A THIRD SEASON OF FIELDWORK ON THE SITE OF DUKESFIELD SMELTMILLS, HEXHAMSHIRE

REPORT ON ARCHAEOLOGICAL EXCAVATIONS AND MONITORING CARRIED OUT BETWEEN MAY AND DECEMBER 2014

by

THE ARCHAEOLOGICAL PRACTICE LTD.

for

THE FRIENDS OF NORTH PENNINES

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SUMMARY

This document reports on a third phase of archaeological fieldwork, including excavation and monitoring works, carried out at Dukesfield Smeltmills, on the Allendale Estate in Hexhamshire, where background documentary work and two previous phases of excavation had provided contextual information regarding the archaeological and historical development of a lead smelting works active from at least the mid 17th century to around 1840. The work carried out in 2014 was largely research-based, seeking to develop and enhance the findings of the previous two seasons of archaeological work.

In 2014 fieldwork comprised several phases of activity in advance of and during works carried out by the main contractor for building works, thus requiring close cooperation between the archaeological and structural works teams. In May 2014 the monitoring of landscaping work on the south-west side of the arches and chimneys revealed a shallow depth of overburden against the side of the arches, with a buried stone revetment wall extending at right angles from the arches wall, halfway down the slope.

Later in May, 2014, three sites were chosen for research excavation. The sites included were the area north of the Arches end wall (Site A), where a wall had been uncovered in 2012; the leat on the west side of the Hall burn (Site B), opposite to the arches, also first examined in 2012, and the site of buildings remained shown on early site plans east of the arches on the north side of the Hall burn (Site C), some surface remains of which remained visible. Additional excavation work subsequently took place at Sites B & C, principally in July and November 2014, with a further day spent on Site A in late December 2014. In addition to work on the main trenches, additional work involved exposing structural remains running below and parallel with the leat in Site B and eastwards from the north face of the arches structure in Site A. Other sites examined were a stone feature on the south side of the road some 70 m west of the arches - possibly remains associated with a waterwheel shown on an 1802 plan of the site - and the outflow of the diverted Hall burn into the Devil's Water, where stone and sub-surface wooden structural elements are visible at low water.

In addition to formal excavation, in September 2014, structural consolidation works were monitored within Site A in September 2014, particularly during machine excavation of a linear pit exposed by excavation, and Site B was further prepared for consolidation works.

The results of excavation in Area A included the discovery of a wheel pit and, associated with it, floor surfaces and sleeper walls, probably for the installation and operation of bellows in the smelting hearths area. The range of features revealed in Area A is thought highly likely to be functionally related to those of even more complex character found in Area B, where a wooden-shuttered enclosure or channel was uncovered on the north side of the previously-excavated, hearthstone-lined leat, and a range of stone-built features north and north-east of the leat(s) are likely to have functioned as supports for launder structures and spill-ways during at least two major phases of industrial activity. In Area C were revealed two or more phases of stone-built structures which are thought likely to relate partly to flood-management and partly to buildings seen in that part of the site on an early 19th century plan, the character and purposes of which are unknown but thought likely to relate to storage or administration.

1. INTRODUCTION

The fieldwork reported here was carried out as the third phase of the Dukesfield Smelters and Carriers Project run by the Friends of the North Pennines, the overall aims of which are to restore the Dukesfield arches, reveal the industrial history of the site and encourage the exploration of the area by residents and visitors. Following initial evaluation of the site in 2012, the FNB secured a Stage 2 HLF grant to facilitate the main phase of structural consolidation works in Summer, 2013. The archaeological fieldwork carried out in 2013 revolved around the requirements of the structural works schedule, focussing on recording features revealed during site clearance works undertaken to enable consolidation work, but the work carried out in 2014 was more research-based, seeking to develop and enhance the findings of the previous two seasons of archaeological work.

The archaeological fieldwork was directed by Richard Carlton of the Archaeological Practice Ltd. with the assistance of Marc Johnstone of AP Ltd., buildings historian Peter Ryder and a volunteer team led by historian Greg Finch and the industrial archaeologists, Ian Forbes and Pete Jackson, with special thanks offered to a recent convert to Industrial Archaeology, Pete Lee, who led excavations on the leat area. Thanks are also offered to the tenant farmers of Dukesfield Hall Farm, Andrew and Kath Swallow, who provided valuable local knowledge to the project team and aided them in site clearance work.

1.1 Purpose of Archaeological Work

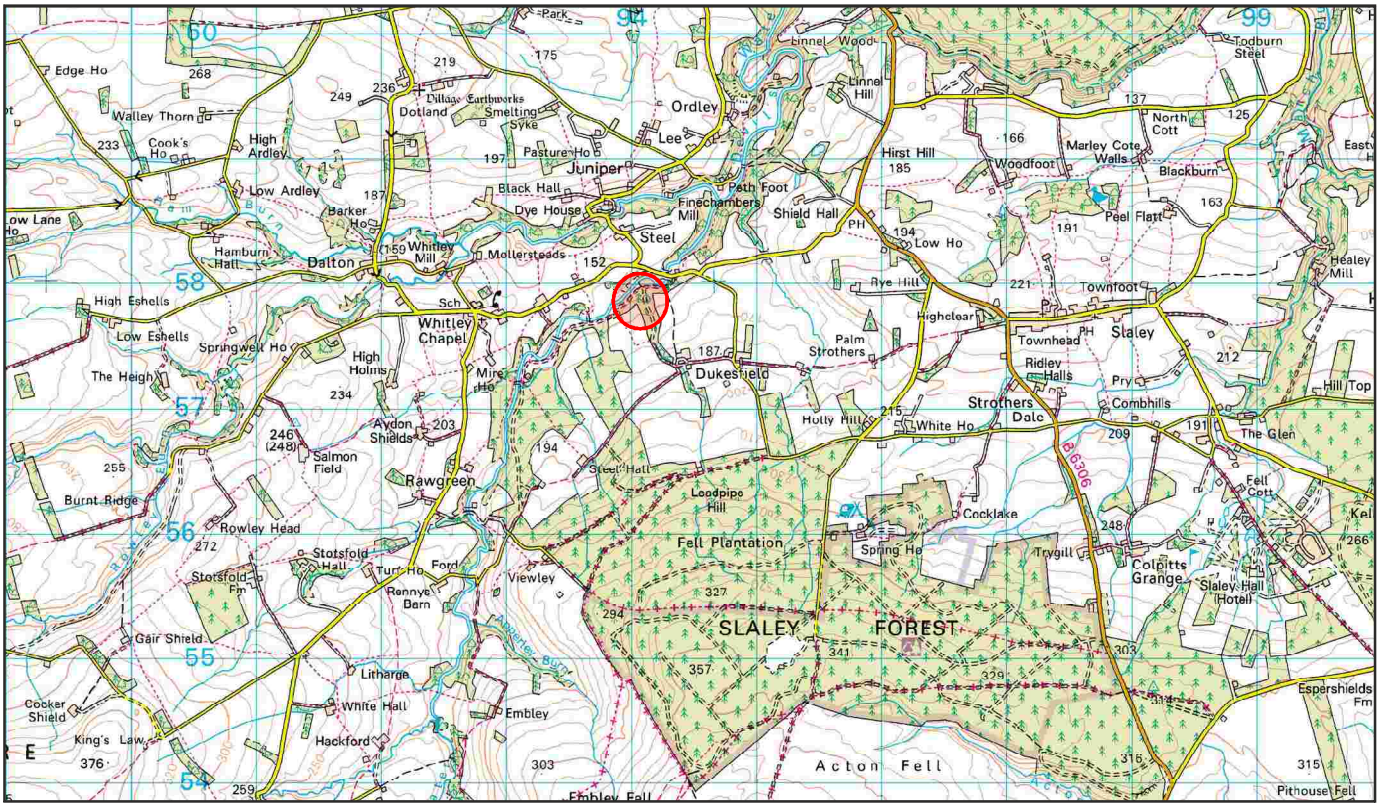
The following is a report on a programme of archaeological fieldwork carried out on the site of the industrial complex known as Dukesfield Smeltmills, on the Allendale Estate in the Parish of Hexhamshire, some eight kilometres south of Hexham Northumberland, centred on NGR NY 942580. The site sits upon a narrow haugh between the south bank of the Devil's Water and a wooded bank running up to Dukesfield Hall at West Dukesfield.

1.2 Cultural Heritage Background

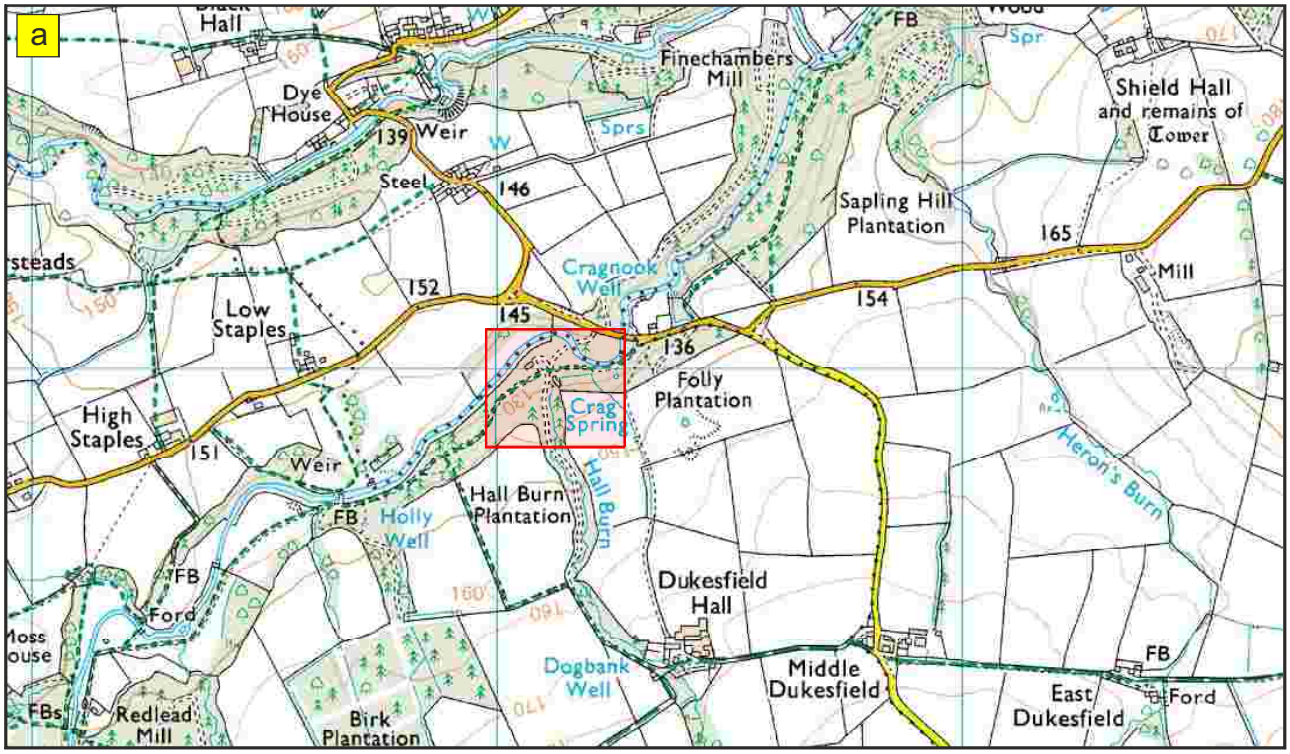
[NOTE: A more detailed summary of the history of the site is provided in the report on fieldwork carried out in 2012 (TAP 2013), which draws upon extensive research carried out by Greg Finch and colleagues from the *Friends of the North Pennines*]

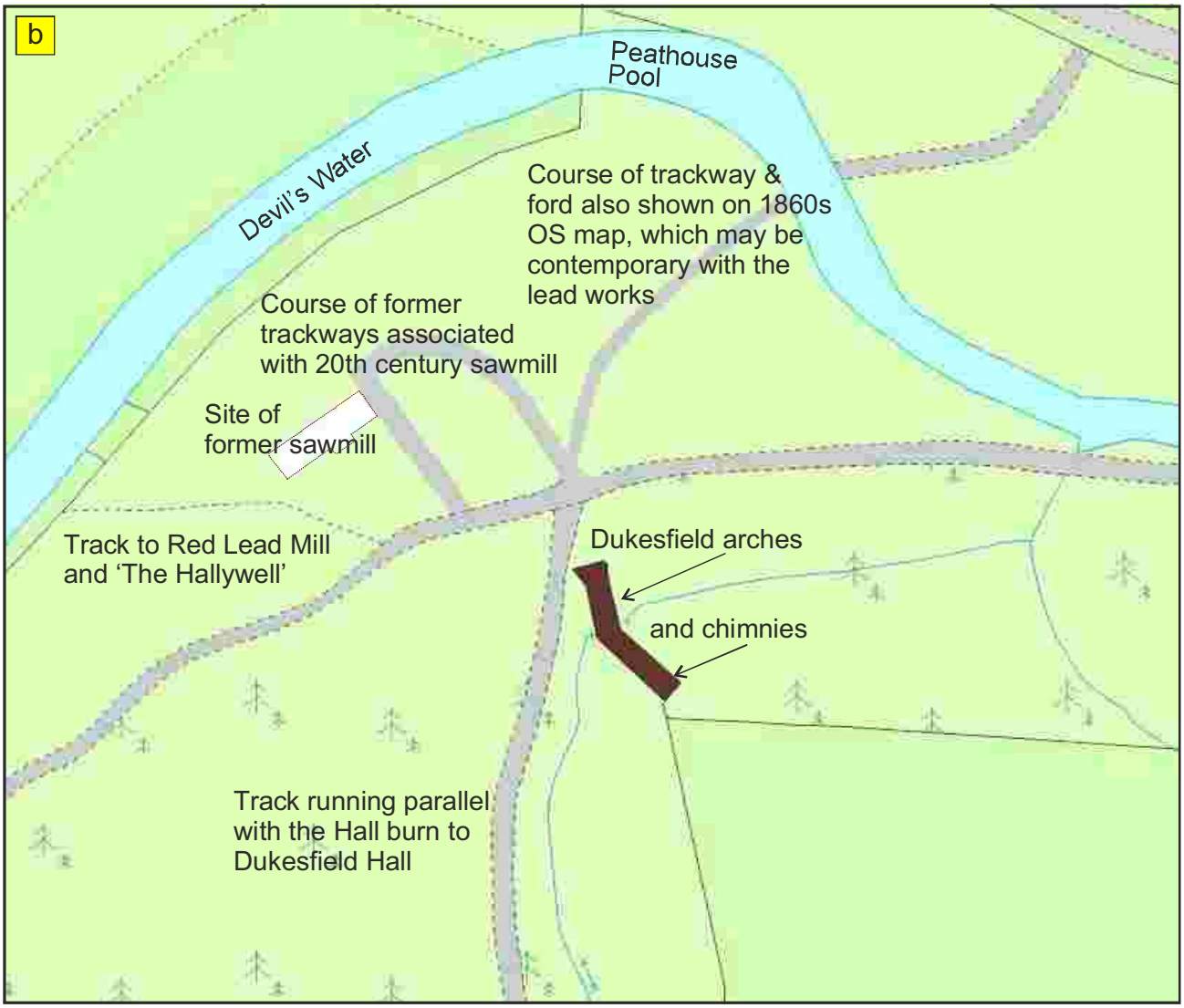
Dukesfield and Red Lead Mill are two of a cluster of at least five currently-known lead smelt mill sites in Hexhamshire dating from the mid-late 17th century. Their position some 3 miles north of the nearest lead veins means that they used ores brought in from Allendale and Weardale, the cost of this being offset by the ready availability of wood and relative ease of onward transport. Lead smelting appears to have been long established in the area: lead slag remains consistent with 'bail hill' smelting have recently been found close to the site, such as at Beil Brow, on the western bank of the Devil's Water, and there is documentary evidence of coppice management and 'bails' at Dukesfield in the 1550s, when a lease of

***Illus. 01**: The Location of Dukesfield south of Hexham.*



***Illus. 02**: The Location of the Dukesfield leadworks site east of Whitley Chapel and west of Slaley.*





Illus. 03 & 04*: The Location (03: above) and layout (04 :below) of the Dukesfield smelt mill site as shown on modern Ordnance Survey plans of the area.*

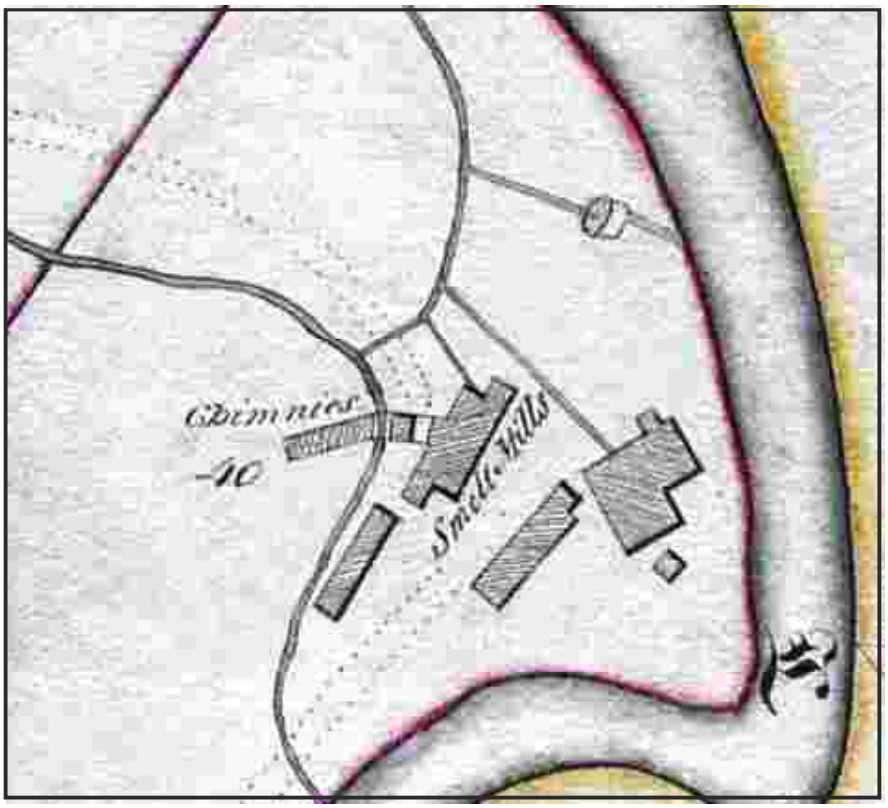
Dukesfield in 1551 (*NRO Blackgate Deed B.20/1*) gave permission to smelt lead in 'bails' or bale-hills.

The Dukesfield estate, comprising several farms on the east bank of Devil's Water and the mill site, was bought in 1668 by William Blackett, who had been mining lead in the upper reaches of Weardale and the Allen dales for several years. It cannot be confirmed, though it strongly suspected, that the smelting of lead was in operation at Dukesfield prior to Blackett's purchase of the site, but the nearly Blackhall smelt mill was in operation by 1653, and by 1675 five ore hearths and a slag hearth were in operation at Dukesfield, which would have represented a considerable upscaling of any previous smelting operations there. During the 18th century Dukesfield was the most important of the WB Lead Company's mills, with annual smelting fluctuating (according to the price of lead) between 500 and 1,000 tons per year from the 1720s to the late 1760s, increasing to reach around 3,000 tons by 1790, thereafter stabilising at around 3,500 tons throughout the period of the Napoleonic Wars. It is likely that the surviving arches and the graded track running southwards to Dukesfield Hall date from this period of expansion in the second half of the 18th century.

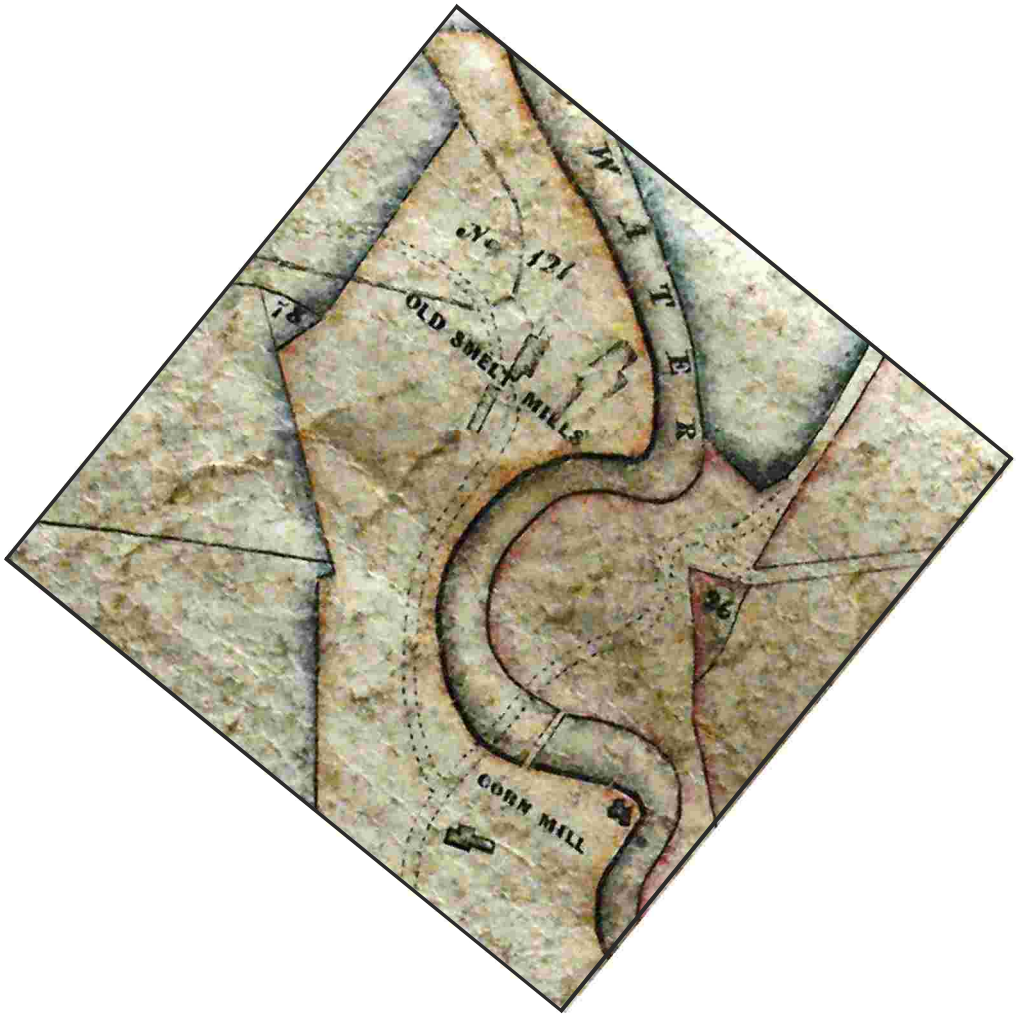
An estate map, surveyed in May 1802 (*Illus. 05*), shows the extent of the mill at its peak of production, when it was processing some 3,000 tons of lead ore annually. The arches structure is labelled on the plan as "chimnies", with its southern arch spanning the Hall Burn, and the trackway from Dukesfield – which gave access to the lead road towards Blaydon - curving through the northern arch. The course of the mill race can be followed westwards away from the site, and a culverted spillway drops beneath the track to Dukesfield Hall, emptying into the Hall Burn, the course of which had been redirected, presumably when the arches were built in the second half of the 18th century, to flow through the arches structure.

The modern trackway to Red Lead Mill runs next to the site of a building serviced by a launder which, given the height of the adjacent mill race, presumably fed an overshot wheel which drove bellows. The 'chimnies', excavated in 2012 and 2013, comprised flues set horizontally along the top of the arches, drawing fumes away from ore hearths at the northern foot of the arches, feeding into a combined condenser and chimnies complex at its south-east end of the arches. The long building to its east may have been the ore bingsteads as it lies closest to the trackway into the site from the west – excavation in this area in 2014 was designed to test this suggestion - while north of the track, another long building is possibly the peat store, given that the nearby bend in the river is named 'Peathouse Pool'. The large building next to it, also fed by a mill launder, probably housed the reducing furnaces and refinery added to the mill complex in the 1760s, but excavation here in 2012 was inconclusive in regard to its function.. A round structure, also water-fed (indeed, its representation on the 1802 plan is perhaps indicative of a water-wheel), lay to the west, and was perhaps used for breaking/washing slags for re-smelting at the slag hearths. The mill was described in 1821 as containing 2 roasting furnaces, 5 ore hearths, 2 slag hearths, 2 refining furnaces and 1 reducing furnace.

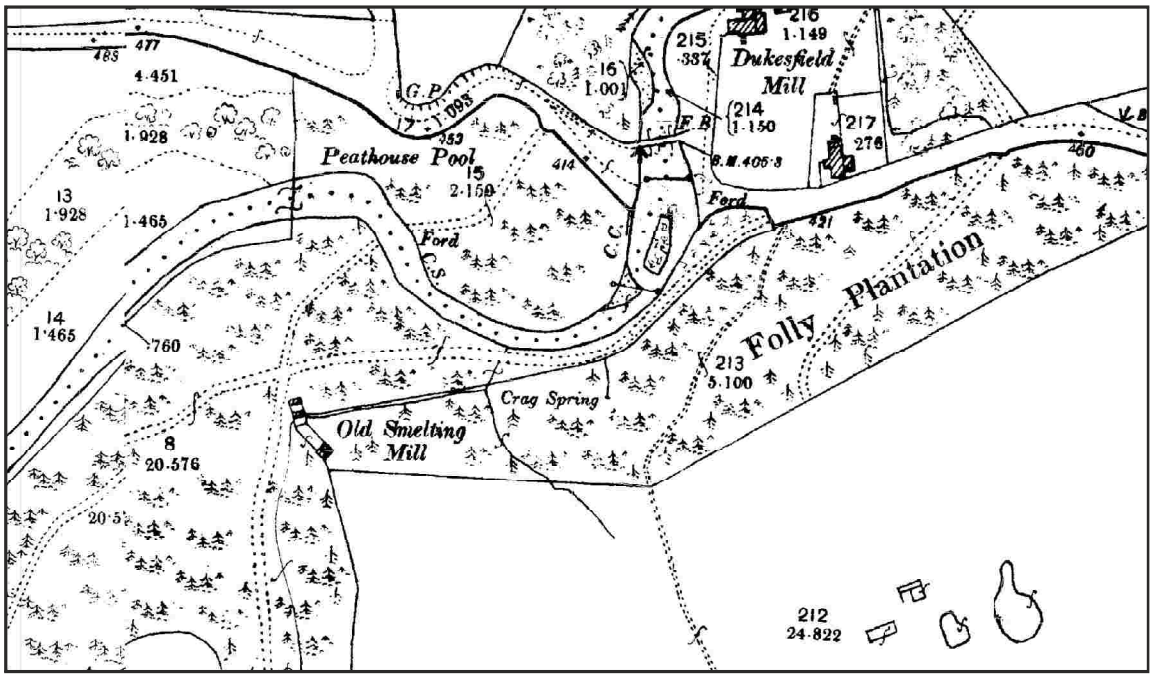
The somewhat terse diaries of Thomas Dixon, an ore smelter at Dukesfield in the 1830s, provide some indication of how the mill worked in its final years until closure of the bulk of the plant in 1835 (Linsley 2006), an occurrence brought about by improving methods of transportation, notably the Newcastle to Carlisle Railway, under construction at that time. Smelting ceased in 1835, but the annual accounts show that small amounts of 'washing', presumably of old slags, continued until at least 1840. An estate map of 1848 shows the



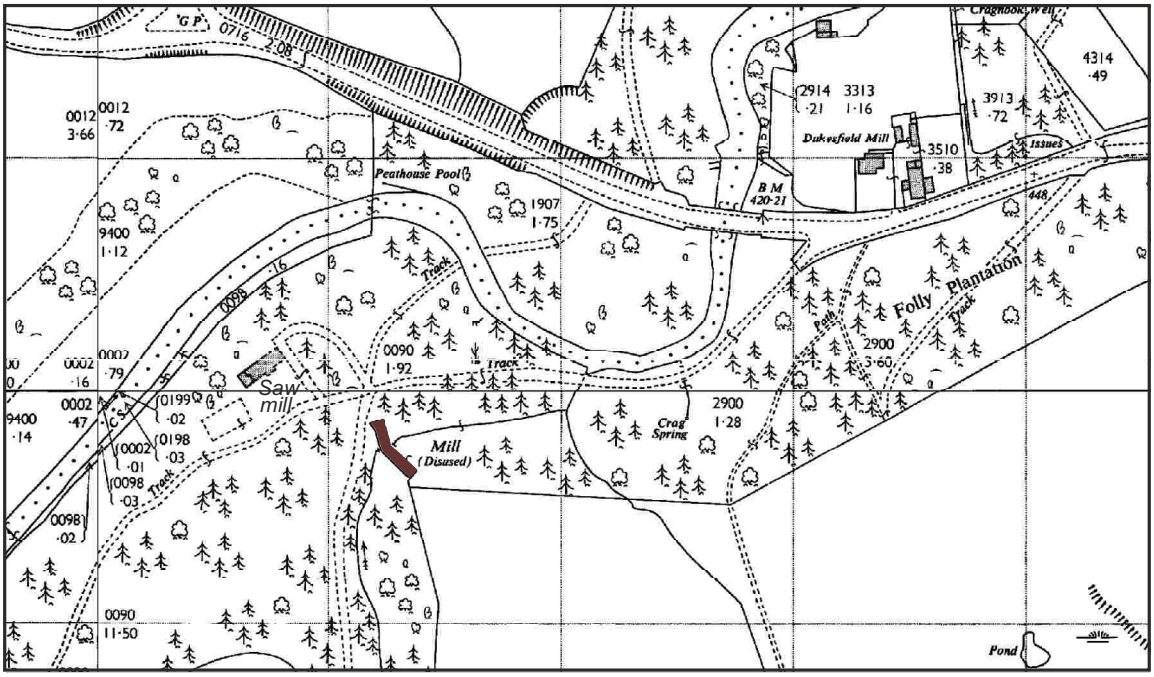
***Illus. 05**:*
A plan of the smelt mill works taken from an estate plan of 1802.



***Illus. 06**: The partly dissembled works shown on an estate plan of 1848 (orientated to allow comparison with the 1802 plan, above).*



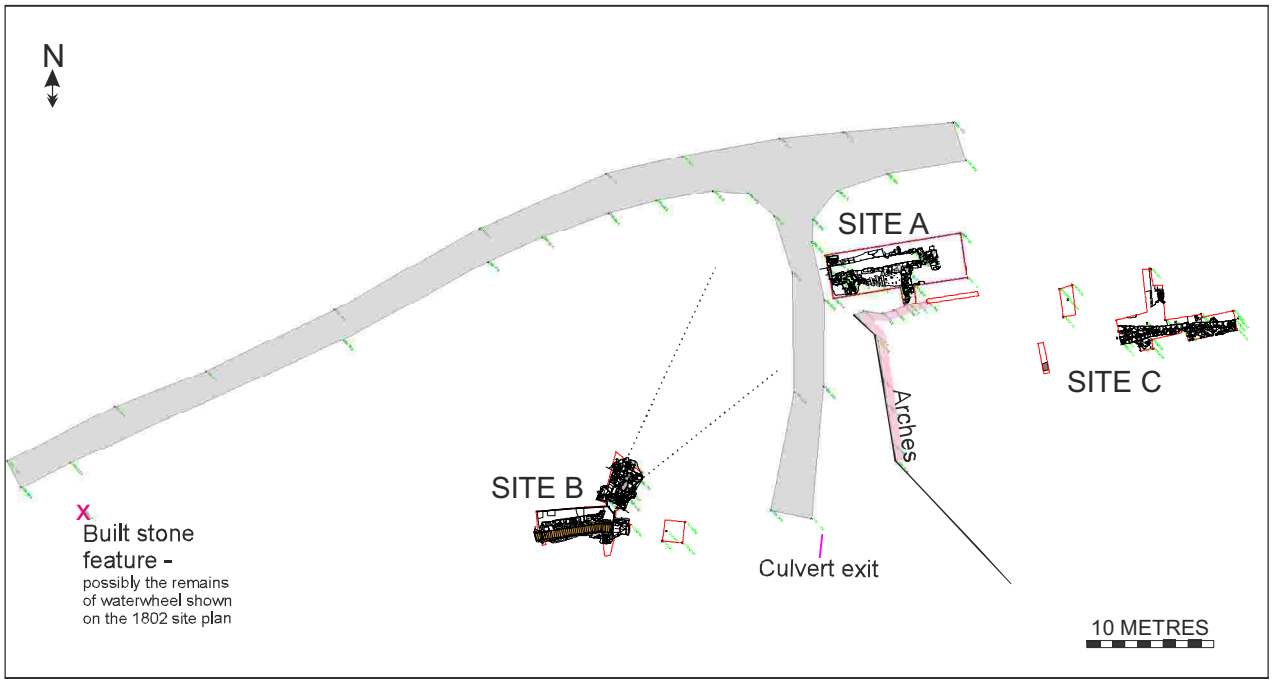
***Illus. 07**: Extract from the 2nd edition Ordnance Survey plan (1890s) showing the Dukesfield lead smelt mill site in context.*



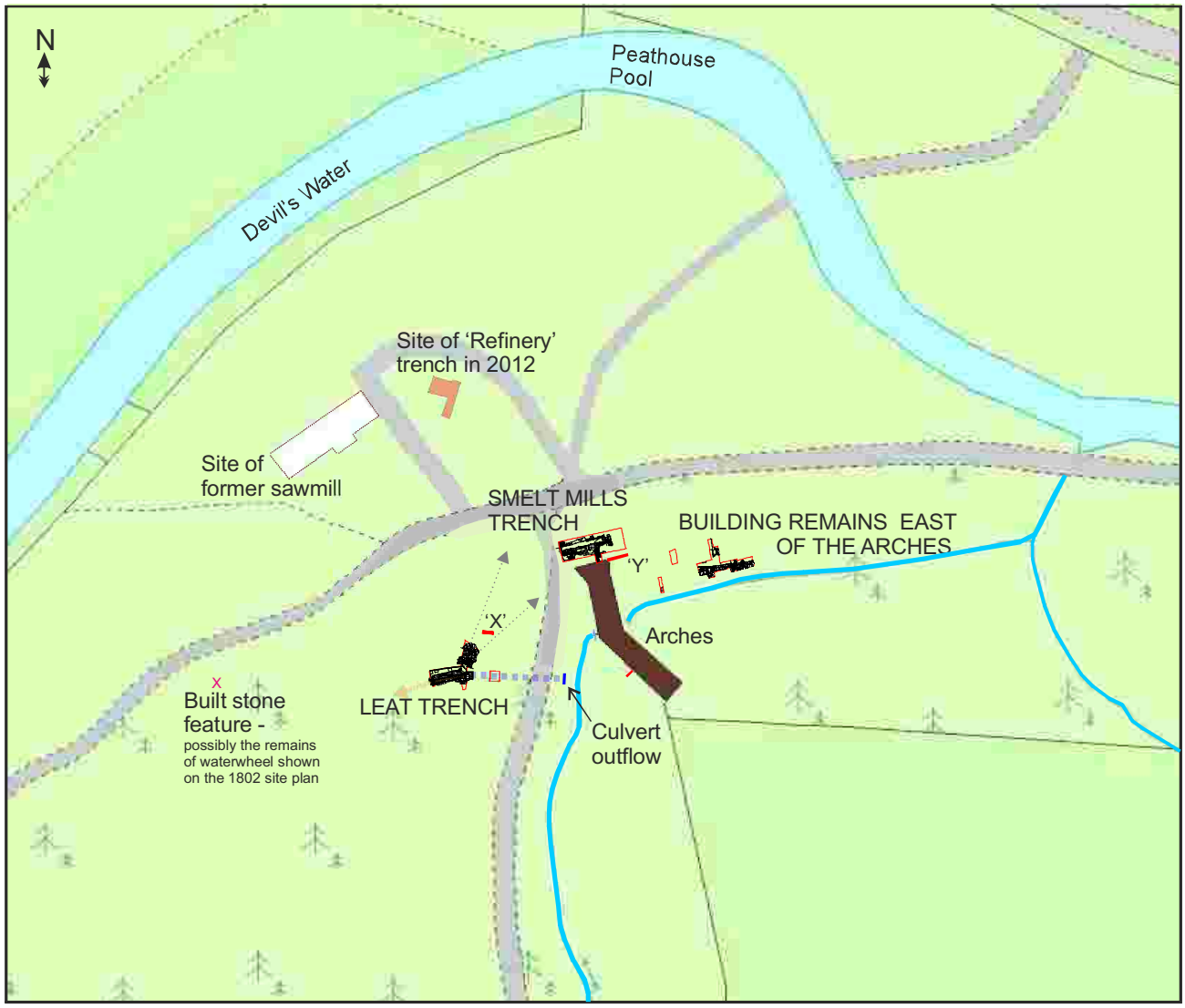
***Illus. 08**: Extract from a 1960s edition Ordnance Survey plan showing the Dukesfield smelt mill site in context - note saw mill north-west of the arches.*

dismantling of the mill buildings to be well underway and perhaps nearly complete. Later plans, including the first edition of the Ordnance Survey series published in the 1860s, show the works in their present state, with no buildings surviving other than the arches, but with the original trackways along the valley bottom and from the arches to Dukesfield Hall, still present.

Previous excavations carried out on the site in 2012 and 2013 had fully-exposed the chimnies/condenser structure at the south-east end of the arches, as well as revealing the lower (eastern) part of the leat and enigmatic built remains of the presumed refinery site to the north and smelt mills site on the north side of the arches. However, with the exception of the chimnies and arch-top flues system, none of the principal structures on the site, including those shown on the 1802 plan and others presumed to pre-date the major 18th century reorganisation of the site, had been exposed sufficiently to allow understanding of their function and inter-relationships. Consequently, a further season of site investigation was proposed in 2014 in order to achieve a more complete understanding of some of the features previously-identified as part of the wider smelt mills complex.



Illus. 09: *Location of archaeological Investigations carried out in 2014 (below, on OS base map).*



2. FIELDWORK PROGRAMME

2.1 Aims

The main aims of the archaeological fieldwork elements carried out in 2014 were to build upon the results of research- and conservation-led work carried out in previous seasons by exploring sites identified as of particular interest.

2.2 Methods

Fieldwork was carried out in several phases in advance of and during works carried out by the main contractor for building works, thus requiring close cooperation between the archaeological and structural works teams.

2.2.1 PHASE 1: Landscaping on the south-west side of the arches and chimneys, May 2014 (see *Photograph 01*).

This work involved the use of a mechanical excavator to remove the build-up of overburden against the south-west side of the arches and chimneys, with a view to exposing more of the side wall of the structure and impeding access to the top of the arches from that side. A related aim was to remove spoil removed from the chimneys excavations from the north-west facing slope in order to improve its appearance and allow creation of a pathway from the Hall burn crossing to the newly-exposed chimneys.

While the results of this work were successful in terms of landscaping, the depth of overburden against the side of the arches proved less than expected, resulting in only minimal additional exposure of the arches and chimneys south-west face. An unexpected discovery, however, was that of a buried stone revetment wall extending at right angles from the arches wall. This wall appeared to be of unbonded sandstone, but its further exposure was suspended in order to avoid damaging it with the machine, so the method of its construction, as well as its dimensions, could not be deduced. It was proposed to reinvestigate this feature by hand at a future date.

2.2.2 PHASE 2: Excavation, May 2014 (see *Photographs 02-34 & 36-38*).

Excavation sites chosen in advance comprised:

SITE A: The area north of the Arches end wall, first examined by an evaluation trench in October 2012, was reopened with the aim of establishing the extent, depth, character and chronological phasing of remains known or suspected to be present there. Specifically, it was considered important to examine the character and function of a wall, first excavated in 2012, to determine whether it is associated with the documented smelting hearths structure, or part of an earlier phase of construction. Its structural relationship with the current arches structure was investigated by excavating a narrow sondage from a main trench running east-west in front of the arches end wall, up to the footings of the arches.

SITE B: The leat on the west side of the Hall burn, opposite to the arches, was reopened in

order to expose for conservation some features previously revealed by excavation in 2012. In addition to exposing features for consolidation and display, the aim of these excavations was also to answer questions about the nature of the water supply to the smelting mills over time, and for that reason the leat trench was expanded lengthways to the west and laterally to the north in order to investigate the water run-off system from the leat north- and north-eastwards towards the smelting hearths and other facilities powered by water-wheels. A small test-pit was also opened at the west end of the flat area above the culvert, just east of the culvert entrance from the leat.

SITE C: Buildings shown on early site plans east of the arches on the north side of the Hall burn, south of the entrance trackway, some remains of which had been traced on the surface in 2012, were investigated in order to elucidate their function within the site.

2.2.3 PHASE 3: Monitoring of Conservation works, September 2014.

Structural consolidation works were monitored within Site A in September 2014, particularly during machine excavation of a linear pit exposed by excavation. Consolidation works to the culvert entrance in Site B in Summer 2014 and, subsequently, within the leat itself were not monitored, but the site was prepared for consolidation by excavation and its partial infilling was also monitored (*Photo. 35*).

2.2.4 PHASE 4: Monitoring of additional excavations in July and November, 2014

(see *Photographs 39-41*).

Additional excavation work took place at Sites B & C, principally in July and November 2014, with a further day spent on Site A in late December 2014. In addition to work on the main trenches, additional work was carried out to expose walls running below and parallel with the leat and eastwards from the north face of the arches structure. Other sites examined were a stone feature on the south side of the road some 70 m west of the arches - possibly remains associated with a waterwheel shown on an 1802 plan of the site, and the outflow of the diverted Hall burn into the Devil's Water, where stone and sub-surface wooden structural elements are visible at low water.

Photo 1:

Photo 2:

Photo 3:

Photo 4:

Photo 5:

Photo 6:

Photo 7:

Photo 8:

Photo 9:

Photo 10:

Photo 11:

Photo 12:

Photo 13:

Photo 14:

Photo 15:

Photo 16:

Photo 17:

Photo 18:

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Photo 35:

Photo 36:

Photo 37:

Photo 38:

Photo 39:

Photo 40:

Photo 41:

Photo 42:

3. RESULTS

Results are given here for the three main sites, the north end of the arches (Site A), the leat area (Site B) and the area north-east of the arches (Site C) where building remains were investigated.

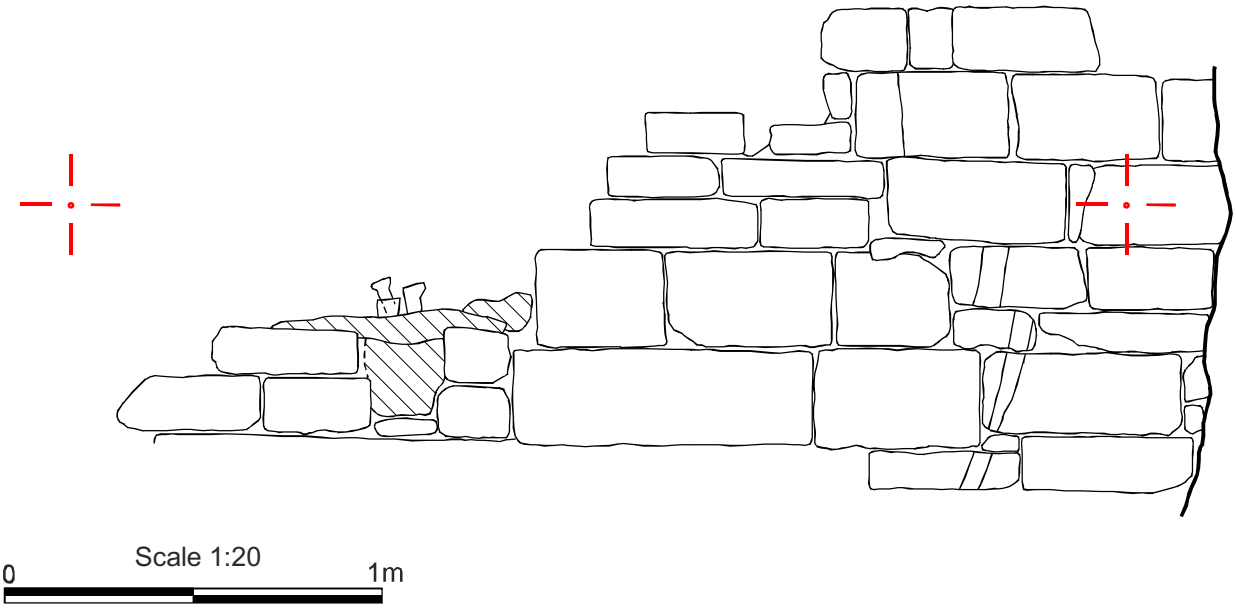
3.1 SITE A: NORTH OF THE ARCHES

A trench measuring 12.8 m long (east-west) by 4 m wide was opened at the north end of the arches structure in the position of a smaller trench, opened in 2012, which uncovered the top of a wall running north-south. The trench was excavated to further investigate the stone wall which, it is strongly suspected from historic map and documentary evidence, sits within the area of the former smelting hearths.

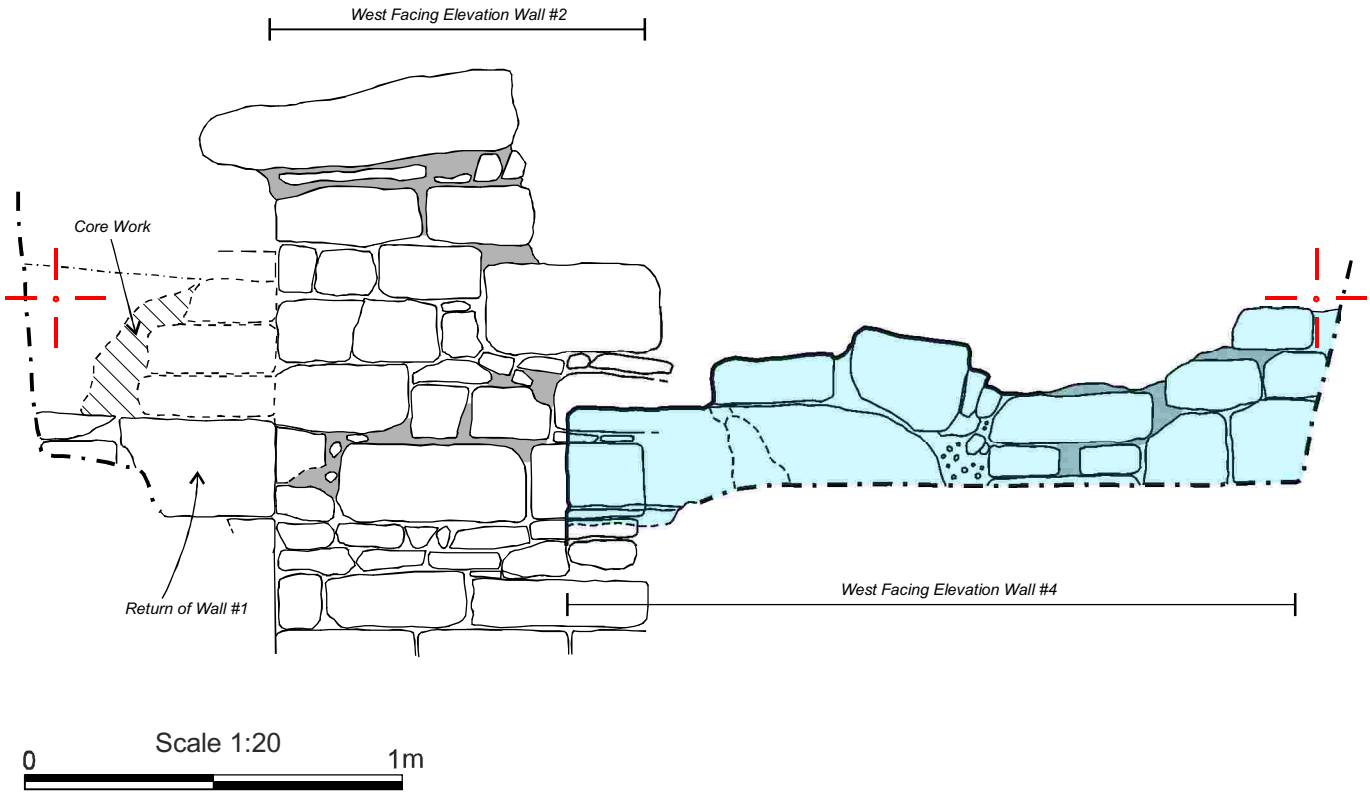
Description (*Illus. 10-12 and see Photos 02-14*)
Excavation of a variety of mixed fills, largely comprising sandstone and brick rubble within a mortar-rich matrix, revealed a number of principal features, as follows.

Running east-west along the north side of the trench was a deep, rubble-filled pit (see **[01]** on *Illus. 10*), formed of sandstone walls which had collapsed in places, notably in the centre of both the north and south side, leading initially to erroneous interpretations of its overall form. Subsequent excavation revealed it to be some 8.10 m long, 0.80 – 0.90 m wide and at least 3 m deep from the top of the highest surviving remains at the west end to the deepest excavated point of its corbelled west face. The west end, including north and west sides, were of coursed, tooled sandstone blocks of consistent size in the side walls but thinner with depth in the end wall. The east end, while of similar masonry and also corbelled inwards (westwards) with depth, was of poorer construction, with interrupted coursing and signs of a possible rebuild near the east end of the north wall. At this point a wooden feature **[02]** appeared to have been inserted, apparently comprising two beams set orthogonal to the north wall of the pit, the western one sitting in a recessed socket within the wall and jointed or bolted to another timber running parallel with the wall and sitting level with the eastern N-S beam. Much of this feature had rotted away, making it difficult to understand its original form, with the E-W timber surviving only as an organic impression on stonework. Three iron bolts also survived, apparently connecting (or at least perforating) the remains of the E-W timber and western N-S timber in its crude stone socket. Decayed timberwork **[03]**, probably also comprising the remains of N-S beams, also occurred in the corresponding position on the south side of the pit but was too decayed to determine any discrete structural components. The only other features of note in the walls of this structure were bolts and metal strips – most prominently at c. 2 m depth in the corbelled west wall – and, at similar depth in the west end of the north wall, the stub of a wooden insert. In the absence of alternative explanations, these features could be tentatively and provisionally interpreted as the remains of some kind of internal wooden casing for the pit. No other structural features were revealed within the fill or in the wall structures of the pit – interpreted as the wheel pit for a waterwheel powering bellows associated with the lead smelting process - but the collapsed sides of the central section may be significant since this is where the bearing for a large wheel would have been located. The depth of wall collapse in the central 3 m long section remains

Illus. 10: Plan of Trench 1 (Smelt Mills), Dukesfield Arches.



Illus. 11: *East Facing Elevation #1 of Wall #1, Area A Wheel Pit.*



Illus. 12: *West Facing Elevation #2 of Wall #2 and #4, Area A Wheel Pit.*

unknown because the pit was not excavated to sufficient depth here; the first 2 m at the west end and 2.9 m at the east end survived more completely.

On the north side of the pit no other features of note were recorded except at the extreme west end (see following). The presence of very large pieces of masonry, some of them infilling the pit, others overhanging it, suggested the presence of a large structure (perhaps solely comprising, or in addition to, the north side of the pit itself) to the north of the wheel pit. In the extreme north-west corner of the trench, on the north side of the pit, at relatively shallow depth consistent with the upper courses of surviving wheel-pit masonry, was an area of compacted, burnt waste material **[04]** associated with stonework which, on the west side at least, appeared potentially *in situ*. These remains were interpreted as those of, or derived from, a possible furnace, with the stone and brick remains possible those of a furnace structure. These remains corresponded with similar structural remains and deposits in the south-west corner of the trench on the south side of the wheel pit, where a similar deposit of gritty burnt waste **[05]**, comprising black cinder and ash, appeared to be associated with brick- and stone-work (although it should be cautioned that brick and stone rubble lie strewn over the entire south side of the trench, especially at the east and west ends (adjacent to the north-east and north-west corners of the arches structure) much or all of it probably derived from chimney or flue structures connecting the smelt mills building with the arches). Unfortunately it was not possible to excavate further to the west (under the road) and time constraints meant that a proposed extension southwards, in order to investigate the relationship between putative hearth floor and arches structure, also did not take place.

The burnt material interpreted as possible hearth floor (or hearth waste) deposit sat upon an apparent platform bounded on the east side by a rough stone wall **[06]** and, immediately east of it at lower level, an apparently integral (though slightly oblique) south-eastward return **[07]** to the east end of the surviving section of south side wheel pit wall. [06] & [07] seem to be related, probably as different phases of the same feature, or with [06] representing an elevated extension of [07]. Some 4.4 m east of rough wall [06] is another wall **[08]**, that first uncovered in 2012, which proved to be 0.75-0.80 m wide, of poor, loosely-bonded construction and up to three courses in height. An southward extension to the trench showed that it extended to the north wall of the arches, but had largely been robbed away in the last metre of so on its approach to the arches – it was unclear whether it had been robbed in order to build the arches, which seems unlikely, or removed at some later stage, perhaps to allow access along the north face of the arches, which seems more likely, especially as there seemed to be associated flagged flooring **[09]** on its west side.

Between the two structures [06]/[07] & [08] was an area of loose, mixed grey waste material **[10]**, probably comprising spent fuel as well as other mineral waste and mortar, upon and within which were preserved timber beams. Most prominent were a group of three such timbers **[11]**, their north ends truncated, arranged orthogonal to the north wall of the arches and some 2 metres from it, each 0.19 – 0.22 m wide and spaced c. 0.25 m apart. The timbers sat upon an apparent *ad hoc* blackened floor deposit of compacted burnt deposits and cobbles **[12]**, below which, almost underlying the eastern of the group of three timbers, were the remains of another timber **[13]**, its preserved north end extending as far as the rear (hidden) face of the south wall of the wheel pit. The remains of other timbers were recorded on an east-west orientation, one **[14]** associated with the area of decayed timber [03] on the west side of wall [08], the other **[15]** apparently abutting or running under platform edge [07] close to the west end of the trench.

The other feature of note recorded in association with the wheel pit was a raised platform **[16]** contiguous with, or set back 0.50 m from, the east end wall of the wheel pit. The main platform feature, founded on large, slightly-projecting rubble blocks, was of two parts, the western, square part comprised of mortar bonded ashlar and rubble masonry with a hearth stone (incl. v-shaped *tuyere* opening) forming its south side, stepping down to a similarly-constructed but shorter (E-W) eastern section. It was not clear whether a large stone partly filling the gap between raised square platform and end of wheel pit also formed part of the platform, but this seemed likely. A possible corresponding raised platform **[17]** occurred at the west end of the wheel pit, but could not be closely investigated because it extended under the roadway there.

In late December 2014 a brief, final episode of investigation took place when the eastwards extension to the north wall of the arches structure was investigated by means of trial pits along its course until the presence of large trees prevented further exploration. It was found that the east-west wall forming the north side of the arches continued as a narrow, 0.60 m wide, mortar-bonded wall eastwards for at least 4 metres (see 'Y' on *Illus. 09*).

Interpretation
The features revealed in this trench include a wheel pit, 8.1 metres long and up to 3 m deep, occupying the bulk of the north side of the trench, with various floor deposits framed by north-south aligned stone platforms or sleeper-walls between the wheel plit and north wall of the arches structure.

Arguments are presented in the Discussion (Section 2.3.4, below) concerning the possible diameter of the wheel and height of the axle, which must have been considerably above that of the surviving walls. In essence, height level data taken during the excavation suggests that while a wheel of c. 8 m diameter could have been accommodated by the available fall of height from launder head to mill race outflow, a wheel diameter of 7.6 metres (25 feet) is more realistic.

The features south of the wheel pit are suggestive, based on precedents such as Lumb Clough Mill site in Yorkshire (Dickinson et. al 1975), of mountings for bellows, with the rough stone walls serving as supports for the blast pipe end of the bellows and the rest of the structure being mounted on timber baulks, of which no remains have survived, unless related to the substantial wooden slats found embedded in floor deposits. No secure evidence for in situ hearth structures or deposits was found, but burnt deposits found at either side of the west end of the wheel pit suggest possible locations for such features. The presence of at least two layers of timber flooring between the putative stone support features suggests that more than one phase of operation could be reflected in the features and deposits found there. This is made more likely by historical documentary evidence and archaeological evidence from the leat area (see above0 which suggests at least three main operational phases for the smelt mills – one depending direct us of the Hall Burn as a water supply and two using weirs on the Devil's Water to supply water from the west via a leat. It is entirely possible, therefore that the wheel-pit and features excavated to the south of it are unrelated, or that the wheel pit and one of the floor surfaced revealed to the south are related, but that other surfaces reflect the re-use of the smelt-mills following abandonment of the wheel-pit, with bellows powered from a putative replacement wheel-pit to the west with, as suggested in

Appendix 1, its shaft taken over to the old hearths where they were supported by a substantial pillar base [16] built at the east end of the original wheel pit.

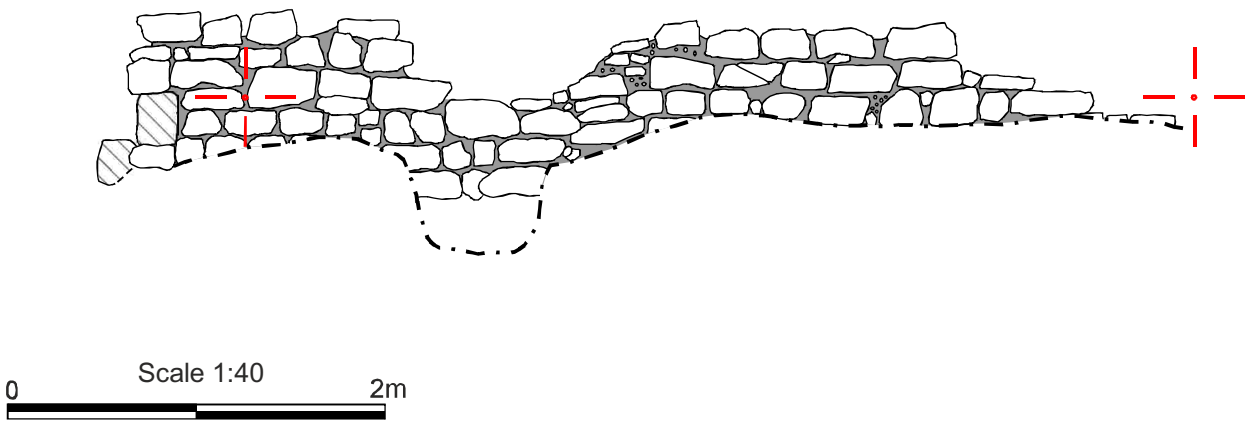
3.2 SITE B: THE LEAT COMPLEX

Trench 1 – in two parts, the main east-west portion being 7.6 m (max. length) x 3.4 m (max. width), with a north-east extension 4.8 m (max. length SW-NE) and 3 m (max. width NE-SW) In May 2014 excavations took place in the leat, re-excavating the area exposed in 2012 and extending at the west end and on the north side of the east end where the leat enters the culvert. Excavation also took place on the north-facing bank of the leat, where it was assumed that the launder(s) led off north-eastwards. In July 2014 excavations took place on the north side of the stone- and hearthstone-lined leat and on the north-facing bank, at the east (culvert) end, exploring likely lauder outflow structures. These excavations briefly resumed in November 2014 in order to fully record the structures revealed.

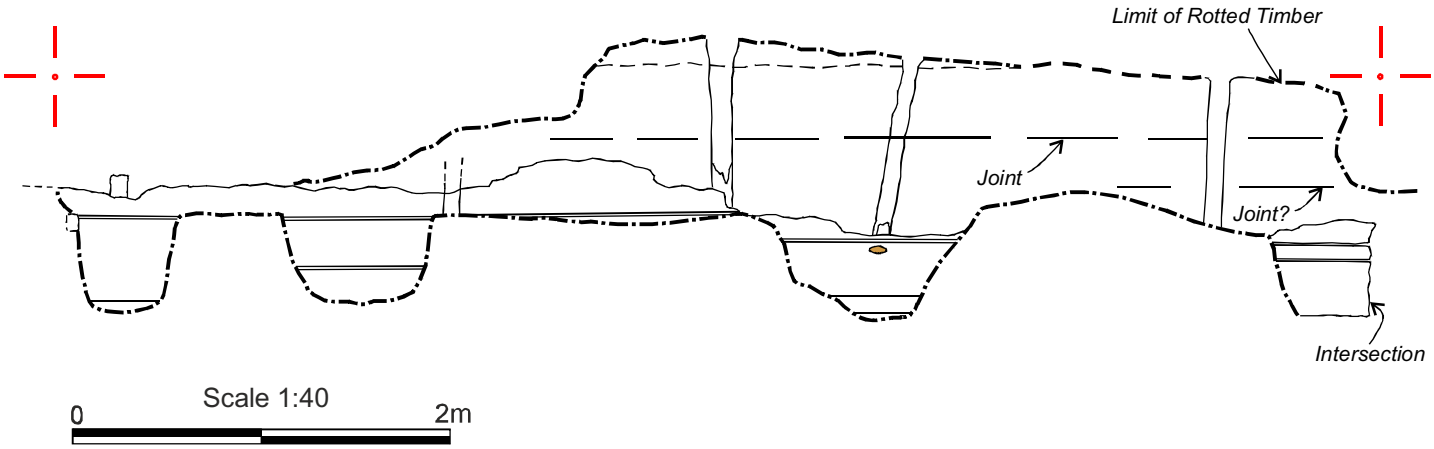
A detailed account of the excavations as they progressed, along with suggested interpretations, is provided in Appendix 1 by Pete Lee, principal excavator of the leat area in 2014. The following account is a briefer examination of the same subject, also provided with interpretations as appropriate, which is intended neither to summarise or conflict with the descriptions provided in Appendix 1.

Description (*Illus. 13-16 and see Photos 15-34*)
Excavation of the leat revealed a floor of reused hearthstones **[01]** previously exposed in 2012, enclosed by roughly constructed rubble walls **[02]** (on the south side) & **[03]** (on the north), that on the south side being largely robbed-out. The total length of leat floor exposed was 8.8 m, the western 7.2 m of which comprised a total of 41 hearth stones c 0.69 m long, averaging c 0.17 m wide, laid side to side and fused by rusting into a single, continuous unit. At the west end hearth-stones, or parts of hearth-stones, were also used to form the foundations of the north and south boundary walls, which survived on the north side up to 0.60 m high, but had been robbed away above foundation level on the south side to expose coarse, core material. Significant additional features at the west end of the leat, where it was extended in May 2014 beyond the limit reached in 2012, included a slot **[04]** 0.11 m wide which extended into the wall foundation layers on either side of the leat floor. On its west side was a hearth stone apparently deliberately-angled obliquely NW-SE to the course of the leat, on approximately the same orientation as that of a poorly-constructed brick wall **[05]** uncovered in 2013 – could this be the remains of an exit from the leat to the middle of the three launders shown on the 1802 site plan, or perhaps *an ad* hoc run-off for water backing up to the east? Also found in this area in 2012 was a socketed stone which may also have been part of a launder or run-off exit from the leat, with water flowing along the dressed face and the socket holding a sluice gate preventing water from flowing west (this would make most sense if the lower end of the leat served as a kind of mill pond, supplied from the east). Three alignments of the leat can be identified over the 8.8 m exposed. Beginning in the west it changes course by c. 10 degrees from ENE towards due east – an extension of the pattern taken further west to bring it from its out-take on the Devil's Water - then, halfway along its course, changes again, more subtly, in the same direction by another degree or two and, finally, from the point at which it meets a chute-like watercourse from the south, by another 10 degrees towards ESE from where it continues on a straight course towards its outflow on the Hall burn.

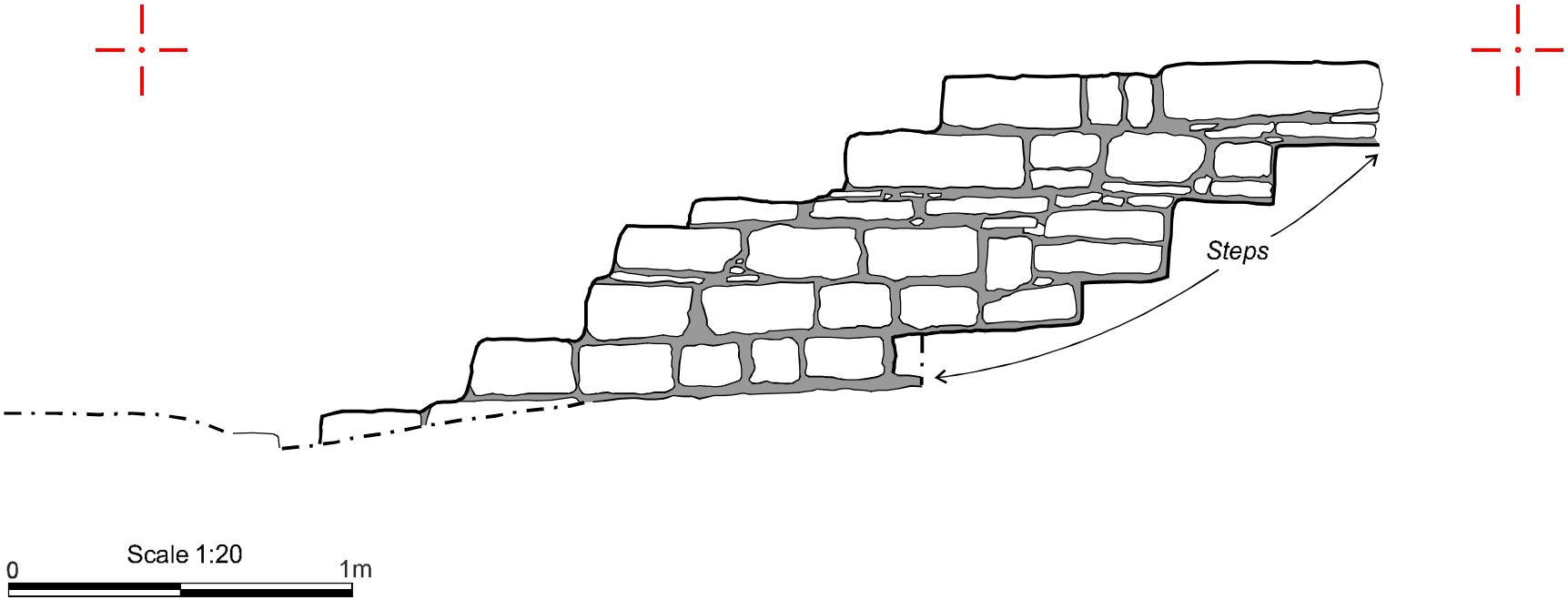
Illus. 13: *Plan of Site B (Leat Trench) showing water supply features including a presumed launder platform on the north-east side of the leat.*



Illus. 14: *North Face of a wall which formed the outer north-facing elevation of the north side of the hearthstone-lined leat and/or the south side of an earlier wooden-shuttered channel or enclosure.*



Illus. 15: *South Facing Section of timber-shuttered holding pond or channel.*



Illus. 16: *West facing section of the launder platform structure on the north side of the leat.*

Extension of the leat excavations northwards and north-eastwards revealed numerous features of note. First, the north-face of the north-side leat wall [03] was revealed as a well-made, clay- or earth-bonded structure of coursed masonry with a gently battered face which, unlike the south face, was well-preserved. Further excavation of the coarse, sandy gravel fill **[05]** north of the north wall of the leat revealed a vertical face of wooden rails, or shuttering, which continued beyond the east end of the battered stone-built leat wall and extended westwards at least as far as the western sluice-gate floor slot. This wooden structure, up to 1.5 m high (where explored by means of test pits) and comprised of rails c. 0.25 m deep and 0.07 m thick, was interrupted at irregular intervals by four vertical, or near vertical gaps, 0.10 m wide, interpreted as post slots for rails subsequently removed, presumably by decay; alternatively, for some kind of water management system. This timber face has clearly been constructed to line a vertical cut in an existing (though not necessarily natural) earthern bank, meaning that the vertical timbers could have been temporary arrangements. A further section of wooden facing **[07]**, though without obvious rail slots, was uncovered east of the leat wall, running N-S against the west end of the north side culvert wall. The latter section of N-S timberwork continued at floor level across the culvert opening, on the east side of a floor slot **[08]** of similar width to that at the west end of the leat (see above) **–** both being interpreted as sluice gate slots - with a further branch **[09]** extending at that level south-east underneath, but at an oblique angle to, the south wall of the culvert structure. In the north-east corner of the enclosure created by the two plank-lined or shuttered faces was another planked face **[10]**, arranged obliquely to stagger the otherwise acute angle between the main E-W and N-S faces whilst maintaining the integrity of the enclosure. This short, oblique section of timber face was secured by posts placed at either end on the external north-east side. All features of this timber, including the position of the pegs in relation to its overlapping north-west end and abutting south-east end, indicate that this timber was designed to resist force (of water) applied from the south and west sides.

The arrangement of timbers suggests that it was originally constructed as a single feature, or at least in a single phase. It seems possible that it was intended to form a pond-like enclosure, fed by the chute from the south **[11]** (described in 2012) adjacent to the south side of the culvert entrance, with its south side perhaps being somewhere close to the position of the current south side of the later stone- and hearthstone leat. Alternatively, its south side was formed by the current well-dressed north side of the later hearthstone-lined leat and it served a similar purpose, bringing water from the west. A further option, suggested by the seemingly rather clumsy nature of the diagonal planking shutting off the north-east corner, is that it was at some stage converted from the former option to the latter, requiring a run-off into launders extending north-east from the north-east corner.

Additional features of note in the leat include those previously described in 2012, such as the aforementioned cobbled chute [11] entering from the south and, opposite it, a double thickness of hearthstones **[12]** perhaps creating the base of a sluice in this location, which would have been necessary in order to control flow to launder(s) and culverted run-off from the later stone-and-hearthstone leat. Credence is added to this view by an additional short piece of timber **[13]**, found at floor level extending between the west side of the culvert north wall and joint between the two hearth stones, apparently forming the north end of the slot next to the culvert entrance. More hearth stones **[14]** underlie and extend north-east beyond the north-east corner of the battered north wall of the stone-&-hearthstone leat, with which they are likely to be contemporary.

Compacted clay **[15]**, together with a hearth stone, filled the north-east corner of the shuttered enclosure, probably serving as a blocking when the latter went out of use. Under the clay fill in the north-east corner of the shuttered enclosure was a cobbled surface **[16]** of similar character to the chute on the south side of the later leat, suggesting the apparent continuation of the stone chute [11] into the base of the launder-exit area, indicating a relationship of the stone chute with the earlier (wooden phase) enclosure (the relationship of the stone chute with the later leat is also suggested by the incorporation of a hearth stone in the north-sloping floor of the chute [11] at its north end where it joins the flat, hearthstone-lined floor [01] of the later leat). Sandier material lay above and around the clay fill in the north-east corner of the shuttered channel/enclosure, while the majority of the shuttered enclosure to the west, as mentioned above, was infilled with compacted, riverine sandy gravels [05], becoming siltier with depth. Except, as noted above, in the north-east corner, no clearly manufactured floor to the wooden enclosure was discovered, but the ground became stonier below the level of the bottom plank, suggesting that the floor was formed of natural boulder clay or bedrock.

Further excavations were carried out on the north-east side of the apparently-modified north-east corner of the wooden enclosure, with the aim of determining the course and nature of launders taking water out of the leat(s)/holding pond to the north and/or north-east. This eventually involved the partial removal of a cobbled surface reported in 2012 extending over the north part of the infilled shuttered enclosure. Immediately north-east of the north-east corner of the shuttered enclosure was a deposit of apparently-layered, large, flattish stones **[17]** which appeared to have been placed there and blackened underneath, as if (on the basis of observations elsewhere) they had been in a flow of water. Although lacking clear structural form, the form and arrangement of these stones suggested the possibility that they could have formed the roof of a culvert over a channel between leat and launder – this suggestion is discussed more extensively in *Appendix 1*. Further excavation revealed a number of stone-built features on various alignments, as follows:

The most prominent feature uncovered in this area was a well-built stone wall **[18]** on a SW-NE alignment, its south-west end projecting towards the north-west end of the truncated north-east corner of the wooden enclosure. The wall ran for some 2.8 m before returning to the south-east, forming a neat, square-cornered platform feature, the east side of which was not revealed but presumably lay under the east baulk of the trench. A cobbled and flagged floor surface **[19]** was revealed on the north and west sides of the platform feature, that on the west leading to the foot of a short flight of heavily-worn stone steps **[20]** arranged alongside the SW-NE wall and leading to the top of the bank above the north side of the shuttered enclosure. The steps, which seemed to be turning towards the west, as if onto the bank above the shuttered enclosure, appeared to have been truncated by the deposit of large, flattish stones [17] mentioned above. Below the latter was a NW-SE alignment of stones **[21]**, apparently a wall, lined on the south side by a wooden plank (only partially-revealed) running north-east of, but at a slightly different alignment to, the short section of wooden planking forming the truncated north-east corner of the shuttered enclosure. This stone and timber feature appeared to form an integral part of a larger structure bordered on its north-east side by another alignment of stones **[22]**, faced on the north-east side, the two alignments framing a short stone chute **[23]** of similar nature, though much shorter and with a steeper gradient than, the chute [11] on the south side of the east end of the hearthstone-lined leat.

Thus, the structure north-east of the leat(s) can be characterised as two raised, built features, that on the south side, containing a short chute [23], falling 0.47 m, sitting above and within, and on the same alignment as, the larger structure defined by faced walls [18], more or less flat in profile (there is a 0.35 m height difference between the bottom stone of the chute feature and upper surface of the platform feature at its extreme north end) which is bounded by steps on its west side. At the south end of the clearly built features a deposit of flattened stones [17] appears to seal the area between the stone features described and the shuttered enclosure, in so doing providing a basis for the cobbled surface **[24]** first seen in 2012. The only other feature of note in this complex of features is an alignment of stones **[25]** running SW-NE between the foot of the stone chute [23] and north end of the main platform feature [18], but at an oblique angle to it. It may be that this was created as an accidental product of excavation, but if not could represent the course of a launder to the north-east.

Interpretation

An extended interpretive discussion of the results of excavation is given by Pete Lee in *Appendix 1*. The following attempts to summarise that which can be stated with some certainty.

It is now clear that what appeared, on the basis of the 2012 excavations, to be a relatively straight-forward leat feature providing water to operate waterwheels in the main industrial working area to the north and north-east, is a much more complicated, multi-phased complex of features. What is clear is that a linear enclosure at least partly bounded by wooden shuttering was infilled and succeeded by a stone-walled, hearthstone-lined channel. It remains unclear how the stone chute on the south side of the later channel and the stone features on the north-east side of the shuttered channel or enclosure relate to these two main features.

However, it may be postulated that the first development on the steeply sloping valley side was a shuttered enclosure used to channel and contain a head of water to supplement or replace the direct Hall Burn source. The shuttered structure was dug into the bank, with timber shuttering on both sides, or restricted to the north, with a faced stone wall on the south side, and spoil from the excavations used to strengthen and widen the outer bank. The new supply, using water taken off the Hall Burn some distance upstream - where enigmatic and suggestive stone structures are still visible (see *Photo. 42*) - and led northwards along its western valley side, supplied an overshot waterwheel, the pit for which was revealed by excavation in 2014, by means of a launder. In this scenario, it is also possible that such a holding pond also supplied water to the north (i.e. towards the position of the Refinery shown on the 1802 site plan), via launders exiting further west along the shuttered channel/pond, notably in the position of the floor slot revealed at the west end of the current excavations. It also remains possible, however, that the shuttered enclosure, or channel, was simply an earlier version of the subsequent hearthstone-lined leat supplying water from the original or first phase weir on the Devil's Water

Whatever the original function of the shuttered structure, it was subsequently infilled, perhaps when the new dam was created to improve the head of water from the Devil's Water, a process completed by 1802, but which probably occurred rather earlier, possibly when the smelting capacity of Dukesfield Mill was increased around 1750. Pete Lee (in Appendix 1) speculates that this may have involved the development of a different waterwheel to the west

of the original structure, in the flat area of ground to the west of the Dukesfield Hall track. The new dam is probably contemporary with the stone and iron-lined leat, although it is possible that the latter couldinitially have been fed from the old weir on the Devil's Water before it proved inadequate. The culvert at the east end of the leat was built at the same time as the new leat to act as an overflow run-off. Adjacent to it, the east end of the former shuttered (channel or pond) enclosure was not infilled, except at low level (to the top of the diagonally placed plank), since that area was required as an exit route for water supplying a launder from a new, raised level. Hearth stones were reused in a position obliquely across the former shuttered enclosure to act as foundations for a wall, perhaps enhanced by shuttering and the floor level at this exit was raised to the level of the new leat bottom (level with the top of the diagonally-placed plank in the north-east corner of the former shuttered enclosure).

It is likely that the substantial stone features north of the east end of both the shuttered and stone-built channels served both phases of water supply. The stone chute looks like a water run-off device, in which case it is likely to have served the earlier shuttered-channel enclosure, with water raised by the now-truncated diagonal NE end planking spilling over onto it.

Such a feature would have been rendered redundant in the later phase by the culverted run-off, unless the supply from the new leat to the launder was imperfectly sealed, warranting the use of an additional run-off or drainage mechanism in that position. The remaining substantial stone structures in this area seem likely to have been constructed to carry a substantial wooden launder connected to the leat exit, thereby maintaining the head of water and allowing its gradual descent to the overshot waterwheel(s) below. Lee (*Appendix 1*) suggests that a new wheel-pit was constructed west of the arches powering bellows for new hearths in an extended mill building (as shown on an 1802 plan of the site) as well as the old hearths at the foot of the Arches. He also suggests that the new wheel was oriented north/south, with a shaft taken over to the old hearths, where a solid and substantial pillar base built at the east end of the original wheel pit could have carried the shaft and its bearings. This suggestion is plausible but remains unproven pending further excavation.

Trench 2 – a small test-pit 1.5 m x 1.5 m was excavated on the artificial platform above the culverted run-off from the east end of the leat. Excavation revealed a sandy deposit sitting directly upon the vaulted roof of the culvert. No other features or finds of any kind were made during this small-scale excavation.

Trench 3 – On the north side of the launder-head complex at the east end of the leat a small test-pit was excavated over the site of a possible wall feature to reveal a wall face up to seven courses and 1 m high, the depth of which was not ascertained. The wall (see 'X' on *Illus. 09*) ran on an east-west course close to the foot of the leat bank, the course of which it followed. It is thought likely to have served a role in constructing or demarcating the course of the leat bank but may, alternatively, have served another purpose.

3.3 SITE C. BUILDING REMAINS EAST OF THE ARCHES

Buildings are shown on early site plans east of the arches on the north side of the Hall burn, south of the entrance trackway, some remains of which had been traced on the surface in

2012. Visible remains of walls were investigated in order to elucidate their form and function within the site. One main trench was opened with two smaller supplementary trenches to the west.

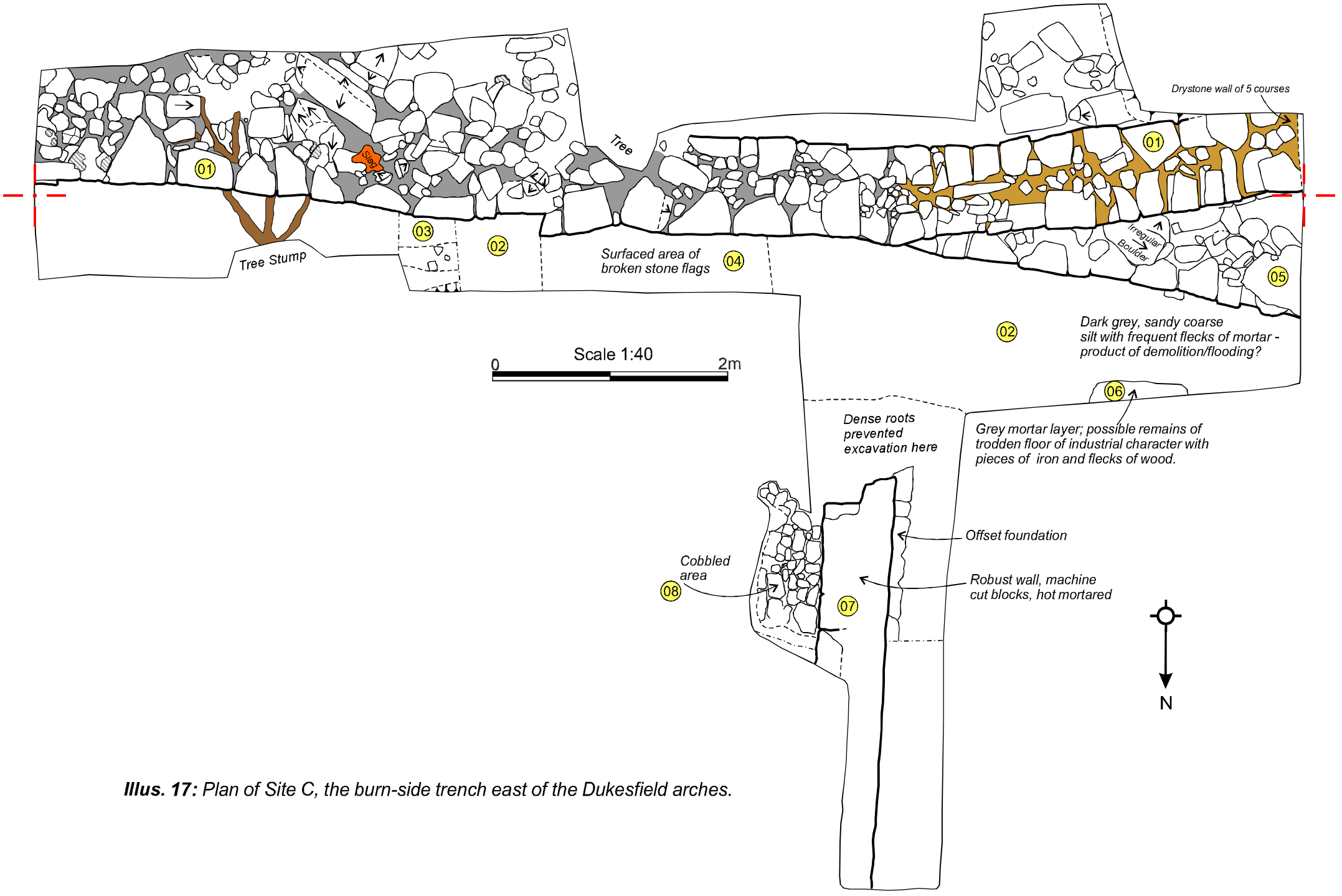
Trench 1 – 10.8 m (E-W) x 7.6 m (max. N-S)

Description (*Illus. 17-18 and see Photos 35-37*)
The excavation revealed a number of walls. The first wall **[01]** extended along the entire south side of the trench. It was of rubble stone construction, 0.80 m wide, comprising two faces of crudely faced sandstone pieces with a narrow rubble core. The wall was on two alignments, the eastern two-thirds being a little south of east in its projection eastwards, the west part being a little south of west in its projection westwards; the course of both alignments was more-or-less straight. The wall appeared un-bonded at the west end (or at least any mortar-bonding had not survived), but the longer eastern part appeared mortar-bonded, despite which a large section on the south side at its east end had suffered from erosion where it approached the diverted course of the Hall burn more closely than in the west. The tumbled nature of its south face (and apparent slippage of the north face) here prevented accurate measurement of its original width, but indications are that it did not vary from the measurable west and central sections. Several test pits were excavated against the north face to determine its depth and search for any buried floor surfaces or indications of possible function. The test pit excavations revealed the wall to comprise at least seven courses of masonry surviving up to a height of at least 0.75 m from original foundation levels. No firm floor structure was reached in the test-pit excavations which revealed a deposit of mixed rubble **[02]**, containing fragments of pantile and stone roofing tile, above a dark, waterlogged, organic-rich deposit **[03]**. Whether a solid floor surface lay below this was not ascertained. A possible surface of broken stone flags **[04]** was reported at shallower depth on the north side of the wall in its central section, however.

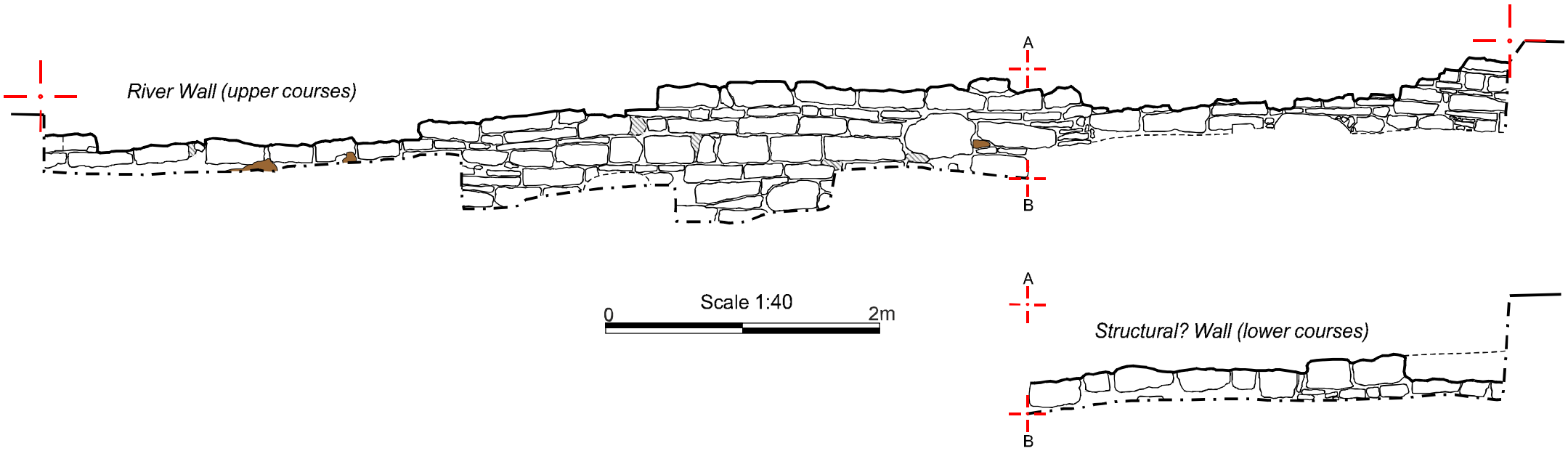
Further excavation at the west end of the trench revealed the lower courses of a second wall **[05]**, of similar construction to the first but mortar-bonded and clearly structural (load-bearing), running under and at an oblique angle to the drystone wall described above. The width of the underlying wall could not be determined within the trench since its south face was obscured by the overlying drystone wall, but it appeared to be at least a metre wide, suggesting that it could have formed part of an early structure. A metre of so in front (north of) wall [05] was a concentration of compacted mortar containing industrial waste deposits **[06]** and suggestive of a beaten floor deposit.

An extension to the trench was made to the north in order to investigate potential floor deposits and/or a return to the putative enclosed building suggested by the underlying wall described above. This revealed, some 1.9 m north of the north face of the burnside wall, a wall **[07]** on a north-south alignment, 0.62 m wide and surviving up to two course high with an underlying off-set rubble foundation course of rough cobbles. This wall was well-built and bonded with strong mortar or cement, suggesting a fairly modern origin, almost certainly as part of a load-bearing structure. The wall, including its foundation course, appeared to end, or to have been deliberately truncated, at its south end, while on its east side at its south end were the remains of a cobbled floor **[08]**.

The functions and relationships of the three walls are difficult to determine. The underlying wall [05] certainly pre-dates wall(s) [01], which is itself perhaps of two phases. Wall [08],



Illus. 17: *Plan of Site C, the burn-side trench east of the Dukesfield arches.*



Illus. 18: *North Facing Section of overlying walls east of the arches.*

however, is of different character to the others and a structural or functional relationship with any of them appears unlikely on the basis of different character and quality of build, as well as wall width and alignment. On the basis of the latter it is easiest to see a relationship between wall [07] and the east part of the riverside wall [01] which runs nearly orthogonal to it. None of the finds – principally ceramic and stone roof tile, but also including scraps of metal – found during the excavation shed any additional light upon the function of the structures uncovered or their inter-relationships. The riverside wall is likely to have performed a role, in part or exclusively, in flood defence, preventing serious inundation of water and, more importantly, the destructive effects of erosive material carried by the burn in spate. The other, probably more load-bearing elements of the complex, notably walls [05] and [07] were probably roofed structures, but in the absence of significant quantities of burnt material or ore, it is considered likely that their function was related to storage or stabling.

Two additional exploratory trenches were excavated to the west of the main trench, one of which showed that the wall line [01] extended westwards by at least another 6 6.5 metres along the burnside, but which otherwise produced no significant results.

4. DISCUSSION

Excavation in 2014 focussed on the re-excavation and expansion of two sites previously explored, namely the leat and smelting hearths areas, with a third site to the east of the arches on the north side of the Hall Burn. The latter site revealed two or more phases of stone-built structures which are thought likely to relate partly to flood-management and partly to buildings seen in that part of the site on an early 19th century plan, the character and purposes of which are unknown but thought likely to relate to storage or administration. The complex range of features revealed at the other two sites are thought highly likely to be functionally related to each other, since the lower (smelt mills) site at the north end of the arches depended for its power supply upon run-off from the leat above.

Elevations taken during several site surveys indicate a fall of 3.78 metres from the top of the excavated remains of the wheel pit in the smelt mills trench to the outflow of the diverted Hall Burn on the Devil's Water. Assuming that the outflow position is close to the current Hall Burn-Devil's Water confluence, the bottom of the wheel pit can have been no more than 3 metres below the surviving top of the wheel pit walls – allowing a minimum of 0.75 m fall to the outflow position which itself would surely have been raised a little above normal river level to account for river level rise after rainfall - suggesting that the bottom of the wheel pit was indeed reached during the current excavations.

Survey points taken at the bottom of the shuttering in pits cut into the silty rubble infill against it suggest that the bottom of the wooden shuttered enclosure, or channel, may not have been provided with a significant gradient – thereby supporting the 'mill pond' theory. Two points, taken 2.75 m apart, indicated a 0.01 m (1 cm) fall from east to west, while a third point, taken at the bottom of the shuttering near its intersection with the diagonal (blocking) timber, returned a height measurement exactly the same as the middle point. However, it should be cautioned that the bottom of the timbers need not be equivalent to, or mirror, the bottom of the channel or enclosure it lines. The bottom of the shuttering (i.e. possible bottom of wooden channel/enclosure) at the presumed exit point to the launder is 3.96 m above the highest surviving point of the wheel-pit, making the top of the (surviving) shuttering (1.40 m above the lowest point uncovered in the test-pit) some 5.36 m above the highest surviving point of the wheel-pit. The bottom of the shuttering is measured as 0.48 m lower than the adjacent point on the hearthstone-lined leat; the level of the latter falling gently by 0.12 m from the (sluice) slots at the east and west ends of the excavated area.

This evidence suggests that a total of c. 8.36 metres height difference was available for use between the top of the wooden enclosure/channel and bottom of the wheel pit. Therefore, accounting for the necessary fall of the launder from outflow to top of overshot mill-wheel, the available diameter of mill wheel would have been c. max. 8.2 m, roughly the same as the measured length of the wheel pit (8.1 m). However, this should be regarded as an extreme maximum figure, since it is unlikely that the take-off into the launder from the wooden enclosure/channel would have been at the maximum height of its walls, likely that the allowance for rising river levels would have been more generous and possible that the wheel pit was timber-lined, thereby reducing its available length. A wheel diameter of 7.6 metres (25 feet) would seem more realistic. In that case, the wheel axle would have been set some

half a metre or more above the surviving wheel-pit remains, at or a little above current ground level.

It is quite possible, however, that the take-off of water into the launder was at a rather lower level, closer to that indicated by surviving timberwork and associated stonework across the corner of the shuttered north-east enclosure/channel. However, this would have resulted in the loss of at least 0.70 m in available height fall from launder exit to the bottom of the wheel pit, resulting in a reduction in the wheel diameter to around 7 metres (23 feet).

The wooden mill pond feature implied by the measured levels detailed above could have been filled either or both from a secondary leat from the Hall Burn, outflowing at the position of the surviving cobbled chute on the south side of the excavated area, or via a leat from the Devil's Water at lower level to the later, hearthstone-lined version, but the former seems more likely. Perhaps there was a later attempt to reuse the wooden channel as a leat (rather than a pond) supplied from the Devil's water, which failed, resulting in the construction of the new dam and raised, parallel leat to the south. However, this, along with most other interpretive suggestions concerning water supply to the Dukesfield smelt mills over the two centuries of their operation, remains a speculative interpretation.

The development of the later stone-&-hearthstone-lined leat resulted in a rise in floor levels by half a metre, but it is unlikely that this new channel was designed to be watertight, holding a raised level of water; rather, it was designed as a channel for continuously flowing water. The measured levels suggest a height difference of about 0.25 m between the bottom of the leat at its east end and the line of stones, lined on its south side by a plank, at the point of outflow to the launder. This suggests a water height in the later channel of c 0.25 m, perhaps less, implying that the diameter of the wheel served by this means would have been of the same order as the more modest option suggested for the earlier arrangement (above); in the region of 7 metres. Could it be, then, that the wheel pit as excavated served the earlier arrangement (assuming the wooden shuttered enclosure acted as a pond rather than as a channel) and that a putative later wheel pit elsewhere (perhaps west of the first, as suggested in *Appendix 1*) was of somewhat smaller diameter? This particular speculative suggestion could be tested by further excavation.

The stone-built features north and north-east of the leat(s) are likely to have functioned as supports for the launder structure and spill-ways for leaking or excess water, but whether during the putative first of second phases described above, is unclear. The steps on the west side would probably have provided secure access to the bank-top above the wooden pond/channel enclosure for maintenance or operational purposes. It appears, however, that this system was abandoned at some point, presumably when the shuttered enclosure was abandoned, the steps and stonework to the east being covered by relatively unstructured stonework which appears, in part, to have served as a base for the cobbled surface first uncovered, in part, in 2012 at or immediately below current (bank top) ground level. The cobbling and, to an extent, stonework infill below it presents a problem because it seals any outward channel between leat and presumed launder. This can only be explained by the presence of a conduit, for which the structural evidence did not appear completely convincing (although see *Appendix 1* for suggestions to the contrary), or by assuming that the sealing and cobbling of the former channel site took place following abandonment and dissembling of the launder system. Why this should have taken place, however, when it would have been far simpler simply to prevent inflow of water from the Devil's Water, is

unclear. The cobbled surface implies that the leat was still being used, albeit (in the above scenario) without a launder at the east end. Perhaps a launder was still in operation further west, requiring access between it and the sluice gate to the steeper, culverted run-off channel.

It remains to comment on the features revealed on the south side of the wheel pit in the smelt mills area, since these are the remains of structures which consumed the power generated by the water supply discussed above. These features are suggestive, based on precedents such as Lumb Clough Mill site in Yorkshire (Dickinson et. al 1975), of mountings for bellows, with associated hearths located close to both ends of the wheel pit. The presence of layers of timber flooring between the putative bellows support features suggests that more than one phase of operation could be reflected in the features and deposits found there, which would be entirely in keeping with the historical documentary evidence and archaeological evidence from the leat area, which suggest at least three main operational phases for the smelt mills. Further excavation on the west and north-west sides of the wheel pit excavated in 2015 would assist with the elucidation of these interpretive problems.

5. REFERENCES

Carlton, R & G Finch, 2012, *Dukesfield Lead Smelt Mill Arches: Community Heritage and Conservation Project;* The Historical Metallurgy Society, Research in Progress Conference, Tuesday 6th November, 2012, Research Beehive, Newcastle University.

Carlton, R, 2012, *Fieldwork on the site of Dukesfiled Smelt Mils in 2012*. Unpublished Report by The Archaeological Practice Ltd. for The Friends of North Pennines.

Carlton, R, 2014, *Fieldwork on the site of Dukesfiled Smelt Mils in 2013*. Unpublished Report by The Archaeological Practice Ltd. for The Friends of North Pennines.

Dickinson J M. Gill M C & Martell HM, 1975, Lumb Clough Lead Smelting Mill, British Mining No. 1, 5-17.

Linsley, S. M, 2006, *The Life and Times of Thomas Dixon 1805 – 1871.* Wagtail Press, Steel, Hexham.