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The Alum Works and other industries at Kettleness, North Yorkshire: an archaeological and historical survey

Marcus Jecock, Christopher Dunn, Ann Carter and Mick Clowes

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1. INTRODUCTION, SITE LOCATION AND SUMMARY

Between July and September 2002, a team of English Heritage (EH) archaeological investigators carried out field survey and investigation of the site of the disused alum works at Kettleness, North Yorkshire. The survey was undertaken as part of a wider, thematic, project, initiated by the former Royal Commission on the Historical Monuments of England (RCHME), to investigate selected alum sites in North Yorkshire and Cleveland as a follow up to recommendations in EH's Monuments Protection Programme's (MPP) Step Reports for the alum industry nationally (Gould 1993a; Chitty 1996). Several of the alum works in the north-east of England are threatened by coastal erosion, and consequently MPP had recommended a directed research programme of survey (and, ultimately, excavation) in advance of the sites' eventual destruction and loss. Since the threat arises from natural forces, such a programme is beyond the scope of PPG16 developer funding. RCHME merged with EH in April 1999, and the project has since been taken forward within EH as the Alum Industry Module of the Step 4 Industrials Recording Programme (Topping 2000). Two sites were selected for survey: Kettleness and Loftus. Because of their precarious locations, and in order to construct a permanent three-dimensional record of them, field investigation was preceded by, and built on the results of, photogrammetric mapping and aerial transcription. For Kettleness, such mapping and transcription took place in the autumn/winter of 2000-01; field enhancement was originally scheduled to follow on immediately after, but was delayed by a year until summer 2002 because of the outbreak of Foot and Mouth Disease across northern England and the resulting restrictions imposed on countryside access.

Historically, alum played an important role in the success of the English textile industry, where, before the advent of modern chemical dyes, it was used as a mordant to 'fix' natural dyes and prevent them running and fading with time. In chemical terms, alum is a double sulphate of aluminium in conjunction with an alkali, normally either potassium or ammonium. Although it is the aluminium sulphate which is the active ingredient, pure crystals are highly soluble and also hygroscopic (that is, they readily absorb water from the atmosphere); hence the preference for using alum whose crystals are less soluble and easier to keep and transport (Almond 1975, 11; Rout 2002a, 25). Before the 15th century, alum could only be made from minerals such as alunite, which already contain the required double sulphate. Alunite does not have a wide distribution, and is completely absent from the British Isles; at the time, therefore, alum had to be imported into England from the Mediterranean and Asia Minor, and was correspondingly expensive with supplies prone to interruption from wider geo-political events. In the 15th century an alternative process was developed in northern Europe, based on the extraction of aluminium sulphate from shale, to which the alkali was subsequently added. The methodology appears to have been a closely guarded secret and knowledge spread only slowly, but by the mid-16th century efforts were being made in England to locate shales suitable for the new technology, and to establish a rival domestic industry. These attempts initially centred on the Isle of Wight and Dorset but were unsuccessful, and it was not until 1604 that the first viable English alum works was established at Slapewath, near Guisborough in North Yorkshire (Rout 1998; Pickles 2002). Accordingly, alum manufacture has been cited as the earliest branch of the inorganic chemical industry in England (*eg* Morrison 1981, 3; Miller 2002a, 1). Recently, however, Allen, Cotterill and Pike have pointed out that ferric sulphate (also known as copperas or green vitriol), was being manufactured on a commercial basis in southern counties by 1579 (Allen *et al* 2001). Copperas had a variety of uses, but could also function as a dye fixative.

The new shale-based technology required shales containing aluminium in combination with at least 5% iron pyrites (iron disulphide), in order to provide a source of sulphuric acid to convert the alumino-silicates to aluminium sulphate (Rout 2002a, 19). Although such 'alum shales' occur fairly widely across England, the first successful exploitation was of shales outcropping in and around the North York Moors, which thereafter became the main centre of the domestic industry. These North Yorkshire shales lie beneath a considerable thickness of overburden, and consequently the quarries were located around the fringes of the moors where the shales are exposed in escarpment edges and valley sides, and on the coast where they outcrop in the faces of sea cliffs. At least 24 alum quarries are known to have operated in the region between 1604 and 1871 (Pickles 2002, 8). Over time, it was the coastal sites that prospered, probably because of cheaper transport costs linked to their proximity to shipping routes.

The new process involved burning or 'calcining' the quarried shale on a bed of faggots and gorse (locally called 'whin') in large clamps, which burned slowly for several months. This set in chain a sequence of chemical reactions within the rock, after which the calcined shale was barrowed into tanks with water to 'steep'. The resultant 'liquor', which comprised a saturated solution of aluminium and other sulphates, was then conveyed to the alum house where it was concentrated by boiling, a source of alkali added, unwanted by-products removed, and finally the alum crystallised out and purified (Rout 2002a, 19-24). Because of the large quantities of both shale and fuel needed – it has been estimated that 100 tons or more of shale and 6 tons of coal were needed to produce 1 ton of alum (Morrison 1981, 10-12) - all stages of manufacture almost always took place in and around the quarry. The trade was the basis for much wealth locally, including that of the Mulgrave Estate on which the Kettleness works lies. Since the majority of the alum was shipped out, it also played a part in the rise of Whitby as a port (whose prosperity in the 18th and 19th centuries was not solely based on its fishing fleet as is often supposed). However, the Yorkshire alum industry became increasingly uncompetitive, particularly following the patenting of the Spence process in 1845 which treated waste shale from coal mining directly with commercially produced sulphuric acid (Pickles 2002, 17). The last Yorkshire works closed in 1871.

Kettleness is the first of the Yorkshire alum sites to appear in this EH report series. Field survey was carried out to Level 3 standard (as defined in RCHME 1999, 3-5), backed up by less intensive documentary research confined to readily available published sources and a limited trawl of historical archive material. A set of colour ground photographs was also taken by an EH photographer as part of the recording process: some are reproduced in the present report, while a full listing is attached at appendix 1. This appendix also contains details of the vertical aerial stereo-imagery taken in 2000 as the first stage in mapping the site.

The works lies on the coast at National Grid Reference (NGR) NZ 833 160 some 8km north-west of Whitby, on Kettleness promontory which forms the east side of Runswick Bay (Fig 1).

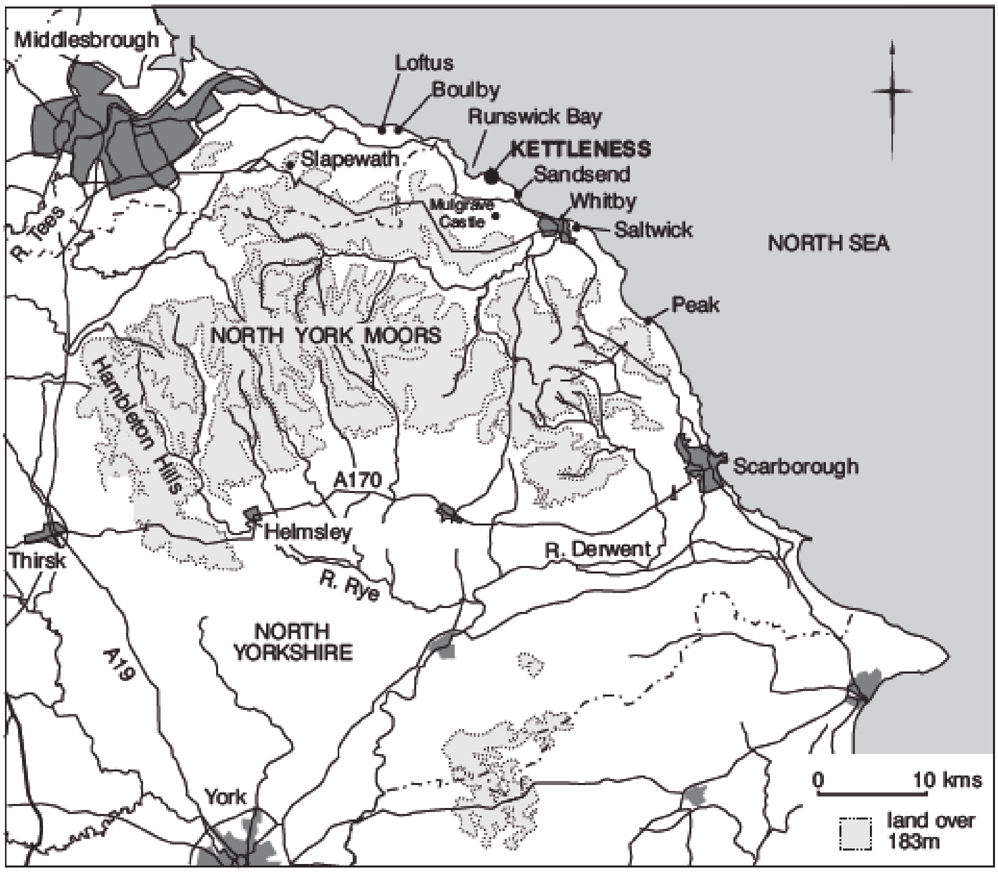

Figure 1 General location diagram

It was set going in 1727, and was worked almost continuously directly by, or by lessees on behalf of, the Sheffield and Phipps families (successive owners of the Mulgrave Estate) until it finally closed in 1871. At least four other alum quarries operated at varying times on the estate: one situated on the coast at Sandsend, the other three located a little inland close to Mulgrave Castle. The latter had all been abandoned by shortly after the turn of the 18th century, and were subsequently incorporated into a landscape setting laid out around the castle to designs by Humphrey Repton; the Kettleness quarry may have been started as a replacement for them. Kettleness hamlet is first mentioned in parish records at around the same time as the works opened (David Pybus, pers comm), suggesting it was created specifically to accommodate alum workers. However, the majority of this early hamlet appears to have been situated at the foot of the cliffs within Runswick Bay, where the alum house was also initially located; all were destroyed in a landslip at the end of 1829. The core of the hamlet then moved to its present location on the cliff top south-west of the works, whilst a new alum house was built on the west side of the headland within the quarry. At closure in 1871 the works was mothballed, but in 1875 the decision was taken to start dismantling the infrastructure for its scrap value. Since then, what was left behind has decayed and parts have fallen into the sea as the cliffs have continued slowly to recede.

Although the broad range of features which survive at the site had already been listed by the MPP prior to the present investigation, the survey has nevertheless identified much that is new; it has also refined or questioned previous interpretations, and has quantified the current state of preservation. For example, it has shown that portions of two banks of steeping pits and associated structures on the east side of the headland, plus elements of the later alum house on the west side, are all slowly but surely being destroyed by cliff recession; part of the top end of the original access track to the works also disappeared in a major cliff collapse as recently as August 1999. Furthermore, the survey has located part of a probable liquor-trough tunnel, the routes of sundry other troughs or pipes, and the sites of a number of previously unknown buildings and calcining places; it has also cast doubt on the claim that an extant mound within the quarry is an undismantled clamp. The remains of a small staithe are visible at low tide in Runswick Bay near the foot of the promontory, as are several lengths of rock-cut rutways. Whilst the survey has found documentary evidence to show that the staithe should be associated with the early alum house (whose probable site has also been identified), it has not been possible completely to discount a previous suggestion that the rutways are associated with ironstone quarrying on the foreshore, for which there is documentary and archaeological evidence. Two shipwrecks identified by the survey on the reef around the headland are both probably of 20th-century origin and unconnected to either the alum or ironstone trades.

In addition to alum and ironstone, the survey has found evidence for the exploitation of jet and cementstone on the headland. The jet seam, which lies just below the lower limit of the profitable alum shale, was mined principally, but not exclusively, in the 19th century (the Mulgrave area was already well known for jet by the 17th century), and indeed the survey has found physical evidence of jet mines which appear to pre-date the alum works. Cementstone from within the alum shale started to be kept and processed into cement from 1811, but the industry has left no physical trace at Kettleness apart from a probable trial drift mine. A number of fossil plesiosaurs have also come from the quarry: the story of two discovered in the 1840s during shale extraction, and their place in the history and development of palaeontology, is related by Osborne (1999); a third exposed more recently by erosion of the quarry floor was excavated and removed to the Yorkshire Museum in 1999.

The site was evaluated for statutory protection as part of MPP and graded as 3-star (Gould 1993b), and in 1998 the area of the quarry was accordingly scheduled as an ancient monument (RSM 29545). All features on the foreshore are currently excluded from the scheduling, however. The headland is potentially an extremely hazardous place with steep, overgrown spoil dumps, and crumbling sea cliffs liable to collapse at any time without warning. In addition it is private property, with no automatic right of public access. Unauthorised visits are therefore not only ill-advised, but also a matter of trespass.

2. GEOLOGY, TOPOGRAPHY AND LAND USE

Kettleness alum quarry occupies almost the entire area of a small promontory which juts out northwards into the North Sea, briefly interrupting the overall north-east aspect of the Yorkshire coast between Teesside/Middlesbrough and Whitby. On the promontory's west side is Runswick Bay, a partly-flooded syncline, while on the east side the coastline resumes its south-easterly course towards Sandsend and Whitby (Fig 1). The promontory is broadly triangular in shape, with a long, thin, northern point widening out to a broad southern base (Fig 2). According to the Ordnance Survey (*eg* 1856; 1894; 1972b) the point is properly called Kettle Ness, but the name appears to have been corrupted to Kettleness early on when transferred to the alum works, a form which by association is now often applied to the promontory as a whole; the Ness itself seems more commonly referred to as Kettleness Point (*eg* Fig 5; Young 2000, 61-5). Kettleness is also the name of a small hamlet and farm situated on the cliff top immediately south-west of the alum works.

The sea cliffs at the base of the promontory are between *c* 80m and 100m high, and are comprised mostly of Jurassic shales of the Upper Lias sealed by a cap of carboniferous sandstone *c* 8m - 12m thick, above which in turn is a layer of glacial till or boulder clay (Howarth 1962). The top 50m or so of the shales consist of the Alum Shale Series, so called because of their past exploitation for the manufacture of alum, although Winter (1810, 246) reports it was the uppermost 30m or so which were most prized. Underlying the alum shales are the Jet Rock Series and Hard Shales, both with a lower sulphur content and therefore ignored by the alum makers. Various forms of calcitic, carboniferous and sideritic concretions which occur within these divisions of the Lias shales - either at random or in stratified horizons - have also seen commercial exploitation. The two principal such minerals are cementstone and jet, although pyrites nodules weathering out of the cliffs onto the foreshore were also collected in the early 19th century; a series of ironstone seams underlying the Hard Shales have also been mined at locations along the coast, including, briefly, from the foreshore at Kettleness.

At the foot of the cliffs a gently-sloping wave-cut platform is exposed at low tide extending for some distance offshore (Fig 2), before dropping away quickly into deeper water. This platform is commonly referred to as the reef, and in many places is made up of a whole series of smaller, wave-cut platforms, each terminating in a low 'scar' or ledge of *in-situ* rock, the product of differential erosion of the near-horizontally-bedded strata. Major landslips can bring down many thousands of tons of shale, sandstone and other rocks onto the reef. Over time, the shales and more finely comminuted material are washed away by the tides, leaving behind the larger boulders of sandstone and harder-wearing material. These foreshore boulder fields can be extensive, and are useful as indicators of the sites of historical cliff collapses. Indeed, a finding of the present survey is that a boulder field on the Runswick Bay side of the headland (Fig 3) probably marks the toe of a documented landslip in late December 1829, which destroyed the early alum house and staithe at the Kettleness works. A contemporary description (Anon 1829) bears all the hallmarks of the slip having been of

Figure 2. Digital orthophotograph of Kettleness Alum Works, produced from a run of overlapping vertical images. Topographical names and selected features mentioned in the text have been added. Note the extent of the reef which surrounds the headland at low tide (NMR AEL/00C/515, frames 9664-76)

Figure 3. General view of the boulder field on the reef in Runswick Bay which marks the original extent of the 1829 landslip. The remains of the staithe which have re-emerged from beneath the toe of the slip are arrowed (NMR AA040227)

the rotational variety, the most common form of cliff collapse along this stretch of the Yorkshire coast: a segment of cliff shears along a plane some distance back from the edge, probably weakened by percolating ground water or by the removal of previously fallen material from the foot of the cliff, forcing the weakly-jointed shales at the base out and forward onto the foreshore; the overlying strata then drop down to fill the void but can often remain largely intact (Lee and Clark 2002). At Kettleness, the heel of the slide's footprint is evidenced by just such a 16m-17m vertical displacement in the sandstone cap at the top of the cliffs (Fig 42). The overall area which seems to have been affected is highlighted on Figs 2 and 11. A second major landslip occurred in August 1999, immediately west of and partly overlapping with the 1829 collapse; its limits are clearly visible on Fig 2.

The present survey has also shown that wind and water erosion are affecting parts of the quarry, and have combined to lower parts of the quarry floor by, in places, several metres since the alum works closed in 1871. This erosion is still active. Three areas are worst affected, all defined by the green scarps on Fig 11. Something of the extent and effects of the erosion on the east side of the headland are quite clearly visible in Fig 4, which shows that the northern side of the concrete base of a coastguard structure (section 6.5 below) - which must have been formed by pouring concrete into a hole dug into *in-situ* shale bedrock - is now fully exposed. The photograph also demonstrates how a stone gutter (which originally brought water to the steeping pits within the alum works) has served to protect a ridge of the underlying shale, whilst all around it the shale bedrock has weathered away.

It seems reasonable to assume that prior to the opening of the alum quarry, the carboniferous sandstone cap would have extended over the entire surface area of the promontory with the possible exception of Kettleness Point itself. The surface of the headland would, therefore,

Figure 4. View west across the quarry floor from close to building 1, showing the depth of surface erosion. Note how in the middle distance the stone gutter has protected the shale beneath it, while behind it the side of the concrete base for the coastguard breeches buoy is gradually being exposed. (NMR AA040240)

have been at very much the same level as the ground immediately to the south, and in all probability would have been mostly an extension of the then agricultural landscape with fields extending to the cliff edge on all sides. However, the quarry itself is now a landscape of exposed shale bedrock and of spoil dumps colonised in places by rough grasses, heather and gorse. Panoramic views across it can be gained from the Cleveland Way coastal footpath which follows a farm track immediately above the quarry, but the quarry itself is private property with no automatic right of public access.

3. PREVIOUS RESEARCH

Many recent synthetic papers on the alum industry contain passing references to Kettleness, but unlike for example Boulby and Saltwick (Chapman 1975; 2002; RCHME 1993; Marshall 1994), no detailed archaeological study of the works itself has yet appeared. Prior to the present survey, all fieldwork has tended to be limited in scope and/or investigated only particular aspects of the site; in addition, such work has not seen full or proper publication.

The earliest investigation of archaeological features at Kettleness seems to have been by the Moldywarps Speleological Society from Teesside, who between *c* 1973 and 1975 entered various of the jet mines in the sea cliffs. They explored and eventually produced detailed plans of four such mines situated on the west side of the headland immediately adjacent to the later alum house, but appear not to have understood what they had found since their unpublished typescript reports refer to the features as 'alum mines' (Gary Marshall, pers comm). This was followed in the early 1980s by an investigation of foreshore rutways in Runswick Bay, conducted by John Owen as part of a wider study into such features along the north-east Yorkshire coast. Although he produced two scholarly accounts of his findings (Owen 1986; 1987), both papers are principally overviews drawing attention to the existence, origins and general distribution of a previously unrecognised feature-type, and contain no detailed survey work. The first proper appraisal of the overall level of archaeological survival at Kettleness was carried out in 1993 by Shane Gould for Step 3 of MPP. However, this was a rapid field assessment to determine what survived on the ground and again involved no survey or detailed report-writing (Gould 1993b). A local researcher, David Green, subsequently visited the site in 1996 and produced a sketch survey together with a short commentary (deposited in the North Yorks Moors National Park Authority Sites and Monuments Record (NYMNPA SMR), record 07452). Although he misinterpreted aspects of what he saw, his survey is nevertheless useful in that it records features buried/destroyed by the 1999 cliff collapse.

Several researchers, particularly David Pybus, Roger Pickles, Gary Marshall and Peter Barton, have delved into different aspects of the documentary record for Kettleness and have amassed detailed personal knowledge, but again relatively little has been published and none in a form specific to the site. Gary Marshall has referred extensively to a (supposedly 19th-century) plan of the Kettleness alum house deposited in the Northumberland Record Office (NRO), whilst Peter Barton has made use of Chancery records pertaining to Kettleness existing at the Public Records Office (PRO), but both have done so only in the context of general overviews of the alum industry (Marshall 2002; Barton 2002).

Fieldwork for the present EH survey has been accompanied by a limited search for primary documentation as well as by a reading of this secondary literature. Sources consulted at first hand by EH for the current study, both published and unpublished, are listed in the bibliography.

4. DOCUMENTARY SOURCES AND HISTORY

This chapter reviews the history of, and documentary sources for, Kettleness alum works at some length, but also presents briefer accounts of the history of the cementstone industry, jet mining and ironstone extraction on the headland. Each industry is discussed separately below.

4.1 Kettleness Alum Works

Until the present study, little has been published on the history of Kettleness alum works and there has even been uncertainty over the exact year it was founded. According to the Reverend George Young writing in the early 19th century, the works was established *c* 1728 (Young 1817, 811), implying it was started by Edmund Sheffield, 2nd Duke of Buckingham, to whom the manor of Mulgrave then belonged. But Edmund was only 12 years old at this time and legally still a minor, and Peter Barton has recently suggested from a study of Chancery records deposited in the Public Records Office that the works was instead set going in 1729 under Sheffield's mother and legal guardian, Katherine, the dowager duchess (Barton 2002, 79).

Papers in the Mulgrave Castle Archives (MCA) reveal the true date and genesis of the works. Work on preparing the quarry and constructing the necessary processing plant and infrastructure was already in hand in July 1727 under the direction of Ambrose Newton, acting on behalf of the dowager duchess (MCA II/13/94). A 'calcining place' had been completed by late February 1728, and shale began to be mined and burned shortly thereafter although Newton seems to have died before the first alum was ready, probably in late 1729 (MCA II/13/31 and II/60/15); four years later this calcining place was described as measuring 80 yards long by 20 yards wide by 12½ yards deep (73.1m x 18.3m x 11.4m). After Newton's death, construction work was carried on by his family, and by April 1732 an alum house, assay house, cooper shop, liquor house, kelp house, alum weigh houses, two warehouses (the larger for alum, the smaller for stocks and utensils), counting house, blacksmith shop, plumber house, coal yard and staithe, had all been completed; these seem to have stood on a low 'platt' of ground near the foreshore, approached on the landward side by a road terraced into the hillside. In addition, the Newtons had dug a waterway to bring water from Goldsborough, plus three large ponds to store it in, and had also constructed within the quarry a drift 'thro the east Coyn of the work to carry out the bad rock etc', plus nine [steeping] pits and four large 'rusievers' (receivers or ?cisterns); they had also erected 'a dwelling house upon the Hill & stable barn & house for cattle to work the farm there' plus dwellings and a cow house for the alum-maker and his helper (MCA II/13/3, 5 and 31; II/4/25). The alum house was said to be *c* 30 yards long by 20 yards wide (27.4m x 18.3m). The staithe extended for 40 yards, and was 2 yards wide by 4 yards high (36.5m x 1.8m x 3.65m), and had four 'stoops' (posts) associated with it, although until it was ready Chancery records indicate that supplies and materials brought in by ship were being landed near to the Sheffield's other coastal alum quarry on their Mulgrave estate, situated above Sandsend some 4km to the east (Barton 2002, 79), and transported overland. The Sandsend works had been operating since *c* 1615, and was proving very profitable to the Sheffield family.

In 1735 Edmund died unmarried and without male issue, and the manor reverted to the Crown. The story is now best followed through leases and other documents in the North Yorkshire County Records Office (NYCRO) and Whitby Literary and Philosophical Society Library (WLPSL). For a year or so it seems that alum-making continued under royal control, but in 1736 the Crown advertised a 31-year lease on Mulgrave manor in the pages of the *London Gazette*. Several bids were received, including one from Katherine, the dowager duchess, to whom it was granted for a fine of £12,000 and an annual 'allom rent' of £1,200 (NYCRO ZNG(W) *History of Allom Making*). The lease was issued on 21 March 1738, but ran from 24 March 1737. Appended to it are inventories of both Sandsend and Kittleness (*sic*) works (WLPSL PB5066). These show that Sandsend, not surprisingly, was the larger and more valuable property, with stores and utensils worth £3461 18s 11d against £528 1s 3d for Kettleness. But the Kettleness list contains clues which suggest that it, unlike Sandsend, was not then actively producing alum: 8644 (?cubic) yards of 'cap or rubbish' had been removed exposing 26,966 yards of bared shale, but no stores of 'burnt mine' (burned shale) are mentioned; equally revealing, supplies of kelp were laid in but no whins (gorse) or coal, and Kettleness had a stock of 80,000 bricks, compared to just 28,000 at Sandsend. Thus preparatory stripping of overburden would seem to have taken place in the quarry, but no shale recently dug or burned; in addition the large quantity of bricks is indicative of the works being in the throes of a major campaign of expansion or repair (in 1732 there were said to be nine steeping pits and four receivers at the works, but in 1737/8 only five and two respectively, are reported). The inventories also contain details on where supplies of the various raw materials were coming from: a proportion of the kelp needed for alkali production was obtained locally, but by far the greatest quantity was brought in from Northumberland and Orkney (at Sandsend the recorded ratios between the three sources are 24:37:39); coal was imported from Sunderland.

Katherine died in 1742/3, and a series of accounts made on behalf of her executors for the period down to Christmas 1746 (WLPSL PB3026) suggest that although the Sandsend works continued operating, Kettleness lay idle from 1736 until late 1741, supporting Young's statement to this effect (Young 1817, 811). This was most probably due to the depressed state of the market, since in 1736 alum was retailing for under £10 per ton. By 1740, however, prices were back up to over £12 (Young 1817, 816), and in 1741-2 the executors' accounts (folio 74) record that Katherine spent £794 15s 2d repairing and adding to her Kettleness works; the repairs were reportedly completed in July 1741 (MCA II/13/32). Her alum-makers at Kettleness, Richard and Ambrose Newton Jnr, had produced just over 62.5 tons of alum before her death and manufactured a further 497 tons up to April 1746, for all of which they were paid £8 per ton. The alum was shipped to the Duchess' warehouse at Coxes Wharf in Southwark, from where in 1745 it was retailing at between £10 and £14 per ton. After shipping costs of 15 shillings a ton, this means that the gross profit to the estate on Kettleness alum in this five-year period was in the range 25 shillings to 5 guineas per ton. The accounts also include costs for guns and cannon to defend the works against privateers.

Katherine bequeathed Mulgrave manor, and thereby Sandsend and Kettleness alum works, to her grandson, Constantine Phipps, by her first marriage to the Earl of Anglesey. The long period during which the estate was in the hands of the executors, and their tardiness in settling bills, seem to have taken its toll on the Newtons, however, and papers in the Mulgrave Castle Archives suggest that they had become disenchanted with their tenure of the works before 1751, and may have produced little alum between then and 1754 when they finally relinquished the lease (MCA II/56/1-13). According to Young (1817, 811), Kettleness once more lay idle between 1755 and 1767 as trade was disrupted by the Seven Years War with France (1756-63), and the price of alum fluctuated. However, it remained, potentially at least, a valuable asset, and Phipps renewed the lease of Mulgrave manor from the Crown twice, first in 1760 for a period of 21 years, and second in 1766 for a further eight years, both to be computed from the expiry of the preceding lease; in each case the rent was unchanged at £1200 per year (NYCRO ZNG(W) *History of Allom Making*). The first renewal has appended to it inventories of both alum works, but these simply reprise the 1737 lists since the lessee was required to ensure that when the works reverted to the Crown they were surrendered with at least the same stores and utensils as had been present in 1737 (WLPSL PB5073). In the case of the second renewal, the 'rent' was apparently offered by Phipps as a series of annual instalments towards the purchase of the lease. In effect, this meant that the family extended their tenure of the manor to 1797 after which they expected to own it outright, although there were later disputes with the Crown over how the document should be interpreted (NYCRO ZNG(W) *History of Allom Making*). Activity at Kettleness resumed in 1767, when Phipps spent £317 8s 7½d repairing the staithe, and although no records have been found detailing actual production figures of alum, production must have recommenced since in both 1768 and 1769 the estate accounts record the sale from Kettleness of small quantities of 'slam', a waste product of alum manufacture (MCA II/61/11-13).

Phipps was created Baron Mulgrave of New Ross in 1767, but died in September 1775. A valuation of his household and alum works in Yorkshire taken at the time of his death, shows that the alum house at Kettleness had been lengthened by about a third since 1732, and that the stock of other buildings there was also now appreciably larger:

> Buildings – One Allum House in good repair, length 42 yds: Breadth 21½ yds within; containing Fire Roof, Settler & Cooler Roofs; Tun Rooms; Two Alum Warehouses and a Work Room over one of them; Coopers Shop; Assay Room; One Setler, Eight Coolers, One Urine Cistern, a Muther Cistern & Washing Cistern: Blacksmith and Barrow Makers Shops; A Plumber Room, Allum Makers House and Counting Office, One Mount for taking Account of Coals delivered; under which is the Lime House; one Lime Kiln out of repair; A Cobble Shed; A Liquor House containing one Lee & two Liquor Cisterns; One Kelp Warehouse, Three Lee Ponds and a Water Cistern; One Large Liquor Cistern with a Dwelling House over it; A Coal yard walled in, & a Staith to Secure it &c; Six Old Pitts & Three New Ones for Steeping of Allum Mine; Three Pitt Cisterns, A Pump Shed & A Water Pond; Three Swivel Guns (MCA XI/5/5 pp 46-7).

Phipps was succeeded as the 2^{nd} baron by his son, Constantine John, later Lord Mulgrave of Mulgrave. Constantine John was friendly with Joseph Banks (the two had met whilst at

Eton) and the latter stayed at Mulgrave Castle in August 1775, only a month before Constantine John succeeded to his title. Whilst at Mulgrave, Banks toured the alum works and made a written record of his observations. The original account does not survive, but a later copy made by a close acquaintance, Dr Charles Blagden, is now preserved at Yale University and has recently been published together with a short commentary. Although there is nothing in the published text to show which of the two works on the Mulgrave estate Banks visited, the commentary's title implies it was Kettleness (Thornton 2000). George Colman, who toured the works at the same time, also wrote and later published his own observations (Colman 1830, 185-6). This second eye-witness account is far less detailed, but both versions nevertheless offer useful insights into the methodology of quarrying and alum manufacture as practised on the estate in 1775. The information need not be reviewed in detail here, but has been used to inform aspects of chapters 5, 6 and 7 of the present report.

The Kettleness alum house was further enlarged in 1785 when three extra evaporating pans were added (Roger Pickles, pers comm, quoting a letter from George Dodds, manager of Boulby works). A snapshot of the enlarged works is contained in another inventory drawn up in October 1792 on the death of Constantine John. It is worth quoting the first page in full, for comparison with the earlier inventory taken at the death of his father shows that Constantine John had expanded and improved the building stock at Kettleness in other ways too:

> Buildings, One Alum House, Length 180 feet (with three Roofs Viz, Fire Roof, Settler Roof, & Cooler Roof), Tun Room, Weigh Room & Alum Warehouse, Cooper Shop, Plumber Room & Assay-Room, Two Settlers, Two Muther Cisterns, Eleven Coolers, One Urine Cistern, and two Washing Cisterns Blacksmith & Barrow-maker Shops, and a Wareroom over them; One Liquor Cistern with a Dwelling House over it; Two Kelp Warehouses & Four Dwelling-houses over one of them, Three Lee Ponds & a Water Cistern One Liquor-House containing One Lee and Two Liquor Cisterns. A Coal Yard walled round & a Staith to serve it &c. A Cinder and Lime Shed, a Mount for Making Acc[t] of Coals Delivered, under which is a Cow-House and Stable: One Lime-Kiln (out of repair), and a Boat Shed. Six Old Pitts & Eight New ones for the Steeping of Alum Mine, Three Pitt Cisterns, a Pump Shed & Two Water Ponds (NYCRO ZNG 576/3RA/1157).

Neither the 1775 nor the 1792 inventory accurately locates any of these structures, but the fact that the coal yard was said to be associated with a staithe suggests that most of the buildings lay on or close to the foreshore, almost certainly in the same area first developed prior to 1732. The most likely position for these structures is in Runswick Bay since this is the more sheltered side of the headland. This was certainly the position occupied by the alum house in late December 1829 when 'together with a respectable dwelling house occupied by the superintendent, Mr Truefitt, and seven cottages built for the accommodation of the workmen', it was destroyed in a cliff collapse. All the buildings were then described as lying 'near the sea shore, beneath a very lofty cliff, along the side of which the public road leading down to the works was excavated' (Anon 1829, 23).

The earliest surviving maps of Kettleness are of 18th-century date, but are of little help in locating the original, pre-1829, alum house and associated buildings more precisely. County maps of the period were all surveyed at scales of 1 inch to the mile or smaller, and depict the area of Runswick Bay only crudely: Jefferys' map of 1772, for example, shows Kettleness as a generalised group of six buildings clustered on the west side of a rather inaccurately drawn headland, and does not name the alum works although the nearby quarries at Loftus, Boulby and Sandsend are all indicated. The only extant large-scale maps of this period are those produced to accompany the Lythe Enclosure Award in 1777 at the scale of 8 chains to the inch (NYCRO ZW(M) 1/61a), and an undated (but probably mid-18th-century) map of Goldsborough township at the larger scale of 4 chains to the inch in the Public Records Office (PRO MPE 1/393). The former does not depict the whole of the headland, although it does name a group of three buildings standing on the approximate site of the present hamlet, as 'Kettleness', all discrete from the 'allum works' which is portrayed as a schematised quarry on the coast a little to the north: the crude nature of the depiction, however, means it is unclear whether the works lies at the top or bottom of the sea cliff. The second township map (Fig 5) contains very similar information, but depicts the alum house

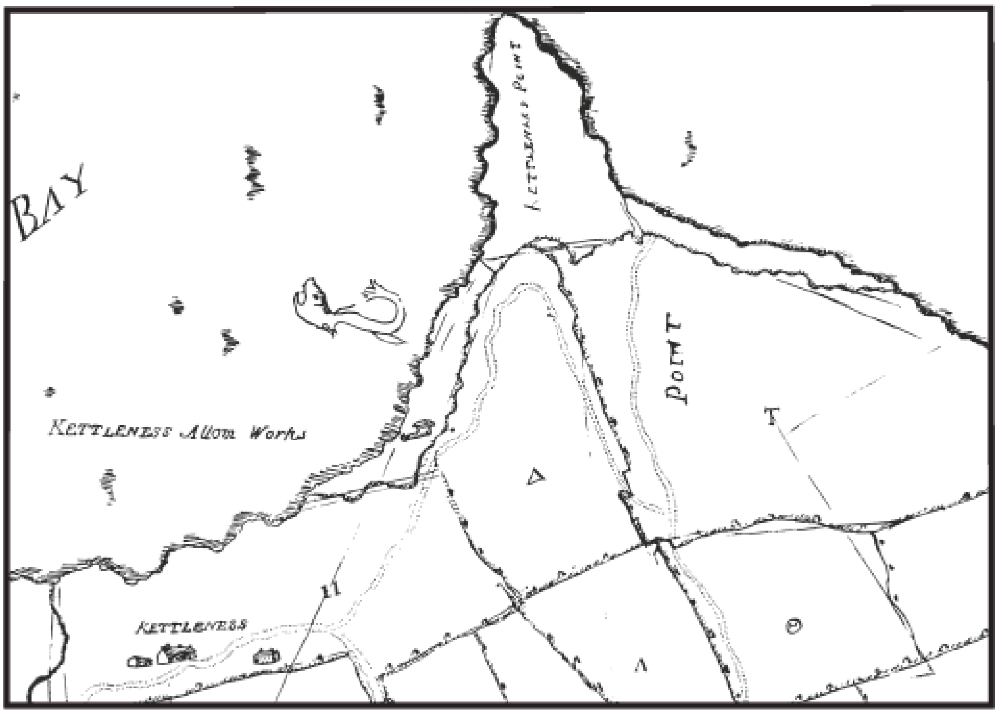

Figure 5. Extract from a tracing of the Goldsborough township map, PRO MPE 1/393 (Pybus collection, copyright reserved)

as set slightly back from the foreshore beneath a sea cliff or quarry face; in addition it shows what appears to be the then limits of the quarry, plus the surrounding field and road pattern. (In the PRO this map is calendared as '?late 17th century', but such an early date is impossible given that the alum works was not operational before 1729; see also section 7.1.1 below). Because of metrical and angular inaccuracies within the map individual features can only be positioned approximately, but the evidence does suggest that the pre-1829 alum house lay in the region of NZ 831 159.

Constantine John was without male heir at his death in 1792, and the estate passed to his brother, Henry, the 3rd baron, later 1st Earl Mulgrave. Few records have been located on how the works performed or were managed during Henry's ownership, although between 1804 and 1810 the annual output of alum at Kettleness grew from 291 tons to 661 tons, accompanied by a correspondingly marked increase in costs from £14 9s 13d per ton in 1804 to a peak of £21 3s 4½d in 1809, before reducing slightly to £17 5s 11d the following year (MCA X/2/10, 12, 14, 16 and 17). This may have been partly due to mismanagement of the works by Henry's then alum maker, William Mackridge, for in October 1809 the alum house was reported as being in poor repair and Mackridge had just been removed from post (MCA XI/2/238). Strangely, the same Mackridge was re-employed a couple of years later in 1810-11 to make new coolers, pans and cisterns, and to build an assay house at the works, although it is unclear whether this involved repairs to existing structures or an expansion of the alum house. In the same period he was also contracted to make 'two new pits upon the old pit-hill at Kettleness', and to construct a new calcining place, cisterns and two new pits at the 'Prospect Work' (MCA VII/5/28.60-62), perhaps indicating that the quarry had been or was about to be extended.

Following the cliff collapse at the end of 1829, Henry had the alum house rebuilt in a new position on the cliff top within the quarry on the west side of the headland overlooking Runswick Bay, in the location where it is shown by the earliest Ordnance Survey mapping (Fig 6) some twenty years later (Ordnance Survey 1856; hereafter referred to as the OS first edition 6"). However, no records have yet been found pertaining to what must have been a major work, undertaken at great cost to the estate.

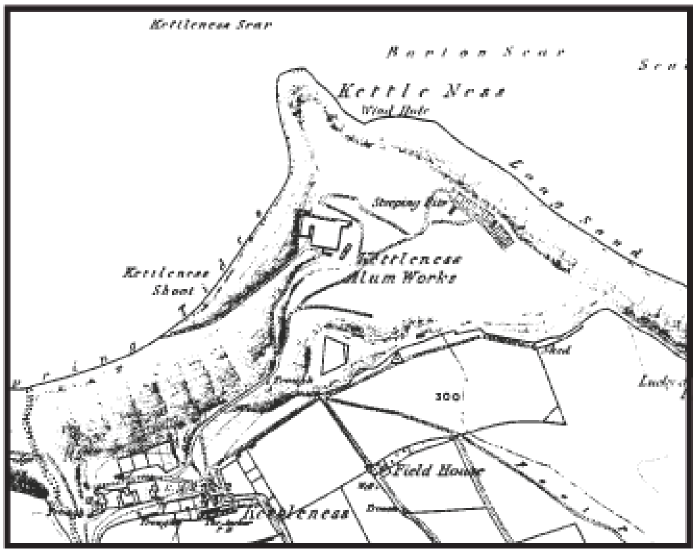

Figure 6. Kettleness Alum Works as mapped at 1:10560 scale in 1852. (Reproduced from the 1856 Ordnance Survey map)

A prospect of Kettleness published in 1853 (Phillips 1853, plate 27) shows buildings at the base of the headland within the bay (Fig 7), and must therefore have been drawn prior to 1829 and depict the buildings and shape of the coastline before the collapse. Few details can be made out with clarity, but the alum house is portrayed as a single-storeyed range beneath a pitched roof, with four windows in its seaward elevation and a tall chimney stack behind; another building which lies to its right is of unknown function, but may be the superintendent's dwelling.

A plan of 'Kettleness alum house' (Fig 8) deposited in the Northumberland Record Office (NRO 3410 plans 1/53) is also likely to pre-date 1829. The plan is without known context or precise date, but is calendared in the NRO catalogue as being a 19th-century document. Marshall (2002, 31) has suggested that it depicts the new, post-1829, alum house within the quarry (his quoted date of 1819 is in error). However, the overall ground plan does not

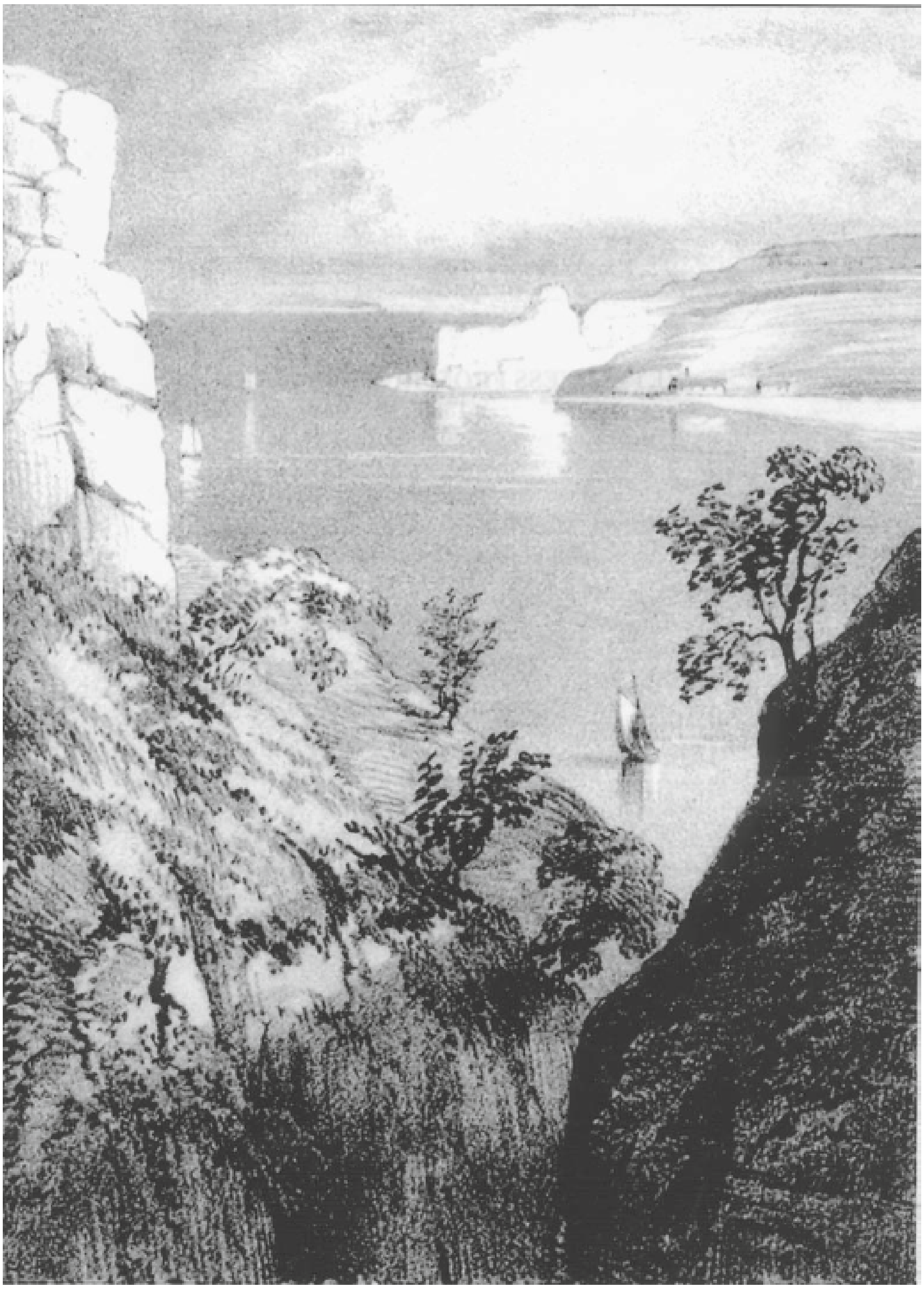

Figure 7. Prospect of Kettleness, probably pre-1829 since it shows the old foreshore alum house. (Reproduced from Phillips 1853, plate 27)

equate well with that recorded on the OS first edition 6" (compare Figs 6 and 8), and it seems more likely that the alum house depicted is the old one near the foreshore. Indeed, evidence to support the identification comes from a close comparison of the plan with the descriptions of the old house contained in the 1775 and 1792 inventories. Neither description corresponds to the plan exactly (the plan depicts only certain parts of the overall works anyway, and thus the coal yard, staithe, cinder and lime shed, mount/cow house, lime kiln and boat shed, etc, named in the inventories are omitted), but the closest match - in terms of the overall dimensions of the alum house, the number of coolers, and the naming of the cisterns - is with the earlier document. It may be, therefore, that the plan actually records a phase of the alum house's development at a point in time somewhere between the dates of the two inventories. The naming of 'kelp houses' on the plan is a further indication that it

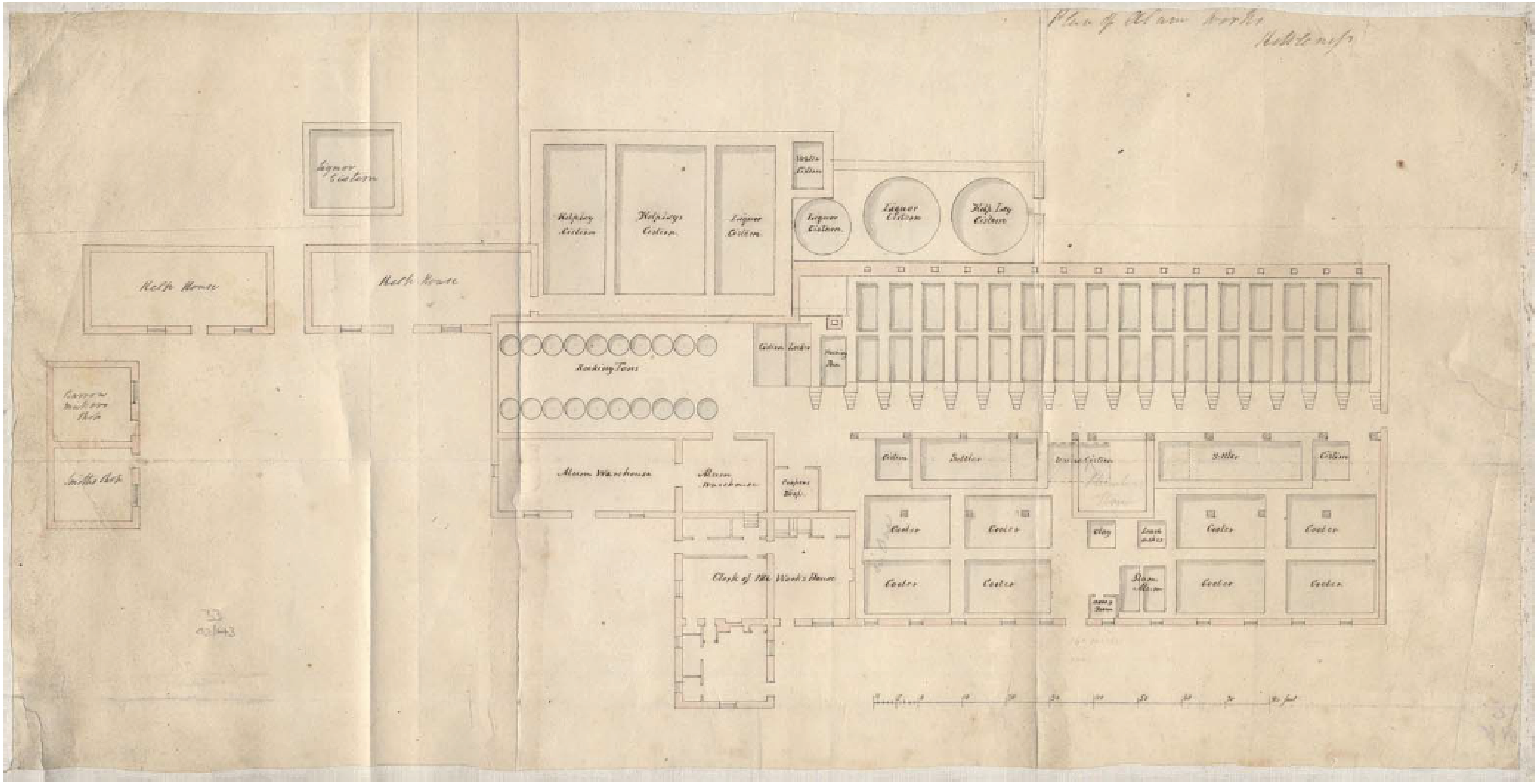

Figure 8. Plan of Kettleness Alum House (NRO 3410 plans 1/53). The document is calendared as nineteenth-century and has been assumed to depict the later alum house which operated between 1831 and 1871, but is more likely to a late eighteenth-century plan depicting a phase in the development of the original alum house destroyed in 1829. (Reproduced by permission of the NRO and North-East Institute of Mining and Mechanical Engineers, copyright reserved)

should be dated to no later than the first quarter of the 19th century (and thus cannot depict the new house in the quarry) as by this time pure muriate of potash (potassium chloride), produced as a by-product in the soap industry, was supplanting kelp as the alum-maker's alkali of choice (Rout 2002a, 23; Marshall 2002, 40).

An early 19th-century engraving of a Yorkshire alum works (Walker 1814; reproduced in Marshall 2002, 29) shows men barrowing shale into steeping pits with a cluster of stone-built sheds visible behind, and has also been claimed to portray Kettleness (*eg* Singer 1948, 278-9). However, others have suggested that the works depicted is Sandsend (*eg* Chapman 1975, 26), and on present evidence it would seem unsafe to identify the engraving with a particular place.

Following the cliff collapse at the end of 1829, the Kettleness works remained idle until the new alum house within the quarry was completed in August 1831 (WLPSL PB2884). Henry died in 1831 and was succeeded by his son, Constantine Henry, 2nd Earl Mulgrave and later 1st Marquis of Normanby. By this time, the entire Yorkshire alum industry was facing increased competition from the works at Hurlet outside Glasgow (Pickles 2002, 16), and the market price of alum was once more declining to under £10 per ton. Copies of sundry accounts spanning the years 1831-4 and 1839 (WLPSL PB2886-8) record that there was still money to be made from alum manufacture, but also that profits were being boosted by the sale of coarse Epsom Salts (magnesium sulphate), a by-product of alum. Thus, in February and March 1839, Kettleness produced 82 tons of alum at a cost of £7 13s 5d per ton, and sold it to Agents at £9 4s, but additionally sold 40 tons of Epsom Salts at 35 shillings a ton, making an overall gross profit for the two months of £195 1s 10d. At the same time, efforts were in hand to find ways of reducing costs and improving efficiency. For example, in December of that year Michael Theaker was appointed constable at Kettleness to help prevent theft of coals from ships delivering to the coal yard, and from the coal yard itself (WLPSL PB709), while by 1844 a mechanical crusher had been installed to break up the shale prior to burning (Osborne 1999, 255), a task previously performed by hand (Thornton 2000, 15). The works was still owned by Lord Normanby, but since late 1842 had been let out to Messrs Liddell and Gordon (WLPSL PB805). Liddell and Gordon quit the works in March 1845, at which time an inventory and valuation lists, amongst many other things, fourteen steeping pits containing liquor (how many others existed but were empty is not stated), and sixteen front and sixteen back evaporating pans in the alum house; a separate Epsom Salts House is also mentioned. The vacant lease was taken up by William Moberly in May 1845, who held it for the next nine years (MCA X/3/24, 25 and 35).

The new alum house within the quarry is shown in a sketch made in 1856 (WLPSL PEF351), thought to be by Mary Weatherill (R Pickles, pers comm). The sketch (Fig 9) probably contains a degree of artistic licence, for it depicts three separate building ranges parallel to the cliff edge, each with its own fenestration, whereas the nearly contemporary OS first edition 6" (surveyed 1849-52) suggests the two eastern ranges formed a single block under one roof (Fig 6). However, there is no reason to doubt other aspects of the sketch, such as the tall chimney at the far end of a fourth range set at right angles at the rear of the complex, plus a number of tracks leading onto and across the headland, most of which can be

Figure 9. Sketch of Kettleness Alum Works (WLPSL PEF351), dated September 1856 and thought to be by Mary Weatherill (Whitby Literary and Philosophical Society, copyright reserved)

married to detail depicted by the OS. Interestingly, four posts are shown protruding from the water in Runswick Bay; these are probably guide or mooring posts for ships entering the bay to deliver coals and take off alum, and may even correspond to the four 'stoops' mentioned in 1730 (this section above). The perspective of the sketch is such that sight of anything situated on the farther, east, side of the headland is excluded from view, but the OS map portrays three small buildings or structures and two banks of steeping pits here, set immediately adjacent to the cliff top; twelve pits are depicted in the longer northern bank, six in the shorter southern bank.

Constantine Henry died in 1863, and the estate passed to his son, George Augustus Constantine, the 2nd Marquis. By 1864, Henry Armstrong had taken over as works proprietor at both Kettleness and Sandsend (Slater 1864, 715), but despite all efforts the Yorkshire alum industry could not compete with the more efficient operations at Hurlet and the factories using the Spence process, and found itself priced out of the market (Pickles 2002, 17). Kettleness and Sandsend ceased manufacturing alum in 1871, although the Sandsend quarries may have remained open for a while longer for the mining of cementstone (see section 4.2 below). Both alum works were mothballed pending any upturn in the market, but by early 1875 Lord Normanby had authorised the dismantling of the Kettleness alum house for scrap: £921 had been received from the sale of lead by December of that year, although other metals still awaited disposal (MCA XI/4/170 and 173). By the time 25"-mapping finally reached the area in 1893 (Ordnance Survey 1894; hereafter referred to as the OS first edition 25"), the alum house at Kettleness was de-roofed and in ruins (Fig 10), perversely enabling us to see details of its internal layout not present on the OS first edition 6" fifty years earlier. The map also preserves for us a quite detailed plan of the topography of the quarries as abandoned in 1871.

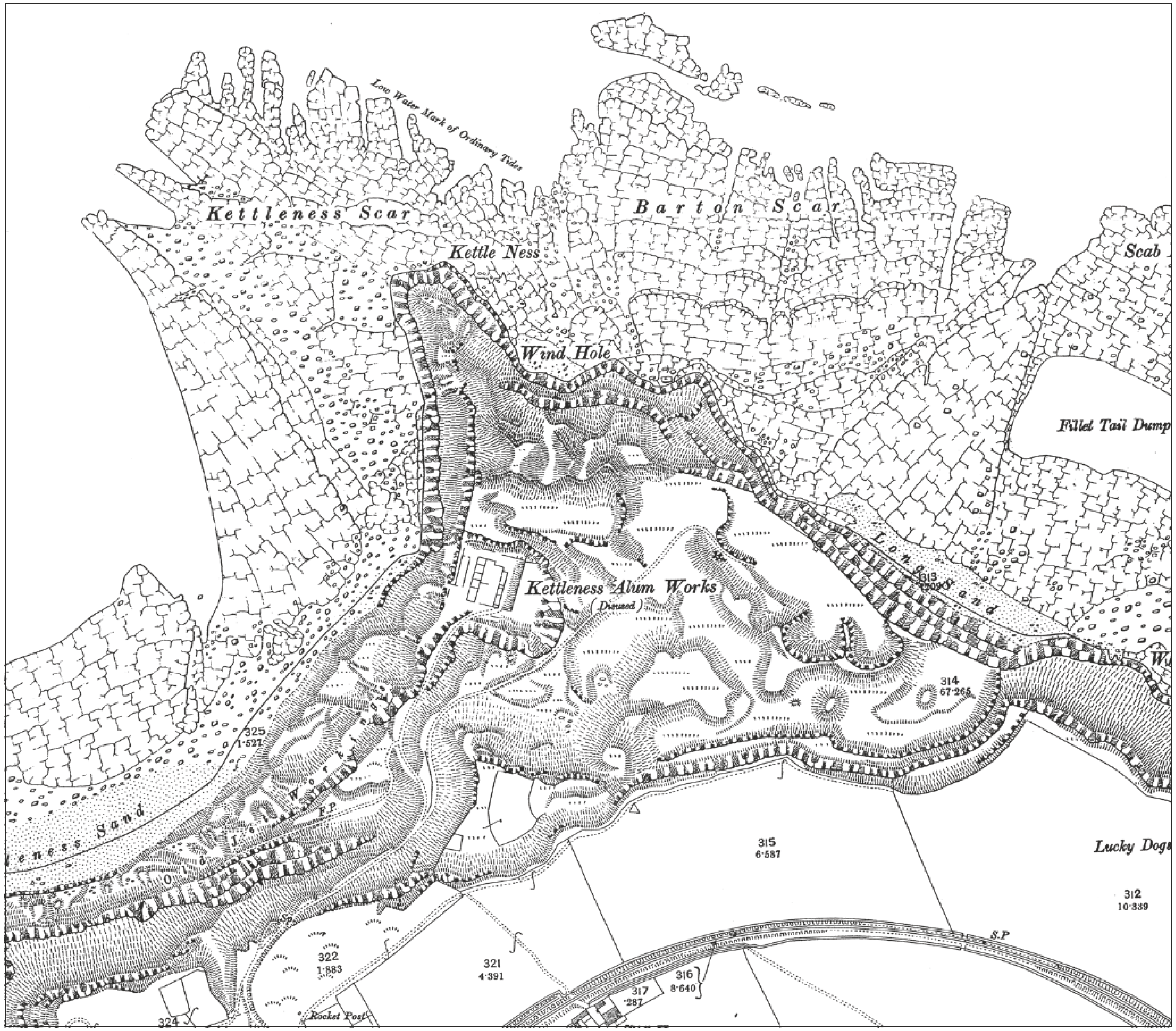

Figure 10. Kettleness Alum Works as mapped at 1:2500 scale in 1893. (Reproduced at 1:3000 scale from the 1894 Ordnance Survey map)

4.2 Cementstone

Cement manufacture was started at Sandsend in the early 19th century by Henry, 1st Earl Mulgrave. The alum shales contain a scattering of argillaceous limestone nodules ('doggers'), particularly numerous in the uppermost sub-division of the alum shales (called, appropriately, the cementstone dogger) but occurring throughout the rock, which tests showed could be ground down to produce a natural cement. Accordingly, in 1811 Henry erected the Mulgrave Cement Works near to East Row Beck, just inland from his alum house at Sandsend, and began cement manufacture using nodules emanating from the quarries at both Sandsend and Kettleness (the yield was approximately 1 ton of cementstone to every 60 tons of shale); doggers were also gathered off the foreshore at low tide as the cliffs weathered. Henry's son, Constantine Henry, the 1st Marquis of Normanby, sold the business in the 1850s, but the cement works continued to receive supplies from the two alum quarries until their closure in 1871, after which time nodules were obtained from adits driven into the quarry and cliffs at Sandsend. The cement works finally closed in 1935 (Morris 1984, 38-42).

4.3 Jet

The Whitby area has had a long association with jet. Unlike cementstone, jet does not occur within the alum shales, but is confined to a narrow, intermittent seam located at a lower level in the cliffs within the eponymously named Jet Rock Series Shales. It was worked and traded widely in the prehistoric, Roman and Viking periods (Sheridan and Davis 2002), but at these early times was probably collected from the foreshore after storms and cliff collapses rather than mined. References to medieval working of jet are few, but begin in the late 14th century. By the early 17th century the North Riding Sessions Rolls contain entries to several people resident in the Skinningrove and Newholm/Dunsley areas (the latter near to Sandsend) whose occupation is given as 'jeators'. Owen (1975, 16) has expressed doubt that mining for jet pre-dates 1840, although more recently McMillan (1992, 73) has suggested that these 17th-century jeators were miners. Certainly, the Mulgrave Estate was already well known for its jet by *c* 1613, as recorded in Drayton's poetic work, *Polyolbion* (quoted in McMillan 1992, 18):

> The rocks by Moulgrave, too, my glories forth to set, Out of their crannied cleeves, can give us perfect jet.

The real heyday of jet, however, was the first three quarters of the 19th century when the mineral acquired previously unseen levels of fashionability. A plethora of small mines were dug into the sea cliffs and also inland exposures. At the time landowners controlled the activity and profited from it by granting leases to prospectors, and this is likely to have been the way that exploitation was organised in earlier centuries too. The sea cliffs at Kettleness were particularly prized and productive, but mining them was a dangerous business. The recognised technique was called 'dessing' and involved suspending men by ropes from the cliff top, who, once seams had been located, rigged catwalks along the cliff face and dug short adits to follow the lode. Many miners were killed in accidents involving falls, either because they slipped or were struck by falling rocks (McMillan 1992, 18-21). The industry declined markedly after the 1870s.

4.4 Ironstone

Exploitation of the ironstone deposits on this part of the Yorkshire coast began in the early 19th century. There are several seams, and sideritic nodules also occur randomly within the shales. Two seams in particular were exploited, known as the top seam and the main seam: the former overlies the Alum Shales, the latter underlies the Hard Shales (see chapter 2). Initial exploitation seems to have comprised simple collection of ironstone nodules which had eroded onto the beach, but in 1827 the Tyne Iron Company of Newcastle sent James Bewick to survey the coast for workable deposits, and Bewick's report identified Kettleness – where the top of the main seam was exposed on the beach at sea level - as the most promising. Bewick thought the ironstone simply required to be broken up and shipped off, but no action was taken (probably because difficulties were anticipated in chartering ships suitable for beaching in the bay) until 1838, when the Wylam Iron Company purchased the royalty from Lord Normanby. The new company commenced operations, and were initially very successful in shipping the ironstone to their furnaces on the Tyne, but soon found their operations hampered, as feared, by the weather and unavailability of shipping in the winter months (Bewick 1861). It is unclear for how long the Company kept up their efforts, but Owen (1986, 29-30; 1987, 215) has suggested that a series of rock-cut rutways which survive on the Runswick Bay side of Kettleness are connected with this activity rather than with the alum works. Attempts to work foreshore ironstone exposures were also made elsewhere along the coast (Owen 1978), but most attention thereafter switched to inland mines. A couple of small trials dug later in the century to investigate the top seam in the cliffs above Runswick Bay near to Kettleness appear to have been without profit (David Pybus, pers comm); both lie outside the area of the present study.

5. THE PROCESS OF ALUM MANUFACTURE

The technical aspects of alum manufacture have been described in detail elsewhere (*eg* Winter 1810; Young 1817, 812-14; Almond 1975; Rout 1997; 2002a; Marshall 2002; Miller 2002b), and only a general outline need be given here. The overall technique is reasonably well understood, although there are unresolved questions concerning the specifics of certain stages of the process. Precise practices varied between individual works anyway, and the industry also saw limited changes and improvements over its lifetime. Details on the method followed at Kettleness at particular times are known from several sources, including estate records, inventories and eye-witness accounts (although sometimes not without contradiction), but what follows is mostly a generalised description of the overall process. Each stage of manufacture was carefully positioned in and around the quarry so as to take advantage of gravity flows and minimise the amount of effort expended in moving materials between one stage and the next.

5.1 Quarrying

The first step was to expose the shale by stripping away the cap or overburden. At Kettleness, the cap comprised up to *c* 12m of sandstone, all of which was removed by hand: in 1736 the rate paid for this task was 3d a (cubic?) yard (WPLSL PB5066), although forty years later the reported rate had doubled (Joseph Banks quoted in Thornton 2000, 14). The shale was then hewn, again by hand, using picks and iron bars, and shovelled into barrows (Winter 1810, 248; Almond 1975, 11). The generally accepted wisdom (*eg* Miller 2002b, 108), based on contemporary accounts and illustrations, is that the quarries were worked in a series of wide terraces, thereby progressively enlarging and deepening the quarry and giving the active face an overall stepped appearance. It has been suggested (RCHME 1993, 6-7) that shale was also extracted from individual bowl-shaped quarries, or 'scoops', cut down into the wider quarry floor, but the Kettleness survey evidence suggests such scoops are better interpreted as calcining places rather than shale quarries (see chapters 6 and 7). Whichever the quarry technique, according to eye-witness accounts at Kettleness in 1775 the high, perpendicular quarry faces were known as 'depes', and were worked from small ledges onto which the workmen were lowered by ropes (Banks quoted in Thornton 2000, 14; Colman 1830, 186n). Individual terraces or areas of quarrying were apparently called 'desses' (Young 1817, 812), a term also current in jet-mining (section 4.3 above).

5.2 Calcining

The quarried shale was loaded into wheelbarrows and taken to the calcining place, where it was piled up and set alight in order to institute a series of chemical reactions within the rock and so produce the desired aluminium sulphate. According to Rout (1997, 15) the shale was not screened prior to being added to the clamp (that is, broken down into a pre-determined size), although to the contrary at Kettleness in 1775 Banks (quoted in Thornton 2000, 15) observed that the shale was pulverised by men wielding hammers before being set alight, and Winter (1810, 248) also states that the shale was broken into small fragments; by 1844 the same procedure may have been performed by a mechanical crusher (Osborne 1999, 255). In the early 19th century, it was reported that the general method of clamp construction was to pile comminuted shale to a depth of 4 feet (1.2m) over a bed of faggots and whin, and set the whole lot ablaze; new heaps were then started around the base of the first, and more shale added, until a single mound had been constructed perhaps 90 to 100 feet (27.5m to 30.5m) high, and 150 to 200 feet (45.75m to 61m) in diameter (Winter 1810, 248; Young 1817, 812). Clamps had to be fired before they reached too great a height or else the flow of air through the shale necessary for combustion was impeded and the desired chemical reactions did not take place (Rout 1997, 30-2), but there is limited pictorial and excavated archaeological evidence to suggest that by the mid-19th century, clamps were being built with stone-lined tunnels or flues at their base leading to a short, vertical chimney designed to draw air into the centre of the mound, and ensure a more uniform reaction throughout (Rout 1997, 33-4; Chapman 2002, 66-7). Other contemporary eye-witness accounts record smaller clamps. Clamp size and construction may well have varied over time, therefore, and also have been dependent on the space available and the economic circumstances of individual works (Miller 2002b, 110).

The chemical reactions taking place within the burning clamps were complex and varied, and the conditions necessary to optimise their occurrence also difficult to control. The theoretical chemistry has now been worked out in detail by Alf Rout (1997; 2002a), but at the time, the alum-makers' knowledge of what was happening within the clamp and how to control it was almost entirely empirical. They knew that once the shale was alight and had reached a certain temperature, combustion became self-sustaining (on account of the heat generated in the oxidation of pyrites and organic matter in the shale), and could be kept going simply by the addition of shale without the need for additional fuel – indeed Rout (1997, 32) has pointed out that larger heaps were, consequently, more fuel-efficient. But trial and error probably showed that 30m was the maximum practicable height after which it became increasingly difficult to regulate the combustion process effectively. Care was necessary to prevent the clamp burning either too vigorously or too coldly, achieved by 'plastering' hotspots with fine, damp shale, or by digging in to the surface to re-invigorate combustion (Winter 1810, 248-9; Young 1817, 812; Rout 1997, 30-2). Chapman (2002, 66) has recently suggested that clamps were also covered in clay and stones to prevent the loss of gases, but, unlike the use of wet, fine shale, the present study has found no contemporary authority to substantiate this. Weather conditions were also a potential problem, for high winds could feed the fire and encourage too fierce a burn. It may have been partly for this reason that Banks (quoted in Thornton 2000, 14-15) noted the tendency for clamps to be built at the foot of a quarry or rock face rather than in the open, in order to afford some degree of shelter. However, such locations may also have been preferred since they would have facilitated the construction of the upper parts of the heap through shale tipped from wooden gantries built out from higher levels within the quarry (*eg* Marshall 1995, 42-3). In the modern literature the archaeological sites of clamps are often referred to as 'calcination bases' (*eg* Gould 1993a, 2), but contemporary accounts seem simply to describe clamp sites as calcining places; the same accounts also imply that such places were cut features, deliberately created, rather than simple floors sited so as to have protection from the weather (section 4.1 above).

Once the clamp had reached its full height and the combustion of pyrites and the organic matter within the shale was complete, the clamp was allowed to cool slowly over a period of months, during which time a second set of low-temperature chemical reactions occurred which further enriched the amount of aluminium sulphate present (Rout 1997, 27-8). According to Young (1817, 812), 8 or 9 months often passed between the initial phases of constructing a clamp, and the time when calcining was complete and the clamp was cool enough to be dismantled.

5.3 Steeping

The next stage in the process was to barrow the burnt shale from the clamp being dismantled into a series of steeping tanks or pits, where fresh water was added to dissolve out the soluble salts, including aluminium sulphate. The standard practice involved washing the burnt shale several times in order to achieve as saturated a solution of 'liquor' as possible. Rout (1997, 37-8; 2002a, 21) has suggested that this would have been best achieved if a four-stage, counter-current extraction process were followed, for which there is documentary evidence in North Yorkshire as early as the 17th century. The process involved immersing freshly burnt shale in liquor which was already concentrated having been passed three times over progressively older batches of shale; the resulting saturated or strong liquor was run off to the alum house (section 5.7 below) and replaced by a weaker solution which had only had been passed over shale twice, in turn replaced by an even weaker solution passed over shale once, and finally by fresh water. Thus the liquor became more saturated as it passed through the pits in one direction, whilst the shale gave up more of its soluble salts with each soaking, and Rout (2002b) has shown how such a four-stage process might have been most ergonomically conducted using a bank of six pits if only a single pump were available. But the actual number of washes used may well have varied, both over time and between works. For example, at Kettleness in August 1775 the shale was reportedly steeped only twice (Banks quoted in Thornton 2000, 15), although reference to 'strong liquor', 'seconds' and 'thirds' in an inventory taken less than a month after Banks' visit suggests that shale was actually being washed three times (MCA XI/5/5 pp48). Contemporary opinion also varied over how long the liquor should be allowed to remain in contact with the shale (Miller 2002b, 113). Rout's suggestion (2002a, 21-3) that a layer of brushwood may have been spread over the floors of the pits before the shale was added in order to facilitate an even flow of liquor through it, seems to pre-suppose that the flow of liquor was continuous (*ie* that liquor was pumped around within each pit).

All available evidence suggests that steeping pits were constructed in the open air without any form of protective covering. Whilst this may have had advantages in hot weather when evaporation would have helped to concentrate the liquor, the reverse happened when it rained as observed by Banks at Kettleness (quoted in Thornton 2000, 15). Banks records that in 1775 the Kettleness pits were built completely of stone and had a holding capacity of *c* 60 cubic yards (45.9m^3) each, which seems to have been the late 18th/early 19th-century industry standard (Winter 1810, 250). There is some evidence to indicate that in earlier periods pits may have had wooden floors and larger volumes (Miller 2002b, 112-13).

Whatever the number of soakings, a multiple-stage, counter-current extraction process meant that either shale or liquor had to be transferred between pits. Liquor was obviously easier to move than shale, and although in theory gravity could have been used to effect most of the transfers, no archaeological evidence has yet been found to suggest that pits were built on different levels. Pumps must therefore have been employed to move the liquor, and indeed old inventories attest to their existence. Even with gravity-feed, one pump would always have been needed with counter-current extraction in order to return the nearly-concentrated liquor to the first pit at the head of the bank containing the freshest shale. However, documentary (and archaeological) evidence shows that pits were not always built in the banks of six suggested as most ergonomic by Rout, and indeed that liquor, rather than moving directly between pits, was often syphoned off into temporary storage cisterns in between washes, and had to be pumped back up (Winter 1810, 250).

Spent shale from the pits was simply tipped over the edge of sea cliffs or into disused parts of the quarries.

5.4 Water supply

Steeping obviously required each alum works to have a large and reliable supply of fresh water. Because demand was periodic, reservoirs or holding ponds were needed to store water emanating from local springs and streams (Miller 2002b, 112). Indeed, there is documentary evidence that in the 18th century Kettleness possessed three water-storage ponds fed by a leat originating in Goldsborough, *c* 1km to the south (section 4.1 above). There has been little or no discussion in the archaeological literature of how the water was conveyed from the reservoirs to the pits.

5.5 Settling

Once concentrated, the 'strong liquor' was run or pumped off *via* stone troughs into one or more settling tanks or cisterns to allow fine shale particles and other solid contaminants to fall out of suspension, before being sent on to the alum house. Excavated and documentary evidence suggests that most works had two settlers, each covered with wooden boards to protect the liquor from rain and wind-borne particles (Miller 2002b, 113-14); Banks implies that in 1775 there was only a single such cistern at Kettleness (quoted in Thornton 2000, 15), although two are listed in an inventory taken in 1834 (MCA X/3/22). Removable covers were presumably needed to allow access for the periodic clearing out of sediment. It seems that this sediment was what the alum makers referred to as 'slam' (*eg* Rout 1997, 39; Chapman 2002, 71), although other sources indicate that the term was also used to cover sediment deposited from the liquor at the alum house after the addition of alkali; the two forms of slam had different chemical compositions (Rout 1997, 41).

5.6 Liquor transportation

Once clarified, the strong liquor was conveyed to the alum house in wooden troughs (Miller 2002b, 114-15) - or just possibly lead pipes (Banks quoted in Thornton 2000, 15) - where it was transformed into alum. The process required large quantities of coal and alkali, and the alum house was therefore sited in order to minimise the distance over which these heavy and bulky raw materials had to be carried: it was far easier and cheaper to run strong liquor under gravity to the alum house, than to transport coal and alkali great distances overland in the opposite direction. For this reason, coastal works where the alum house could be located close to a harbour, had an economic advantage over their inland cousins. But the same consideration meant that the coastal works often had to construct their liquor trough for quite some distance over difficult and shifting terrain in order to link the cisterns in the active part of the quarry to the alum house on the foreshore or cliff edge; because of the need to lay the trough to a constant gradient, stone-lined tunnels were on occasion excavated through the cliffs to accommodate it (Marshall 2002, 27-30; Miller 2002b, 115).

5.7 Alum-house complex

The remote location of many alum houses together with their reliance on, and constant demand for, stone for building as well as iron, lead and wooden utensils, meant that specialist facilities had to be provided on site. Thus it is normal for the alum house proper to be but part of a larger complex of buildings comprising a blacksmith's shop, plumber's shop, barrow-maker's shop and cooperage, whilst the need for on-site storage facilities meant there would also be a coalyard plus warehouses for the alkali and the finished alum. In addition, it was not unusual for the chief alum maker (who may also have a managerial role as clerk of the works) to be provided with accommodation on the premises. Other buildings associated with the alum-house complex could include an assay room, containing the equipment necessary for the checking of the specific gravity of liquor in the evaporating pans.

At the alum house, strong liquor was often boiled to clarify it further, before it was concentrated by evaporation, an alkali added, and the alum separated out from other salts present in the liquor; the resulting alum crystals were then further refined by a process known as 'roaching'. The alum house was laid out so that the liquor could move between each stage under gravity as much as possible. The individual stages are examined in detail by both Rout (1997) and Marshall (2002), and only a generalised outline of the main process need be given here. However, the precise method followed undoubtedly varied between the different works (Miller 2002b, 115), and indeed there is at present only circumstantial evidence that Kettleness undertook the secondary clarification or 'clearing' process, at least at the time of the NRO plan (Marshall 2002, 32).

Strong liquor arriving from the settling cisterns in the quarry was stored at the alum house in 'raw liquor cisterns', from where it was fed under gravity to the 'clearing house' for boiling and further clarification, and thence into the 'cleared liquor cisterns'. Cleared liquor was run into lead pans in the 'boiler house' (at Kettleness this part of the alum house seems to have been known as the 'fire roof') where it was mixed with a proportion of previously concentrated liquor known as 'mothers' and concentrated over coal fires for anything up to 24 to 36 hours until it had acquired a pre-determined specific gravity. The hot liquid was then run off into 'settlers', and an alkali added which caused immediate precipitation of iron, magnesium and calcium salts ('slam' – see also section 5.5 above). At Kettleness, this part of the alum house was termed, unsurprisingly, the 'settler roof'. The alkali source was originally human urine, but by 1730 urine was increasingly being superseded by burnt kelp (seaweed), itself later replaced by a processed form of seaweed known as 'calcined soap workers' lees' or 'black ash', a waste product of soap manufacture. Finally, in the 19th century black ash began to be superseded by 'muriate of potash' (potassium chloride), initially produced as a refined form of soap workers' lees, but after 1839 imported from the Stassfurt Mine in Germany. Potassium sulphate and gas-works ammonium sulphate were other minor sources of alkali in use by the mid-19th century (Rout 1997, 40-4).

Liquor remained in the settlers for several hours, before being decanted off into wood-lined 'coolers' and allowed slowly to reduce in temperature over several days, during which time alum crystallised out on the sides and floor of the coolers, and on wooden boards inserted into the coolers to increase the available surface area. At the end of the period, any remaining solution ('mothers') was drawn off and recycled. This part of the alum house was known as the 'cooling house', or at Kettleness as the 'cooler roof'.

At this stage, the alum crystals still contained impurities such as iron oxides, as well as undesired sulphates. Some of these could be removed by washing with water, alum solution or weak sulphuric acid, but more effective purification was achieved if the crystals were roached, that is re-dissolved in the minimum amount of hot water and the resulting saturated solution run off into casks or 'roaching tuns' housed in the 'tun house', to cool and re-crystallise. After *c* 16 days - by which time the alum had formed a thick lining on the inside of the casks - the tuns were taken apart to expose a solid crystalline block with a liquid centre. The block was drilled to allow the remaining liquid ('tun water') to drain out, before being sawn up and ground into powder; tun water was recycled to the evaporating pans (Rout 1997, 45; Marshall 2002, 40-3).

Rout has argued that the use of a 'purge stream' was necessary at the crystal-washing stage in order to prevent the excessive build-up of impurities within the liquor; thus unlike mothers and tun water, 'washing liquor' was not returned to the main evaporating pans, but was tipped away or, in the 19th century, evaporated and cooled in a separate pan/cooler cycle to precipitate crystals of magnesium sulphate, which could be sold as coarse Epsom Salts for which there was then commercial demand (Rout 1997, 39 and 49-50; 2002a, 20 and 25). Thus, at Kettleness in 1834, there was said to be one 'front pan' and one 'back pan' devoted to the recovery of 'salts' (MCA X/3/22), whilst by 1845 a separate 'Epsom Salts House' is recorded (MCA X/3/24).

5.8 Other buildings

A variety of other structures such as tool stores and sheds for faggots and whins normally stood within the quarries, away from the alum-house complex.

5.9 Transport

As has already been noted (section 5.6 above), an alum works' need for large quantities of heavy and/or bulky raw materials such as coal and alkali meant that transport of goods to and from site was an important economic consideration which determined both the precise location of the alum house, and ultimately even the commercial success or failure of the works itself. Coastal works had a definite advantage over their landlocked cousins in this respect, since they could import raw materials and export the finished product(s) entirely by sea without any of the additional expenses incurred in overland transhipment. The coastal works seem to have followed a range of strategies to ensure shipping could approach as close as possible to the alum house, ranging from siting the house in or above bays where vessels could safely beach (as was the case at Sandsend (*eg* Barton 2002, 80 plate 32)), to the provision of expensive harbour works where the coast was rockier and more exposed, as at the Saltwick works (Marshall 1994). Documentary evidence shows that Kettleness, at least in the first 100 years of its existence, combined both approaches and provided a stone staithe even though the alum house stood at the base of the cliff in the shelter of Runswick Bay. However, following the cliff collapse in 1829 which destroyed the staithe and caused the alum house to be re-sited to a cliff-top position, it seems to have been considered safe for ships simply to beach on the gently sloping reef within the bay.

In recent years attention has been drawn to a number of rutways cut into the rocky foreshore at places around the north-east Yorkshire coast, and the observation made that some seem to be connected with alum works although there are also associations with other industries, such as the ironstone trade. However, in all cases their function seems fairly certain: to guide carts unloading or loading ships beached on the foreshore along safe routes particularly at night and in conditions of poor visibility, and either side of low tide (Owen 1986; 1987).

At Kettleness, access between the foreshore and the later alum house seems to have been by tracks terraced into the cliff, although in similar situations elsewhere inclined planes were constructed as at the Peak works (Marshall 1995, 57). Tracks were also constructed in the floor of the quarries to facilitate movement between activity areas; in addition wooden planks, and later cast-iron plates, were used to create barrow ways connecting the active quarry face to the calcining places. According to Winter (1810, 248), the metal plates measured 6 feet (1.83m) long by 6 inches (0.15m) wide by 0.5 inches (0.013m) thick, and were joined by wooden sleepers.

6. FEATURE CATALOGUE AND DESCRIPTION OF THE FIELD REMAINS

Despite the long history of mineral extraction and industrial activity on the headland detailed in chapter 4, it is almost impossible to divide up the visible archaeological evidence into meaningful phases. The following feature catalogue is therefore not ordered chronologically, but is arranged by industry and process. Four main sections (6.1 to 6.4) cover each of the principal industries (alum, cementstone, jet and ironstone), while sub-sections describe the evidence for discrete processes within those industries; a final, fifth, section (6.5) contains a miscellany of non-industrial features. Not surprisingly, section 6.1 is by far the longest part, and contains ten sub-sections: the first nine correspond to the stages under which the process of alum manufacture has been described in chapter 5, whilst the tenth covers a number of miscellaneous features which cannot on the evidence available confidently be ascribed a particular function. Sections 6.2, 6.3 and 6.4, describing the physical evidence for the cementstone, jet and ironstone industries respectively, are far shorter as these minerals, unlike alum, were extracted at Kettleness but processed elsewhere.

Readers unfamiliar with the way alum was manufactured are advised to read section 6.1 below in conjunction with chapter 5; those unfamiliar with cementstone, jet and ironstone extraction may also find it useful to refer to sections 4.2, 4.3 and 4.4 above.

A copy of the EH survey diagram at 1:1000 scale is attached at the end of this report as Fig 56. For ease of reference, a reduced copy at 1:3000 scale is reproduced at Fig 11, highlighting archaeological features described in the text. A number of windows showing selected areas at the larger scale of 1:500 are reproduced within this section; the locations of these windows are marked on Fig 12.

6.1 Alum

6.1.1 Quarrying

The visible area of quarrying on the headland covers about 90ha (216 acres), but little physical evidence now survives for the manner in which the quarrying was carried out. Documentary evidence states that the first step was the removal of the sandstone overburden in order to expose the shales beneath, which were then dug in a series of steps called ‘desses’, separated by vertical risers or faces called ‘depes’ (sections 4.1 and 5.1 above). By the time the works closed in 1871, this had resulted in a working face *c* 35m high stretching for over 400m east-west across the base of the promontory, which had also moved south in excess of 400m from Kettleness Point where quarrying presumably started. The survey has found evidence, however, that the western third of this quarry face was affected by the great landslip of 1829 (chapter 2), and thereafter appears to have been avoided by the alum workers as too dangerous to mine. The survey has also identified a number of small, bowl-shaped, ‘hollows’ excavated into the shale floor of the wider quarry; these are now backfilled, but their form is clearly different from, and cannot be explained by, the documented method of digging in desses.

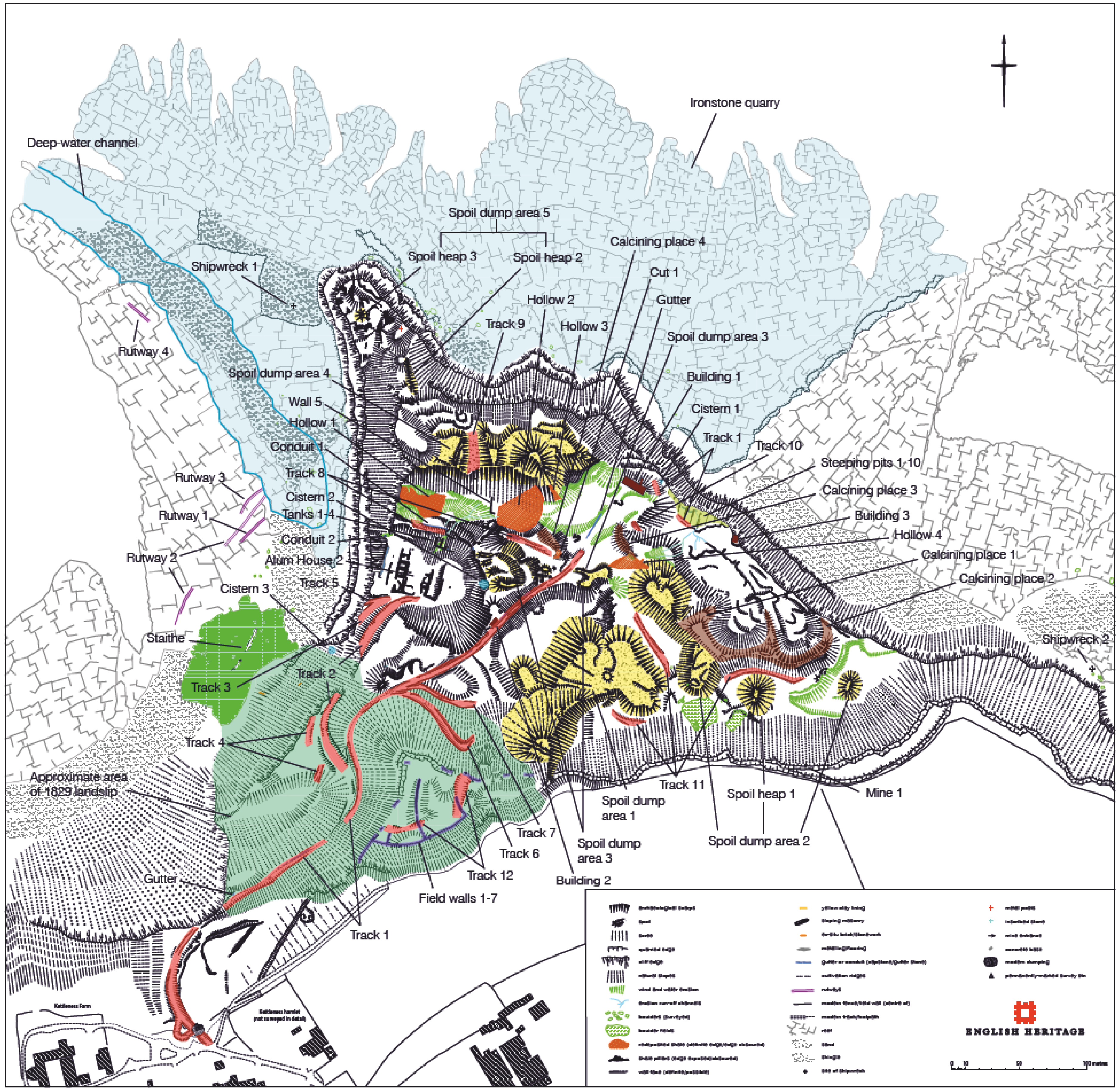

Figure 11. Interpretative diagram of all archaeological features described in the text

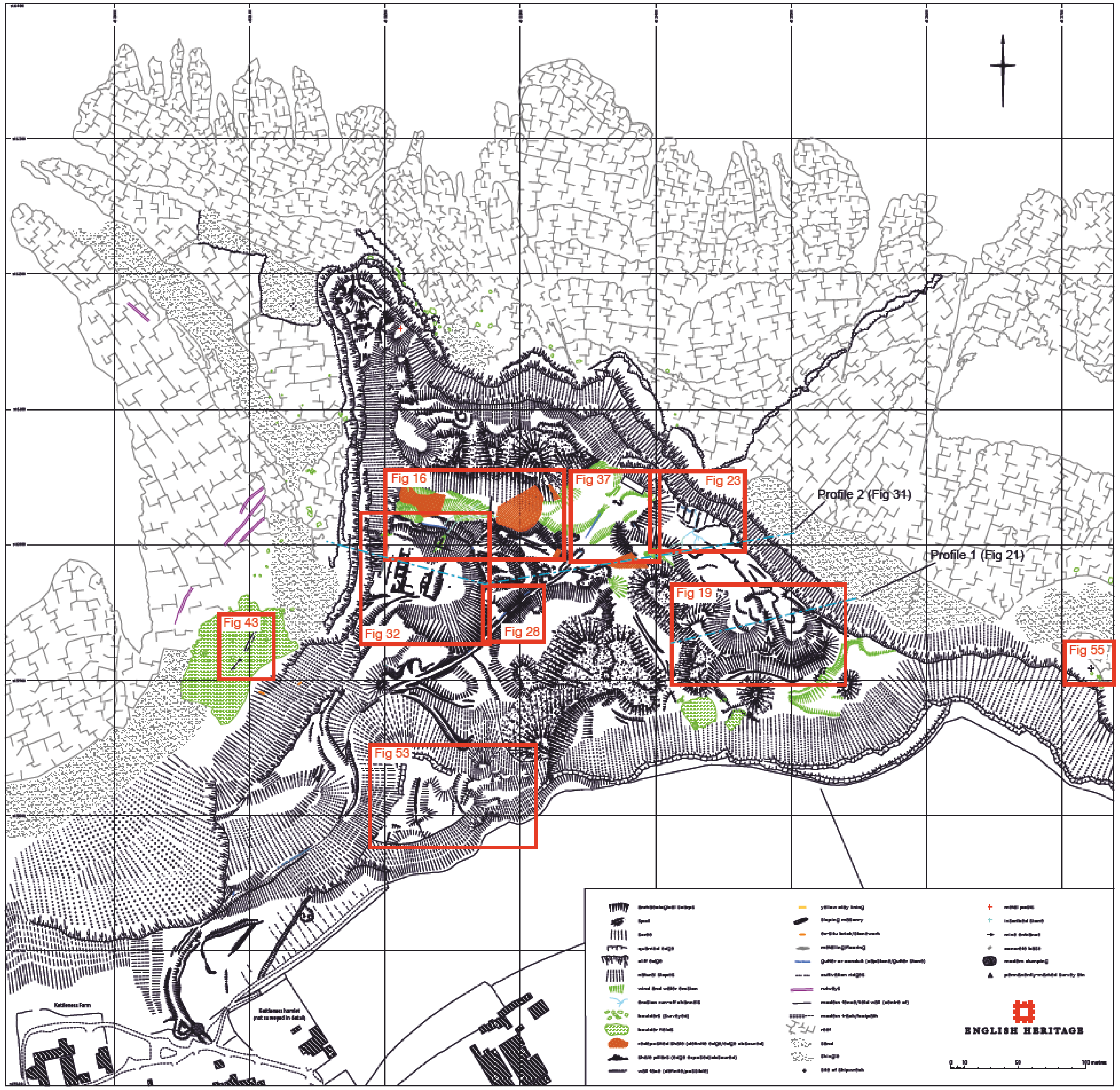

Figure 12. Key diagram for 1:500-scale windows and for profile lines

The main quarry

The OS first edition 25" map (Fig 10) - surveyed in 1893, 22 years after the works closed - shows a series of 'cliff' symbols at the rear of the quarry, suggesting that the working face then preserved more of a stepped appearance - no doubt equating to the long desses mentioned in contemporary documents. However, since 1893 the vertical faces of the lowest desses in the shale have eroded to a near 45º slope, creating an 'undercliff' of shale scree now grassed over apart from areas of recent or active slumping (Fig 13); furthermore, the

Figure 13. General view of the east end of the main quarry face, showing the eroded shale undercliff and the surviving dess in the sandstone cap. The mound in the foreground is allegedly an undismantled calcining clamp, but is more probably a simple spoil heap. (NMR AA040208)

top of the *in-situ* shale at the interface with the sandstone has begun to erode out, thereby undermining the overburden and in places bringing it down. Recent rock falls are evidenced by large sandstone boulders overlying the scree undercliff, and also by the surface of the sandstone cap above having a jagged, red and raw look to it, in stark contrast to areas where the original smooth, vertical quarried face survives which typically exhibits a pale buff colour. Such differences are particularly evident in the central section of the quarry face, where a long length of the original quarried face has been lost completely (Fig 14). At the

Figure 14. General view of the central portion of main quarry face, showing in-situ and eroding sections of the sandstone cap. The shale baulks in the foreground are the remains of calcining places 3 and 4. The two ends of the coastguard breeches buoy are also visible. (NMR AA040261)

east end of the quarry, a ledge is still visible half-way down the cut sandstone face (Fig 13), showing that the sandstone as well as the shale was dug in desses. A series of hand holes laid out in a ladder arrangement are visible in the sandstone further west.

Areas of deeper quarrying and hollows

Large areas of the quarry floor seem to have been dug to roughly the same depth at around 50m-54m above Ordnance Datum (AOD), which would seem to be the level beneath which (at least by the 19th century) the shales were not considered worthwhile mining because of their lower sulphur content (Winter 1810, 246). However, a number of deeper areas exist within the quarry. In two cases these are explicable by the need to site processes at levels lower than the active working face in order to take advantage of gravity flows. Thus, for example, the steeping pits on the east side of the headland occupy a part of the quarry dug down to *c* 46m AOD, whilst alum house 2 on the west side of the headland occupies a broad shelf whose base is at *c* 30m AOD (Figs 11 and 31). But three other areas of deep quarrying cannot be explained away so readily: one is Kettleness Point where the shales are missing down to the height of the jet dogger seam at *c* 20m-25m AOD; the second a band further south where there is evidence for a number of discrete hollows in the main quarry floor which appear subsequently to have been backfilled; and the third a large amorphous area bisected by track 1 lying south of this band, whose base is as low as 42m AOD. The possible significance of the first and last of these areas is discussed in chapter 7, but the hollows are described below. The survey has identified four examples with varying degrees of confidence, all of which are located in a band north and east of alum house 2 (Fig 11); hollows 1-3 are shown at larger scale in Fig 16. On the ground, the hollows now reveal themselves by lines in the quarry floor dividing *in-situ* from re-deposited shale (*eg* Fig 15); it is unclear if they were deliberately backfilled or have silted naturally over time, but the former is perhaps most likely.

Figure 15. Detail of the east side of hollow 1, showing the very clear difference between in-situ shale bedrock on the right and re-deposited shale on the left. (NMR AA040205)

Hollow 1 is centred at NZ 8323 1603 on the west side of the headland immediately north of alum house 2. Its northern limit is obscured by material eroding off an adjacent spoil heap, but sufficient of the other three sides is visible to show it measures *c* 32m east-west by at least 19m north-south; indications that the adjacent spoil heap overlies *in-situ* shale suggest the hollow can only extend a maximum of another 14m to the north and is therefore sub-square in plan. The west edge is now very close to the sea cliff, and cliff recession may well soon expose a north-south profile through the feature. Active surface erosion is also slowly lowering the overall level of the feature's sides and infill (chapter 2 and Fig 16).

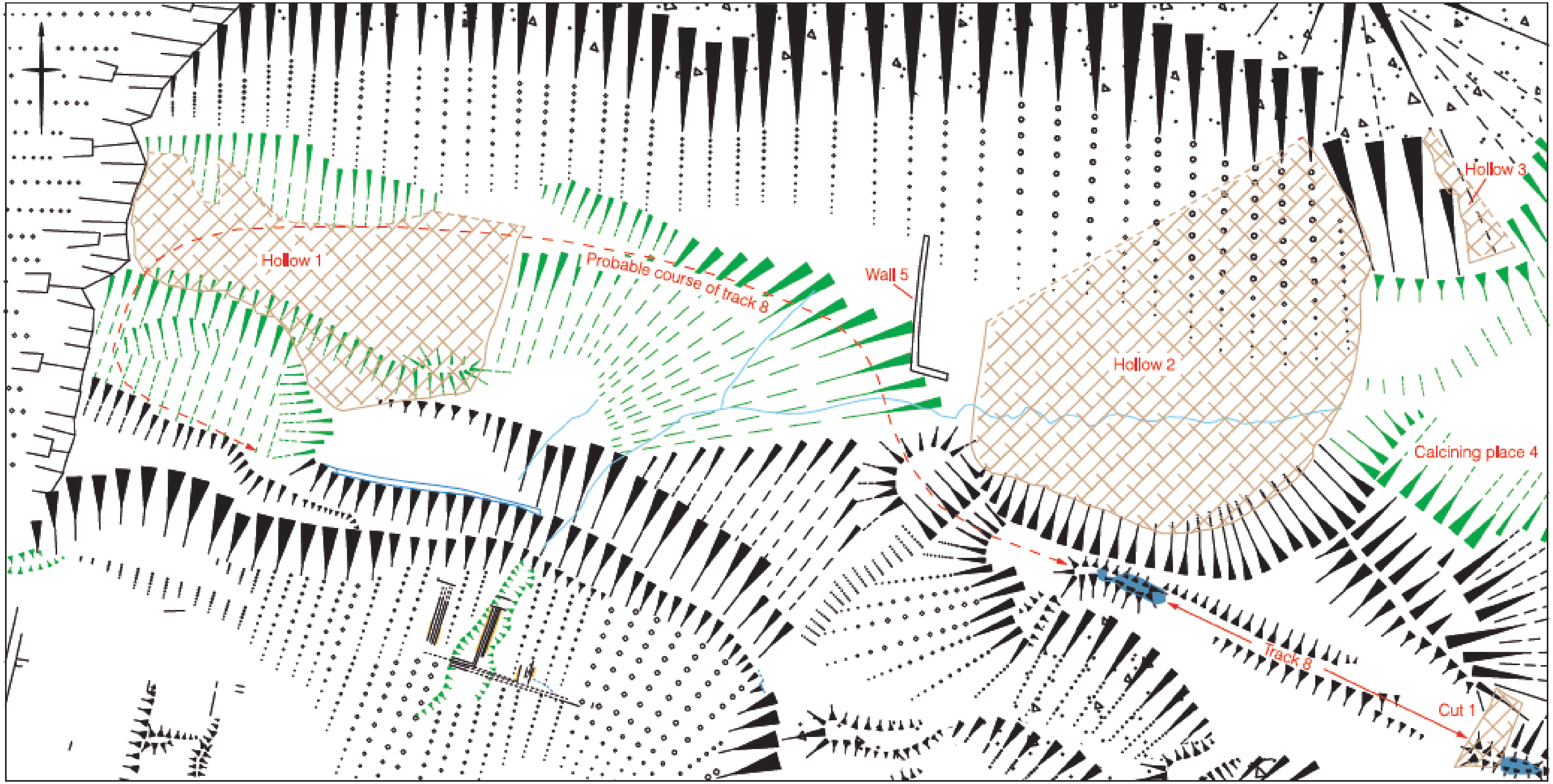

Figure 16. Annotated extract from survey at 1:500 scale, showing hollows 1 - 3 and adjacent features (For key to conventions, see Fig 56)

Hollow 2 lies 40m almost due east of hollow 1, centred at NZ 8330 1602. It appears very similar in size and shape, although in the north its edge is again obscured by material eroding off an adjacent spoil heap. The southern edge and south-east corner survive as a near-vertical cut face standing up to *c* 4.5m above the level of the infill (Fig 17); however, this

Figure 17. Detail of the south-east corner of hollow 2, showing the surviving cut face and the edge between in-situ and re-deposited shale. The baulk of calcining place 4 stands above the cut face. (NMR AA040262)

scarp has undoubtedly eroded back from its former position, and the hollow's original dimensions are likely to be better represented by the base of the existing scarp, making the feature *c* 31m east-west by 35m north-south. The OS first edition 25" map (Fig 10) shows that in 1893 the east side of the hollow also survived as an upstanding scarp, but surface erosion of the shale (chapter 2 and Fig 16) in the 110 years since has removed the top down to a level flush with the infill.

Hollow 3 is suggested by a short cut line in the floor of the quarry 8m east of hollow 2; the visible line runs for *c* 11m from north to south, centred at NZ 83324 16037, before turning through a 90º angle and continuing for 4m to the east, but cannot be traced further because of the obscuring cover of scree. Indeed the exposed length is itself partly obscured and difficult to see, and during survey was best seen after rain when the *in-situ* and re-deposited shale either side of the cut dried at different rates.

A possible fourth hollow lies south-east of hollow 3 in the region NZ 83375 15986. It is completely infilled, and only traceable as a cut line in the surrounding quarry floor between *in-situ* and re-deposited shale. However, much of this area was obscured by scree material eroding off adjacent spoil heaps at the time of survey, and only a short length of edge could be identified.

Spoil heaps

Fig 11 shows the positions of identifiable spoil heaps within the quarry. The extant dumping appears to have been concentrated in five areas: spoil dump area 1, beneath and near the foot of the central section of quarry face; spoil dump area 2, around calcining places 1 and 2 at the foot of the eastern section of quarry face; spoil dump area 3, a small area of shale tipping immediately above and east of alum house 2; spoil dump area 4, a linear band of dumping which runs east-west right across the headland north of alum house 2; and spoil dump area 5, sporadic evidence of dumping overlying Kettleness Point.

Spoil dump area 1 comprises a steep, amorphous, ridge leading down from near the top of the quarry face onto two flat-topped, lobate, mounds which are almost the mirror-image of each other (Fig 14). This whole area is now mostly covered in grass and heather, but individual finger tips can still be identified on the tops of the lobate mounds, while the occasional presence of sandstone fragments through the heather would seem to confirm that the whole area is dumped spoil. It is not clear from where the spoil has originated: the ridge would appear to have been built up from the south by dumping from near the level of the top of the section of quarry face affected by the 1829 landslip; the two lobate mounds from a lower level.

Spoil dump area 2 consists of a series of at least four discrete spoil heaps lying in an arc south and west of calcining places 1 and 2. These heaps are on the whole more conical than those in area 1 and have fewer clear-cut examples of finger-tipping on them, but are covered in sandstone fragments and are clearly dumped spoil. One of the mounds (spoil heap 1; Fig 13) which lies separate from the main complex has been suggested to be an undismantled, even unburnt, calcining clamp (Gould 1993b; Green in SMR records). However, two observations show that the suggestion may be discounted: first, the mound seems to be composed of the wrong material (sandstone fragments are visible on its surface, not shale); secondly, it does not stand within a calcining place, two extant examples of which survive only a few metres to the north (section 6.1.2 below).

Spoil dump area 3 consists of a number of small finger tips either side of the lower section of track 1. The dumping differs from that in areas 1 and 2 in that it seems to comprise mostly small-scale tipping of unburnt shale into an area of deeper quarrying (this section above), and therefore has greater similarity to the dumping of shale into hollows discussed earlier (this section above). A number of small, discrete finger tips are visible both sides of track 1; all seem to emanate from the direction of the track.

Spoil dump area 4, situated north of alum house 2, is a far larger area of dumping of different make-up again. At its west end, apparently unmined shale is overlain by an orange sandy clay, in turn overlain by a fine-grained darker deposit; while at the east end the orange clay is not so visible, and the fine-grained deposit gives way to dumps of predominantly medium-sized sandstone rubble. The orange clay is probably glacial till (boulder clay); the darker deposit is of uncertain origin, but includes small fragments of sandstone and unburnt shale. It is clearly dumped material, nevertheless, for tip lines are visible where it has been cut through by track 9 (Fig 18). The tip lines dip northwards, showing that the material has been dumped from the south. In the west it is unclear how far this area of tipping extends over the neck of Kettleness Point: the neck is eroding and slumping badly, but is mostly grassed over making it impossible to determine from surface inspection alone what is unmined

Figure 18. Tip lines in spoil dump area 4 exposed in the east side of the cut for track 9. (NMR AA040266)

shale which has slumped and what is tip. However, a long ridge (spoil heap 2, see below) must mark its northern limit, for this has visible tip lines dipping southwards, not northwards. Since spoil dump area 4 is cut through by track 9 (section 6.1.9 below), it must pre-date 1856.

Spoil dump area 5 consists of small instances of dumping on the neck and head of Kettleness Point. As already mentioned, a long ridge (spoil heap 2) overlies the neck; its sides are eroding badly, but in so doing a series of 45º-tip lines have been exposed, dipping southwards, showing spoil was dumped from the north. Its make-up is a combination of sandstone fragments and unburned shale. A second dump (spoil heap 3) survives on the Point itself, but is different again in both form and content, being a discrete mound measuring *c* 10m by 8m across by a maximum of *c* 4m high and consisting mostly of red (burned) shale in marked contrast to dumping elsewhere.

6.1.2 Calcining

Gould (1993b) has claimed that 'calcination bases…survive as earthworks at the foot of the quarry' at Kettleness. The locational information is not precise, but the calcination bases referred to must equate to two earthwork features recorded by the present survey close to the east end of the quarry face. However, the term calcining place - for which there is contemporary authority (sections 4.1 and 5.2 above) - seems better suited to describe the extant features than Gould's term calcination base, and will be used here in preference. Gould has suggested that a possible, undismantled, clamp also survives in the same part of the quarry. Two other, previously unrecorded, possible calcining places exist further north within the quarry; the possibility that various other features described above (section 6.1.1) as hollows are in fact calcining places, is explored in chapter 7.

Calcining places

Calcining places 1 and 2 recorded by Gould lie adjacent to each other, centred at NZ 8346 1594 and NZ 8350 1593 respectively (Figs 11 and 19). They are cut, as opposed to built, features, each comprising a U-shaped ridge or baulk of unmined shale enclosing a floor area open towards the north; however, since in this case the two places have been sited side by side, they share a central spine and the defining shale baulk is consequently a W-shape overall. Weathering of the shale and loss of most of the eastern baulk of place 2 through cliff

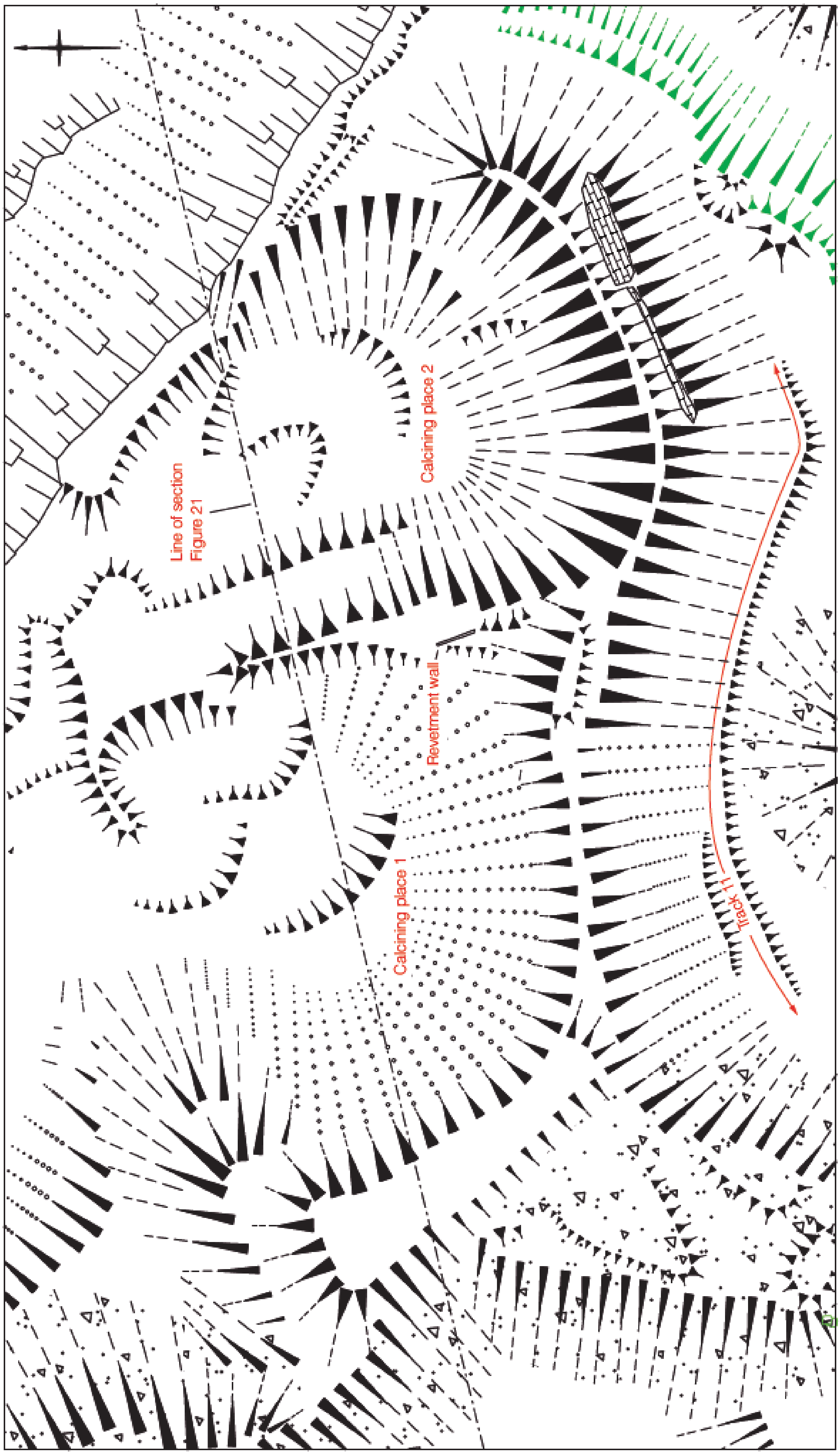

Figure 19. Annotated extract from survey at 1:500 scale, showing calcining places 1 and 2. (For key to conventions, see Fig 56)

recession, means it is now impossible to give precise original dimensions, but the existing internal diameter of place 1 is *c* 47m between (eroded) baulk tops, whereas place 2 may have been somewhat smaller; in both cases the rear baulks still rise between *c* 8.5m and 10m above the silted floors, although the common central spine has weathered badly and is considerably lower. The faces of the baulks now mostly consist of steep (*c* 25º-35º) talus slopes, and in the west the outer face is hidden beneath dumped quarry spoil; whilst the profile of the outer face probably always sloped out from top to bottom in order to impart strength to the structure, traces of walling protruding through the scree on the east side of place 1 (Fig 20) suggest that the inner faces were originally vertical and revetted in stone.

Figure 20. Detail of stone revetment on east side of calcining place 1. (NMR AA040250)

Indications of sloping masonry visible towards the top of the rear outer face of place 2 indicate that the baulk here has been heightened artificially or else required strengthening. Both places are depicted as topographical detail on the OS first edition 25" map surveyed in 1893 (Fig 10), suggesting that they date from the alum works' final period of operation. They do not appear on the 6" map surveyed 1849-52 (Fig 6), but this cannot be read as evidence that they did not then exist, for the earlier map omits topographical detail within the area of the quarry. The existing eroded profile of places 1 and 2, and a reconstruction of how they may have looked originally, is shown in Fig 21.

The sites of two other calcining places may be suggested by analogy with the form of places 1 and 2. Both are situated further to the north, in the approximate centre of the headland (Figs 14 and 22).

Calcining place 3 is suggested by a curving ridge of *in-situ* shale at NZ 8337 1600 which rises up to 3.5m above the present floor of the quarry (Figs 11 and 37). Some of this height

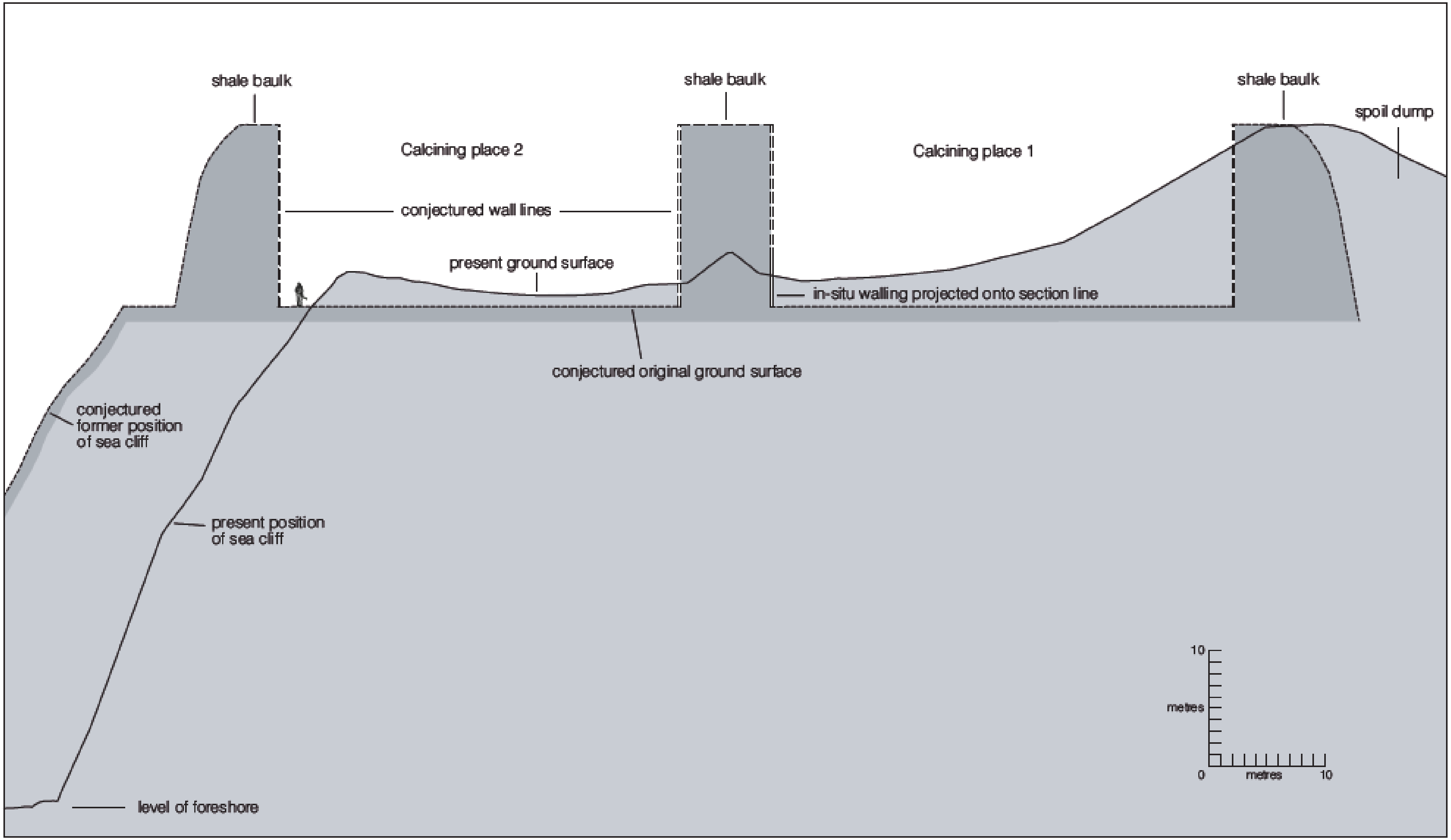

Figure 21. Profile 1 and reconstructed section looking south through calcining places 1 and 2

Figure 22. General view north over calcining places 3 and 4 towards spoil dump area 4. (NMR AA040231)

difference is undoubtedly the product of later wind and water erosion which has lowered the surrounding quarry floor by several metres in the years since the works closed (chapter 2), but erosion cannot account for the overall form of the feature which closely resembles the baulks of the better-preserved calcining places 1 and 2 further south. Only a short arc of baulk survives (it has a chord length of 30m), but this is sufficient to indicate that the feature is probably the base of the western side of a calcining place with an internal diameter of *c* 30m, the eastern and southern sides and higher levels of which have all been removed by later quarrying. The feature is not marked on any known map, but should pre-date the mid-19th century since in the east it is cut by an area of deeper quarrying in the base of which two banks of steeping pits had been constructed before 1852 (section 6.1.3 below).

Calcining place 4 is indicated by a second length of shale ridge or baulk, some 50m west of no. 3, at NZ 8332 1600 (Figs 11 and 16). The baulk stands *c* 3m above the present quarry floor to the west (*c* 4m above the floor to the south and east and almost 7m in the north, but this extra height seems attributable to either surface erosion (chapter 2) or later quarrying (hollow 2, section 6.1.1 above)). Only a short, 22m, length of the baulk survives. Unlike place 3 it has no discernible curve, and consequently it is not possible to estimate the original diameter or be certain on which side the calcining floor lay.

Calcining clamps

Gould (1993b) and Green (in SMR records) have both suggested that a mound in the south-east corner of the quarry at NZ 8347 1589 is an undismantled calcining clamp. The feature is more likely to be a spoil mound (spoil heap 1, section 6.1.1 above).

6.1.3 Steeping

Steeping pits

The remains of a bank of at least ten steeping pits (bank 1), oriented roughly east-west perpendicular to the line of the sea cliff, are centred at NZ 8343 1602 on the east side of the headland (Figs 11 and 23). The bank probably existed by 1852, for its position corresponds with one depicted by the surveyors of the OS first edition 6" map (Fig 6). However, the bank shown on the map appears to contain twelve pits rather than the ten (possibly eleven – see below) visible on the ground today. It is unclear whether this is because the map is in error, or whether the discrepancy should be taken as evidence that additional pit(s) are currently buried beneath shale scree; a third possibility is that the bank was rebuilt sometime after the date of the map, at which time the number of pits was reduced. The map also depicts a second bank of six pits lying immediately to the south (bank 2) at *c* NZ 8347 1598; these are presently buried by shale scree and are only visible in section in the cliff face. A total of between five and fourteen pits are documented at the works in earlier periods, but the available evidence (section 4.1 above) does not enable their positions to be pinpointed.

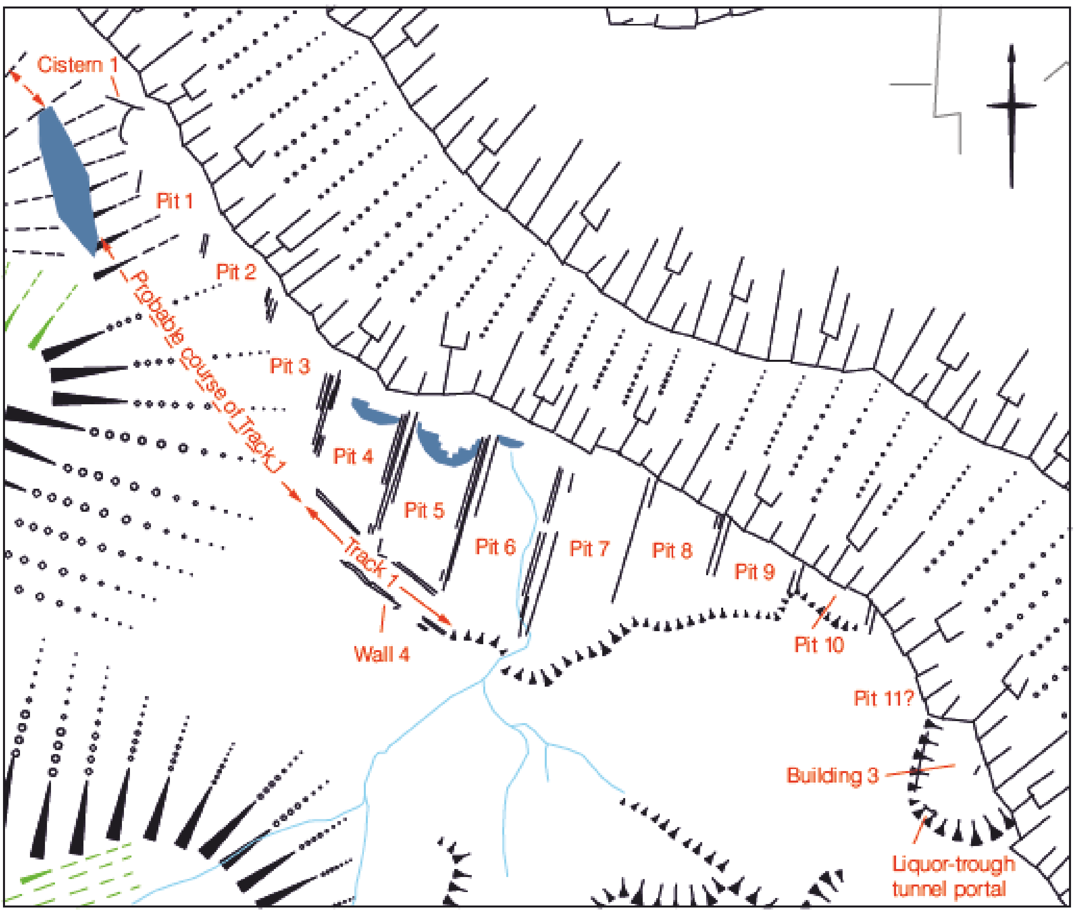

Figure 23. Annotated extract from survey at 1:500 scale, showing steeping pits 1-10 in bank 1 and adjacent features. (For key to conventions, see Fig 56)

Bank 1 lies immediately above the sea cliff, and is being progressively destroyed as the latter recedes. The pits at either end are mostly obscured by wind-blown shale, and only very short lengths of their side walls are visible where they abut the cliff. It is thus possible that further pits exist now completely masked by scree; the presence of a short stretch of road metalling (track 1) just beyond the bank's visible west end makes it unlikely that any more lie in that direction (for the purposes of the present report, therefore, the pits have been numbered 1-10 from west to east), although there is space for an eleventh pit to be situated at the other end of the bank in the gap between pit 10 and the western wall of building 3. Burnt shale from the bank's last use remains *in situ* in at least two of the pits (*eg* Fig 24).

Because of the obscuring blanket of scree, it is hard to observe or interpret details of the pits' construction. Mostly all that is visible are short lengths of the upper courses of the side walls plus small areas of the floors either in plan just back from the cliff edge or in section in

Figure 24. Detail of the eroding ends of steeping pits 1-6, and of cistern 1 beyond. (NMR AA040258)

the cliff face (Figs 24 and 25), but this is enough to show that all the pits have walls of coursed sandstone blocks and floors paved with square stone slabs. Furthermore, the evidence from four of the pits (nos. 4 - 7) at the centre of the bank - which happened to be more exposed than the others at the time of survey - suggests that all were constructed

Figure 25. General view north across the north-west end of steeping-pit bank 1. (NMR AA040256)

with a west wall two courses wide as opposed to an east wall built as a single skin, and that a void approximately equivalent to a single row of blocks between the walls of adjacent pits may have been infilled with yellow clay (*eg* Fig 26). This plus the observation that the floor slabs, too, overlie yellow clay, means it is likely that all the stonework was bedded on and in a bed of clay in order to render the pits watertight. Odd pieces of timber which can be seen protruding out of the cliff face suggest that this bedding clay (or perhaps only the stone side walls?) was itself laid on a framework of wooden piles and sleepers. Indications of a thin clay lining attaching to the inner faces of the pits in several places raises the possibility that the insides were also faced with clay.

Figure 26. Detail of the void between the side walls of steeping pits 5 and 6. (NMR AA040259)

Pit 6 measures at least 14m long, but cliff recession means that none of the pits now survives to its full length. The obscuring cover of scree also makes it difficult to measure widths accurately, but as best as can be judged none of the pits was precisely rectangular or conformed to an exact standard width: estimated widths vary between *c* 4.5m and 4.8m (*c* 14 feet 9 inches to 15 feet 9 inches), while the side walls of pits 4 and 5 lie at an angle of *c* 65º to their visible southern end wall, showing that these two at least were more rhomboidal than rectangular. The visible southern end wall of pit 4 also displays a very definite lip along its inner edge (Fig 25). The purpose of this feature is uncertain, but does raise the possibility that the pits could, if necessary, be protected by a removable covering of timber planks, particularly since a stone at the very start of the western side wall of pit 5 (which survives to a higher level than the rest of that wall) displays a similar recess. A short length of stone wall (wall 4), visible parallel to and *c* 2m beyond the end wall of pits 4 and 5 (Fig 23) is probably a length of walling marking the side of track 1 (section 6.1.9 below).

The OS first edition 6" map (Fig 6) shows that in 1849-52 a second bank of six steeping pits (bank 2) existed immediately south of bank 1, separated only by the width of a building (building 3, section 6.1.8 below). The map also shows that, as with bank 1, the pits in bank 2 were originally laid out perpendicular to the cliff edge, but since the edge here trends more north-west to south-east it means they lie on a different alignment to those in bank 1. The area of bank 2 is now masked by shale scree and no walls are visible on the surface, although unsurveyable wall ends and buried floors could be seen in the cliff face when viewed from the foreshore. It is thus evident that at least part of the bank still survives, but that it, too, is being progressively destroyed by cliff recession.

Temporary liquor-storage cisterns

Cistern 1 is visible in section in the cliff face north of bank 1 at NZ 83403 16047 (Figs 11 and 23), and is being progressively destroyed as the cliff recedes. Its outline was mapped from aerial photographs, but at the time of ground survey its situation was considered too perilous to warrant closer investigation and the feature was only recorded photographically (Fig 27). It consists of a stone-walled chamber *c* 2.5m wide capped by a barrel-vaulted roof, but all interior detail was totally obscured by shale scree. Gould (1993b) has suggested it is a water cistern, but considering its position it is perhaps more likely to be a temporary storage cistern for liquor in between stages in the steeping cycle. It would seem to have existed by 1852, for a small square structure at the northern end of bank 1 on the OS first edition 6" map (Fig 6) is in the correct relative position for it.

Figure 27. Detail of cistern 1 north of the steeping pits. The metalling on the left is probably part of track 1. (NMR AA040216)

6.1.4 Water supply

There is documentary evidence that by 1732 shortly after the works opened, water was brought to site from Goldsborough, *c* 1km to the south, *via* a leat, and was stored at the works in three ponds (section 4.1 above). The present survey has found no evidence for the course of this leat, although the possible location of the ponds is discussed in chapter 7.

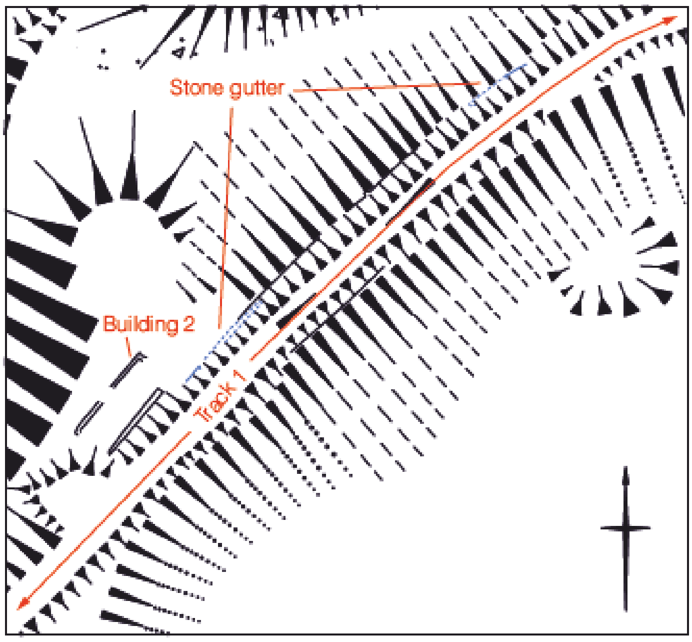

Figure 28. Annotated extract from survey at 1:500 scale, showing building 2 and the gutter alongside track 1. (For key to conventions, see Fig 56)

By the time the works closed in 1871, water seems to have been channelled down to the steeping pits *via* a covered stone gutter laid along the side of track 1 running between hamlet and quarry (Fig 11). It seems likely that the gutter originally ran the whole length of the track, but at the time of survey it was only possible to detect elements intermittently on its north-west side for a distance of about 130m within the quarry between the sites of buildings 2 and 1 (Figs 28 and 37). The visible evidence suggests that immediately east of building 2 where the track crosses a deeper part of the quarry on a raised causeway, the gutter stones were laid on a foundation of sandstone blocks, but closer to building 1 they seem simply to have been founded in a shallow slot cut into the shale bedrock. The gutter was not an open channel, but was covered with flat capstones (Fig 29). Much of the feature east of building 2 has already slipped away as the sides of the causeway have eroded, and stones lie scattered over the shale scree below. Close to building 1, the gutter now appears to run along the top of a narrow shale ridge, but this ridge is actually the product of erosion: surface run-off and wind scour have lowered the floor of this part of the quarry by at least 1m since the works closed, totally removing the track, although the presence of the trough has protected the shale beneath and to either side (chapter 2). Although no stones now survive *in situ* at the north-west end of the gutter close to building 1, the gutter's former line is marked by this ridge; recently dislodged stones have been thrown into the excavation trench dug to remove the fossil plesiosaur in 1999 (section 6.5 below). Bricks visible

Figure 29. View north-east along gutter approaching building 1. (NMR AA040238)

at the edge of the gutter east of building 2 are probably indications of old repair work.

At present there is no definite trace of the gutter alongside that section of track which descends the cliff, but if it also lay on the north-west side, then most is likely to have been lost as the track's outer edge has eroded away: indeed a diagonal line of rectangular stones flush with the track's surface just after the latter begins its descent, are reminiscent of the capstones which cover the extant section of gutter within the quarry (compare Figs 29 and 42), and may indicate that the feature passed from the inside to outside of the track at the top of the cliff.

6.1.5 Settling cisterns

Although the survey has located several cisterns or cistern-like features (sections 6.1.3 above, and 6.1.7 and 6.1.10 below), it has found nothing which may confidently be interpreted as a settling cistern. Circumstantial evidence points to building 3 being a settling-cistern house, but if this identification is correct either all cisterns within it have already been lost to cliff recession or lie buried beneath scree. Building 3 dates to the mid-19th century (section 6.1.8 below); the sites of earlier settling cisterns are unknown.

6.1.6 Liquor transportation

The normal practice at a coastal alum works was to run raw liquor under gravity from the settling cisterns within the quarry to the alum house which could be situated some distance away at the top or bottom of the cliff. The accepted wisdom is that the liquor ran in wooden troughs (or possibly lead pipes) laid on the surface, but occasionally where the location of the alum house dictated, tunnels could be constructed to enable the trough to follow a constant gradient across areas of uneven topography (section 5.6 above).

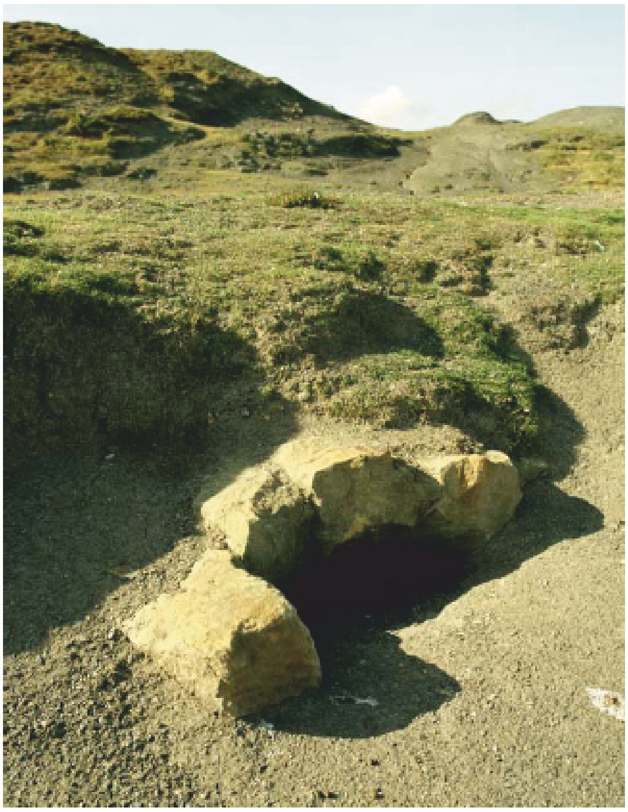

Figure 30. Detail of the vaulted roof at the probable eastern portal of the liquor-trough tunnel. (NMR AA040222)

Gould (1993b) has claimed that such a liquor-trough tunnel exists at Kettleness, describing it as of 'particular quality' although giving no further details of either its form or position. The only possible trace of such a structure visible at the time of survey was part of a vaulted stone roof (Fig 30) mostly obscured by shale scree, at NZ 83457 16001 close to the cliff edge on the east side of the headland immediately south-west of building 3 (Figs 11 and 23). Whilst it is conceivable that the observed feature is part of a water or liquor cistern similar to that evident further north (cistern 1, section 6.1.3 above), its position between banks of steeping pits is a point in favour of an interpretation as the eastern portal of the tunnel identified by Gould. However, other observations militate against such an interpretation: first, the angle of the visible stonework suggests that the feature runs away from building 3 in a south-westerly direction, whereas alum house 2 lies almost due west; and secondly, there is presently no sign of a tunnel emerging at or near the alum house. But neither objection is insurmountable: it is perfectly possible for the tunnel to change direction underground, and for its other end to be masked by scree. A cut in the shale at the top of the eastern side of the alum-house shelf is probably the site of a raw-liquor cistern (cistern 2, section 6.1.7 below), and may mark the approximate position of the tunnel's western portal: the top of the cut is some 2.5m below the height of the tunnel roof at the eastern portal (Fig 31). In addition, a covered stone conduit (conduit 1) which survives intermittently around the northern edge of the shelf on which alum house 2 sits, may represent an extension of the liquor trough; it, too, is discussed in more detail in section 6.1.7 below.

6.1.7 Alum-house complexes

Documentary evidence (section 4.1 above) shows that there were two alum houses at Kettleness. The earliest (alum house 1) stood at the foot of the cliff in Runswick Bay at *c* NZ 831 159, and was in use for almost exactly 100 years (undoubtedly going through several rebuilds and/or enlargements during that time) until destroyed by the 1829 cliff collapse. Its successor (alum house 2), whose ruins survive, occupied a new position centred at NZ 8322 1598 overlooking the bay from the western edge of the alum quarry, as shown on the OS first edition 6" map (Fig 6); it operated for 40 years between 1831 and 1871.

Although alum house 1 was destroyed by a landslip which happened almost 174 years ago, the footprint of that collapse is nevertheless still identifiable on the ground as indicated on Figs 2 and 11. The evidence for a slide has already been reviewed in chapter 2, but corroboration that it can be dated to 1829 comes from the survival within the foreshore boulder field of the foundations of the staithe (section 6.1.9 below) documented as also buried in the collapse. Traces of brick and stonework which are presently visible at two places within the wave-cut cliff face of slumped shale behind the staithe, at NZ 83108 15890 and NZ 83136 15897 (Fig 56), probably derive from the alum house, but seem to be ground-up and *ex-situ*. It is extremely improbable that any *in-situ* remains of the alum house survive beneath the landslip.

The ruins of the replacement alum house (no. 2) occupy a deep, broad shelf in the side of the sea cliff overlooking Runswick Bay (Figs 11 and 32). The floor of the shelf is at least 20m lower than the surrounding quarry, and probably originally measured *c* 60m north-south by at least 80m east-west although the western, seaward, lip has been undermined and weakened by jet mines (section 6.3 below) and has partly collapsed creating a narrow step or ledge at the top of the cliff face (Figs 31 and 48). The main shelf has been excavated out of the lower alum shales normally left unquarried by the alum workers, and must therefore have been created specifically for the alum house. Its sides were no doubt cut vertically, but erosion means they have now receded to a more angled profile and steep talus slopes have

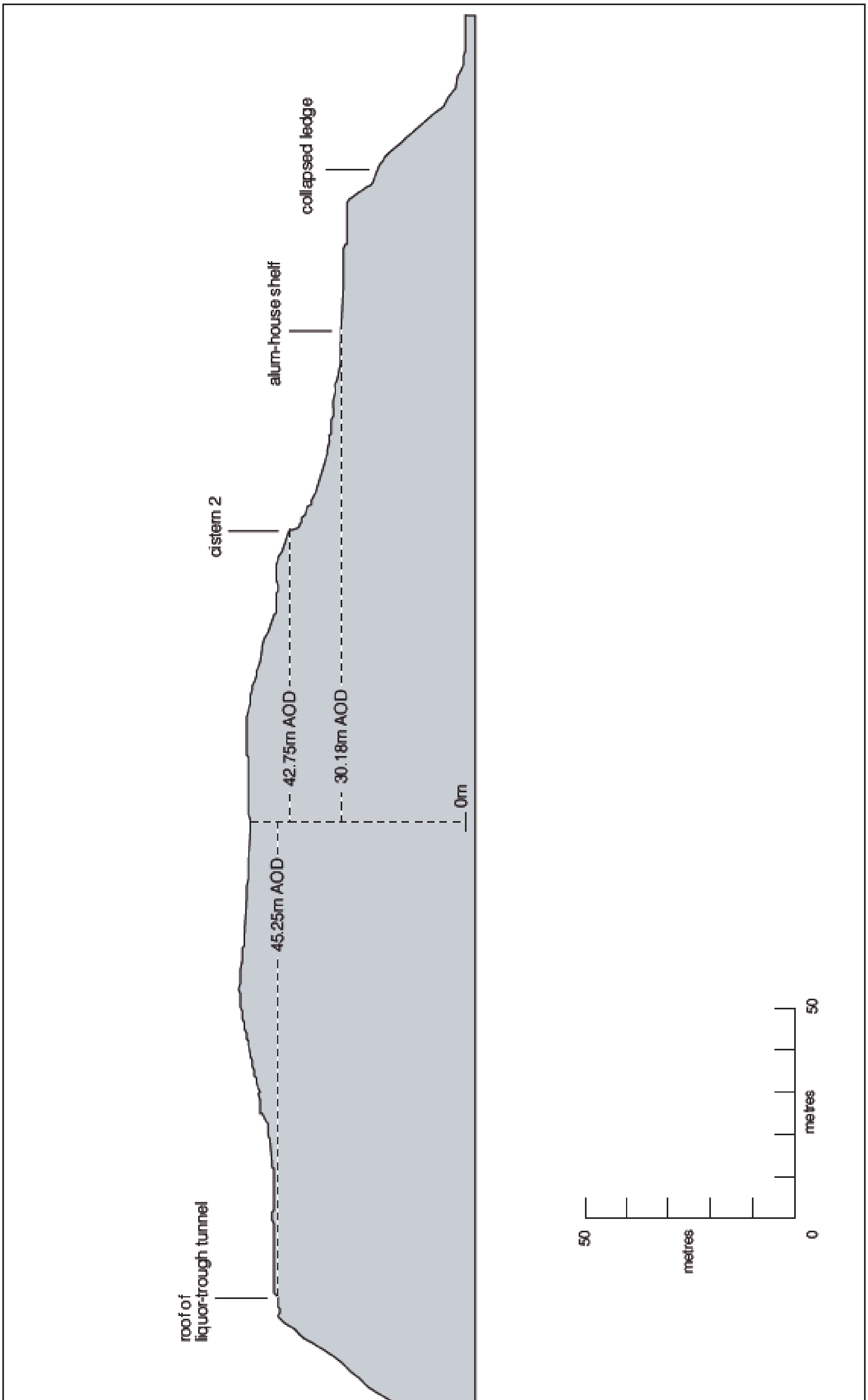

Figure 31. Profile 2 between the eastern portal of the liquor-trough tunnel, cistern 2 and alum house 2.
(For location of profile, see Fig 12)

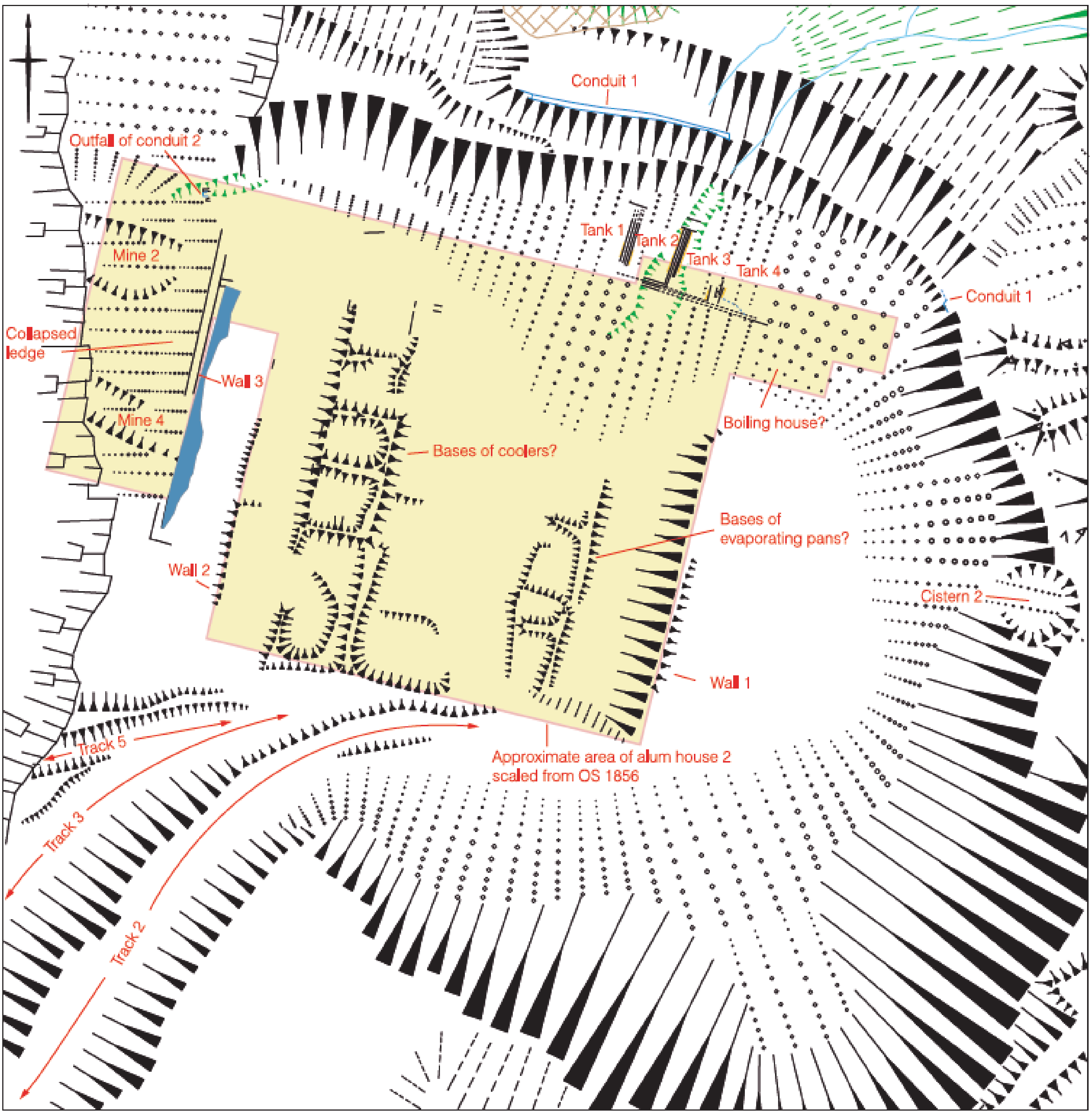

Figure 32. Annotated extract from survey at 1:500 scale, showing alum house 2 and adjacent features. (For key to conventions, see Fig 56)

Figure 33. General view of the site of alum house 2 from the north, showing the alum house being engulfed by scree. Tanks 1-4 lie beneath the talus slope in the foreground. (NMR AA040264)

formed at their feet (Fig 33). This scree is also slowly moving across the floor of the shelf, burying the ruins of the alum-house complex in the process. Grassed-over wall lines up to 0.7m high survive in a number of places towards the centre of the shelf, mostly suggestive of a series of north-south ranges of small rectangular rooms or compartments; otherwise the main visible features are a long west-facing scarp up to 1.7m high located towards the rear of the shelf, with a bank along its top, and a wall and section of concrete floor close to the cliff edge in the process of collapsing onto the ledge (Fig 48). Short lengths of other wall lines are suggested by occasional small scarps and stones, but it is often unclear if the latter are still *in situ*.

The visible features (Fig 32) match well with structural detail shown on the OS first edition 6" and 25" maps (Figs 6 and 10). This cartographic evidence suggests that the extant rectangular compartments are all internal sub-divisions (probably the bases of evaporating pans and coolers) of a single large building whose rear wall is represented by the bank above the west-facing scarp, and front wall by low scarps just back from the cliff edge (walls 1 and 2). It also suggests that wall 3 collapsing onto the ledge is all that now survives of a second, smaller, parallel building which lay west of the first and was attached to its northern end, which has totally fallen over the cliff apart from the eastern wall; the concrete floor on the outside of the wall would seem to be a small external yard or surfaced area between these two parts of the alum house. The western building had already collapsed by 1893 (Fig 10). As already stated, this was because a series of jet mines in the cliff face weakened the floor of the alum-house shelf close to the cliff edge. Although there is no firm evidence for the date of these mines, they seem most likely to pre-date the construction of the alum house (sections 6.3 and 7.3 below). Something of the original external appearance of the alum house can be gauged from the 1856 Weatherill sketch (Fig 9), albeit with reservations about artistic licence (section 4.1 above).

The Ordnance Survey first edition 6" map (Fig 6) shows two other small detached buildings formerly lay on the shelf immediately south of the main alum house, but if anything still survives of these it is now completely masked by scree.

A circular, near-vertical-sided cut in the shale at NZ 83272 15971 is suggestive of the site of a cistern although no stonework is visible (cistern 2). The top of the cut lies at 42.75m AOD; the base is now obscured by scree, but the feature is at least 2.4m deep and has an eroded diameter of 7.5m. Its position at the top and on the east side of the shelf points to it being the site of a raw-liquor cistern, in which the raw liquor arriving from the settling cisterns on the far side of the headland could be stored before beginning its passage through the boilers, evaporators, settlers and coolers of the alum house (see also section 6.1.6 above).

The outlines of at least three, more probably four, tanks arranged in line east-west could be made out with difficulty in the surface of the talus slope against the northern foot of the shelf (tanks 1-4). Each seems to measure approximately 5.2m long by between 3.2m and 3.85m wide. However, surface run-off flowing from the east and north has carved a vertical-sided erosion gully some 1m deep through the scree, and at the time of survey partly exposed the north-western corner of tank 2 (Fig 34), revealing side walls built as a single thickness of

Figure 34. Detail of the silted clarifying tanks north of alum house 2. (NMR AA040252)

stone blocks lined on the inside by *c* 0.15m of yellow clay, and separated from the walls of the adjacent tank by a space equivalent to a wall's thickness which was filled with the same clay-like substance. The rear wall was really only visible in tank 2, but seems to be preserved at least four courses or *c* 0.7m high, and at *c* 0.85m wide is much more substantial than the side walls; a row of upturned roof tiles was partly visible along its back edge. A short length of the tank's front wall was also exposed revealing part of an outlet channel, in the floor of which was yellow clay preserving the imprint of pipework. Comparison with 19th-century OS map detail (Figs 6 and 10) suggests the tanks probably stood within a small building range situated at the north-east corner of the alum-house complex, at the east end of which according to the 1856 Weatherill sketch (Fig 9) was a chimney stack. The tanks' function is unknown, but their proximity to both the stack and a stone conduit (conduit 1) traceable intermittently around the northern lip of the shelf leading from the presumed raw-liquor cistern (cistern 2), suggests they may be boiling tanks for clarifying raw liquor. Conduit 1 consists of stone capstones supported on thin slabs laid on edge (Fig 35), but sits directly on the shale and could not itself have held liquid; it is more likely to have served as a protective cover for a wooden trough or lead pipe, although there is now no trace of any such feature. It has a slight gradient from east to west.

Figure 35. Detail of conduit 1 above the north-east corner of the alum-house shelf. Displaced stones overlie the scree below. (NMR AA040230)

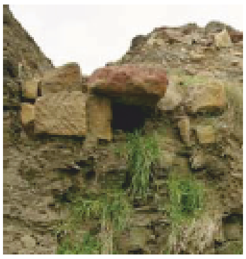

Figure 36. Conduit 2 exposed in the face of the collapsed ledge. (NMR AA040228)

A second stone conduit (no. 2) is exposed in the face of the sea cliff at the northern edge of the shelf/ledge (Fig 36). Its construction is similar to that of conduit 1 (*ie* it has stone sides and cover, but only a shale floor), and must therefore have been intended to protect a lead pipe or wooden trough rather than to carry liquid itself. Its precise function, and where it led from and to, is unknown.

The original access to the alum house was from the south *via* two tracks terraced into the side of the shelf and cliff face, as depicted on the OS first edition 6" and 25" maps (Figs 6 and 10). Elements of both tracks survive, and are described in section 6.1.9 below.

6.1.8 Other buildings

The sites of four mid- to late 19th-century buildings which stood within the quarry but did not form part of the later alum-house complex, are known from archaeological and cartographical evidence.

The remains of building 1 are centred at NZ 83383 16044 close to the cliff edge on the east side of the headland (Figs 11 and 37). The structure consists of a rectangular main range, oriented north-west to south-east roughly in line with the cliff edge, to which is attached

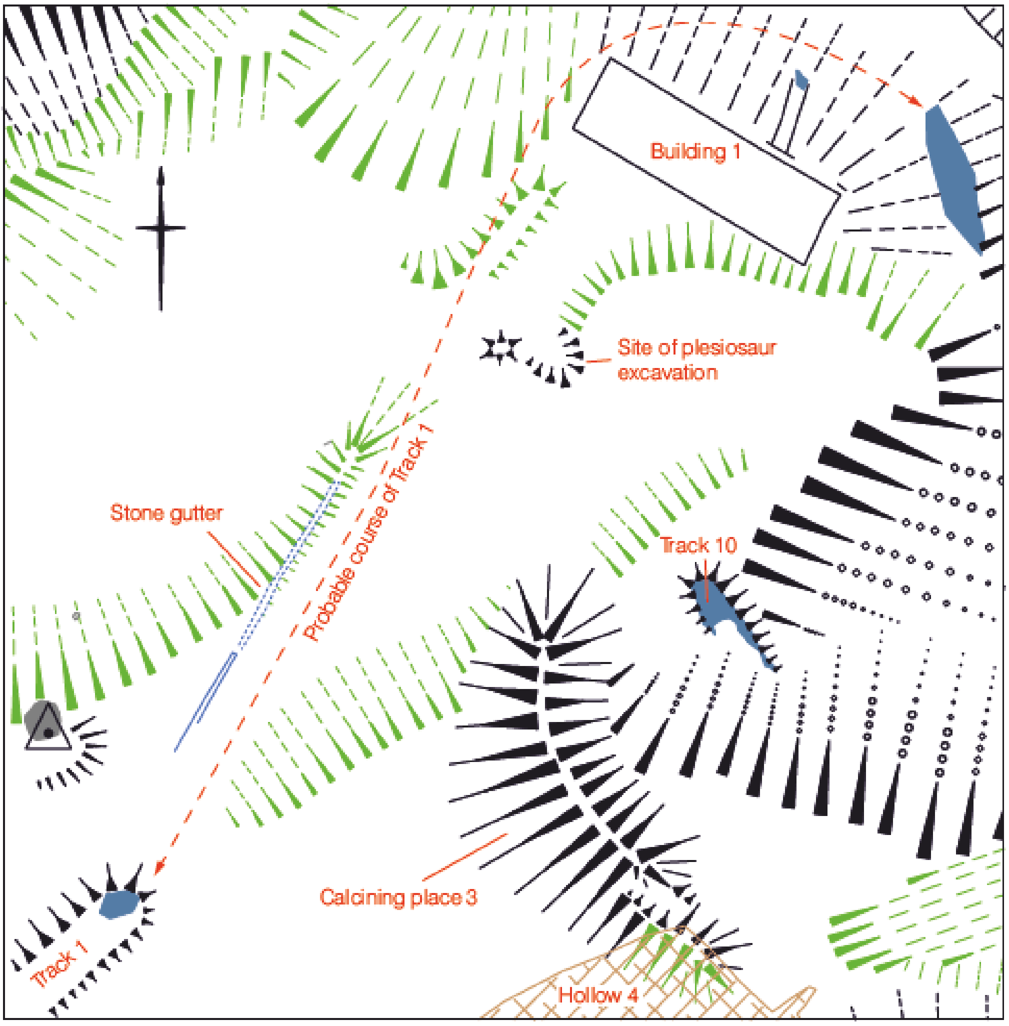

Figure 37. Annotated extract from survey at 1:500 scale, showing building 1, calcining place 3 and the north-east end of the gutter alongside track 1. (For key to conventions, see Fig 56)

about two-thirds of the way along the seaward side and at a slightly skew angle, a somewhat irregular, much shorter and narrower, annex (Fig 38). The external dimensions of the main range are 18.5m by 5.9m (60 feet 9 inches by 19 feet 4 inches), of the annex *c* 4.55m-4.8m

Figure 38. View south-east across building 1 from spoil dump area 4. (NMR AA040214)

by 1.93m (15 feet – 15 feet 9 inches by 6 feet 4 inches). The tops of the walls now lie at the same level as the external shale, and the interior is filled with loose, windblown scree; however, in the south-east corner, scree eroding down from elevated ground on the outside has buried and helped conserve a short length of wall to a height of *c* 1.2m, perhaps six courses higher than elsewhere. Where best preserved at the junction between the main range and annex (Fig 39), the walling can be seen to be *c* 0.25m (10 inches) thick, and to consist of a thin core of rubble sandwiched between skins of faced sandstone blocks;

Figure 39. Detail of the north-east side of building 1, showing the junction of the main range and northern annex. (NMR AA040241)

however, around most of the perimeter only the inner facing blocks and rubble core are now visible, and the course of the outer skin is merely hinted at by a line dividing *in-situ* from re-deposited shale. It is unclear if this line marks the outer edge of a foundation trench – which would indicate that only the lowest foundation courses survive - or is part of a wall trench for a basement in which case a considerable height of walling survives protected by scree; occasional indications of rendering observable on the inner skin of blocks, and the fact that a patch of what appears to be rubble flooring has been exposed by erosion at the far end of the annex at a depth of over 1m below the current level of the rest of the building, support the latter interpretation. Building 1 is not shown on the OS first edition 6", suggesting it dates to after 1852. Its function is unknown. The annex was a later addition as indicated by the fact that it is butt-jointed against the main range; it may represent a loading platform leading out to the edge of track 1.

Building 2 is rectangular in plan, measuring *c* 6.8m (22 feet 4 inches) south-west to north-east by 2.8m (9 feet 2 inches), and lies to one side, and just below the level, of track 1, at NZ 83280 15943 in the approximate centre of the quarry, overlooking the site of alum house 2 (Figs 11 and 28). Only the long walls and the northern returns of the side walls are now visible at the level of the surrounding shale, but traces of rendering on the inner face of the north-west wall in particular suggest that the floor of the building and further courses of walling are masked by scree (Fig 40). No doorway can be made out with certainty, but it was not in the south-east wall fronting the track as this side appears continuous. Strangely,

Figure 40. Building 2 from the south-west. Note the traces of rendering on the inside of the left-hand wall (NMR AA040270)

the stones in this wall all lie at an angle of 45º; the significance of this is unclear, but the most likely explanation is that the wall has fallen outwards. Building 2 does not appear on the OS first edition 6", indicating that as with building 1, it dates to after 1852. Its function is unknown.

The remains of building 3 lie at NZ 83458 16005 right at the edge of the sea cliff on the north-eastern edge of the quarry, in between the two ranges of steeping pits (Figs 11 and 23). It probably pre-dates 1852, for it can be equated with a building shown in this position by the OS first edition 6" map (Fig 6), measuring *c* 10m by 4m. However, if so, only the south-western end now survives, the rest having fallen over the cliff (Fig 41). Although the side

Figure 41. The surviving south-western end of building 3. The roof of the liquor-trough tunnel is just visible at left of frame. (NMR AA040223)

walls are clearly visible in section in the cliff face when viewed from the foreshore, for reasons of safety it was not possible to map the position of the southern wall properly, which therefore does not fully appear on the survey diagrams. The function of the building is not known for certain, but it may have housed settling cisterns (section 6.1.5 above).

Building 4 is known only from cartographic evidence. The OS first edition 6" map (Fig 6) shows a building measuring *c* 11m south-west to north-east by 4m situated at *c* NZ 8339 1601 adjacent to the rear edge of the northern bank of steeping pits. The area is now covered by shale scree, and nothing is visible on the surface. The building's function is unknown, but it may have been the precursor to building 1.

6.1.9 Transport

Roads and tracks

Parts of the routes of eleven roads or tracks leading around the quarry and to and from alum house 2 are known from a combination of archaeological (Fig 11) and cartographical (Figs 6 and 10) information. A twelfth track on top of the subsided ground at the head of the 1829 cliff collapse does not relate to the alum works, and is described in section 6.5 below.

Track 1 is a continuation of the existing public road from Goldsborough to Kettleness hamlet, and provided access between the hamlet and quarry but also continued across the headland all the way to building 1 and the mid-19th-century steeping pits on the east side of the promontory. It was probably built at the beginning of 1830 to replace an earlier track on the same general line, destroyed in the great landslip of December 1829, and is itself now severed as it drops down over the edge of the sea cliff where a short length was carried away in the 1999 landslip. For the purposes of description, it can be divided into three sections: an upper section on the top of the cliff, a middle section descending the cliff face down to the quarry, and a lower section within the quarry itself.

The upper section is a hollow way in places in excess of 2m deep, but is now severed from the rest of the track by the recent cliff collapse and is therefore disused and grassed-over.

The middle section is a steep terraced way, followed for the most part by a modern footpath down to the foreshore and quarry. Patches of stone metalling are visible, but mostly the original surface has either worn away or else is buried beneath slump. A diagonal line of flat, rectangular stones which cross the track near the top of the cliff (Fig 42) probably marks the course of a covered gutter or channel taking water down to the steeping pits (see also section 6.1.4 above). Short stretches of walling survive along the track's outer edge, showing that it was formerly stone-revetted, but this revetment has now mostly fallen away, presumably taking further evidence for the gutter with it. However, half-way down the cliff where the track levels out to swing north and then back east around part of the 1829 landslip, a 24m length of the revetment is well-preserved up to *c* 2m high (Fig 42). The survival of this one stretch is mainly due to the fact that it does not lie immediately above a steep slope, but has no doubt been aided by the modern footpath here briefly deviating from the route of the track to run at the foot of the revetment. OS map evidence shows that the track originally forked just before the revetment with a lower branch giving access to alum house 2 (see track 2 below); the modern footpath seems to follow the start of this fork.

Figure 42. View north-east along track 1 from the edge of the 1999 cliff collapse. In the foreground a diagonal line of capstones presumably marks the course of the gutter taking water to the steeping pits, whilst in the middle distance the slumped sandstone marks the heel of the 1829 landslip. (NMR AA040237)

The lower section of track 1 across the quarry floor is carried on a causeway in order to maintain a steady gradient for the water channel laid along its northern side (section 6.1.4 above). The north-east end of the track is now mostly missing, destroyed by surface erosion (Fig 11 and chapter 2), but OS map evidence (Fig 6) shows that in 1852 it ran towards the site of building 1 and turned sharply south-east to pass behind the two banks of steeping pits; a short length of metalling which survives immediately north of bank 1 plus wall 4 parallel to the western edge of the pits (Fig 23), would seem to correspond to the depicted course. A number of subsidiary routes which branched off this lower section of track 1 and led to other parts of the quarry are described below (tracks 5, 6, 7 and 11).

Track 2 connected track 1 with the floor of the alum-house shelf in the west side of the quarry. Its route took it across the side of the 1829 landslip and the sea cliff above Runswick Bay, and only discontinuous sections now survive because of cliff recession (Fig 11). However, the full original course is recorded on both the OS first edition 6" and 25" maps (Figs 6 and 10).

Tracks 3 and 4 connected alum house 2 with the foreshore in Runswick Bay, and as with track 2 were both terraced across the site of the 1829 landslip. Track 3 was the earlier route, in use until at least 1852 for it is shown on the OS first edition 6" map (Fig 6), but had eroded away and been replaced before 1893 by a more southerly route (track 4) branching from near the top end of track 2 (Fig 10). Only isolated short lengths of either track now survive: of track 3 at the very south-west corner of the alum-house shelf (Fig 32), of track 4 just after its departure from track 2.

Little is now visible on the ground of track 5 which the OS first edition 6" map (Fig 6) shows ran around the southern, western and northern sides of alum house 2. The southern and northern sections no doubt still survive beneath scree - indeed a very short length is visible close to the present cliff edge south of the alum house (Fig 32) - but the western section had already been lost before 1893 through the collapse of part of the floor of the alum-house shelf (section 6.1.7 above, and compare Fig 10).

Tracks 6 and 7 both survive as earthwork features, branching off south-eastwards from track 1 near the start of its lower section across the quarry floor. Track 7 is visible as a slight terrace at the base of material brought down by the 1829 cliff collapse, while track 6 is terraced into and rises up the side of that material. It is unclear where they originally led, but both fade out after about 50m near the edge of the mounds of spoil dump area 1 (section 6.1.1 above); they were probably already blocked and out of use by 1852, for the OS first edition map (Fig 6) shows a length of track coming off track 1 and ending in a similar position. However, it is not clear which of the two earthwork features the map is depicting.

Track 8 is shown on the OS first edition 6" map (Fig 6) branching off the north side of track 1 close to the site of building 2, and passing above the east and north sides of the alum-house shelf before looping back east and rejoining track 1. Only slight traces now survive on the ground: a narrow, eroding ledge in the shale floor of the quarry north of the alum house, and a raised causeway capped in places by rubble-stone metalling close to where it rejoins track 1 (Fig 16).

Track 9 is evidenced as a cut through the large area of spoil heaps north of the alum house. Although not depicted on either of the 19th-century OS maps, it is visible on the 1856 Weatherill sketch (Fig 9), and was probably constructed to give access to the Point and north side of the headland to allow tipping of waste material over the cliff edge.

Track 10 is suggested by a short (8m) length of possible rubble-stone metalling centred at NZ 83384 16014, protruding out from beneath the base of shale scree immediately east of calcining place 3 (Figs 11 and 37). The orientation of the metalling suggests that the track ran south-east to north-west; if so, it may have been associated with calcining place 3, and be part of a route connecting that place to the contemporary steeping pits (whose location is unknown).

Track 11 is represented by a slight earthwork running south between spoil dump areas 1 and 2 (section 6.1.1 above). It is not shown on either of the 19th-century OS maps, but appears designed to give access between track 1 and the foot of the working quarry face. Its southern end is now partly blocked by the talus slope beneath the quarry face, but seems to have forked to both east and west where short lengths of terracing survive behind the spoil heaps.

Staithe

According to documentary evidence, a staithe existed in Runswick Bay by 1729 to service ships delivering fuel and alkali to, and taking alum off from, alum house 1 on the foreshore. Both house and staithe lasted for 100 years, until destroyed in the great landslip of December 1829 (section 4.1 above). Although a new alum house was built overlooking the bay (section 6.1.7 above), there is no evidence that the staithe was rebuilt; instead, it seems to have

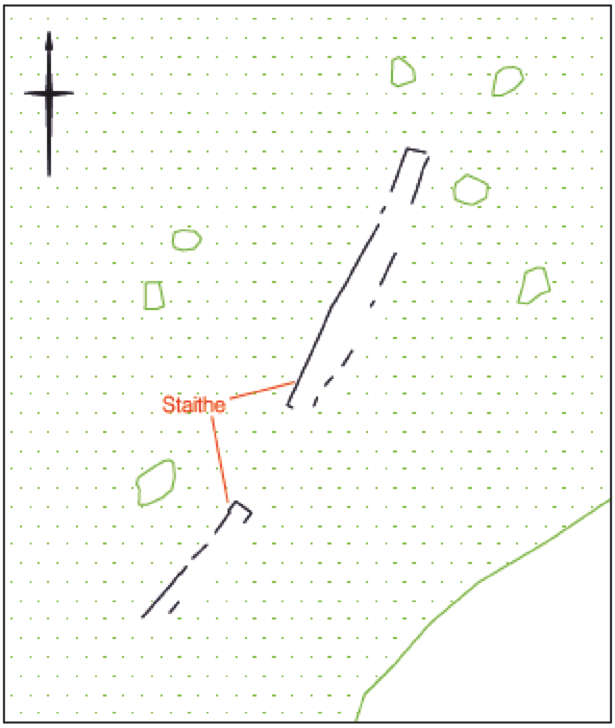

Figure 43. Annotated extract from survey at 1:500 scale, showing the staithe in amongst the boulder field on the foreshore. (For key to conventions, see Fig 56)

Figure 44. The foundations of the staithe in Runswick Bay, looking south-west. (NMR AA040242)

been replaced by a series of rock-cut rutways leading out from the foreshore to a 'deep-water channel' in the floor of the reef (this section, below).

The staithe's foundations have re-emerged since 1829 as the shale which engulfed it has been eroded by the tides (Figs 11 and 43). The remains were first recognised in 1996 by David Green who sketch-plotted their position (in SMR records), although mis-interpreting them as part of a breakwater. The feature is now much reduced from its original recorded height of 4 yards (3.65m), and in places is missing completely, but sections of walling oriented roughly south-south-west to north-north-east survive over a length of 36m centred at *c* NZ 8310 1592. The front or seaward edge is best preserved, with large, faced, sandstone blocks surviving in places two courses (0.8m) high, but short stretches of the rear edge can also be made out, indicating that the feature had a maximum width of *c* 2m (Fig 44). These dimensions match almost exactly the length and breadth (40 yards by 2 yards) recorded for the staithe in 1729 (section 4.1 above).

Rutways

The existence of rutways cut into the reef along the north-east Yorkshire coast, including one, possibly two, examples at Kettleness, was first discussed by John Owen about 20 years ago (Owen 1986; 1987), although he undertook no detailed survey. In 1996 David Green identified two further examples, and sketch-plotted all four (in SMR records). The lack of multiple, overlapping tracks, suggests strongly that they are not the product of wear but are deliberate creations, presumably intended to guide carts along a safe route across the reef when it was dark or foggy, or before the tide had fully come in/gone out. The present survey has now accurately mapped these features for the first time, and also extended the length over which they may be traced. Because of their worn nature it is difficult to measure the gauge precisely, but the distance between the inner edges of paired ruts is in the order of *c* 1.25m (4 feet 1¼inches). Owen thought that the Kettleness examples were related to ironstone extraction, but the fact that three of the four known examples lead out from the foreshore points to these three being connected with the alum trade instead. All four examples are described below, while their possible associations are discussed further in chapter 7.

Three of the rutways (nos. 1-3) are centred at NZ 8300 1590 (Figs 11 and 45), and lead out from the direction of the shore to the southern end of a 'deep-water channel' in the floor of the bay which floods before the surrounding reef. The channel is not natural, but a product of ironstone quarrying (section 6.4 below); however, it seems subsequently to have been re-utilised as a deep-water route for shipping entering the bay. The rutways run parallel to each other, about 6m-8m apart, and are aligned roughly south-west to north-east in line with the orientation of the ruined staithe but 50m or so seaward of it. Rutway 2, the middle one of the three, is the best defined being traceable intermittently over a distance of 117m and surviving

Figure 45. The three parallel rutways, nos. 1-3, cut into the reef in Runswick Bay as seen from the headland. (NMR AA040209)

up to *c* 0.08m deep; there are slight indications (not surveyed, but visible on Fig 46) that it represents a re-cut of an earlier route on a slightly different line. Rutways 1 and 3 to south and north are less well defined, being shallower and surviving now for only 25m back from the channel's edge: it is unclear if this is because they were cut more shallowly in the first place, were less heavily used, or are older and have suffered to a greater degree from tidal erosion. The northern ends of rutways 2 and 3 curve towards each other as they reach the

Figure 46. Detail of rutway 2 in Runswick Bay, looking south-west. Note indications of shallower ruts slightly left of each of the obvious examples. (NMR AA040207)

channel, suggesting that they originally joined in a tight arc; if so, the tracks may represent two halves of a single turning circle where carts heading out along one route could turn and come back along the other without leaving the safety of the ruts.

The fourth rutway (no. 4) survives as a faint, isolated 20m length centred at NZ 8302 1617 at the north-west corner of the channel, some 150m further out to sea. Its orientation is roughly at 90° to the other rutways, in line with the edge of the channel. Of all the Kettleness rutways, it is perhaps the most likely to be connected with ironstone extraction, for its position suggests it is connected with larger ships which could not sail fully into the bay. The matter is discussed further in chapter 7.

There is no firm indication of date for any of the rutways, although they are presumably all broadly contemporary. Since nos. 1-3 skirt round the edge of the boulder field which overlies the staithe, they should post-date the 1829 landslip. These three also now end on the edge of the deep-water channel excavated in 1838 (section 6.4 below), but it is unclear if they have been cut by, or lead to, it.

6.1.10 Miscellaneous alum features

Cut in shale

A number of cut edges in the quarry floor dividing *in-situ* from re-deposited shale have already been described as hollows (section 6.1.1 above). However, a much smaller rectangular cut (cut 1) is also visible at NZ 83327 15993 (Figs 11 and 16), measuring *c* 7.5m by 3m and oriented north-north-east to south-south-west. It has been infilled, and appears to be crossed by track 8 (section 6.1.9 above) which should mean it pre-dates 1852. Its function is unknown.

Walls

The base of an L-shaped wall constructed out of rubble sandstone blocks is centred at NZ 83278 16030 immediately west of hollow 2 (Figs 11 and 16). This wall (no. 5) extends for *c* 12m north-south, before turning east for 3m and terminating. Its purpose and date are unknown.

In 1996 David Green (in SMR records) recorded a section of wall associated with timbers and coal on the foreshore at *c* NZ 8301 1582. The spot now lies buried beneath the 1999 landslip, and nothing was visible during EH ground survey. Green seems to have thought what he saw formed part of the evaporating pans within the alum house, but the mention of coal together with the reported absence of brick, suggests it is perhaps more likely to be part of the alum-house coal yard known from documentary evidence (section 4.1 above).

Cistern

At the time of ground survey, a fragment of double-skin wall was visible in section in the cliff face at *c* NZ 83158 15920, above the presumed site of alum house 1 (Figs 11 and 47). Its position meant it could not then be investigated or recorded other than photographically, but it had fallen onto the foreshore by September 2003 when the site was re-visited briefly, at which time the stones were observed to have a slight curvature to them and to be associated with yellow clay. This suggests that it may have formed part of a cistern (no. 3).

Figure 47. The possible side wall of cistern 3 in the cliff face at the edge of the 1829 landslip. (NMR AA040244)

6.2 Cementstone

Mines

The cementstone industry is largely without material trace at Kettleness, since the nodules were recovered as a by-product of quarrying the alum shale. However, the entrance to a mine gallery (mine 1) visible in the face of the old alum quarry at NZ 83510 15835 (Fig 11) immediately beneath the sandstone cap, is at the correct altitude for the cementstone dogger. The roof was collapsing at the time of EH ground survey and the adit could not be entered safely to see how far it extended back, although in 1996 it was reported as being only 10m long (David Green, in SMR records). This information, and the lack of any visible, engineered approach, suggests that it is probably no more than a short-lived, exploratory working to test the seam. It probably dates to 1871 or shortly thereafter following the cessation of quarrying the alum shale.

6.3 Jet

Mines

Although jet mines exist in the sea cliffs all around the headland at Kettleness, they were mostly excluded from the present survey since their entrances lie high up in the face of near vertical cliffs and are only visible from the foreshore. The survey did discover and record a number of de-roofed jet mines, however, in the area immediately west of alum house 2, and on Kettleness Point.

Several mine galleries have been revealed by the collapse of part of the floor of the alum-house shelf, resulting in the formation of a ledge *c* 38m long by 20m wide by 8m deep at the edge of the cliff (section 6.1.7 above, and Fig 32). Four mine entrances were still just visible at the time of EH ground survey: three (mines 2-4) in the eastern face, and one (mine 5) in the southern face (Fig 48) of the ledge, although the roofs of all were collapsing badly; the

Figure 48. The collapsed ledge at the edge of the alum-house shelf. Note the entrance to mine 5 at right of frame, and wall 3 (part of the alum house) along the top of the rear edge of the ledge. (NMR AA040229)

location of mines 2 and 4 was emphasised by the presence of parallel scarps in the floor of the ledge which presumably reflect the position of underlying gallery walls masked by slump (Fig 32). Although now inaccessible, all four mines were explored and mapped between *c* 1973 and 1975 by the Moldywarps Speleological Group from Teesside, who found that the three east-facing examples (nos. 2-4) ran back into the shale a maximum of about 30m and were connected by cross galleries, while the north-facing mine entrance (mine 5) led to two short galleries cut at right angles but not inter-connecting with mines 2-4 (Gary Marshall, pers comm). At the time these features were described as 'alum mines', but from their height and position it is clear that they are in fact part of a string of jet workings which formerly existed in the cliff face above Kettleness Sand as indicated on the OS first edition 25" map (Fig 10); most of the other mines are now obscured by shale scree or have been destroyed by later cliff collapses, but at least two still survive immediately south of the ledge (Fig 49). It is unclear whether these mines pre- or post-date the construction of alum house 2 (their dating is discussed further in section 7.3 below), but the map description of them as 'Old Jet Workings' shows they were all disused by 1893.

Figure 49. Jet mines in the cliff face south of alum house 2. (NMR AA040245)

The alum shales are totally missing from the area of the Point, revealing a landscape of upstanding blocks of *in-situ* shale separated by horizontal cuts running out to the cliff face (Fig 50). These are best interpreted as the pillars and walls of a series of interconnecting, de-roofed mine galleries, and are at the correct altitude - about 25m AOD - for the jet dogger seam. The fact that the shales are now totally missing from above the mines, points to them having been broken into by alum workers; in addition, a dump of shale (spoil heap 3,

Figure 50. A de-roofed jet-mine gallery on Kettleness Point. (NMR AA040255)

section 6.1.1 above), reddened as if calcined, overlies part of the de-roofed galleries (Fig 51). Taken together, this evidence suggests that these particular jet mines pre-date the opening of the alum quarry in 1727, but again the issue of dating is explored further in section 7.3 below.

Figure 51. General view north over Kettleness Point, showing the difference in ground level and the evidence of red (calcined) shale overlying the de-roofed jet mines. (NMR AA040267)

From the foreshore, many mines are also apparent in the cliff face on the north-east side of the headland between Wind Hole and White Shoot (Fig 2), but the present survey has not recorded their positions.

6.4 Ironstone

Quarrying and shipping

A vertical step up to *c* 1.5m high at the base of the northern and western faces of the headland would seem to represent the edge of opencast ironstone quarrying on the reef (Fig 11), for a number of thin ironstone bands (diagnostic of the top of the main seam) are visible in the face of the step. The step is traceable along practically the entire west face of the headland overlooking Runswick Bay, and continues along the northern face for *c* 300m past the Point before it turns to the north-east and runs out to sea. The seaward extent of the quarrying is less easy to determine: north of the Point it may well extend as far out as the low tide mark, but within Runswick Bay its western extent is probably represented by the far edge of the deep-water channel (Fig 52). Different depths of quarrying are evident within

Figure 52. The ironstone quarry in the floor of Runswick Bay. The western extent of the quarry is highlighted by the channel flooded by the incoming tide; note also the step at the foot of the sea cliffs. (NMR AA040236)

the area so defined, separated by near-vertical working faces describing a series of 90º-turns at right angles to the prevailing run of fault lines within the reef (Fig 11). Narrow slots, now filled with shingle, have been cut running away at 45º from two such working faces, both connecting with the deep-water channel; whilst these may have been to help drain water left behind by the tide, they would also have acted as access routes for carts running between the deeper areas of the quarry and shipping beached in the channel. Rutway no. 4 (section 6.1.9 above) parallel to the side of the channel near the low-water mark, probably served a similar function. Documentary evidence dates the ironstone quarrying to a single season in 1838 (section 4.4 above).

6.5 Non-industrial features

Roads, field boundaries and cultivation ridges

The 1829 landslip which buried the early alum house, also caused a portion of the top of the cliff above the west end of the quarry to subside by *c* 16m-17m (chapter 2). The whole area affected by the landslip seems subsequently to have been avoided by the alum workers,

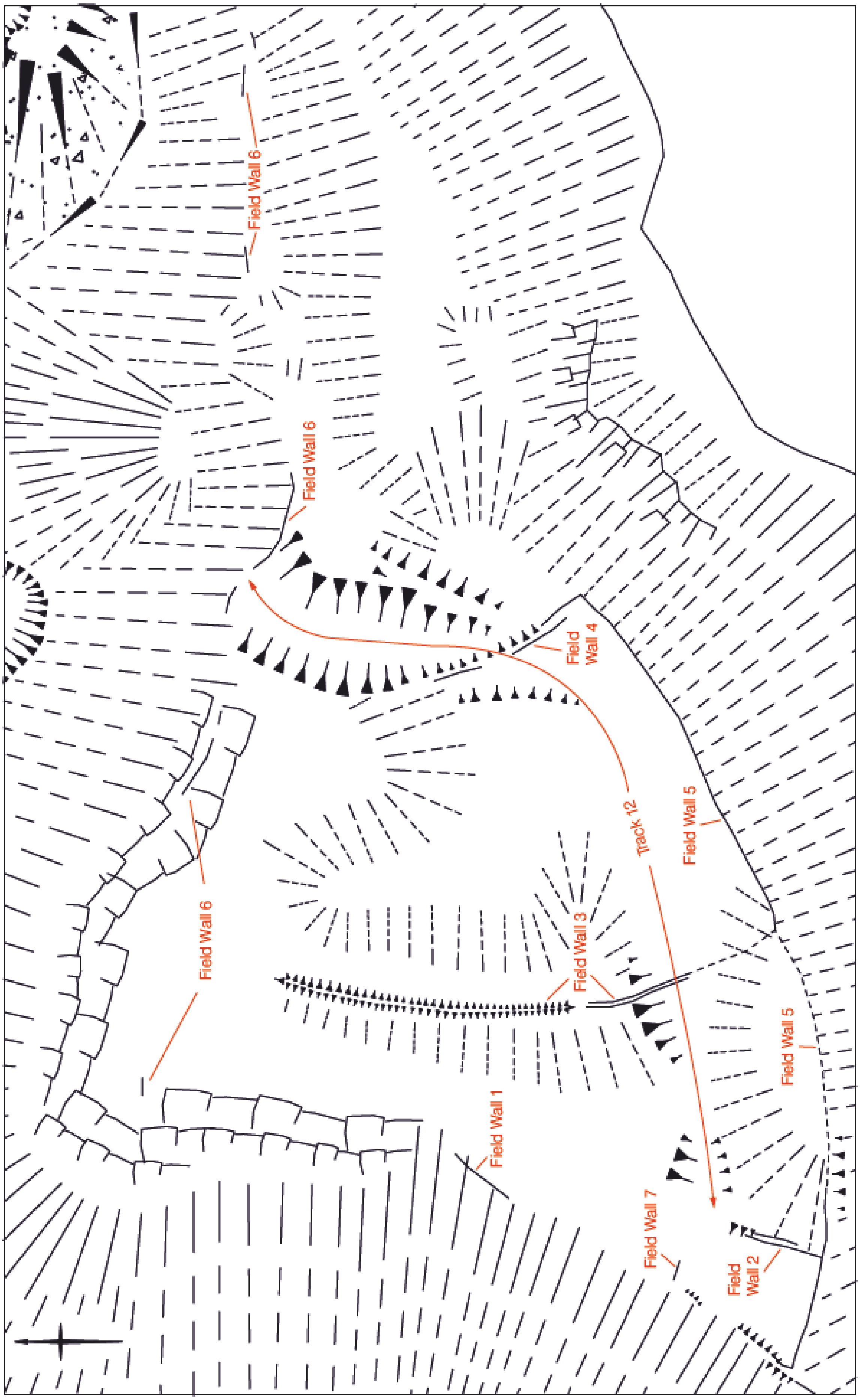

Figure 53. Annotated extract from survey at 1:500 scale, showing features on the slumped cliff top at the head of the 1829 landslip. (For key to conventions, see Fig 56)

with the result that a small part of the pre-1829 road and field pattern has become fossilised in earthwork form on the triangular area of subsided ground at the head of the slip (Figs 11 and 53).

Track 12 survives as two short stretches of hollow way up to 1.4m deep at the western and northern edges of the subsided area. There are few indications of the road's course between these two stretches, but the area was covered by coarse vegetation at the time of ground survey and slight remnants could easily have been overlooked. Traces of four field walls (nos. 1-4) now cut across the road's line, while two others (nos. 5-6) run east-west at the front and rear of the subsided area, and traces of a seventh joins field walls 1 and 2, dividing the whole area up into a series of irregular enclosures. Field wall 3 may originally have been contemporary with track 12, but was subsequently extended across it. The course of field wall 6 is now intermittent, having in places collapsed as the northern edge of the subsided ground has eroded.

The position of the road and also of field wall 3 accords very well with features shown immediately adjacent to the quarry edge on an 18th-century map of Goldsborough township (Fig 5). However, the other walls now block the line of the disused road and indicate that following the 1829 collapse, this patch of ground was re-divided into a series of small enclosures, probably paddocks for grazing stock. The largest enclosure certainly existed by 1852 for it is shown, albeit somewhat inaccurately, on the OS first edition 6" map (Fig 6); the portrayal was corrected for the first edition 25" (Fig 10).

Other field boundaries and/or paths are evidenced by scarps on the outskirts of Kettleness hamlet close to the start of track 1 (Fig 11). They do not correlate with any 19th- or 20th-century map detail, but are presumably of that date. Short lengths of a truncated furlong of cultivation ridges also run up to the cliff edge.

Coastguard structures

A concrete base at NZ 83339 16007 in the floor of the quarry (Figs 56 and 4) originally held a metal upright forming one end of a breeches buoy; two wooden posts concreted into the shale *c* 7m to the north are anchor points for bracing cables. The southern end of the buoy - a metal rail set into the ground - still stands close to the modern field wall above the main quarry face (Fig 14). According to local information the buoy was erected by the coastguard sometime after World War II

The ends of what look like two metal scaffold poles have been set almost horizontally into the ground *c* 0.5m apart on the east side of Kettleness Point at NZ 83211 16160 (Fig 56). Their purpose is unknown, although they, too, are most likely to be connected with the coastguard in some way.

Boundary stone

A large letter 'B' has been carved into a sandstone boulder on the edge of the 1829 cliff collapse at NY 83200 15910 (Fig 56). Its date is unknown, but it is probably some kind of boundary marker. It is unlikely to be in its original position.

Seat base

A rectangular concrete platform at NZ 83114 15754 (Fig 56) by the side of the middle section of track 1 is modern and the base for a park-type seat, which because of the problems of cliff recession has been relocated to the top of the cliff.

Shipwrecks

The survey has identified the remains of two shipwrecks on the reef around the headland. Shipwreck 1 lies on the Runswick Bay side of the Point, at *c* NZ 8313 1617; shipwreck 2 at White Shoot below Lucky Dogs Point on the east side of the promontory at NZ 8372 1591 (Figs 2 and 11). Both wrecks are of ships with metal hulls. The former was not visible on the vertical aerial imagery and its scattered remains only observed during ground investigation (Fig 54), but the deck ribs and part of the keel of the latter were plotted from aerial photographs (Fig 55). Neither wreck was surveyed or investigated in detail on the ground.

Figure 54. Shipwreck 1 viewed from Kettleness Point. (NMR AA040254)

A number of ships are recorded as lost off Kettleness Point, including in the late 19th and early 20th centuries the steam fishing trawler, *Wolf Hound*, operating out of Hull which ran aground in fog in December 1896, the British steamer, *Onslow*, lost in 1911, and the Swedish steamer, *Vanland*, torpedoed off the Point in 1917 (Young 2000, 62-5). No doubt, others have been lost since. At present, however, none can be correlated definitely with the observed wrecks.

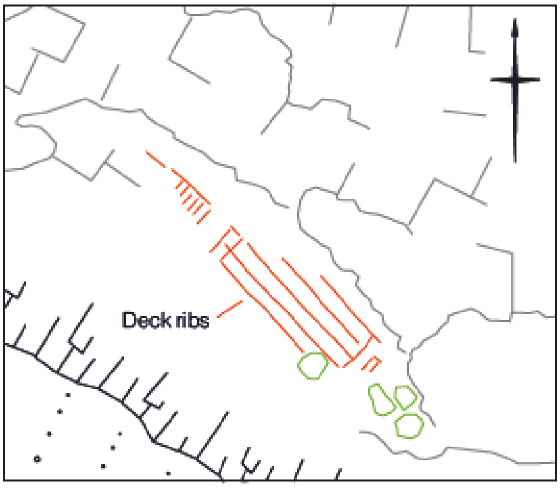

Figure 55. Annotated extract from survey at 1:500 scale, showing shipwreck 2. (For key to conventions, see Fig 56)

Fossil excavation

A few years ago a fossil plesiosaur embedded in the shale bedrock began to be uncovered by surface erosion of the quarry floor (chapter 2) close to the site of building 1. In 1999 the fossil was removed *en bloc* by palaeontologists from the Yorkshire Museum. The site of the excavation can still be seen as a horseshoe-shaped delve at NZ 83373 16031 (Fig 37), into which casual visitors have subsequently thrown stones from the nearby gutter. A small shale mound to the west is upcast from the dig.

7. DISCUSSION AND CONCLUSIONS

The EH survey has produced evidence for the extraction of at least four kinds of mineral at Kettleness: shale (for the manufacture of alum), cementstone, jet and ironstone. No doubt the sandstone cap was also used as building stone within the alum works - it may even have been sold locally, for it was reported to be a good freestone that hardened upon exposure to the atmosphere (Winter 1810, 243) - but since the activity has left no discernible physical trace other than the vertical face of sandstone at the rear of the alum quarry, its extraction is only mentioned in passing below in connection with mining of the shale.

The documentary and archaeological evidence for each of the four main industries has already been outlined in chapters 4, 5 and 6. The following discussion is offered chiefly as a general commentary on the survey's findings, but also highlights a number of questions about the site and its importance and potential for further investigation before parts are lost totally to cliff recession and other erosive forces. For convenience, discussion of the alum works is divided into two phases – before and after the great landslip of 1829 – since this was probably the biggest single event affecting the development and layout of the site.

7.1 The alum industry

7.1.1 The early alum works: 1727-1829

The EH investigation has located previously unread documents which show that although alum was not produced before 1729, work on the infrastructure of the Kettleness alum works commenced as early as 1727. A calcining place had been finished by February 1728, and various buildings and other structures completed a year later including, most importantly, the alum house and associated staithe near the foreshore in Runswick Bay, and steeping pits and cisterns within the quarry; in addition a road had been constructed giving access to the alum house (and presumably also to the quarry) from the top of the cliff (section 4.1 above). However, there is very little evidence, either documentary or archaeological, for where any of these features actually stood.

A map of Goldsborough township (Fig 5) is perhaps our best source of evidence for the topography and early layout of the site. Since it depicts two cliff faces on the headland, it seems reasonable to interpret one as the natural sea cliff, the other as the edge of the quarry. Logic would predict that quarrying began either on the western side of the headland and moved east, or at the Point and progressed south, since these areas were closest to the early alum house within the bay. Judging from the map it was mainly the latter - with the quarry face having reached approximately 120m inland from the tip of the Point by the time the map was made - although quarrying had evidently also taken place in a limited fashion along the headland's western flank, perhaps in order to make room for processing facilities such as calcining places and steeping pits. Unfortunately the map is not securely dated: in the PRO it is attributed to the late 17th century, but given that the works was not operational before 1729 a mid-18th-century date seems more likely. The fact that the PRO curate it as part of the records of the Office of Land Revenue points to it having been commissioned at a time when the manor reverted to the Crown or was the subject of litigation. Both scenarios are known from the mid-18th century: reversion on the extinction of the male line occurred in 1735 on the death of Edmund Sheffield, 2nd Duke of Buckingham, while in 1767 Constantine Phipps altered the settlement of his estates by Act of Parliament (David Pybus, pers comm) sowing the seed for later disputes with the Crown over the question of whether 'alum rent' was still payable on Kettleness. The comparatively limited amount of quarrying depicted on the map might be thought to favour a date of, say, pre-1750, but a date as late as 1767 may not be impossible given that the works had then been in existence for 40 years but had lain idle for almost half that period (between *c* 1736 and 1741, and again from 1755 to 1767 - section 4.1 above).

The only structure which the map shows within the works is the alum house, portrayed as standing in the south-east corner of the bay close to the foreshore. Although the map is not a metrically accurate document, this portrayal is nevertheless sufficient to indicate the early alum house stood at *c* NZ 831 159 (section 4.1 above), a siting the present investigation has been able to corroborate circumstantially from the archaeologically attested position of the staithe (section 6.1.9 above). Whilst it is extremely improbable that any of the alum house survives *in situ* beneath the landslip which destroyed it in 1829 (section 6.1.7 above), the investigation has argued that we nevertheless already possess a record of its layout in that a supposedly 19th-century plan (Fig 8) previously believed to of the post-1829 alum house is more likely to date to the late 18th century (section 4.1 above). The present study has also suggested that a length of walling and evidence of coal recorded by David Green in 1996 about 100m further west around the shore of the Bay, marks the site of the early coal yard (section 6.1.10 above), although the area has since been destroyed by the 1999 landslip.

There is little direct evidence for how the shale was mined at this period. It has been suggested that at some Yorkshire alum works, the sandstone overburden may have been removed by digging the shale from beneath and allowing the stone to come down under its own weight (*eg* Pybus and Rushton 1991, 49), but all available evidence, both documentary and archaeological, suggests that at Kettleness the sandstone was always quarried: there are documentary references to workers being paid between 3d and 6d in the 18th century to perform this task (section 5.1 above), while the smooth, vertical appearance of the sandstone in those parts of the quarry face which survive *in situ* (section 6.1.1 above) shows that the overburden was still being removed by hand when the works closed in 1871. Eye-witness accounts from 1775 attest that the shale was then hewn in long steps called desses (section 5.1 above), although physical evidence to substantiate this has been destroyed by subsequent quarrying. Documents also state that, in 1732, a 'drift' existed 'thro the east Coyn' of the quarry, in order 'to carry out the bad rock' (section 4.1 above). The interpretation of the latter remark seems straightforward enough: a tunnel had been dug from west to east through the headland in order that waste material encountered within the alum shale (pyrites nodules, cementstone doggers, *etc*, and perhaps even the burnt shale from the steeping pits) could be tipped into the sea on the east side of the headland; the need for the tunnel is less clear, but was presumably so as to avoid having to dump the waste into Runswick Bay which potentially would create navigation hazards for vessels approaching the alum house and staithe.

There is also very little evidence for the location or form of structures within the quarry at this time. Documents which record the dimensions of the first calcining place at the works - said to be in excess of 73m long by 18m wide by 11m high (section 4.1 above) - imply that it was probably a cut feature excavated into the shale, but do not state where it lay. If the works were operating to capacity, we might predict that within a short time there would have been at least two, if not three, such places, since this would have enabled one clamp to be left to cool for the 8 or 9 months which is reported as standard practice (section 5.2 above) whilst a second was constructed and fired, and a third taken apart and the shale barrowed to the steeping pits, but analysis of wage books suggests that alum works were not always run at capacity and that shale extraction could be episodic (Harrison 1975, 22-3). Although we therefore do not know how many calcining places existed at any time, logically we might expect that the earliest would be sited around the western or northern fringes of the quarry. If so, it is possible that a number of features identified by the survey and described as hollows (section 6.1.1 above) represent their backfilled sites. Apparently similar features have been identified at Boulby, where on account of their large size and extant form they were labelled 'quarry scoops' and interpreted as bowl-shaped quarries re-used as calcining places (RCHME 1993, 6-7). However, since contemporary documents record that calcining clamps could themselves be substantial features and, certainly at Kettleness, were raised within deliberately engineered structures, it would seem reasonable to see such hollows or scoops as designed specifically for the purpose of calcining rather than old quarries put to fortuitous re-use. Clamps are recorded as reaching up to 45m-60m across and 30m high (section 5.2 above); hollows 1 and 2 at Kettleness are both in the order of 35m across, and so fit well with this documented size range. The form of both calcining places and clamps is discussed further in section 7.1.2 below.

The western and northern fringes of the quarry are also the most likely locations for the 18th-century steeping pits. There seem to have been 9 pits for most of this period, rising to 14 by 1785 (section 4.1 above), although there is no evidence for where exactly they were located. The investigation has found documentary evidence that in 1810-11 two new pits were constructed on 'the old pit-hill' and two more plus a calcining place at the 'Prospect Work'. While little can be made of these references without knowledge of where the named locations lay within the quarry, it does suggest that pits were sited close to whatever part of the quarry was being worked and were replaced with new ones as the active face moved further away. If, as seems likely, old pits were simply abandoned, early examples may survive beneath scree or later dumping in the deeper parts of the quarry floor; however, if they lay on the cliff edge above Runswick Bay, they will have been dug away in 1830 to make way for alum house 2 (section 7.1.2 below). Wherever their location, a liquor trough will have connected them to a raw-liquor cistern above alum house 1 on the foreshore: it may even be part of this cistern which survived until recently in the cliff face on the edge of the 1829 landslip (cistern 3, section 6.1.10 above).

There is no firm evidence for how water was conveyed to the pits at this time. Springs do occur within the alum shales (*eg* Ordnance Survey 1972a), but are unlikely to have provided an adequate or reliable source. Indeed it is documented as early as 1732 that water was channelled to the works from Goldsborough and stored in ponds: three such ponds are documented at this time, although later inventories mention only one in 1775 and two in 1792 (section 4.1 above). None of the records states where the ponds were located, but since the features are always referred to as ponds rather than cisterns, it is most likely that they were clay-lined reservoirs situated on the cliff top in and around Kettleness hamlet. The present investigation has found no definite evidence of such reservoirs (the earthwork remains of a possible ploughed-out example at *c* NZ 8325 1555 were seen from the public road during ground survey but not more closely investigated). The survey has been able to demonstrate, however, that after 1829 water was taken down to the quarry *via* a stone gutter laid alongside track 1, the main access road (sections 6.1.4 and 6.1.9 above). If the presumption for reservoirs above the quarry is correct, a similar arrangement to deliver water to the pits probably existed alongside the track's 18th-century predecessor.

7.1.2 The later alum works: 1830-1871

The great landslip of December 1829 which destroyed the staithe and alum house 1 in Runswick Bay effectively closed the works for the best part of two years. A replacement alum house (no. 2) was built on the cliff edge within the quarry, but was not operational before August 1831 (section 4.1 above). The time delay was no doubt partly due to the fact that a large shelf had first to be dug at the edge of the cliff before construction work could start, in order for the house to be at a lower level than the steeping pits and receive liquor from them under gravity. The shelf's dimensions suggest nearly 10 000 cubic metres of shale were excavated (section 6.1.7 above), although it is unlikely that any of this was added to the calcining clamps since by this time the alum workers knew that shales at the level of the shelf were too poor in sulphur to be worthwhile processing (Winter 1810, 246). Instead, the likelihood must be that all this shale was dumped. Furthermore, the survey has produced evidence which indicates that the landslip, as well as bringing material down onto the reef, affected the south-west corner of the quarry face which thereafter was avoided by the alum workers as too dangerous to mine (section 6.1.1 above). It is thus conceivable that parts of the quarry also needed to be cleared of rubbish - most obviously boulder clay and sandstone, but quite plausibly shales which had become intermixed with, and therefore contaminated by, overburden - thus adding to the volume of material to be moved.

If such a very large quantity of material had to be disposed of, the question must be where. The obvious solution of tipping it over the nearest cliff edge would have risked clogging up shipping approaches in Runswick Bay, whilst disposing of it over the east side of the headland may also have been problematical if the steeping pits were already sited here at this date. The only option may have been to dump the shale on and over the headland's northern tip. At present, such a scenario seems the most plausible explanation for the great band of spoil heaps which stretch across the northern end of the promontory (spoil dump area 4, section 6.1.1 above), especially the presence of till and the mixed deposit of shale and other material overlying it; it also provides a context for the shale backfill to the hollows/

possible early calcining places identified by the survey (sections 6.1.1 and 7.1.1 above). Against this explanation, however, is the evidence of the Phillips' sketch (Fig 7), which if earlier than 1829 as suggested (section 4.1 above), indicates the dumps existed before the date of the landslip. A programme of scientific soil analysis would no doubt contribute greatly to determining the origin of this large volume of material.

Although the landslip was a major interruption and challenge to the alum works' operation, as well as a serious financial burden, there is no evidence that it brought about changes in the time-honoured techniques of mining and processing shale. Once the destroyed infrastructure had been replaced and the quarry floor cleared of débris, shale would once more have been dug by hand and barrowed to the calcining places. The survey has recorded two reasonably well-preserved calcining places (nos. 1 and 2) in the south-east corner of the quarry which must belong to the final decades of the works' life, and the possible partial remains of two others (nos. 3 and 4) further north which may well be their immediate predecessors (section 6.1.2 above). Unlike the earlier, pre-1829, calcining places, however, which if correctly identified were 'hollows' cut down in to the shale (section 7.1.1 above), these extant post-1829 examples consist of upstanding baulks fashioned for the most part out of *in-situ* shale bedrock. This raises the possibility of a developmental typology, but the difference in construction technique may be more apparent than real, and be a response to geological factors and/or the space available within the works. For example, if a place were constructed below the level of the profitable alum shales (in order to allow for barrowing of shale downhill) its form would be akin to a simple hollow, but if the place were constructed at a higher level within workable alum shales, it might take the same form initially but over time would have the shale dug away from around the outside resulting in upstanding baulks similar to those at Kettleness. The evidence from places 1 and 2 at Kettleness which are best preserved suggests the inner faces were lined or revetted in stone.

It is uncertain exactly how clamps were raised within these calcining places. Most modern commentators would accept that they were built up from wooden gantries running out from the desses in the active quarry face to tipping platforms sited above the clamp (*eg* Miller 2002b, 110). However, given that early 19th-century accounts of calcination state that just over a metre's depth of shale was laid on a bed of whin and faggots before the clamp was set alight, and that additional shale was then added around the base and top of the already burning clamp until the desired size and height had been reached (section 5.2 above), any wooden gantry supports would have burned away if they intruded into the area of the clamp as depicted on Marshall's suggested reconstruction (Marshall 1995, 43 figure 2). This observation not only provides a ready explanation of why calcining places had to be engineered structures whose sides could take the weight of a tipping platform (although how that platform was rigged over such a large span is itself a problem), but also calls into serious question claims that large free-standing mounds visible at several alum sites, including Kettleness (spoil heap 1, section 6.1.1 above) and Boulby (*eg* Chapman 2002, 66), are undismantled clamps. It is unclear how the implications of this observation can be reconciled with a painting of Ravenscar alum works by H B Carter in 1843 (reproduced as the frontispiece in Miller (ed) 2002) which shows two free-standing clamps: in the foreground an apparently completed example in the process of burning, and behind it a second one presumably cooling. But intriguingly, behind the second mound four figures stand on what appears to be the remains of a third clamp already mostly dismantled, while behind that at the foot of the quarry face lies a rectangular structure defined by shale baulks, very similar in form to the upstanding calcining places 1 and 2 at Kettleness and presumably defining a fourth clamp under construction. If so, the clamps in the foreground may represent a degree of artistic licence, and be attempts on the painter's part to convey more clearly to the viewer clamps at different stages of calcination. Alternatively, the places which surrounded those clamps may already have been removed in order to add the shale in the baulks to the new one under construction. At face value the latter suggestion could be advanced as an argument in support of identifying spoil heap 1 at Kettleness as an undismantled clamp, but against it is the fact there is no evidence of a clamp under construction nearby. Sandstone rubble is visible on the Kettleness mound's surface anyway; while Chapman (2002, 66) has stated that clamps were capped with clay and stones, contemporary accounts attest only to the use of fine wet shale. In summary, although the earthwork form of the mound is typical of having been created by tipping off a wooden gantry, when all the evidence is considered it is best understood as a spoil heap at the foot of the quarry face, not a clamp. The Carter painting also depicts what has been interpreted as a horizontal tunnel into the base of the larger clamp in the foreground, designed to draw air into the interior and provide a more uniform burn (see also section 5.2 above); the survey has found no evidence for the use of such flues at Kettleness.

The survey has shown that sixteen or seventeen steeping pits survive at Kettleness, arranged in two banks of ten or eleven, and six. Map evidence indicates that the pits date from at least 1852 and are probably contemporary with calcining places 1 and 2, while archaeological evidence shows that they lie at a slightly lower level to allow for barrowing of the burnt shale downhill. But they are also reasonably close to and at a lower level than the putative calcining places 3 and 4, and it may be that the pits serviced those earlier places as well. Both banks are now buried beneath shale scree eroding off nearby dumps which means that what survives is protected from the worst effects of weathering. Ultimately, however, both banks will be completely destroyed by cliff recession which has already removed their north-eastern ends. Comparison of the position of the cliff edge on the Ordnance Survey first edition 25" map in 1893 with that recorded by the present survey suggests that the top of the cliff here has receded by about 5m in 100 years. On this basis, parts of the pits may survive for another 300 years, albeit with cumulative loss of information and detail. However, overall cliff-recession rates do not tell the whole story: in the short interval between the site being photographed from the air in July 2000 and surveyed on the ground in July 2002, one and in some places two courses of the exposed floor slabs in pits 4, 5 and 6 had disappeared, presumably loosened by surface run-off eroding the cliff top faster than the base. The pattern of these run-off channels undoubtedly changes periodically after periods of heavy rainfall; thus all of the pits are potentially at risk of accelerated loss, not just the three presently affected.

The overall dimensions and method of construction of the Kettleness steeping pits, and even their rhomboidal plan (section 6.1.3 above), appears broadly comparable with those excavated by Chapman at the New Works at Boulby, which date to between 1784 and 1871

(Chapman 2002, 66-7). The excavation showed that the Boulby pits were connected to a wooden liquor trough contained within a stone culvert running along their seaward edge and leading to three circular cisterns situated at the end of the bank, although no evidence is reported for how the pits were supplied with water. If a culvert/liquor trough existed in the same position at Kettleness, it has already eroded over the cliff, although part of a cistern survives north of the pits (cistern 1). At Boulby, the excavator considered that liquor was pumped directly between pits, and that the cisterns there were for temporary storage of the final strong liquor (Chapman 2002, 68). However, the present survey has suggested that at Kettleness cistern 1 may have been for temporary storage of liquor in between stages of the wash cycle. (Gould's suggestion that it is a water cistern cannot be discounted without further investigation, but the matter is probably only capable of final resolution by excavation and the structure is in a very dangerous position at the edge of the cliff and has already been partly lost through cliff recession). The Kettleness evidence does raise the possibility, however, that the Boulby cisterns may have been for settling or temporary storage of liquor in between washings.

Map evidence shows that at Kettleness a rectangular building formerly existed between the two banks of pits, most of which has already been lost to cliff recession. Its position on the cliff edge meant what survived was too dangerous for close investigation, but the survey has argued (sections 6.1.5 and 6.1.8 above) that its siting in relation to the pits and in line with what appears to be the portal to a tunnel, is strong if circumstantial evidence that it housed settling cisterns. The siting of cisterns beneath other buildings is documented at Kettleness in 18th-century inventories (section 4.1 above), and can also be paralleled at Loftus (Hunt *et al* forthcoming). If not a cistern house, it is possible that building 3 was some kind of pump house.

Only a very small part of one portal to the liquor trough tunnel is exposed at Kettleness (section 6.1.6 above). The orientation of the visible stonework suggests its course is initially towards the south-west rather than directly west towards the new alum house, but this may be to take advantage of existing deeper areas within the quarry floor which would have enabled parts of the tunnel to be constructed on a cut-and-cover basis rather than needing to be dug through shale bedrock. It is likely that it emerged at or near a circular cut in the shale above the alum house, which the survey has suggested is the site of a raw-liquor storage cistern (cistern 2, section 6.1.7 above). Although the exact route of the tunnel is not known, the relative heights of the two suggested portals means that any liquor trough within it would have had a gradient of less than 1 in 80 (1.3%).

It has been widely assumed that a plan of Kettleness alum house (Fig 8) preserved in the NRO, depicts alum house 2 whereas the present investigation has argued that the plan is more likely to be of alum house 1 on the foreshore (section 4.1 above). Documentary evidence suggests, however, that the general design and layout of the two alum houses may not have been very different. Indeed, if the design of the old house 'worked', there would have been little incentive to change a tried and tested formula when designing the replacement structure. Marshall (2002, 35) has drawn attention to what appear to be two rows of internal roof supports on the NRO plan - one along the back wall of the settlers and the other passing through the coolers - indicative of the building having three separate roof spans, and all the inventories describe both houses in terms of the same three functional areas, namely the fire roof, settler roof, and cooler roof. None of the 18th-century inventories specifically mentions evaporating pans, but we may reasonably assume that these were accommodated within the 'fire roof', and are to be equated with the unnamed double row of 32 pans which the plan portrays at the rear of the building adjacent to the rocking tons - an arrangement which appears to have been replicated in alum house 2 for an 1845 inventory differentiates between front and back pans (section 4.1 above). Marshall (2002, 32) has suggested that the back pans were for boiling raw liquor to clarify it, and the row of front pans for concentrating the liquor once clarified. Whilst this may have been so in alum house 1 for no boiling or clarifying house is indicated on the NRO plan, the survey has found archaeological evidence which suggests that alum house 2 had a dedicated clearing house (tanks 1-4, section 6.1.7 above), an arrangement paralleled at other alum works such as Peak (Marshall 2002, 38); if so, front and back pans in alum house 1 may have all been for evaporation, and it is possible that the Kettleness works did not undertake clarification before 1829.

Little of the floor plan of alum house 2 is now visible on the ground. However, the survey has shown that fairly substantial wall lines still survive beneath an ever encroaching and deepening blanket of scree. A series of rectangular compartments probably represent the supports for the front evaporating pans and perhaps the coolers. Map evidence shows that another building range formerly existed west of the 'cooler roof', at the edge of the sea cliff, although this had collapsed into the sea before 1893 undermined by a series of jet mines dug into the cliff face beneath it. Its function is unknown, but possibilities include an alum warehouse or the clerk of the works' house. Map evidence also records the positions of two rectangular buildings south and south-east of the alum house proper in 1852. One of these may be the separate Epsom Salts House recorded in 1845 (section 4.1 above).

The survey has located the sites of a number of buildings within the quarry which were not part of the alum-house complex (section 6.1.8 above). There is no documentary evidence for their functions, although it has been suggested that one (building 3) situated in between the two 19th-century banks of steeping pits may have housed settling cisterns. It is likely that one other, most probably building 2, functioned as a tool store. Gould (1993b) has suggested building 1 is a laboratory, but the task of measuring specific gravities of liquor in the pits is unlikely to have warranted such a large building by itself; it may therefore have doubled as a workshop or blacksmith's shop. A structure of similar proportions and in a similar relationship to steeping pits has been excavated in the 17th/18th-century Rockhole, or Old, Works at Boulby and was found to contain a fireplace (Chapman 2002, 65-6). However, the building's exact function was not determined.

Until 1829, the Kettleness works possessed its own staithe where raw materials were landed and alum shipped out. The advantages of the staithe were probably twofold: it afforded the alum house – then situated on a 'platt' of ground at the foot of the cliff (section 4.1 above) - a degree of protection from the sea, while at the same time permitting the unloading and loading of vessels at almost any state of the tide. The staithe was buried in the great landslip of December 1829, however, and there is no evidence, documentary or archaeological, that a replacement was built elsewhere within Runswick Bay. Instead the only physical evidence for shipping facilities after this date are four rock-cut rutways (section 6.1.9 above). Owen (1986; 1987) has suggested that these date to 1838 and relate to a short-lived period of ironstone quarrying on the reef, since three of the four (rutways 1-3) head out from the shoreline to the edge of the quarried area. But Owen's logic is questionable: given that the ironstone quarries were only workable for a very limited period either side of low tide, it seems likely that the ore would have been transferred directly onto vessels beached close-by rather than carted ashore. As rutways 1-3 lead out from the foreshore, it seems far more probable that they were created following the cliff collapse in association with alum house 2 and remained in use until closure of the works in 1871. Further evidence for this association comes from the observation (section 6.1.9 above) that rutway 2 appears to have been re-cut at least once on a slightly different alignment: this is unlikely to have happened if the rutway was only in use for a single year. A fourth rutway (no. 4) further out in the bay may indeed be connected with ironstone extraction, however (section 7.4 below).

7.2 Cementstone

The cementstone industry has left practically no archaeological trace at Kettleness. Cementstone was quarried here for 60 years from 1811 until closure of the alum works in 1871, but since the doggers were mostly found overlying the alum shale evidence for their extraction was destroyed immediately after by the digging of shale; in addition the doggers were not processed on site but transported (presumably shipped round the coast) to the Mulgrave Cement Works at Sandsend (section 4.2 above). The investigation has uncovered documentary evidence, however, which suggests that the timing of the opening of the cement works was heavily influenced by events at Kettleness, in particular the immediate availability of a large supply of cementstone doggers, for references to the new 'Prospect Work' coupled with the construction of new steeping pits in 1811 (section 4.1 above) suggest that the Kettleness alum quarry was about to be extended.

Manufacture of cement at Sandsend continued until 1935, some 65 years after the closure of the Kettleness quarries. During this period, it is reported that the cement works obtained supplies locally from mines in the sea cliffs and the face of the disused alum quarries in and around Sandsend. But the identification of a drift mine dug into the cementstone dogger at Kettleness shows that trials were also made here.

7.3 Jet

Jet is undoubtedly the earliest of the four industries identified at Kettleness. The mineral had presumably been collected from the foreshore since prehistoric times, but documents hint that by the 17th century it was being mined from the sea cliffs as well (section 4.3 above). The survey has now produced evidence which substantiates this inference in so far as some of the jet mines at face value appear to pre-date the start of the alum works.

This is particularly the case on Kettleness Point where the shales are totally missing down to the level of the jet dogger seam and a number of de-roofed mine galleries have been exposed (section 6.3 above). The simplest explanation of this evidence is to say that the mines have been broken into by alum workers – most probably in the very early days of the works before it was appreciated that shales at this level were too poor in sulphur to be worth quarrying – and that the mines therefore pre-date the opening of the alum works in 1727. However, other explanations are also possible: the shales above the level of the mines may simply have collapsed because the degree of (later) jet mining rendered them unstable; or the missing shales were removed by jet prospectors attempting to opencast what remained of the jet seam after the alum workers had moved on. The second explanation can be dismissed straightaway, for it is extremely unlikely that opencast extraction would have left pillars of upstanding shale as recorded by the survey. The first explanation cannot be dismissed so readily, but is rendered less plausible by the presence of a mound of burned shale (spoil heap 3, section 6.1.1 above) overlying the de-roofed mines, and by a second spoil heap (spoil heap 2, section 6.1.1 above) a little to the south which has been built up from the north. It is difficult to explain these features other than as evidence that the alum shales were worked to a lower level on Kettleness Point than elsewhere, and broke into pre-existing jet mines.

Other possibly early mines have been recorded on the west side of the headland beneath the shelf excavated for alum house 2, which subsequently partly collapsed due to the presence of those mines (see also section 6.1.7 above). It is most unlikely that the mines were dug whilst the alum house was operational, but it is less clear whether they already existed when the alum house was built, or were dug after alum manufacture ceased in 1871. Since jet mining was reportedly in decline in the 1870s, the former is perhaps the more likely.

7.4 Ironstone

Ironstone extraction seems to have been limited to a single episode in 1838, when part of the main seam outcropping on the reef below the headland was broken up and shipped north to furnaces on the Tyne. Although the quarried area is extensive (section 6.4 above), documents suggest it was limited to a single season before difficulties chartering ships suitable for beaching within Runswick Bay brought operations to a halt (section 4.4 above). Previous commentators have suggested that rutways within the bay are associated with this very short, if hectic, period of activity, but the present investigation has suggested that three are more probably associated with the alum trade (section 7.1.2 above). A fourth which lies much further out to sea on the edge of a deep-water channel (rutway 4, section 6.1.9 above) may well relate to ironstone traffic, however. This part of the reef is only revealed for a very short period either side of low tide, and the likelihood must be that the rutway is connected with vessels beaching nearby. Since we know from the position of the staithe that ships used in the alum trade were fully capable of sailing right into the bay before 1829, it suggests these vessels were those chartered in 1838 to take away the ironstone.

8. SURVEY METHODOLOGY

The survey was carried out using a combination of photogrammetry, aerial transcription, and ground survey. Thus, as well as a two-dimensional interpretative survey diagram, EH possesses a high-quality three-dimensional terrain model tied in to Ordnance Survey National Grid (OS NG) as a permanent record of the site's topography.

The photogrammetric and aerial transcriptions were produced from twelve 1:3000-scale vertical stereoscopic photographs which EH commissioned from Simmons Aerofilms Ltd in July 2000. In October 2000, a permanently-marked local base station was established on site and OS NG co-ordinates brought in *via* a Trimble 4800-series Global Positioning System (GPS) receiver and the OS network of passive GPS stations. At the same time, differential-GPS surveying was used to geo-reference a network of eight control points on the photographs. All GPS data were processed using Trimble Geomatics Office (TGO) software. During subsequent fieldwork in July 2002, the base station was re-observed against the OS GPS active-station network and updated NG co-ordinates calculated *via* the OSNT02 transformation (but using broadcast rather than precise ephemerides).

The images were scanned at a 25-micron pixel resolution using a high definition photogrammetric scanner. This gave an approximate ground size of 9.5cm per pixel. The restitution of the stereo-imagery was carried out on a digital photogrammetric workstation (DPW) using BAE Systems SOCET SET software. The RSME errors of the eight control points were 2.3cm, 1.5cm and 0.9cm in the x, y and z axes respectively. A digital terrain model at 1-metre grid spacing was produced using the automatic terrain extraction module of the DPW. An orthophotograph (a true-to-scale image where the scale errors in the image caused by camera tilts or ground-height displacements are rectified) was also produced from the aerial images.

Archaeological and topographical features visible on the images were then extracted from the stereoscopic view as a series of 3D vector lines. A 1000-scale plot of these data was taken into the field in July 2002, checked as much as possible from ground observation, and new or revised detail added, again using Trimble GPS equipment. The data sets were edited and merged within an AutoCAD 2000i environment. Revised plots at 1:500 and 1:1000 scale were subsequently taken back out into the field, checked and interpretative notes added; any revision at this stage was carried out using graphical techniques, and digitised into the AutoCAD file.

The co-ordinates of, and a guide to re-locating, the permanently-marked base station can be found in appendix 3 of this report. Details of the archived stereo imagery are included in appendix 1.

9. ACKNOWLEDGMENTS

Many English Heritage staff have contributed to the survey: Mick Clowes set up the photogrammetric model; Ann Carter undertook the aerial transcription; Christopher Dunn, Marcus Jecock and Amy Lax put in the GPS control framework; Marcus Jecock and Christopher Dunn carried out ground survey; Keith Buck took ground photography of the site. The report was researched and written by Marcus Jecock, and edited by Christopher Dunn; drawn illustrations are the work of Philip Sinton.

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PB5066 *Crown lease of the Mulgrave Estate, 1738*
PB5073 *Crown lease of the Mulgrave Estate, 1760*

Appendix 1: The archive and photographic record

A survey archive of the field plans and supporting background information such as the Project Design and selected correspondence, has been deposited with the NMRC in Swindon under Collections reference AF 00108, where it is available for public consultation upon request. Digital data exist as a series of SOCET SET and AutoCAD files; these are currently held at the EH office in York, and are also publicly available upon request.

The vertical aerial stereo-imagery is archived at the NMRC under sortie no. AEL/00C/515, frames 9664-8 and 9670-6, original EH ground photography as photographic job number 2K/04489; individual frame captions of the latter deposit are listed below:

AA040205 Detail of the eastern edge of hollow 1
AA040206 The north-east end of the stone gutter conveying water to the 19th-century steeping pits. Note how the trough has protected the underlying shale bedrock from surface erosion
AA040207 Detail of rutway 2 in Runswick Bay, viewed from the north-east
AA040208 Spoil heap 1 (alleged calcining clamp) at the base of the main quarry face
AA040209 Rutways 1 - 3 in Runswick Bay, viewed from the headland
AA040210 Detail of the eroding floor of steeping pit 5 on the north-east side of the headland
AA040211 Detail of the silted tanks immediately north of alum house 2, as revealed by erosion of the talus slope
AA040212 General view of Runswick Bay from Kettleness Point
AA040213 General view north across the alum workings from inside the quarry
AA040214 View south-east across building 1, with the steeping pits beyond
AA040215 Detail of the northern end of the staithe in Runswick Bay
AA040216 Detail of the eroding cistern 1 on the north-east side of the headland
AA040217 Detail of shipwreck 1 in Runswick Bay below Kettleness Point
AA040218 Detail of the northern end of the staithe wall in Runswick Bay
AA040219 Detail of conduit 1 north of alum house 2
AA040220 General view of conduit 1 north of alum house 2
AA040221 Wall 5 north-east of alum house 2
AA040222 Detail of the vaulted roof of the eastern portal of the liquor-trough tunnel
AA040223 The remains of building 3 and the eastern portal of the liquor-trough tunnel, viewed from the south
AA040224 General view north across the 19th-century steeping pits on the north-east side of the headland
AA040225 General view north across the 19th-century steeping pits on the north-east side of the headland
AA040226 General view north across the alum workings from the top of spoil dump area 2. Note the upstanding shale baulks marking the sites of calcining places 3 and 4
AA040227 General view of the staithe wall and surrounding boulder field in Runswick Bay (representing the toe of the 1829 cliff collapse), viewed from the headland

AA040228 Detail of the end of conduit 2 exposed in the west side of the headland

AA040229 Jet mines 2 - 5 and the collapsed ledge at the top of the cliff immediately west of alum house 2

AA040230 Detail of conduit 1 north-east of alum house 2

AA040231 General view north across the alum workings from the top of spoil dump area 2. Note the upstanding shale baulks marking the sites of calcining places 3 and 4

AA040232 General view west across the alum workings from the top of spoil dump area 2.

AA040233 General view of the alum workings from the top of the cliff at Kettleness Farm

AA040234 General view of the alum workings from the top of the cliff at Kettleness Farm

AA040235 General view of the staithe wall and surrounding boulder field in Runswick Bay (representing the toe of the 1829 cliff collapse), viewed from track 1

AA040236 The 'deep-water channel' in Runswick Bay

AA040237 View east along track 1 linking Kettleness hamlet and the alum works, from the edge of the 1999 cliff collapse

AA040238 View north-east along the stone gutter conveying water to the 19th-century steeping pits, showing constructional details

AA040239 The site of the 1999 fossil excavation, containing displaced gutter stones

AA040240 View west across the alum workings from close to building 1 showing the depth of surface erosion

AA040241 Detail of the junction of the main range and annex of building 1

AA040242 Detail of the staithe wall in Runswick Bay, looking south-west. The figures are marking the front and rear edges

AA040243 Detail of the staithe wall in Runswick Bay, looking south-west, without figures

AA040244 Features in the cliff face, particular cistern 3, near the site of the 1829 cliff collapse

AA040245 Jet mines in the cliff face near alum house 2

AA040246 General view south along the west side of the headland showing the edge of the ironstone quarry at the foot of the cliff

AA040247 Possible traces of alum house 1 within the remains of the 1829 cliff collapse. Note the red bricks at right of frame, and ground-up sandstone walling at left of frame

AA040248 Detail of the bricks exposed in the remains of the 1829 cliff collapse

AA040249 Dr Simon Thurley, EH Chief Executive, inspecting the 19th-century steeping pits at Kettleness

AA040250 Detail of inner stone revetment to calcining place 1

AA040251 Detail of spoil heap 1 (alleged calcining clamp) and the main quarry face behind

AA040252 Detail of the silted tanks immediately north of alum house 2, as revealed by erosion of the talus slope

AA040253 General view of the 1829 and 1999 cliff collapses, from alum house 2

AA040254 General view of shipwreck 1 in Runswick Bay, from Kettleness Point

AA040255 A de-roofed jet-mine gallery on Kettleness Point

AA040256 General view across the 19th-century steeping pits and cistern 1 on the north-east side of the headland

AA040257 Detail of the lip in the rear edge of steeping pit 4

AA040258 Detail of the floors and walls of steeping pits 1 – 6, and of cistern 1 beyond, as exposed in the cliff edge

AA040259 Detail of the side walls of steeping pits 5 and 6.

AA040260 General view of the eastern side of the alum workings, looking south-east from spoil dump area 4

AA040261 General view of the centre of the alum workings, looking south from spoil dump area 4

AA040262 Detail showing the eastern and southern edges of hollow 2, and the remains of calcining place 4 behind

AA040263 Detail showing the eastern and southern edges of hollow 2, and the remains of calcining place 4 behind

AA040264 General view south across the alum-house shelf in the west side of the quarry

AA040265 A de-roofed jet-mine gallery on Kettleness Point

AA040266 Tip lines in spoil dump area 4, exposed in the east side of the cut for track 9

AA040267 General view of the de-roofed jet mines and spoil dump area 5 on Kettleness Point

AA040268 General view of the cliffs west of Kettleness

AA040269 General view north across the alum-house shelf, showing conduit 1 and spoil dump area 4 behind; the scree-covered tanks are visible within the erosion gully

AA040270 Detail of building 2 looking north-east

AA040271 General view south-west over the alum-house shelf, showing the encroachment of scree across the remains of alum house 2

Appendix 2: Concordance of NMR numbers

MONUMENT TYPE/NAME	NGR	NMR No
Kettleness Alum Works	NZ 833 160	NZ 81 NW 53
Alum House 1 (site of)	NZ 831 159	NZ 81 NW 64
Alum House 2 (remains of)	NZ 8322 1598	NZ 81 NW 65
Staithe (remains of)	NZ 8310 1592	NZ 81 NW 66
Steeping pits (remains of)	NZ 8345 1600	NZ 81 NW 67
Rutways 1-3	NZ 830 159	NZ 81 NW 68
Rutway 4	NZ 8302 1617	NZ 81 NW 69
Jet mines	NZ 833 160	NZ 81 NW 70
Cementstone mine	NZ 83510 15835	NZ 81 NW 71
Ironstone quarrying	NZ 833 162	NZ 81 NW 72
Shipwreck 1	NZ 8313 1617	NZ 81 NW 73
Shipwreck 2	NZ 8372 1591	NZ 81 NW 74

Appendix 3: Permanently-marked survey station

A local GPS base station (station 1) was established on site over a brass rivet drilled into the southern edge of the concrete base of a former breeches buoy near the centre of the quarry. Its position is marked on Fig 56.

Station 1.

OS NG (OSTN02):	Easting 483,339.872
	Northing 516,006.351
	Elevation 50.945
ETRS89	Latitude 54º 31' 57.00022" North
	Longitude 0 º 42' 49.09317" West
	Height 98.180

ENGLISH HERITAGE

NATIONAL
MONUMENTS
RECORD

The National Monuments Record is the public archive of English Heritage. It contains all the information in this report - and more: original photographs, plans old and new, the results of all field surveys, indexes of archaeological sites and historical buildings, and complete coverage of England in air photography.

World Wide Web: http://www.english-heritage.org.uk

National Monuments Record enquires: telephone 01793 414600

National Monuments Record Centre, Great Western Village, Kemble Drive, Swindon SN2 2GZ

Figure 56. English Heritage earthwork plan of Kettleness Alum Works, reproduced at 1:1000 scale