed sample in excess of 5mm, including some large pieces of barytes. The material in this chute has therefore been processed to remove most of the gangue, perhaps by hand picking.

Finally sample 24 derives from fill 201 of drain 193. This sample was again dominated by barytes with very little gangue; the latter comprising occasional small fragments of iron-rich dark or orange-coloured stone, grey limestone and fluorspar. Over 85wt% of this sample consisted of fragments under 5mm in size (Figure 10), suggesting that the fill had been crushed or passed through a sieve. Although this chute was recorded as an earlier phase on the basis of stratigraphy (Giecco 2007), the nature of the fill again suggests that it is contemporary with the other chutes; its lower level position relative to the other conduits may be because it is carrying a finer, more refined product from the final stages of the processing.

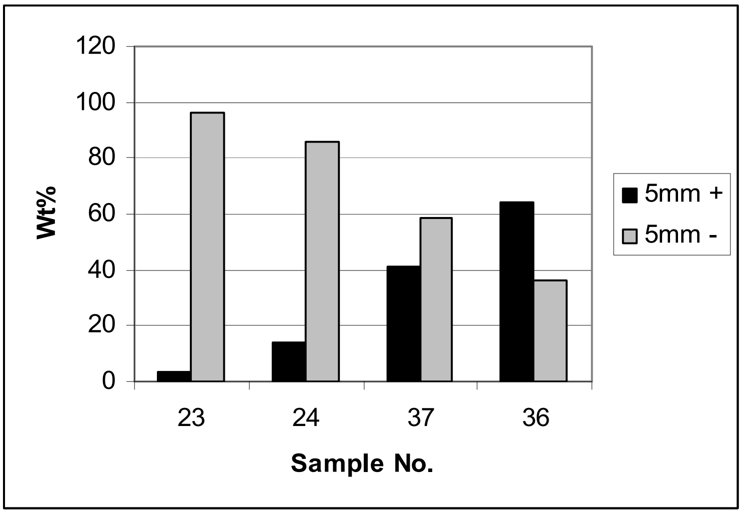

Figure 10: The proportions of each processed sample from the chutes in Trench 1, greater than (+) or less than (-) 5mm in size, by weight %. Note that the fraction under 250 microns is not represented since it was removed during sample processing.

Documentary accounts suggest that waste from lead ore extraction may have been reworked on occasion for barytes. No clear evidence of this was found amongst the samples examined, although it is likely to be difficult to detect. The lead ore dressing waste in the vicinity of the mills is gravel-sized, which would make recovery of barytes more difficult, and so reworking may have taken place primarily amongst the waste tips nearer to the lead levels, where initial separation of lead ore and gangue took place.

Trench 2

This trench was sited in the northwest corner of a small stone building, subject to erosion. Deposits 102 and 103 above the floor surface in this area were thought to derive from the adjacent crushing plant although another possibility was that the building was used for mineral storage at some point. Although no samples were taken for mineralogical examination from this building, some of the environmental sample residues were examined because of specific questions raised following the archaeological investigation (Giecco 2007).

The samples from this area are clearly distinct from the barytes-dominated samples characteristic of the timber chutes in Trench 1, but broadly similar to those from elsewhere on the site (for example Trench 4) in terms of the minerals present and the size range represented. The samples contain a large proportion of dark-coloured, iron-rich stone and calcite, with grey limestone, quartz and some barytes also present. The material is likely to be waste from lead ore processing, derived from the earlier phase of use at the nearby crushing plant (Giecco 2007). The samples do not indicate the function of the building in Trench 2; if it was used for mineral storage, no evidence of this survives.

Some hammerscale (a waste micro-slag from iron smithing) was detected in samples from this trench (Campbell pers. comm.) and slag heaps were also noted in the vicinity of building 78 during survey (Hunt and Ainsworth, forthcoming). Only small quantities of hammerscale were found, rather than the large amounts necessary to indicate the location of a forge conclusively, but it can be taken as further evidence that there probably was one in this area.

Trench 3

This trench was located over the remains of a bridge abutment and there were no samples for analysis from this area.

Trench 4

On the opposite side of Scordale Beck to Trenches 1 and 2 were the remains of three circular buddles, used for mineral processing, in varying states of preservation (see 75 in Hunt and Ainsworth 2007) thought to date to the mid-19th century (Hunt and Ainsworth, forthcoming). This is consistent with the increasing introduction of round buddles from the middle of the century (Palmer and Neaverson 1989, 338). There were no surviving bases in any of buddles and therefore the fine sediments found in them were thought to have either leaked beneath the floor when the buddles were in use or re-deposited when the floor was removed or rotted away (Giecco 2007). One side of buddle A had been completely eroded whereas buddle C, although the smallest, was better preserved. Numerous samples were taken from deposits in the buddles, including several monoliths.

A similar suite of minerals appeared to be present in most of the buddle samples as in Trench 2, with limestone dominating. The orange- and dark-coloured stone present is iron-rich, often containing detectable lead, zinc or copper. Numerous calcite fragments and some quartz are also present. The buddle fills appear to be re-deposited waste from the lead ore processing that took place on the site in the 19th century. The buddles were also constructed over waste from previous lead ore processing operations.

Buddle A

Sample 17 (a monolith) showed contexts 139-140, which were made up of fine, orange-brown sediment. Low levels of lead were detected in the sediments, rather than the elevated levels that might be expected for an *in-situ* deposit, so this fill is not likely to be associated with the use of the buddle.

Buddle B

A series of samples were taken from this central buddle including sample 8 (a monolith), which contained dark purplish-orange sediment with gravel-sized material at the bottom. Numerous thin, black bands, derived from organic matter, were visible halfway along the length of the monolith. As suggested by Giecco (2007) this could be the remains of a wooden buddle floor, although none survived intact in any of the buddles excavated. None of the black bands was continuous, suggesting that the fill was re-deposited. The overall concentrations of lead and zinc detected were low.

Samples 34 (context 158, a sandy gravel in the bottom of the buddle), 32 (context 145), 27 (context 160 on the east side), 31 (context 154) and 35 (context 144) were also examined and found to consist of fragments largely under 5mm, again probably re-deposited waste from lead processing. Sample 27 contained numerous lumps of iron pan, which is a corrosion product formed in the presence of iron metal, in this instance worn down into rounded fragments and re-deposited by water. Sample 31 also contained a pot sherd.

Buddle C

Samples 28 and 33 (both context 150) from buddle C were broadly similar to the upper fills of buddle B, in terms of the suite of minerals present and the size range of fragments. Sample 33 also contained lime-rich mortar and an iron object.

Trench 5

This trench investigated the remains of a small rectangular building that butted up to a wheel pit, again subject to erosion, referred to as mill 27 by Hunt and Ainsworth (2007). This mill is thought to have been constructed late in the 19th century and is also shown in a photograph, possibly dating to the 1890's (Hunt and Ainsworth, forthcoming). It appears to be linked by a timber conduit to mill 29, and so related in function in some way. Deposits of dressing waste are now exposed through erosion (Hunt and Ainsworth 2007). Finds included large mounting blocks and corroded iron plate.

A number of samples were taken from this building, mainly occupation layers, but these unfortunately provided little indication of the building's use. For example samples 10 and 14 contained sherds of window glass, iron objects and fragments of wood. Sample 10 also contained large lumps of firm, black ,organic material, and small pieces of hammerscale (a waste slag from iron smithing). Samples 13, 14 and 16 contained large quantities of lime mortar, making identification of the minerals present difficult. Sample 13 also had a large organic component and more fibrous material.

A small conduit in Trench 5 was thought to contain water lain discharge from equipment housed in the building, such as dressing machinery, however the primary fill (182) was not sampled and, since the timber lid did not survive, contamination is likely. Subsequent fills in the drain (127, sample 11, and 134, sample 9) were unusual because of the absence of larger fragments, for example nearly 80wt% of sample 11 was less than 2mm in size with many of the larger pieces being clearly intrusive, such as mortar or window glass. The range of minerals was similar to elsewhere on the site (for example in Trenches 2 and 4), including calcite, quartz, iron-rich dark or orange-tinged stone, some limestone and barytes. Sample 9 also contained a large proportion of mortar, some iron sheet, wood and an organic, fibrous material, all re-deposited from the occupation layers of the building. Although the fine particle sizes of the fills in this conduit are atypical, they cannot be confidently identified as waste from the later stages of lead ore dressing because of the extent of the contamination in these contexts. No evidence for the extraction of other minerals, such as barytes or witherite, was found in these samples, therefore this mill may have had a limited working life since it appears to have been disused since lead ore processing ceased in the late 19th century.

DISCUSSION

Carruthers *et al*. (1916, 30-32) describe the barytes mining operation at Scordale in 1915. At that date, barytes was extracted from flats on Amber Hill. The authors report that barytes is also known at several other places in the valley and had been worked 'on the north side of Great Augill, opposite the old galena crushing-mills' from a flat of barytes under the Whin Sill. Barytes was also worked in the Great Scar limestone behind the old crushing mill, in a vein about 0.9m thick and flats 0.9m to 1.2m thick. In the 1915 account, these workings are described as 'disused for many years'.

In a later edition of the Geological Memoirs, Wilson *et al*. (1922) state that only barytes was being worked in 1921, from two old lead levels of the Hilton Mine to the north of Great Augill and on the south-east side of the valley. The barytes flats were found 'between the top of the Melmerby or Great Scar Limestone and the hazel, a bed of sandstone from 2ft to 6ft in thickness, which intervenes between that limestone and the overlying Whin Sill' and the flats in the limestone were most productive. The spar was 'mostly high grade platey white barytes' but 'translucent crystalline masses also occur' and 'fluorspar, though not found in commercial quantities, is fairly common'. Calcite was not common and quartz was reportedly absent. The authors state that the Amber Hill workings are closed.

The samples from the conduits in Trench 1 match closely the description of the material processed in 1921, for example the absence of calcite and fairly common fluorspar. Therefore the final phase of use of mill 29 was probably processing barytes from the old lead levels to the north of Great Augill in the early 1920s.

Photographs of mill 29 (Giecco 2007) show a timber chute emerging from the southern-most corner leading to a loading area below with a traction engine. The samples from the conduits in Trench 1 are increasingly processed as they progress from the north-eastern to the south-western end of the trench (Figure 8), with more gangue removed and different degrees of coarseness, consistent with the layout suggested by the photograph. Although in 1921 the final stages of mineral dressing took place two and a half miles away at Hilton, the spar was 'roughly picked and washed on a grate' on site (Wilson *et al.* 1922). Earlier accounts of the practices of Scordale Barytes Limited in 1915, albeit further down the valley, provide more detail, describing how the material was first washed on a 5/8 inch (~16mm) grate, followed by hand-picking and crushing on another 5/8 inch grate. The material passing through the first grate was jigged on a six strands to the inch (~4mm) sieve (Carruthers *et al.* 1916). There is fairly good agreement between these size ranges and those observed for the samples from Trench 1, for example sample 36 comprises fragments under 16mm in size, whereas sample 24 comprises fragments under 5mm in size and mostly under 2mm (Figure 10). Therefore similar methods (hand-picking, crushing and sieving) appear to have been used in the final phase of barytes processing in mill 29.

The size-range of the lead ore dressing waste covering much of the site, largely between 1 and 5mm, is consistent with accounts describing how minerals were only reduced to gravel or sand size, rather than 'slimes', in order to minimise the number of separation processes required later (Palmer and Neaverson 1989). The 'slimes', consisting of fine particles of less than 1mm, were processed in buddles (Palmer and Neaverson 1989). The samples from buddles A to C at Scordale, however, were much coarser, re-deposited material.

RECOMMENDATIONS FOR FUTURE SAMPLING, ON-SITE ANALYSIS AND POST-EXCAVATION ANALYSIS

Where permissible and practical, it may be advantageous to incorporate sampling into the survey programme. Only a small number of features were investigated archaeologically and sampled, however, a large area of the valley incorporating many features relating to mineral extraction was recorded by the EH Archaeolgical Survey and Investigation Team, including tailings on washing floors, waste in timber chutes, ore bins and deads from worked levels. Examination of samples from such features may aid interpretation of the features.

Portable XRF machines are also available, allowing on-site identification of materials. The range of detectable elements is less than with laboratory machines, but elements from phosphorus to uranium can be detected. This may be a useful alternative when extensive sampling is not practical.

Other simple techniques could be used on-site to help confirm mineral identifications, for example dilute hydrochloric acid (HCl) reacts with carbonates causing them to fizz.

Samples that provide the best indication of the function of a structure or origins of a deposit are those taken from protected, enclosed features, such as lidded chutes, or more sheltered, remote locations, such as levels higher in the valley, as opposed to open features in the flooded zones, such as the buddles, or contaminated deposits, for example where the lid of a chute has collapsed. Similarly, primary fills are more informative than secondary fills.

A small (0.5 litre) unprocessed sample should be retained from each deposit of interest so that the fraction under 250 microns can be examined if required, for example using petrography. (With this technique grains of 63 to 250 microns in the sample are identified using transmitted light and minerals such as fluorspar, calcite and mica can be distinguished in this way). In features such as buddles, where small particle sizes are likely to be of most interest, a larger unprocessed sample should be retained.

Up to 5 litres of sample should also be taken from deposits of interest and processed using standard environmental methods, floating onto a 250 micron mesh with a 500 micron mesh being used for residue. Although the size fraction smaller than 250 microns is lost, it enables the remaining fragments to be identified more quickly, because they can be clearly seen.

Possible in-situ deposits in features where the deposition sequence of minerals is important, such as in buddles, can be sampled for examination under laboratory conditions using tins or monoliths. In practice this is usually only possible with fine deposits. Multiple kubiena tins are preferred to the monolith tins because the latter do not easily fit in the in-house spectrometer. For longer sequences, an alternative would be to use a length of plastic pipe, which can be sectioned as required later in the laboratory. Alternatively analyses could also be outsourced to laboratories with larger capacity XRF equipment.

CONCLUSIONS

A gravel-sized waste material from lead ore dressing covers much of the area investigated. In some cases this waste has been re-deposited in cut features, such as the buddles in Trench 4. In other instances, the waste is sealed by features relating to more recent activity, such as the timber chutes containing barytes in Trench 1. This complicates interpretation of samples taken from the site, as many appear to be variations of this waste material, and are not necessarily relevant to the function of the features of interest.

Although there are references to witherite being stored in buildings on the site (Giecco 2007), no witherite was identified in any of the samples examined. Either the witherite was stored elsewhere, or no evidence of it now remains.

The timber conduits in Trench 1cut waste tips, probably from lead ore processing, for example during an earlier phase of activity at mill 29 prior to the closure of the mine in 1876 by the London Lead Company (Giecco 2007). The deposits in the timber conduits themselves are associated with barytes extraction, known to have taken place from the late 19th century into the 1920s (Wilson *et al.* 1922). The more robust conduit in the north of the trench brought barytes-bearing rock into the area for processing. The material in subsequent conduits suggests that the rock was hand-picked and passed over grates, with the products emerging at the south-western end of the trench.

The function of the small building in Trench 2 is unknown but the waste in the area appeared to be from lead ore extraction, perhaps from earlier phases of activity at the nearby mill. Reports of hammerscale and slag are consistent with suggestions that a smithy is likely to have been sited nearby (Hunt and Ainsworth, forthcoming).

The circular buddles in Trench 4 may have had wooden floors (Giecco 2007). Although the gravel-sized deposits found within them appear to be waste from lead ore processing, both the size-range and composition of the fills suggest that it is re-deposited rather than *in-situ*. The buddles are also cut into earlier lead ore dressing waste.

Survey and archaeological investigation indicate that substantial machinery was housed in the building investigated by Trench 5, such as required by a dressing mill (Giecco 2007; Hunt and Ainsworth 2007). Unfortunately the samples from this area were dominated by lime mortar and other re-deposited material, which did not help to clarify the function of the structure. No evidence for the processing of barytes or witherite was found, however, and it is likely that the building was intended for lead ore dressing.

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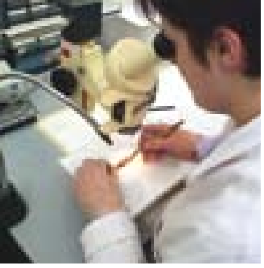
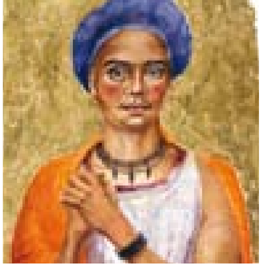
APPENDIX 1

Table 2: The different size fractions in various processed samples, by weight %. Note that the fraction under 250 microns is not represented since it was removed during sample processing.

Sample	Over 16mm	5mm - 16mm	2mm - 5mm	Under 2mm
23	0.0	3.7	7.4	88.9
36	2.3	61.7	21.9	14.1
24	0.5	13.5	54.8	31.1
37	4.8	36.7	31.3	27.1
11	4.6	11.8	5.6	78.1



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