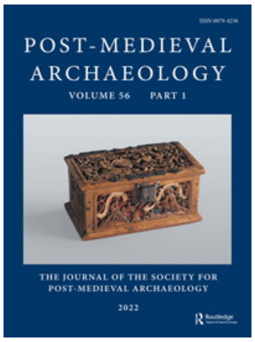

Post-Medieval Archaeology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ypma20

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To cite this article: Mark Kincey, Chris Gerrard & Jeff Warburton (2022) Metals, mines and moorland: the changing lead mining landscapes of the North Pennines, UK, 1700-1948, Post-Medieval Archaeology, 56:1, 1-27, DOI: 10.1080/00794236.2022.2058221

To link to this article: https://doi.org/10.1080/00794236.2022.2058221

Published online: 11 Apr 2022.

Post-Medieval Archaeology **56/1** (2022), 1–27

Metals, mines and moorland: the changing lead mining landscapes of the North Pennines, UK, 1700-1948

By MARK KINCEY, CHRIS GERRARD *and* JEFF WARBURTON

SUMMARY: Intensive metal mining considerably altered many British upland landscapes between the 18th and 20th centuries, modifying both subterranean and surface environments and fundamentally changing the character of local settlements, infrastructure and society. However, our understanding of the landscape-scale patterns of development through time in mining districts is still limited. In this study, we take an interdisciplinary approach to understand the historical development of the mining industry within a nearly 200 km^2 area of the North Pennines, UK. Our approach combines documentary and cartographic records, archaeological mapping, and geomorphological analysis of changes to the physical environment. We demonstrate pronounced spatio-temporal variability in the intensity of mining and the nature of associated landscape impacts. Production time series data indicate a widespread intensification of operations during the 18th century, with archaeological evidence suggesting that the environmentally destructive practice of hushing, a hydraulic mining technique, was also widespread during this period. The scale of ore production from subterranean mines increased considerably throughout the mid-19th century, before a rapid decline from the late 1800s onwards. The influence of large mining corporations reached into all aspects of the local economy and society; altering the settlement patterns, infrastructure and demographics of the area and shaping the finances, health and wellbeing of the miners and their families. The environmental and societal changes that accompanied the mining industry were profound, resulting in mining districts with a distinctive landscape character and legacy that persist to the present day.

INTRODUCTION

Between the 18th and 20th centuries, many of the upland landscapes in Britain were transformed by metal mining. Networks of subterranean tunnels and superficial landforms associated with the mining of ore and the deposition of waste significantly modified the physical environment.[1] Given that a large workforce and infrastructure was required to support the processing and transport of materials, and to meet the subsistence needs of miners and their families, there were sometimes profound changes to the character of local settlements and their social structures.[2] This combination of pronounced physical and social change created industrial mining districts of distinctive character.[3]

Lead mining in Britain has been the subject of both national archaeological assessments[4] and regional or local studies, particularly in areas where the industry was most prevalent, such as the Peak District,[5] Lake District[6] and the Yorkshire Dales.[7] In particular, the lead industries of the Pennines have

DOI 10.1080/00794236.2022.2058221

received attention,[8] including overviews which were penned during the declining years of the industry in the late 19th century.[9] There are also interdisciplinary studies which focus on the geological landscapes of the Pennines,[10] as well as detailed surveys of mining sites in particular catchments.[11] Most recently, Historic England's '*Miner-Farmer Landscapes of the North Pennines*' project has significantly increased knowledge and awareness of the multi-period archaeology of the Northern Pennine Orefield through aerial and ground surveys.[12]

The management and long-term preservation of historic metal mining landscapes is complicated by the nature of the remains themselves, which are often not easily conserved or adapted to other uses after active mining has ceased.[13] For example, nearly 11% of Grade I and II* industrial buildings are deemed to be 'at risk' by Historic England, compared with only 3% of Grade I and II* buildings of other non-industrial types.[14] Linked to this, although the significance of surviving industrial remains has been widely acknowledged for several decades,[15] the perception of industrial sites has often been that they are somehow inherently less significant than other archaeological remains.[16] This may be because they tend to belong to the relatively recent past, or due to their location in inaccessible upland and marginal areas, or possibly that they are regarded as intrinsically hazardous because of the potential for contamination from legacy sediments.[17] Whatever the perception, the consequences of these views have been that industrial remains such as lead mining landscapes have often experienced much higher rates of decay and destruction than other comparable archaeological site types.[18]

Although our understanding of landscape-scale patterns of historic metal mining has increased in recent years, important questions still remain regarding interactions between the historical development of the mining industry and associated spatio-temporal variability in changes to both the physical landscape and the social structure of the mining districts. This study investigates these themes within an area of the North Pennines, an internationally significant historical orefield in terms of metal production,[19] technological development,[20] social innovation[21] and documented environmental impacts.[22] We aimed to assess how, and to what extent, the landscape of the North Pennines was altered by lead mining operations during the period 1700-1948, and sought both to document the nature and intensity of changes through time and to explain temporal variability in landscape impacts. Finally, the economic and societal repercussions of lead mining on the North Pennine region are considered, including both the short-term changes experienced during the period of active mining and longer-term legacies through to the present day.

Given the inherent interdisciplinary nature of the topic, we take a holistic approach to investigating mining landscapes that integrates archaeological data, historical documentary and cartographic records, and geomorphological analysis of changes to the physical environment. This approach, which can be broadly defined as historical-geographical in focus, recognises the complexities involved in studying industrial landscapes. The traditional division of industrial archaeology into studies focusing on either the technological innovations or the social impacts of industrialisation has been rightly critiqued as imposing unnecessary and simplistic boundaries onto what is, by its very nature, a multifaceted subject area.[23] Instead, integrative approaches that aim to consider the various interconnections between industrial processes and accompanying societal changes should be applied where possible.[24] In this study, we take this approach, but also analyse changes to the physical environment, one aspect which is particularly important when considering historic mining landscapes. In part, this is because the distribution of mining sites is determined to a large degree by the presence of minerals and sufficient surface water supply to power the processing machinery,[25] but also due to the considerable long-term impacts that mining has had on the natural environment.

STUDY AREA: ALSTON MOOR, NORTH PENNINES

The geographical focus for this study incorporates 197 km^2 of the catchments of the upper South Tyne, the River Nent and Black Burn, the two major tributaries of the upper South Tyne, and the upper Tees as far downstream as Cow Green Reservoir (Fig. 1). Administratively, the area lies mostly within the modern county of Cumbria and includes all of the land north of the Tees and east of Black Burn within the civil parish of Alston Moor, with the remainder comprising the upland Pennine sections of the east-west aligned Eden catchment parishes. Elevations range from 258 m on the floodplain of the South Tyne downstream of Alston, up to 893 m on the summit of Cross Fell, the highest peak in the Pennine Hills. The majority of the surface rocks forming the North Pennines were deposited during the Carboniferous Period (359- 299 MA) and typically comprise cyclical sequences of sedimentary deposits resulting from the periodic fluctuation between marine and fresh water inundation of the gradually subsiding Alston Block.[26] Extensive mineralisation of the numerous faults created by the Carboniferous deformation of the Alston Block occurred within the Permian (299- 251 MA), resulting in the rich mineral deposits of lead, zinc, fluorite and barytes for which the orefield is internationally recognised.[27]

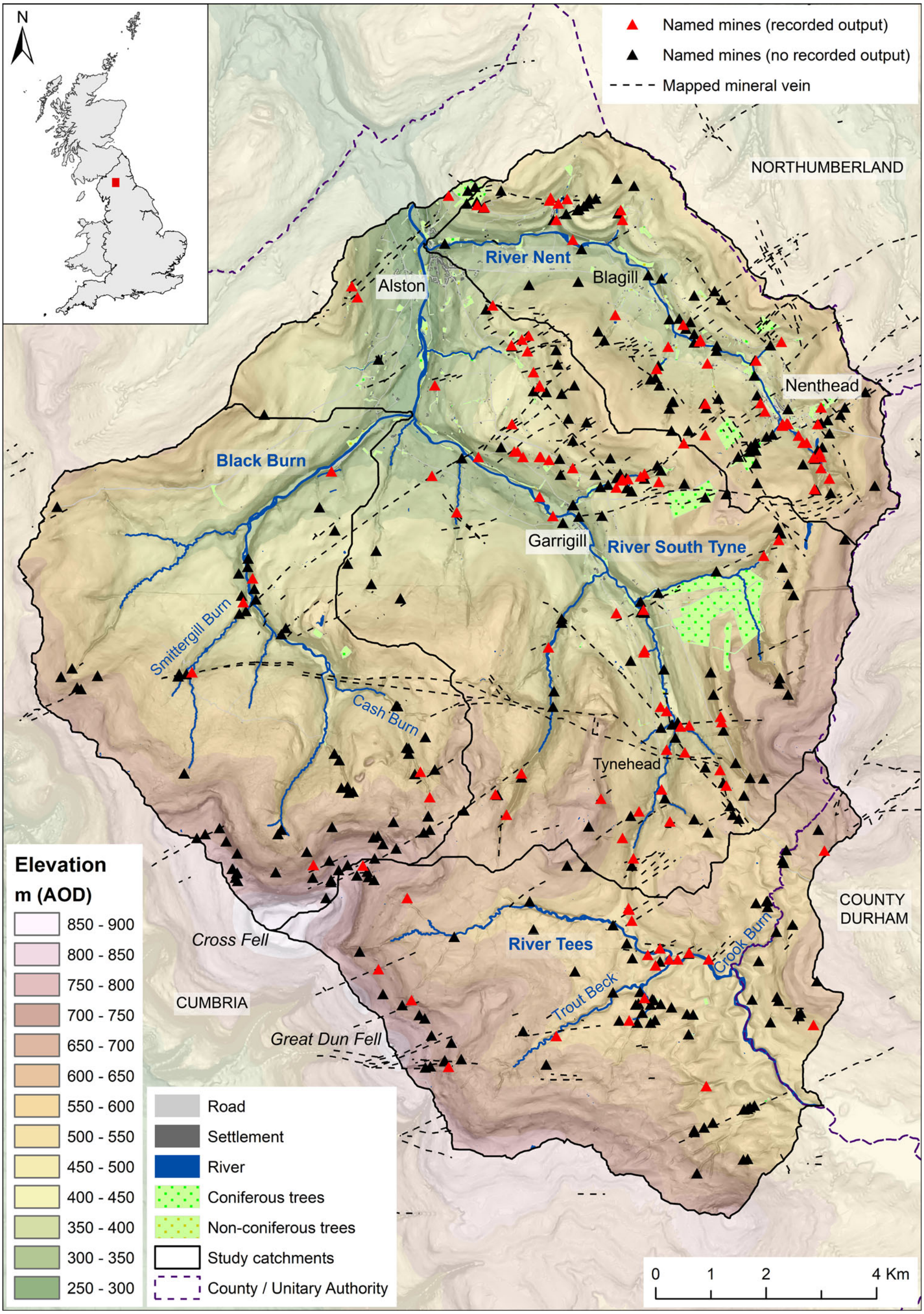

FIG. 1
Location of the study area in the North Pennines, UK, showing the distribution of named lead mines and key topographic features (DEM data © GetMapping 2009).

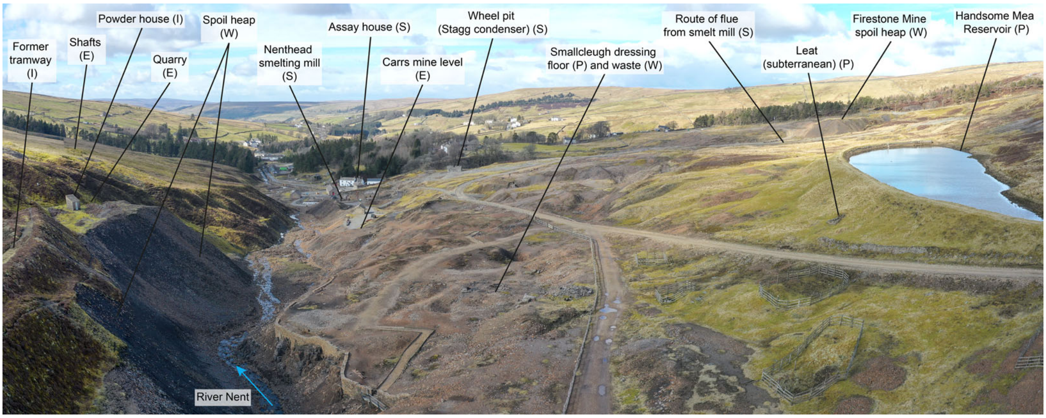

FIG. 2
Oblique drone photograph of mining remains at Nenthead, upper Nent valley, showing a range of mining landforms relating to each of the five broad categories defined in the classification scheme: extractive (E), infrastructure (I), processing (P), smelting (S) and waste (W).

Mining of ore deposits in the area may have started during the Romano-British period[28] but the evidence is largely circumstantial and relates primarily to the physical association between Romano-British sites such as Whitley Castle, located 3km downstream of Alston, and the focus of later mining operations.[29] The intensity of the later lead mining operations has often obliterated earlier workings. One possible exception is the lead workings on the floodplain of the South Tyne upstream of Garrigill, which were attributed to Roman period mining by Raistrick and Jennings,[30] though later surveys found nothing clear to confirm this.[31]

The earliest documented evidence for lead mining here is a lease of 1130 AD which mentions the Carlisle Silver Mine and probably refers to the silver-rich lead ore deposits on Alston Moor.[32] The importance of the 'Mines Royal' on Alston Moor is confirmed by references throughout the 12th-15th centuries to Crown involvement in the allocation of leases and the collection of duty payments.[33] Lead consumption during the medieval period was principally for construction purposes, in particular for roofing, as a form of mortar for bonding masonry in fortifications, and for use in leaded glass windows.[34] This medieval intensification of lead mining is also reflected in other proxy data sets. For instance, the corresponding palaeoenvironmental (pollen) record indicates widespread woodland clearance in Weardale during the 13th century, most probably due to the need to supply timber for the burgeoning lead mining industry.[35]

The lead mining industry in the North Pennines expanded considerably during the 17th century, before reaching its peak during the 18th and early 19th centuries. This expansion reflects the increased national consumption of lead for additional purposes such as shot, typesetting, paint additives and, by the 19th century, electrical equipment such as battery plates.[36] A sharp decline in production followed in the late 19th century, and lead mining had effectively ceased in this part of the North Pennines by the late 1940s. It is this period of rapid development and subsequent collapse, between c. 1700 and 1948, that is considered in detail below.

RECONSTRUCTING THE HISTORIC MINING LANDSCAPE

The spatial distribution of lead mines and mining-related features was compiled from a range of archaeological, cartographic, and documentary sources, with additional GIS-based mapping to supplement these datasets where necessary. Historic England's National Mapping Programme (NMP) covered around 80% of the study area as part of the *Miner-Farmer Project*,[37] producing a detailed record of all multi-period archaeological features visible in aerial photographs and airborne laser scanning data. These sources were supplemented by Historic Environment Records (HER) and new mapping of selected mining-related features from additional aerial photographic coverage. To provide a comparative historical record of the mining landscape, GIS mapping was also undertaken based on the First Edition County Series Ordnance Survey (OS) maps, the earliest map source (1859-1895) available at a detailed scale (1:2500) for the entire study area.

Five broad classes of features were defined based on the mining workflow: extractive, infrastructure, processing, smelting and waste (Fig. 2). The First

TABLE 1

Summary of historical mining disturbance by individual catchment area in the study area.

Catchment	Catchment area (km^2)	Number of named mines	Number of named mines with recorded ore output	Number of named mines per km^2	Number of mapped mining features		Number of mapped features per km^2		Area of mining disturbance (km^2)		Mining disturbance as % of total catchment area (%)	
					1st Edition OS	NMP	1st Edition OS	NMP	1st Edition OS	NMP	1st Edition OS	NMP
Nent	29.27	128	49	4.36	481	4570	16.4	156.1	0.54	1.17	1.86	3.99
South Tyne	72.36	156	61	2.16	527	5682	7.3	78.5	0.28	0.74	0.38	1.02
Black Burn	49.14	80	10	1.63	314	1057	6.4	33.7	0.2	0.25	0.41	0.79
Upper Tees	46.15	101	21	2.19	227	1062	4.9	43.3	0.13	0.17	0.27	0.71
Total area	196.79	465	141	2.36	1549	12371	7.9	78.5	1.15	2.33	0.58	1.48

Edition OS mapping and NMP survey feature categories were then assigned to one of these five classes. Since there are some feature categories that could relate to more than one stage of the mining process, such as leats and water channels, the class that the historical accounts[38] suggested was most closely related was selected. Generic feature categories, such as buildings, structures, and earthworks, were typically assigned to the infrastructure class in the absence of further diagnostic information.

Each category of mining feature would have impacted differently on the local landscape. For instance, extractive features involve the excavation of ore and associated waste which often leads to significant surface disturbance and generates large volumes of sediment. However, much of this excavated material is then transported to either processing or waste sites, so that the landscape impact of the extractive class largely relates to surface disturbance rather than to sediment deposition. The method of ore extraction also affects the extent of surface disturbance. Subterranean extraction along a mine adit, for example, may create only minimal surface disturbance, particularly when compared with opencast or hydraulic mining techniques, such as hushing. To reflect this level of detail and variability, each feature was also assigned a sub-category label describing the specific feature to which it relates (e.g., shaft, opencast, hush).

In order to consider potential landscape impacts we evaluated the changing magnitude of lead ore output for individual mines. Government mineral statistics provide annual lead production values by named mine for the period 1845-1913 and have been used by other authors to examine temporal patterns in production for specific mining companies working on Alston Moor.[39] To extend this time series, additional output statistics were obtained largely from assorted published and unpublished record office sources containing incomplete records of ore output for selected mines.[40] All relevant records were then tabulated and attributed with mine names, outputs and national grid references, to generate the most comprehensive and detailed compilation possible for the study area. Comparative regional and UK-scale output statistics were also collected, including county-level summaries for Cumberland,[41] County Durham[42] and Westmorland.[43]

DISTRIBUTION AND CHARACTER OF HISTORICAL LEAD MINING OPERATIONS

LANDSCAPE-SCALE SPATIAL DISTRIBUTION OF MINES AND RELATED FEATURES

By linking documentary research to the spatial database of mining features, a total of 465 named mines were identified within the overall study area (Fig.

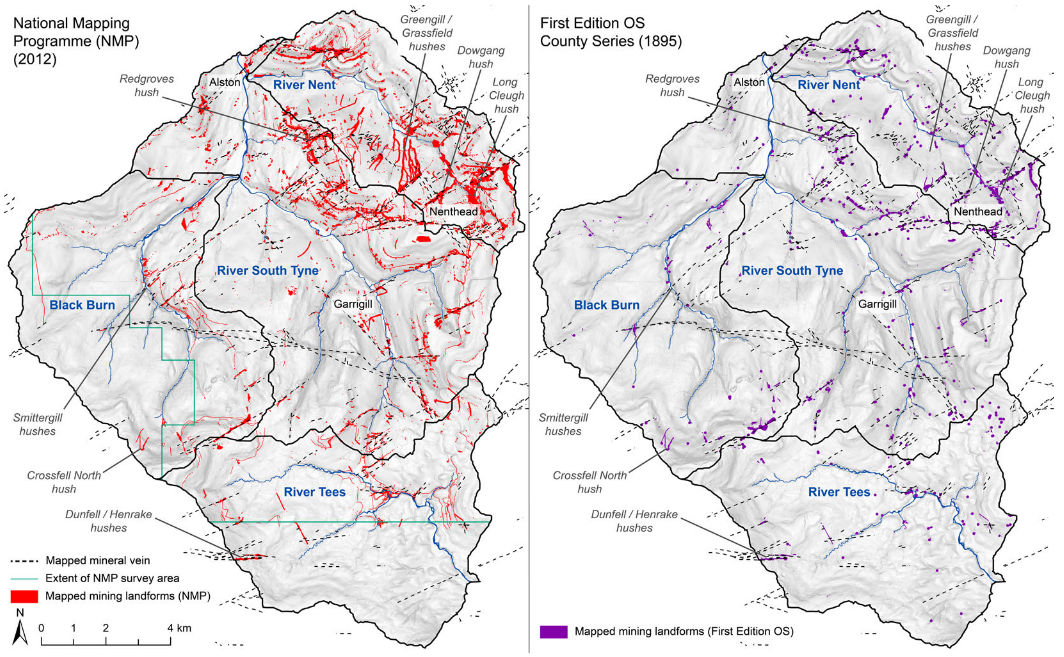

FIG. 3
Distribution of surface lead mining features recorded by the National Mapping Programme (NMP) (left) and mapped from the 1st Edition OS map series from 1859-1895 (right) (NMP data © Historic England; DEM data © GetMapping 2009).

1). The South Tyne catchment contained the most named mines (34%), followed by the Nent (28%), Tees (22%) and Black Burn (17%). When adjusted by catchment area, the Nent was by far the most intensively mined relative to its size, with an average of 4.36 named mines per km^2. In comparison, the Tees recorded 2.19 named mine workings per km^2, compared with 2.17 for the South Tyne and only 1.62 for Black Burn (Table 1).

There are significant clusters of mine workings named in the upper Nent valley, particularly around Nenthead, as well as in the lower catchment around Blagill (Fig. 1). In the South Tyne, the density is highest around Tynehead in the upper catchment and to the northeast around Middle Fell. Black Burn has notable concentrations along the headwaters of the main river and Cash Burn, as well as around Smittergill Head and downstream of the confluence with Smittergill Burn in the middle catchment. The cluster of mines in the upper reaches of Black Burn extends across the watershed into the upper Tees catchment, with an additional concentration near to Great Dun Fell further south along the escarpment ridge. Further significant densities of named mine workings are found around the confluence between the River Tees and Trout Beck, as well as downstream near Crook Burn.

The National Mapping Programme (NMP) recorded 12,371 individual surviving features relating to lead mining from the c. 80% of the study area which it covered, representing an average of 78.5 features per km^2. Significant concentrations of lead mining features were identified towards the north-east and east of the area, especially within the Nent and eastern portion of the South Tyne catchments (Fig. 3). Overall densities within the Black Burn and Upper Tees areas were markedly lower, although with sizeable concentrations around the headwaters of each catchment, as well as around Rotherhope Fell Mine in the lower reaches of Black Burn and at the confluence of the River Tees and Trout Beck. This pattern is reflected in the corresponding proportion of each catchment that has been disturbed by mining, with 4% of the Nent area relating to surface mining features, compared with only 1% for the South Tyne, 0.8% for Black Burn and 0.7% for the Upper Tees (Table 1).

Since the 19th century, OS surveys have recorded only those larger mining-related features which were relevant for inclusion on a county-scale administrative map, such as operational and 'disused' mine

TABLE 2
Summary of mining feature classification by individual catchment area.

Catchment		Extractive		Infrastructure		Processing		Smelting		Waste	
		1st Edition	NMP	1st Edition	NMP	1st Edition	NMP	1st Edition	NMP	1st Edition	NMP
Nent	Feature count	120	1433	209	183	10	803	4	41	138	2110
	Area (km^2)	0.09	0.45	0.02	0.02	0.00	0.08	0.01	0.01	0.43	0.61
	Percentage of catchment area (%)	0.31	1.52	0.06	0.07	0.00	0.27	0.02	0.04	1.47	2.10
South Tyne	Feature count	195	2059	152	236	12	866	3	30	165	2491
	Area (km^2)	0.05	0.24	0.01	0.03	0.01	0.11	0.00	0.00	0.20	0.37
	Percentage of catchment area (%)	0.07	0.33	0.01	0.04	0.02	0.15	0.00	0.01	0.28	0.51
Black Burn	Feature count	87	335	148	90	5	220	1	3	73	409
	Area (km^2)	0.06	0.05	0.01	0.03	0.00	0.05	0.00	0.00	0.13	0.11
	Percentage of catchment area (%)	0.12	0.17	0.02	0.09	0.01	0.17	0.00	0.00	0.26	0.36
Tees	Feature count	81	320	76	49	5	294	0	0	65	399
	Area (km^2)	0.06	0.02	0.00	0.01	0.00	0.07	0.00	0.00	0.06	0.08
	Percentage of catchment area (%)	0.13	0.07	0.01	0.03	0.01	0.27	0.00	0.00	0.13	0.34
Total area	Feature count	483	4147	585	558	32	2183	8	74	441	5409
	Area (km^2)	0.26	0.75	0.04	0.08	0.02	0.30	0.01	0.01	0.82	1.18
	Percentage of total area (%)	0.13	0.48	0.02	0.05	0.01	0.19	0.00	0.01	0.42	0.75

locations; this means that the total number of mining-related features mapped from this source is markedly lower than from the NMP survey (Table 1). However, the spatial distribution of features visible on the First Edition OS mapping and the NMP data are similar (Fig. 3). This suggests that they do reflect the overall pattern of mining activities, with their distribution being largely controlled by the arrangement and productivity of mineral veins within the study area. The underlying geological structure is paramount in determining where the mineral veins occur and, by extension, where the greatest disturbance due to mining activities has taken place.

Quantifying the nature and impacts of surface disturbance

The classification of mapped mining features described above also indicates the nature and extent of surface disturbance. Most of the mapped features from the First Edition OS survey relate to infrastructure associated with mining operations, primarily due to the high number of buildings and structures (Table 2). Extractive features form the next most frequently identified class, followed by the waste, processing, and smelting classes. The classification of the NMP data shows some significant differences which relate to the methods of survey carried out. Infrastructure features are relatively poorly represented in terms of the number of mapped features, for example, when compared to the waste, extractive, and processing classes (Table 2).

When analysed in terms of area impacted, waste features dominate both the First Edition OS and NMP datasets (Table 2; Fig 4). Extractive features are the next most significant class in terms of areal coverage, with the processing, infrastructure and smelting classes being relatively negligible by comparison. Analysis of the broad classification of features on a catchment scale basis shows that the overall trends in the number and area covered by features within each class are relatively consistent (Table 2; Fig. 4). However, there are some notable differences between catchments that suggest both variations in mining activities and the differential survival of mine sites through to the present day. For example, smelting operations were concentrated at only four centralised smelt mill locations in the Nent and South Tyne catchments: Nenthead, Blagill, Tynehead and Cash Burn (0.01 km^2).

The physical impacts of the mining process vary considerably. Extractive features can generate substantial volumes of waste sediment,[44] which is then either stockpiled in features associated with waste or sent for processing to refine the ore further prior to smelting. In the context of historical mining, this

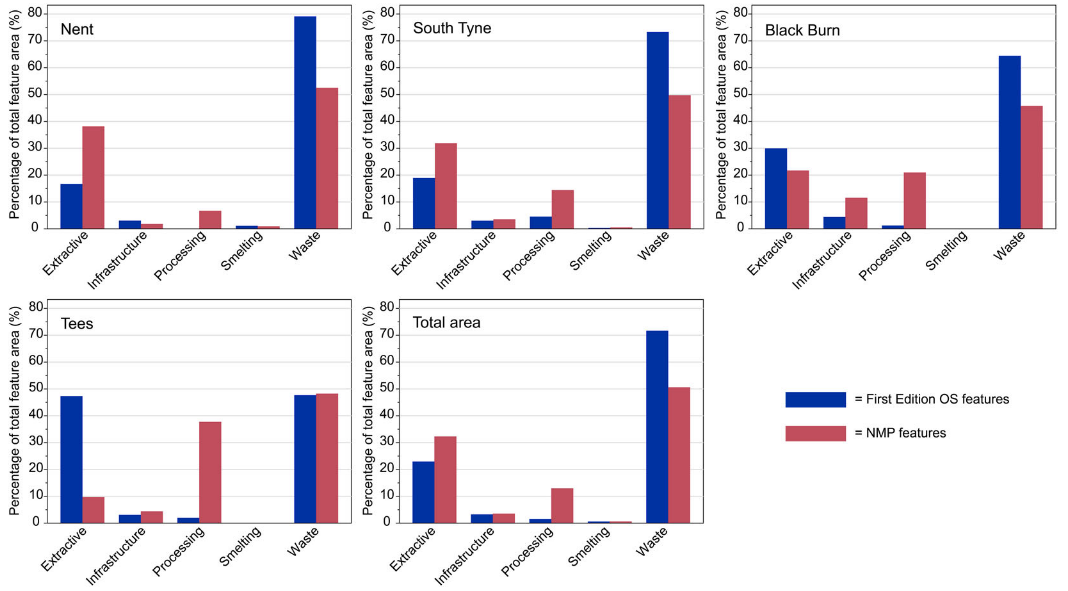

FIG. 4
Percentage of total mapped feature area for each of the five classes within the broad mining feature classification scheme. Data are displayed by individual catchment and for the overall survey area, including results from both the First Edition OS mapping and the NMP survey.

processing stage typically involved the generation and release of large volumes of highly contaminated metalliferous fine sediment into the wider catchment.[45] By contrast, features relating to smelting tend to occur at discrete, centralised locations and generate less waste sediment, even if the environmental impacts of the smelting process could be extensive, due to the potential for the airborne transport of heavily contaminated fine particles across large areas.[46] Features relating to infrastructure include structures that were utilised as part of mining operations but had more limited physical impact in terms of their ground footprint. However, certain infrastructure features, such as tramways and roads, controlled the redistribution of mine sediments to different areas of the landscape and should therefore be considered as important anthropogenic transport pathways, complicating the direct association between site of extraction and associated landscape change.

THE DEVELOPMENT OF THE MINING LANDSCAPE, 1700-1948

Combining the spatial distribution of named mines with the time series record of ore production allows a reconstruction of how the mining landscape developed during the period 1700-1948. In this section, spatio-temporal variability in ore outputs is first described, before the significance of hushing, an earlier and largely undocumented mining technique, is discussed. The wider economic and political factors driving the observed landscape-scale changes in mining operations and productivity are then considered, followed by a discussion of the societal context and implications of lead mining in the North Pennines.

PHASES OF CHANGE

Of the 465 named mines identified within the study area, only 141 (30%) could be linked to documented ore production (Fig.1; Table 1). This relatively low proportion is likely to relate to a combination of factors, among them the differential survival of documentary records. Many of the named mines may also relate to unsuccessful trial workings, so quantified mine outputs are almost certainly an underestimate of total waste sediment production. The subset of 141 is, however, likely to represent the most significant and productive mines.

The total recorded lead ore output from all named mines within the study area during the period 1700-1948 was 443,454 tonnes, an average of over 1788 tonnes of lead ore per year (Fig. 5). Production from named mines within the study catchments throughout the first half of the 18th century is negligible, with only minor peaks in the mid-1720s and 1730s.

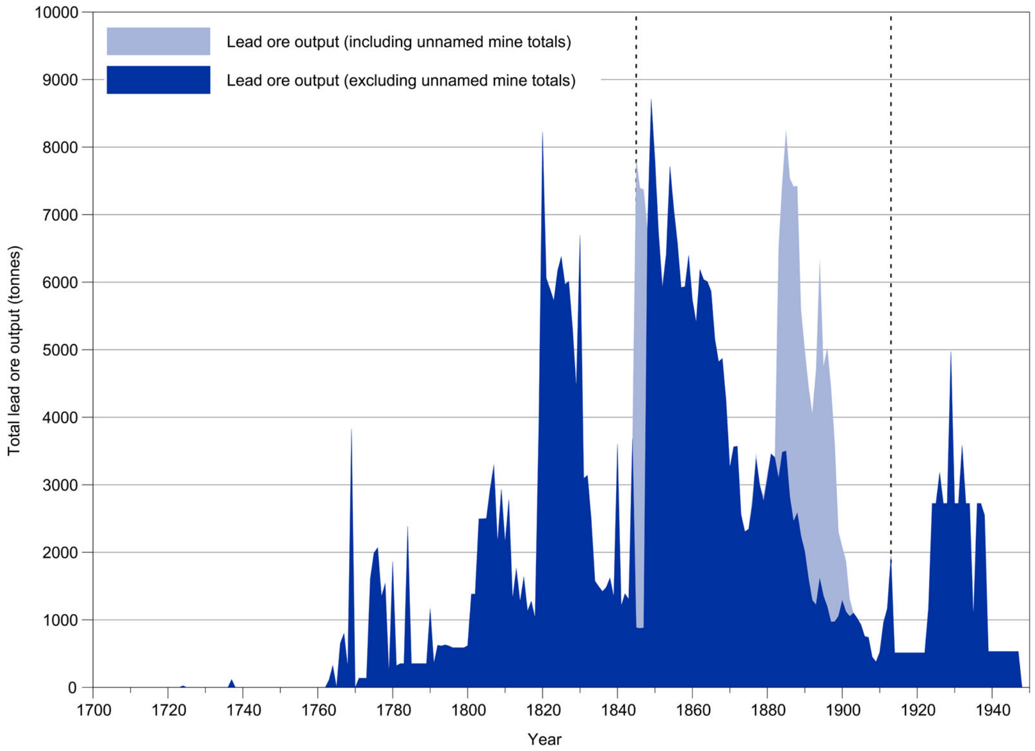

FIG. 5
Total lead ore output for named mines within the study catchments during the period 1700-1948. Additional production peaks relating to general entries with no exact specified location are also included for reference. The two vertical dashed lines represent the start and end of the recording of annual government mineral statistics (1845-1913).

However, this absence does not necessarily indicate that no intensive mining was taking place. Recorded mine outputs are intermittent prior to the introduction of government mineral statistics in 1845 and, while a greater number of records do survive from the mid-18th century onwards, the intensity of earlier mining generally needs to be reconstructed from archaeological evidence.

Documented production increased significantly from 1763 onwards, rising to a sharp peak of over 3700 tonnes in 1769, before a number of lower but pronounced peaks and troughs throughout the 1770s and 1780s. Following a plateau in production of around 500-600 tonnes per year through the 1790s, output increased again for a sustained period between c.1800 and 1815. Despite a decrease between 1815 and 1819, production then soared to over 8000 tonnes in 1820, the second highest annual output during the entire 248-year study period. This major increase in output lasted until a subsequent collapse in the early to mid-1830s, which, with the exception of a peak in 1840, lasted until c.1845 and the start of published government mineral returns (Fig. 5).

The years between c.1845 and 1865 saw consistently high lead ore output, with annual production peaking at 8576 tonnes in 1849 and being maintained at over 5500 tonnes per year for most of the remaining period (Fig. 5). A sharp decline in the 1870s saw production drop to just over 2200 tonnes in 1874, before rising again slightly by the early 1880s. From 1885 onwards the recorded output from named mines continued to fall sharply, reaching a low of only 373 tonnes in 1909, the lowest recorded annual output for approximately 120 years. In contrast, lead ore output from records with no definite spatial location, which includes those assigned to the London Lead Company and those listed as coming from 'Alston Moor', show a major additional peak in production between c.1882 and 1902. This additional production reached a high of 8126 tonnes in 1885, before declining then recovering to a secondary peak of 6254 tonnes in 1894. Since the LLC abandoned their Alston Moor leases in 1882, the majority of this additional unassigned production will relate to mines in the Tees catchment. However, the LLC maintained leases throughout Teesdale and so this output cannot be securely assigned to the portion of the upper catchment within the current study area.

Production recovered from the 1909 low to reach an output of nearly 2000 tonnes in 1913, before dropping sharply to an average of just over 500 tonnes per year between 1914 and 1922 (Fig. 5). This plateau represents the averaging of sparse output records throughout the wartime and early post-war years, with the cessation of detailed government returns in 1913 for a combination of reasons relating to national security and resource prioritisation during the Great War. The 1920s saw another increase in production, reaching a peak of 4897 tonnes in 1929 before a subsequent decline throughout the 1930s. By the outbreak of the Second World War in 1939, annual production had dropped back to just over 500 tonnes. The limited number of recorded outputs during the early 1940s again reflects the privations and intelligence concerns of wartime Britain, set against the backdrop of an already declining industry. Despite this, the war years did see the treatment of dumps of lead tailings at Nenthead, primarily for zinc ore extraction to support the war effort.[47]

By combining the mapping analysis with documentary research into mine production outputs, a clearer picture emerges of spatiotemporal variation in mining operations and its changing intensity (Fig. 6). In general terms, there were clear concentrations of high producing areas in the middle and upper Nent, in the middle reaches of the South Tyne, along the watershed between the Black Burn and Tees catchments, and in the lower Black Burn catchment. Although in general the study area contained a high number of small, low producing mines and a much smaller number of very high producing mines, there was also some variation in this pattern. For example, the Nent had a high proportion of medium and high producing mines, whilst the South Tyne had a much higher number of low producing mines.

Analysis of detailed output trends at 25-year intervals indicates that the Nent and lower South Tyne catchments dominated production during the 18th century (Fig. 6). Peak output continued to be from mines in the middle and upper Nent during the early 19th century, although with a concurrent overall increase in the number of productive mines operating throughout all of the catchment areas. The period from 1850-1874 saw the Nenthead mines again producing the highest combined output from the overall study area, but with the Rotherhope Fell mine in the lower Black Burn catchment also now recording comparable levels of lead ore. The later 1800s saw the consolidation of recorded production into far fewer individual mines, a pattern that was to continue and develop into the 20th century (Figs. 6 and 7). By the 1920s, production was almost exclusively limited to output from Rotherhope Fell and Nentsberry mines, indicating that direct mining impacts contemporary with this date would be largely restricted to these locations and their downstream catchment areas.

Quantifying earlier undocumented mining operations: the importance of hushing

Records relating to ore production for the 18th and early 19th centuries are relatively sparse compared with those from 1845 onwards, when statutory government recording was introduced. Here archaeology provides useful insights, particularly in terms of surface mine workings, but translating the spatial distribution of mapped mining features into quantified disturbance from defined time periods is challenging, not least because of the difficulty in assigning firm dates to relatively undiagnostic extractive features. However, hushing, a surficial hydraulic mining technique which had dramatic impacts on the wider landscape, is one category of surface feature that can be broadly dated with a greater degree of confidence.

Hushing involved the construction of an upslope reservoir and the periodic breaching of the dam to allow the flow of water to remove overburden and rock waste that had been previously loosened through hand excavation.[48] A metal grate was typically positioned towards the base of the hush in which the denser ore material would settle ready for collection. The repeated application of this method led to the creation of huge surface gullies (‘hushes’) and the mobilisation of huge volumes of waste sediment, including both overburden and rock waste (Fig. 8). Hushing was typically conducted for one of three purposes: prospection for new ore deposits, exploitation of known ore deposits, or the reworking of wastes from subterranean workings.[49] The large earthwork hushes characteristic of the North Pennines mainly relate to the first two of these; the morphology of the hush and its relationship to mapped mineral veins often indicates whether it was originally intended for prospection or extraction.

Research into early mining in Welsh[50] and Spanish[51] orefields suggests that the practice of hushing has been used since at least the Roman period but, as we have discussed above, large-scale hushing in this area is currently thought to date mainly between the late 17th century and the early 19th century. Bainbridge[52] comments that the practice had largely ceased and was usually prohibited in mining leases by the 1840s because the creation of massive surface gullies and vast quantities of waste sediment often damaged nearby land and watercourses. On Alston Moor, the last hushes producing ore were probably those at Greengill and Redgroves in c.1820-30.[53]

A small number of hushes are mentioned in surviving lease documents. Those at Smittergill in the Black Burn catchment can be linked to leases of 1803 and 1821, although they are thought to be amongst the latest grants to permit hushing on Alston Moor.[54] Output

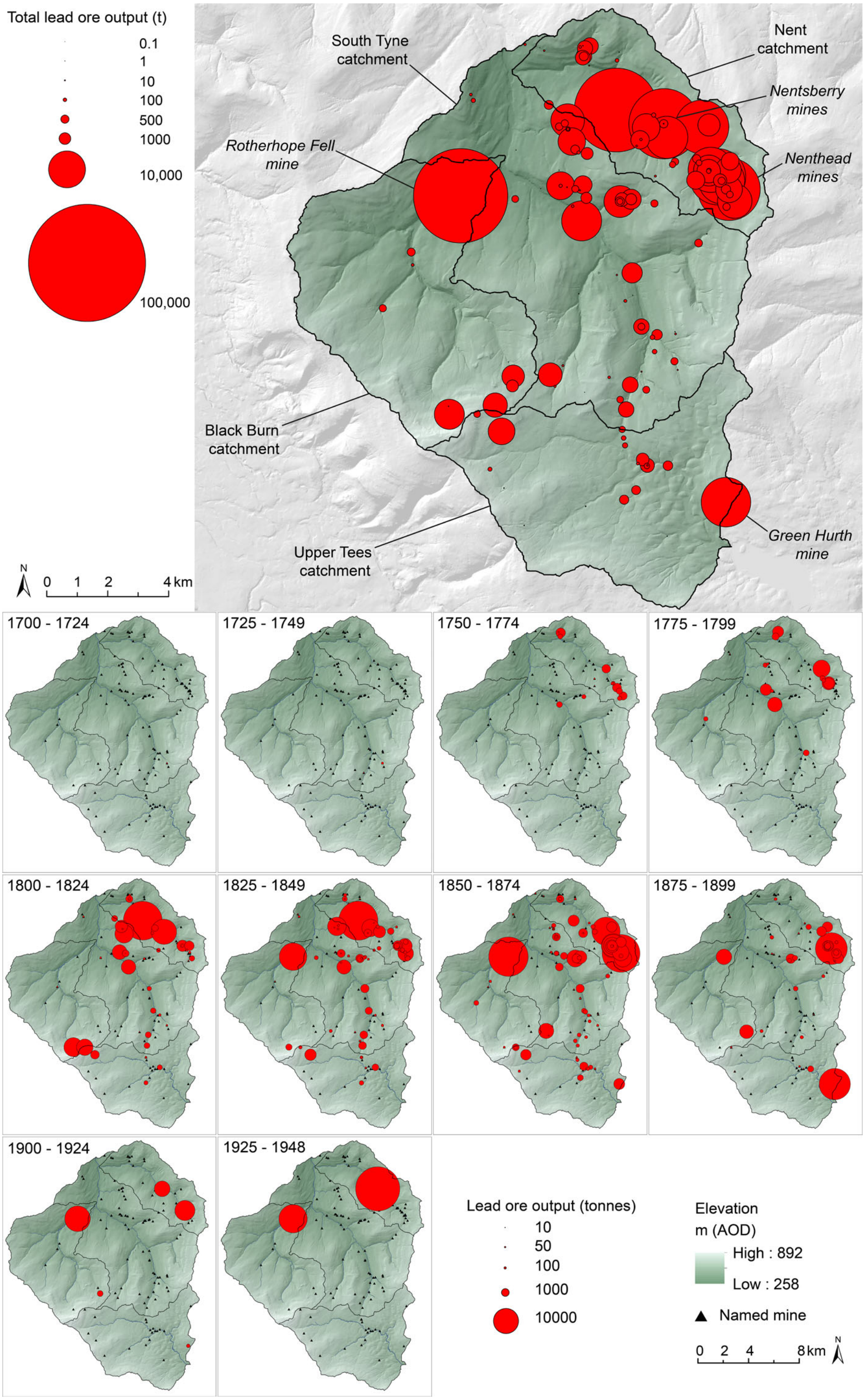

FIG. 6
Maps showing proportional symbols representing total lead ore output in tonnes for the period 1700-1948 (top) and time series of outputs in 25 year intervals (bottom) (DEM data © GetMapping 2009).

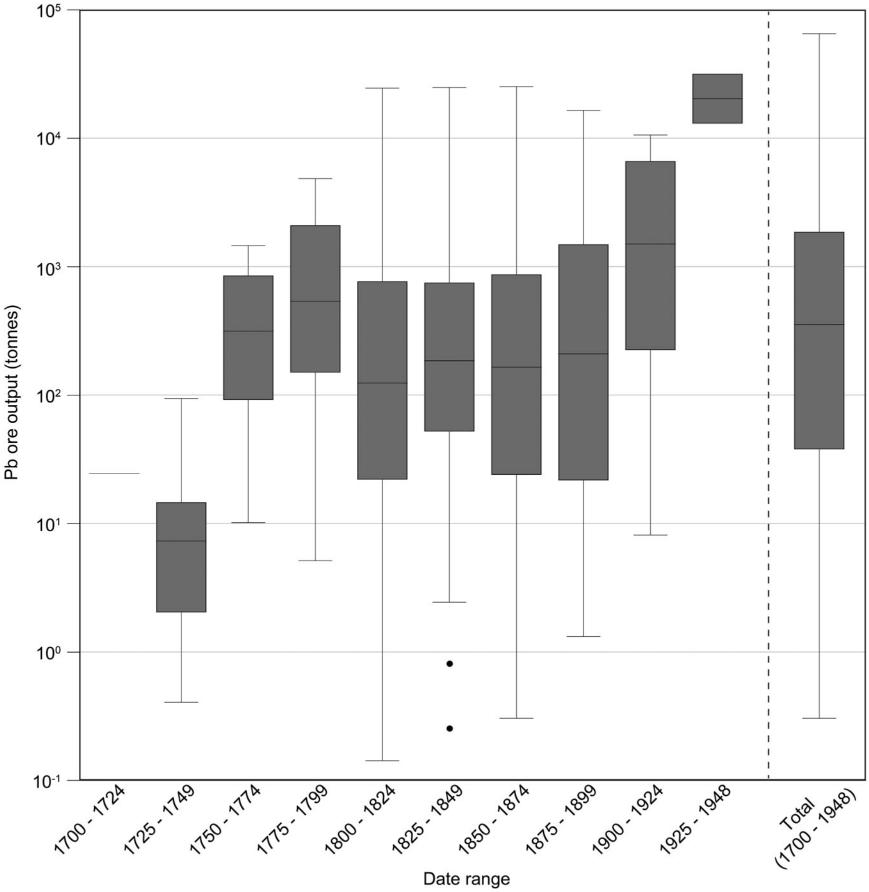

FIG. 7
Box plots showing ore output by 25 year interval, indicating the centralisation of output into a small number of high producing mines by the 1920s onwards. Horizontal lines within the boxes represent the median value, the length of the box represents the interquartile range (IQR), while the whiskers define all data within 1.5 IQR of the nearest quartile. Data points beyond 1.5 IQR are shown individually.

is also recorded from the hushes at Greengill in the Nent catchment between 1745 and 1777, with further intermittent records present until 1839. There was also a lease for the Redgroves Hush area prior to 1736 but it is likely that most of the hushing activity took place here between c.1790 and 1832.

Available documentary evidence of hushing represents only a tiny proportion of the 120 hushes which have been recorded for this research within the study catchments.[55] Spatial variation is again apparent within the distribution, with 59 (49%) being located within the South Tyne catchment, compared with 30 for the Nent (25%), 17 for the upper Tees (14%) and only 14 for Black Burn (12%). Mapped hushes range in length from just 0.01 km up to 1.75 km, with a mean length of 0.30 km. Hush widths vary from less than 0.01 km to 0.42 km and have a mean value of 0.07 km.

Although the average area of the mapped hushes is similar between catchments, their landscape impact differs. The total area covered by hushes is highest within the Nent catchment at ~451,400 m^2, compared to only ~297,350 m^2 for the South Tyne, despite this catchment having almost twice as many examples. The hushes within the Tees catchment covered an area of ~122,200 m^2 and those within Black Burn an area of just ~70,600 m^2. These differences highlight the presence of a series of very large hushes within the Nent in particular, with 80%(~359,600 m^2) of the total hushed area within that catchment relating to eight individual hushes near Greengill, Dowgang, Grassfield and Long

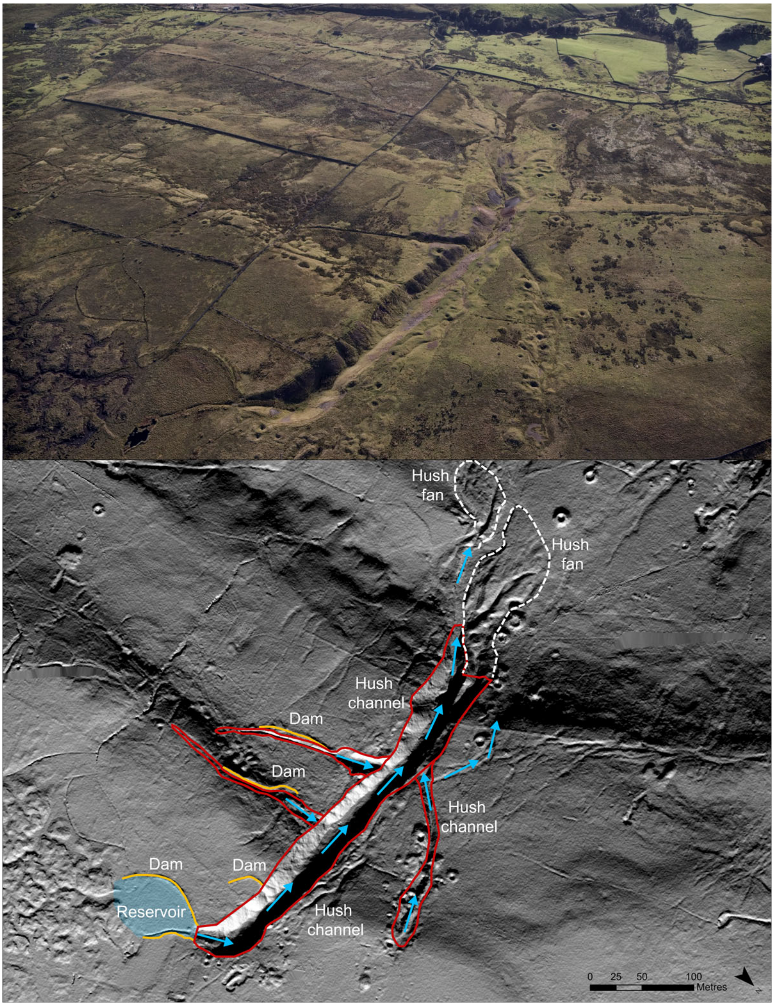

FIG. 8
Oblique aerial photograph (top) and airborne lidar hillshaded DTM (bottom) of Redgroves Hush in the South Tyne catchment (photograph (NMR_20678_52) and lidar data © Historic England). The main hush channel measures over 400 m in length and nearly 40 m wide in places, and displaced an estimated 222,000 tonnes of material. The shafts and surface workings to the north predate the main hush. Mapped hush channels (red), dams (orange), reservoir (blue), deposition fans (white) and water flow directions (blue arrows) are based on Fairbairn (1992).

Cleugh (Fig. 3). Very large hushes can also be identified elsewhere. For example, the area covered by the large hush at Redgroves represents 20% (~60,200 m^2) of the total hushed area within the South Tyne catchment, Dunfell and Henrake hushes together comprise 44% (~54,100 m^2) of the Tees hush area, and Crossfell North represents 21% (~14,800 m^2) of the total hush area for the Black Burn catchment. These large hushes reflect the exploitation of particularly rich mineral deposits, whilst the broader distribution of smaller hushes typically indicates prospection for veins within less mineral rich areas. In total, ~941,500 m^2 has been affected by hushing, representing 0.5% of the entire study area extent.

The scale of impact of hushing on the landscapes of the North Pennines was immense. Estimates of the magnitude of disturbance generated through various mining techniques indicate that hushing produced approximately 1.8 times as much waste sediment as subterranean adit mining.[56] Not only did the technique require all overburden and surrounding rock mass to be removed alongside the vein material, but

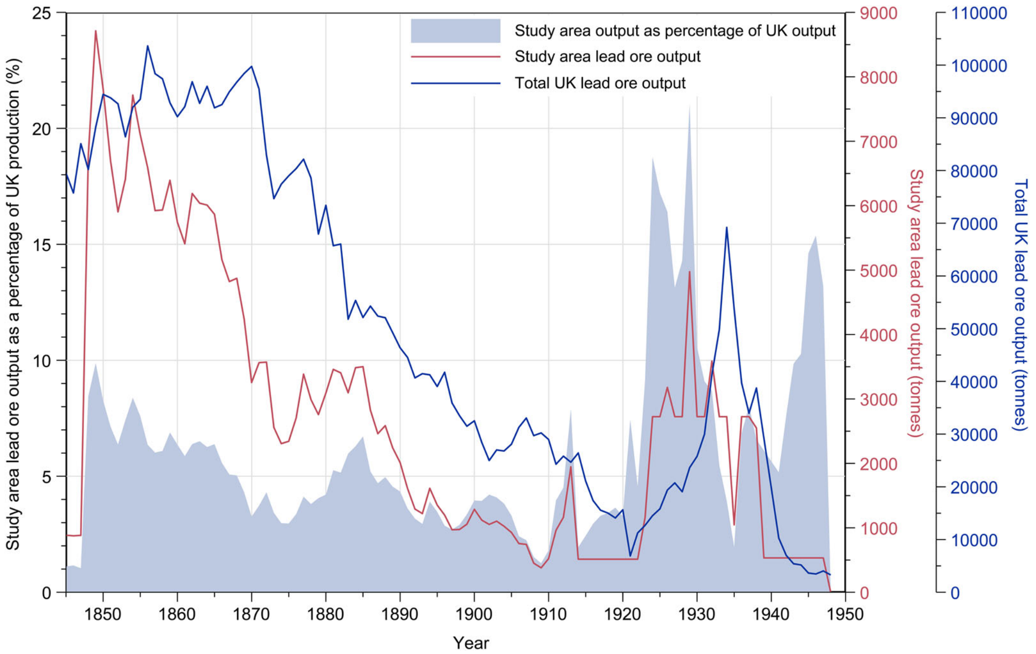

FIG. 9
Comparison of study area output and UK national total output for the period 1845-1913. UK output data were obtained from Burt (1984). Overall UK output was not published in 1939-40 due to the outbreak of the Second World War.

the physical impact of hushing was also amplified by the high degree of connectivity between waste hushed sediments and the wider river network. Less than 1% of the material originally mobilised through hushing is still stored in deposition fans and waste dumps at the outlet of the hushes; the vast majority of the sediment (99%) has since entered river channels and been dispersed downstream.[57]The implications of this for both short- and long-term river channel response are considerable, with many of the major rivers draining the North Pennines showing characteristic patterns of historic aggradation and channel adjustment as a consequence.[58]

Changing fortunes: drivers of temporal variability in mine productivity

The development and subsequent collapse of lead mining in the North Pennines was the combined product of the physical and social characteristics of the local area and the wider national context of fluctuations in the UK lead industry. Locally, the chance discovery of productive veins or increased investment in new mining technologies by companies working in the area undoubtedly had an influence on the fine-scale temporal variation visible in ore outputs during the period 1700-1948. However, the Pennine miners were also operating within the wider context of the overall UK lead industry, which itself was partially reliant on global mining practices and prices.

Comparison with the available data for the entire United Kingdom shows that, despite being a relatively small area of the North Pennines (<200 km^2), output from mines in the study area accounted for an average of 5.9% of the entire UK output between 1845-1913, even reaching over 20% of national production in 1929 (Fig. 9). Temporal variation in local output largely followed the broader national context, with both data sets showing a consistent, albeit fluctuating, reduction in output from the mid-19th century through to the early decades of the 20th century. These were the declining decades of the lead industry, and although there was some recovery between c.1922-1939 (slightly earlier than a similar increase in overall UK production in c.1935), the ultimate fate of the North Pennine mines was inextricably linked to both internal factors, such as the exhaustion of readily accessible high quality ore bodies, and broader national and international influences, such as competition from emerging foreign markets.

The 17th and 18th centuries saw significant changes in the North Pennine orefield and throughout

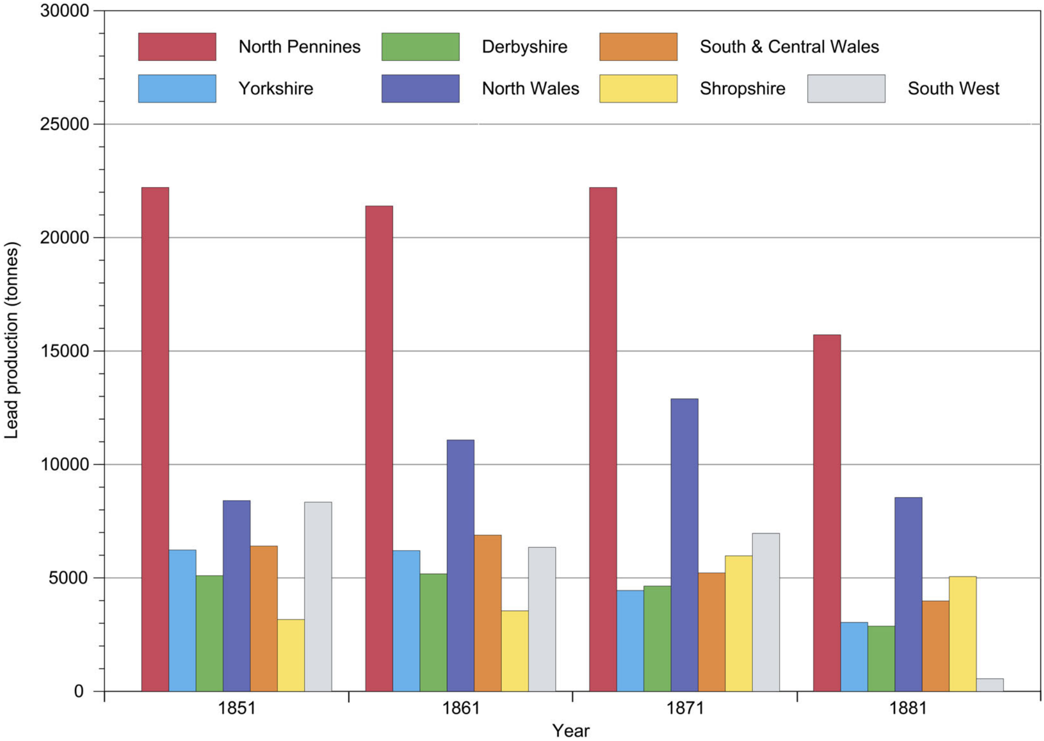

FIG. 10
Lead production by UK region, 1851-1881, showing the dominance of the North Pennines orefield and the decline in production during the later 19th Century (data from Burt 1984, Table 8).

the UK lead mining industry. The Civil War (1642-1651) provided both disruption and opportunity for the industry; trade links were interrupted but the need for a ready supply of lead shot triggered a corresponding rise in lead prices.[59] There were important changes too in the legislation around the ownership of mineral deposits and rights to their exploitation. The high silver content of the lead ores on Alston Moor meant that the mines here had historically been deemed to be 'Royal'; and this terminology persisted until the two Royal Mines Acts of 1689 and 1693. These Acts stated that any mineral deposits were now the property of the landowner and not the Crown, thereby paving the way for the growth of large, private mining corporations.[60] These same companies, including the Blackett-Beaumont families in the Allendales and the London Lead Company on Alston Moor, would go on to dominate the lead industries of the North Pennines until the late 19th century.[61]

The London Lead Company, also referred to as the 'Quaker Company' or the 'Governor and Co.', was initially chartered in 1692.[62] The company had already taken out leases at the Blagill and Tynehead mines in the North Pennines by 1696, but it was during the late 18th century that they came to dominate mining around Alston Moor. The company's operations were primarily centred on the villages of Nenthead and Middleton-in-Teesdale, with the settlement at Nenthead in particular being almost entirely re-planned and developed during the early 19th century.[63] The dominance of the London Lead Company on Alston Moor was paralleled in Allendale and Weardale by the Blackett-Beaumont Company, again a family enterprise with its origins in the late 17th century. The Blackett-Beaumont Company became the largest single employer in the overall North Pennine region during the 18th and 19th centuries.[64] Between them, these two companies dominated the lead mining industry of the area during this peak period of production, although there were still numerous smaller enterprises in control of leases for individual mines.[65]

The growth of lead mining in the UK during the 18th century was driven by the financial impetus provided by the major mining companies and technological developments that improved the efficiency of

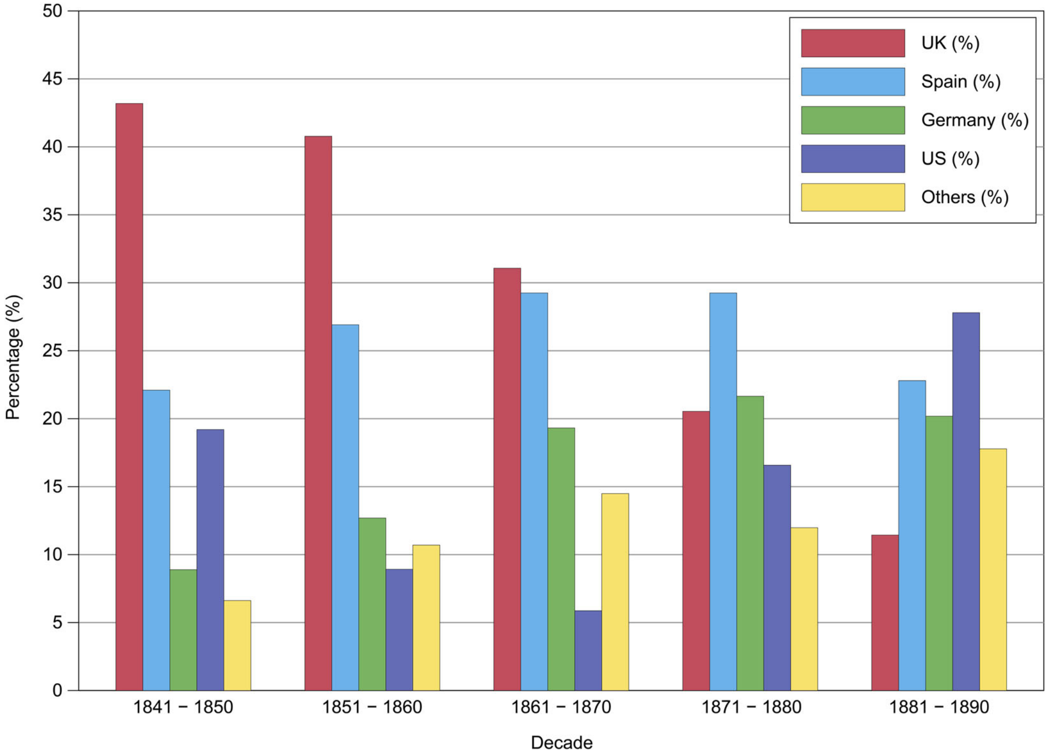

FIG. 11
Percentage of World lead smelter production by main contributing country, 1841-1890 (data from Burt 1984, Table 14). Note the decline in UK production in comparison to the other emerging markets.

mine drainage, ore extraction and processing.[66] These developments were enabled by the broader international context of the 18th-century lead mining industry, including a notable expansion of British trade links and a corresponding decline in output from Spanish and German lead mines. The UK lead industry then continued to expand and prosper during the early to mid-19th century due to increased national industrialisation and urbanisation. The country remained the world's leading producer of lead ore during this time, with the northern counties and the North Pennines in particular being the primary contributors (Fig.10).

National growth during the mid-1800s was significantly challenged by the rapid revival of the Spanish lead industry in particular, later compounded by the growth of lead mining in Germany and the USA (Fig.11). Due to this increased international competition, the price of lead fell from £21 per ton in the 1850s to just £9.50 per ton in the 1890s and it became cheaper for the UK to import ore from abroad than to pay local extraction costs.[67] The collapse of British lead mining in the late 19th century was precipitous. The major mining companies surrendered their leases, the London Lead Company abandoning the area in 1882 and the Blackett-Beaumont Company quickly following suit in 1884.[68] Only the growing economic value of other minerals that had previously been considered unprofitable, such as zinc, barytes and fluorspar, cushioned the economic impact.

The London Lead Company leases were initially taken up by the Nenthead and Tynedale Lead and Zinc Company, and later by the Vielle Montagne Zinc Company of Belgium in 1896.[69] This latter company continued to extract lead and zinc from mines around Nenthead and markedly increased production at Rotherhope Mine further to the west (Fig. 6). Operations on Alston Moor never fully recovered from a shortage of miners during the First World War, and Vielle Montagne finally abandoned their lease in 1948. Isolated mining ventures did continue elsewhere in the North Pennines until the late 20th century, such as the fluorspar mines in Weardale, but these were never as spatially extensive as pre-20th century operations.[70]

BOOM AND BUST: VARYING ECONOMIC AND SOCIAL IMPACTS OF LEAD MINING

Alongside this transformation of the physical landscape, lead mining in the North Pennines had a profound and long-lasting impact on the local economy, society, and population. Time series data underlines the evolving organisation of the mining industry, revealing the switch from a landscape containing numerous small-scale private mining ventures to one dominated by the influence of large mining corporations by the mid- to late 19th century (Fig.7). This shift in the nature and control of the mining industry was accompanied by fundamental changes in the lives of both the miners and the wider local population, primarily as a result of the philanthropic business model adopted by the London Lead Company.

The comprehensive social policy of the London Lead Company impacted on all aspects of the miners' lives, from income and stability of employment, through to housing, education, health and recreation.[71] This emphasis on improving and maintaining the social welfare of the local population was due to a combination of factors, including a practical focus on maintaining productivity and limiting labour disputes, the need to provide for a burgeoning workforce based in a remote location which was isolated from major market centres, and an inherent degree of philanthropy.

The extent to which this philanthropic attitude to their workforce was inherited from the strong Quaker roots of the corporation has been the subject of some debate. Earlier historical studies of North Pennine mining argued that the Quaker influence on the London Lead Company's approach to their employees was considerable, underpinning much of their more charitable and benevolent decision-making.[72] However, recent reassessment of this issue has demonstrated that although several of the founding members of the Company were Quakers, their numbers and influence had declined considerably by the 1740s.[73] Importantly, other large contemporary mining companies with no Quaker origins, such as the Blackett Beaumont Company, also gave land and money to support education and church building, and had comparable wages and medical support packages for their employees. It therefore appears likely that Quakerism may have influenced the early activities of the London Lead Company, but that this influence declined rapidly, with their later philanthropic approach to the workforce being guided as much by capitalist principles.

Local population numbers of the North Pennines fluctuated considerably as the industry waxed and waned (Fig.12). The census figures for Alston with Garrigill parish show that the population increased sharply between 1801 and 1831, before a decline in the 1841 census that reflects the economic depression of the early 1830s.[74] The population had recovered by 1851 but afterwards went into a steady decline, followed by a more rapid fall by the late 19th century, especially after the major collapse of the industry and the associated depression in 1880-82. Although mining did continue at a reduced scale, the population remained relatively low and in decline until the later 20th century. Local variability in population flux was also an important factor, with the market town of Alston having a smaller population than the mining centre of Nenthead in 1861, but twice the population of Nenthead by 1951.[75]

These fluctuations in population indicate considerable movement of people into and out of the mining districts. However, miners in the North Pennines were largely local men in the 18th and 19th centuries,[76] and the statistics therefore tend to reflect local migration between neighbouring mining districts or into other northern industrial centres during times of significant decline in lead mining. For example, between the 1871 and 1891 census returns, Alston lost over 40% of its population (Fig. 12), with many moving away to seek work in the coalfields and ironworks of the lower Tyne, Wear and Tees.[77] Nevertheless, wider emigration did also occur, especially at times when lead prices fell sharply, so that residents of Alston Moor left for Canada in 1818 and the 1820s, as well as for America and Australia in the 1870s.[78]Internationalisation of the mining workforce came in the early 20th century with the arrival of the Vielle Montagne mining company. From 1903, foreign miners were brought in from across Europe to meet growing demand when the local supply of labour proved insufficient. The 1911 census for Alston with Garrigill parish confirms 62 foreign workers in total[79] but most of these men were to leave the district between 1919 and 1926, following a further depression in the industry as a result of the continuing decline in lead prices.[80]

Women were sometimes employed to work on the ore dressing floors but this was rare in the Pennine orefields after the 1840s; employment in the industry was dominated by men and boys over the age of nine.[81] Breakdown of the census figures by gender shows that these working practices were reflected in the overall population (Fig.13). The parish of Alston had a markedly higher proportion of males than both Cumberland and the national average until the collapse of the industry in the early 1880s. From the 1881 census onwards, the male proportion of the Alston population was consistently below the equivalent figure for Cumberland, and even in 1921 below the national average. Analysis by age group demonstrates a notable drop in the percentage of children and corresponding increase in the older population between 1851 and 1911 (Fig. 14). The age groups between c. 20 and 40 show a more complex pattern, with an initial late 19th century decrease then early 20th century increase, probably reflecting the

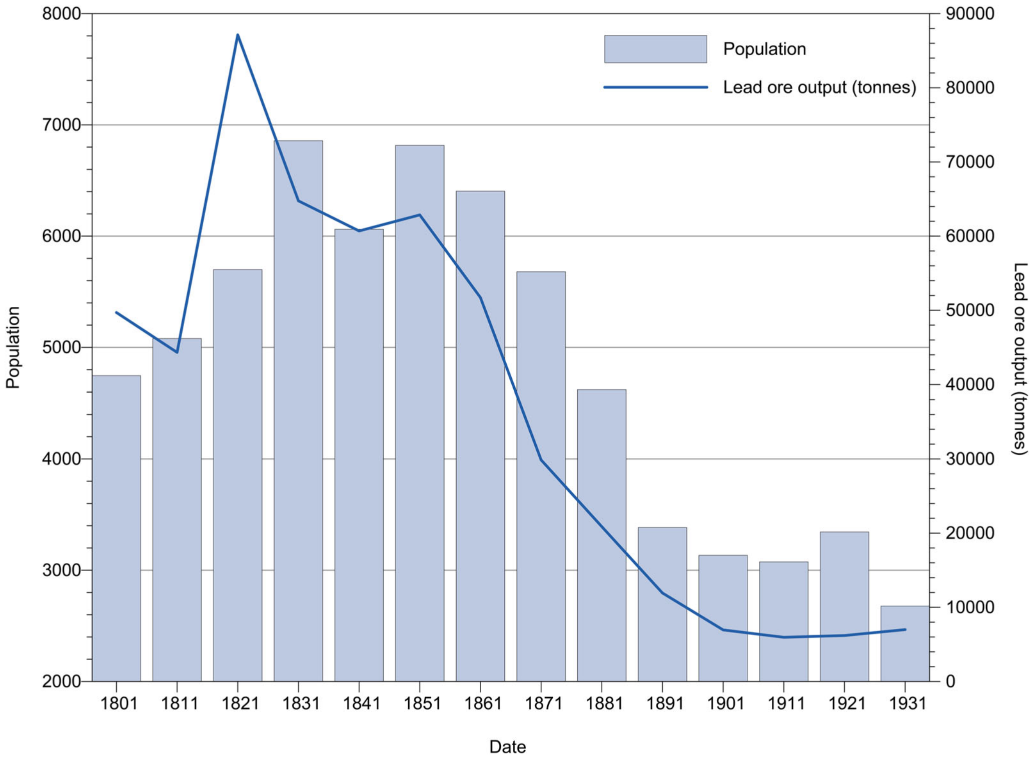

FIG. 12
Census population figures for Alston with Garrigill parish compared to estimated decadal lead ore output during the period 1801-1931 (census data from Vision of Britain website (2014), ore output data from Fairbairn (1993) and the Kingsley Dunham archive (D/Dun 1/12)).

collapse of the industry in the early 1880s and its partial recovery thereafter.

Despite the welfare policies of their employers, life as a lead miner was hard. The life expectancy of metalliferous miners was significantly shorter than non-miners living in the same location, coal miners, and the overall national population.[82] During the period 1837 to 1841, the average age of death of miners in Alston Moor, Allendale, Weardale and Teesdale was just 47.6 years, compared with 61 years for labourers in urban Carlisle, for example.[83] Earlier parish records for Alston Moor for the period 1798-1812 provide similar results, with an average age at death of 51.90 for a population of 245 adult miners, compared with 59 for all other adult males.[84] Premature deaths among metalliferous miners were usually attributed to pulmonary diseases, and in particular 'miners' asthma', a condition caused by dust inhalation leading to fibrosis of the lungs and later recognised as silicosis. However, accident rates were notably lower than in contemporary coal mines, especially in those areas controlled by the London Lead Company,[85] averaging just 1-2 deaths per year on Alston Moor between 1815 and 1920.[86]

The locations of earlier nucleated settlements, such as the market town at Alston, were not necessarily determined by the distribution of mining operations, especially in the middle to lower reaches of the major river valleys.[87] Miners working away at remote locations during the 18th and early 19th century initially lodged in rooms within isolated farmsteads or in purpose-built mine lodging 'shops', but as the industry developed and the workforce grew, additional housing was soon required. Smallholdings in the upper catchments typically consisted of a farmstead and around five acres of land, with the miners being encouraged to supplement and diversify their income through small-scale farming.[88] As housing pressure increased further, entirely new settlements were planned and built by the mining companies, turning groups of isolated farmsteads into entire villages, as occurred at Garrigill in the upper South Tyne valley.[89] Nenthead experienced perhaps the most significant change, developing from a small

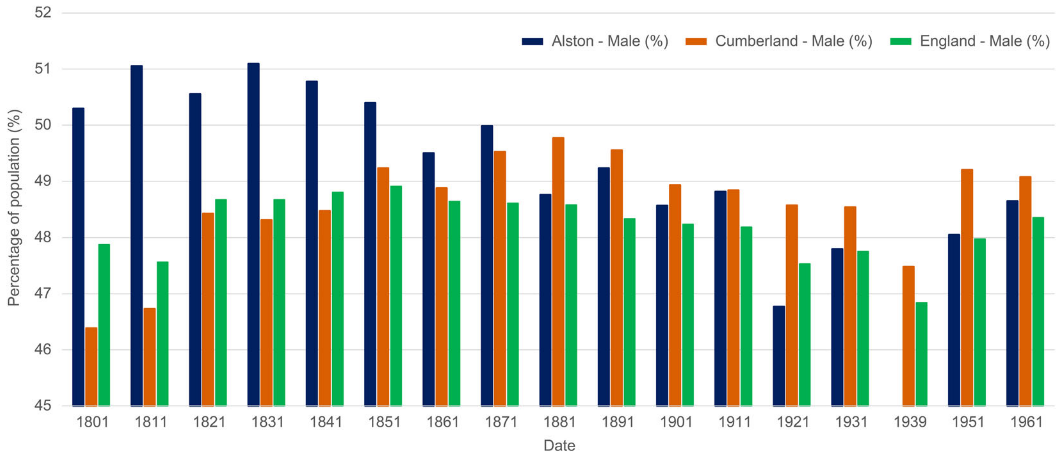

FIG. 13
Comparative census figures showing the percentage of the population that was male for Alston with Garrigill parish, Cumberland county and the entirety of England for the period 1801 to 1961 (census data from Vision of Britain website (2014)).

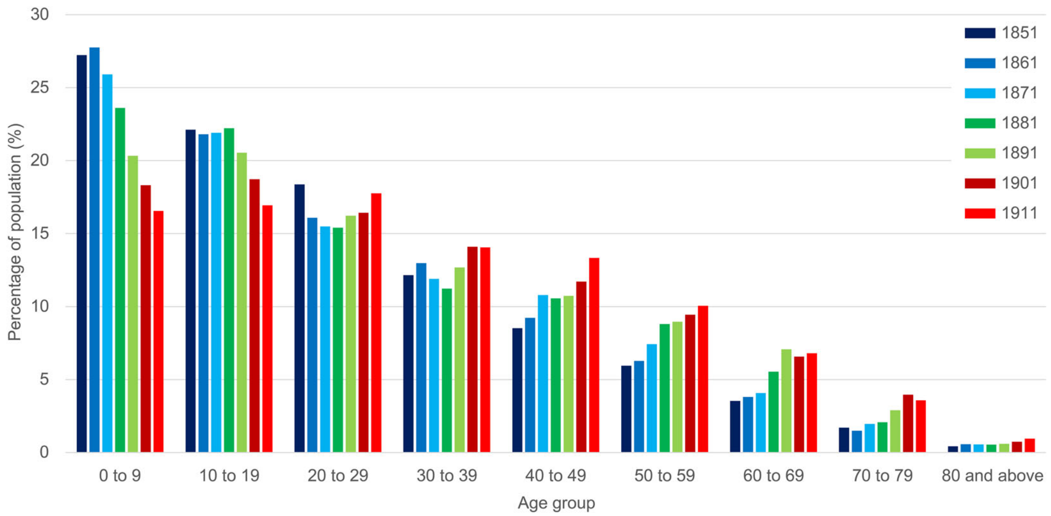

FIG. 14
Census population figures for Alston with Garrigill parish for the period 1851 to 1911, broken down by 10 yearly age group (census data from Vision of Britain website (2014)).

group of cottages and mine buildings in the later 18th century into a large-scale planned village by the late 1820s.[90] The new planned settlement at Nenthead contained 35 cottages, a market hall, school, shop, pub and chapel, all funded at a cost of around £3000 by the London Lead Company (Figs. 15 and 16). Occupancy rates for housing on Alston Moor fluctuated with the lead industry but were generally less than the national average and far lower than in contemporary urban areas. Nevertheless, there was overcrowding at times; census records show that 21% of dwellings in Nenthead housed eight or more individuals in 1851, with one property at Overwater being occupied by 14 individuals.[91]

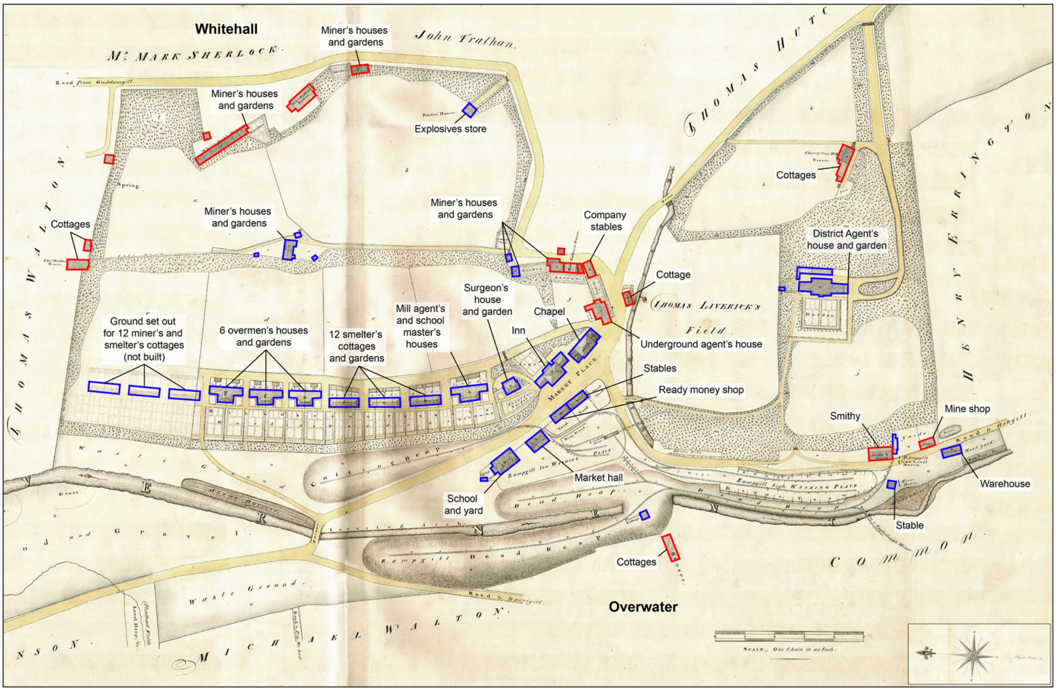

FIG. 15
Extract from the London Lead Company's 1828 estate map of Nenthead showing their redevelopment of the village (©The Common Room, ref. NEIMME/LLC/Plans/2/3). New buildings constructed by the LLC in the 1820s are shown outlined in blue. Buildings outlined in red were already present on the earlier 1820 Alston Moor estate map (CAS, ref. QRE 1/108) and show that the original settlement was initially divided into three much smaller clusters around Whitehall to the east, Nenthead in the centre and Overwater to the west (largely outside the map extent).

The impact of the social policies of the London Lead Company on the mining districts of the North Pennines was profound, mixing genuine concern for the wellbeing of their workforce with sound financial and business principles. Although wages in the lead industry were relatively low, especially in comparison to coal mining, the London Lead Company provided stable contracts and welfare support for their workers. The 'bargain' system of calculating salary payments based on the price of lead was updated by the Company to incorporate a closer link to food prices, ensuring that miners and their families were still able to afford food during periods of low production.[92] A regular monthly advance to each employee effectively guaranteed a minimum wage which was enough to cover core expenses.[93] A welfare fund, financially supported by the Company and based on regular subscriptions from each worker, provided benefits in case of ill health, accident or death, as well as an old age pension for those miners lucky enough to live beyond 65.[94] Importantly, the Company did what they could to keep their workers employed even when ore output from their mines was low. Alternative work in the form of exploration and infrastructure development was provided where possible and the Company sometimes operated at a heavy loss in order to maintain employment for their staff.[95] These policies did not entirely prevent widespread unemployment during periods of significant downturn, such as the depression of the early 1830s, and at times the Company had to reduce its staff in order to maintain its monthly advance payment scheme. However, they did undoubtedly contribute towards making employment with the London Lead Company a more stable and supported experience when compared with other smaller mining ventures or the relative volatility of employment associated with the contemporary coal industry.

The relative isolation of the North Pennine orefield from the major urban markets of northern England was an ongoing issue for the miners and mine companies alike. Longer transport distances tended to lead to higher prices for lead, food, and other goods. Acute food shortages could occur,

FIG. 16
Examples of surviving London Lead Company infrastructure in the village of Nenthead: (a) Wesleyan Methodist Church which was built in 1872-1873 to replace an earlier 1820s chapel on the same location. (b) The ‘Miners Arms’ public house, first built as part of the 1820s development of the village. (c) The ‘new’ Nenthead School, built in 1864 but with predecessors elsewhere in the village dating back to 1818. (d) The Reading Room, which was first built in 1833 before being rebuilt and enlarged in the 1850s. (e) Commemorative cast iron water fountain presented to company agent R.W. Bainbridge by the employees of the LLC in 1877.

especially when supplies of corn were limited and local millers inflated their prices.[96] The short-term response by the London Lead Company to a particularly severe food shortage in 1800 was to purchase an old lead mill and repurpose it as a corn mill, supplying subsidised grain to their workforce and later to the entire mining district.[97]At the encouragement of the Company, the local miners then set up their own Corn Association in the 1840s, which became a forerunner of the Co-operative Societies, allowing the workers to take an advance of money provided by their employers to purchase corn in bulk from Newcastle and transport it to Nenthead at subsidised rates.[98]

The remoteness of the orefield also stimulated the London Lead Company to invest heavily in the local and regional transport network. Following a report by John McAdam in 1823, the Alston Turnpike Trust was inaugurated in 1824 and the local road network had expanded significantly by the 1830s. The Alston Turnpike Trust had responsibility for 130 miles of roads, well above the average for the other trusts in Cumberland (25 miles) and the equivalent national average (19 miles).[99] Not only did this reduce transport costs when moving ore from the mines to the smelt mills and then lead from the smelters to the markets at Newcastle and Stockton,[100] but also it reduced the cost of food transport.[101] The rail network also developed in response to the lead mining industry, with lines being developed along Weardale to Stockton, north from Alston to Haltwhistle, and from Middleton-in-Teesdale to Barnard Castle. Plans for further connections linking Nenthead with Alston and Wearhead were never completed, with roads providing access instead.[102]

The influence of the London Lead Company also extended to personal development and social welfare. In addition to building schools throughout the mining districts, in 1818 the Company made it a condition of employment that a miner’s child should attend both day school and Sunday school regularly (Fig 16c).[103] This stipulation preceded the national government’s Education Act by 52 years and even then the Company’s leaving age was two years higher than the national requirement, being 12 years old for boys and 14 years old for girls. Religious life was underpinned through endowments for the building of churches and chapels, with Methodism coming to dominate the outlying mining areas in particular, but without restrictions being placed on worship of other denominations (Fig 16a).[104] Worker health and sanitation were improved through provision of a public water supply in Nenthead in 1850, with baths and a public wash house being built in the village in 1865.[105] Even the recreation time of miners when not at work was supported by the Company through organised bands, sports clubs, lectures and a Reading Room built at Nenthead in 1833 (Fig 16d), 17 years before the national Public Libraries Act came into force.[106]

When the Vielle Montagne Company took over the mining leases in the area in 1896, they continued many of the traditions of social responsibility developed by the London Lead Company. There was compensation for accidents at work, and social infrastructure was supported with a new Working Men's Reading Room and electric street lighting in Nenthead and funding for an extension to the cottage hospital in Alston.[107] Nevertheless, the collapse of the lead industry in the mid-20th century was a major shock to the economic and social life of the North Pennines. Without mining, the remoteness of the area, combined with marginal agricultural land and a relative lack of resources, meant that unemployment rose and the population declined considerably. In 1948, the year that the Vielle Montagne company finally left the district, Alston with Garrigill was the only local authority in Cumberland where the population was less than that of 1939, and still in steady decline.[108] In 1987, Alston Moor had the highest unemployment rate in the country at 24%, though this did subsequently reduce as former mining communities partially adjusted to changing economic conditions and other sources of revenue were developed.[109] More recently, tourism has helped to increase visitor numbers to the North Pennines, including attractions relating to the mining legacy of the area, such as Killhope Lead Mining Museum in upper Weardale, and holiday accommodation in repurposed historic mine buildings at Haggs Bank and Nenthead in the upper Nent valley.

CONCLUSIONS

This study has assessed how, and to what extent, the landscape and society of Alston Moor in the North Pennines (UK) was altered by lead mining operations between 1700 and 1948. Mapped mining-related features highlight considerable spatial variation in the nature and intensity of mining between different areas, the density of mining operations within the Nent catchment being markedly higher than elsewhere. A pattern of generally low densities of surface disturbance interspersed with localised foci of intensive mining operations characterises much of the South Tyne, Black Burn and Upper Tees catchments. These trends are reflected in the distribution of the 465 named mines within the study area, with the Nent having almost twice the spatial density of documented mines than any of the other catchments.

Classifying the mapped mining features into groups associated with different aspects of the mining workflow highlights the variations in surface disturbance. Features relating to the deposition of waste sediments are the most frequent and spatially extensive, indicating that a considerable volume of mine wastes are still located within the modern landscape. Evidence for ore extraction and processing is also abundant and the environmental impact of these stages of mining is significant because of their historical role in mobilising vast quantities of waste sediments. The spatial extent of features associated with mine infrastructure is limited and smelting is evidenced in only four locations, though documentary evidence suggests that ore from the mines was actually distributed far more widely throughout Northern England for smelting.

Ore production figures are available for 30% of the named mines, with a recorded lead ore production between 1700 and 1948 totalling over 443,400 tonnes. The 18th century was characterised by the gradual development of large-scale mining operations and the intensification of workings in the Nent valley in particular. Although contemporary documentary evidence for hushing is relatively scarce, it is likely that this method of surficial mining also reached its peak during the 18th century, before being largely abandoned by c.1820-1830. Although relatively inefficient, the sheer scale of some of the hushes generated immense long-term impacts on the landscapes of the North Pennines. The early to mid-19th century then saw a rapid increase in the number and spatial distribution of productive mines, with peaks in production in 1820 and 1845-55. A steady decline in the lead industry throughout the later 19th century was followed by a brief revival in c. 1922-1939. As the industry dwindled in the 20th century, production became consolidated into fewer spatially isolated large-scale workings, especially around Nenthead and at Rotherhope Fell mine in the Black Burn catchment. Trends in documented output broadly follow those for the UK lead industry overall, indicating that a combination of both local factors and national concerns was responsible for fluctuations in production. The national collapse of the industry in the late 19th century was rapid and resulted from both internal issues, such as the exhaustion of easily accessible ore bodies, and increased international competition from markets in Spain, Germany and the United States in particular.

Lead mining also had a profound and long-lasting impact on the economy and society of the North Pennines, especially through the actions and influence of large mining corporations such as the London Lead Company. The population of the mining districts fluctuated through time as the industry itself experienced periods of relative boom and bust. Men and working age boys came to dominate the mining workforce of the area, a point reflected in the changing demographics of the 19th and 20th century census returns. Settlement patterns reflect an industry which became more organised and directly managed by the larger companies, with expanded nucleated villages being planned and built at places such as Nenthead and Garrigill. Importantly, this increase in housing stock was accompanied at times by extensive social provision, including guaranteed minimum wages, welfare funds, medical support, educational facilities and recreational opportunities. Broader investment in local and regional transport infrastructure and widespread improvement of agricultural land provided further benefits for both the miners and local population alike. Although the population of the area declined considerably in the later 20th century, the legacy of the mining industry endures to the present day through the numerous mining landforms which still survive and in the character and appearance of the local settlements and their surrounding landscapes.

ACKNOWLEDGEMENTS

This study was partially undertaken with the support of a PhD studentship provided by the Department of Geography, Durham University. The authors gratefully acknowledge Alastair Robertson and Peter Jackson for their assistance with documentary and cartographic sources, as well as the staff of Historic England, both past and present, for providing access to their data and specialist knowledge, especially Stewart Ainsworth, Yvonne Boutwood, Matt Oakey, Dave Went and Al Oswald. A particular debt of gratitude is owed to Don Borthwick for countless invaluable discussions regarding the mining history of the North Pennines and for his comments on an earlier draft of this paper.

NOTES

[1] Palumbo-Roe and Colman, 2010; Macklin *et al.*, 2014; Zalasiewicz *et al.*, 2014
[2] Burt, 1984; Raistrick and Jennings, 1989
[3] Palmer, 2000; Linsley, 2002
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[5] Ford and Rieuwerts, 2000; Barnatt and Penny, 2004
[6] Davies-Shiel and Marshall, 1969
[7] White, 1998; Raistrick, 1975; Roe, 2007
[8] Raistrick and Jennings, 1989; Turnbull, 2006
[9] Wallace, 1890 (reprinted 1986)
[10] Dunham, 1990; Forbes *et al.*, 2003
[11] Coggins, 1986; Fairbairn, 1993, 2009
[12] Ainsworth, 2009; Oakey *et al.*, 2012; Jessop and Whitfield, 2013
[13] Chitty, 1995
[14] Palmer et al., 2012
[15] Stratton, 1990; Palmer and Neaverson, 1995; Falconer and Gould, 2011
[16] Linsley, 1980
[17] Jones et al., 2004
[18] Kincey et al., 2017; White, 1989; Barnatt and Penny, 2004
[19] Burt *et al.*, 1979; Burt, 1984
[20] Raistrick and Jennings, 1989
[21] Raistrick, 1988
[22] Macklin, 1997
[23] Gwyn, 2009; Palmer and Neaverson, 1998
[24] Nevell, 2009
[25] Palmer, 2007
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[39] Almond, 1977; Lawson, 1978; Burt *et al.*, 1979
[40] For a full list of sources seeKincey, 2016
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[42] Burt *et al.*, 1983a
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[47] Dawson, 1947
[48] Cranstone, 1992; Fairbairn, 1992
[49] Cranstone, 1992
[50] Timberlake, 2004
[51] Fernández-Lozano *et al.*, 2020
[52] Bainbridge, 1856
[53] Fairbairn, 1992
[54] Fairbairn, 1992
[55] Forster, 1883 (reprinted 1985); Hunt, 1970; Raistrick and Jennings, 1989; Hutton, 2002
[56] Kincey, 2016
[57] Unpublished data from Kincey *et al* article currently in preparation.
[58] Macklin, 1986; Macklin *et al.*, 1998

[59] Fairbairn, 1993
[60] Turnbull, 2006
[61] Raistrick, 1988; Raistrick and Jennings, 1989; Fairbairn, 2009
[62] Hunt, 1970
[63] Fairbairn, 1993
[64] Hunt, 1970
[65] Fairbairn, 1980; Chapman, 1991
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[67] Burt, 1984
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[69] Almond, 1977; Robertson, 2012
[70] Palumbo-Roe and Colman, 2010
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[72] Raistrick, 1988
[73] McAnelly, 2020
[74] Raistrick and Jennings, 1989; Vision of Britain, 2020
[75] Thain, 1999
[76] Burt, 1984
[77] Raistrick and Jennings, 1989
[78] McAnelly, 2021
[79] Robertson, 2012
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[81] Burt, 1984
[82] McAnelly, 2021
[83] Burt, 1984; Raistrick and Jennings, 1989
[84] McAnelly, 2021
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[104] Turnbull, 2006
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[106] Raistrick, 1988; Jessop and Whitfield, 2013
[107] Robertson, 2012
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SUMMARY IN FRENCH, GERMAN, ITALIAN AND SPANISH

GERMAN

Metall, Minen und Moorland. Die Veränderung der Bleiminenlandschaften in den North Pennines, England, von 1700-1948

ZUSAMMENFASSUNG: Der intensive Metallabbau hat zwischen dem 18. und 20. Jahrhundert viele britische Gegenden geprägt und sowohl die unterirdischen als auch die oberirdischen Landschaften erheblich verändert. In dieser Studie wird ein interdisziplinärer Ansatz verfolgt, um die historische Entwicklung der Bergbauindustrie in einem fast 200km2 großen Gebiet der North Pennines zu verstehen. Hierbei werden dokumentarische und kartografische Aufzeichnungen, archäologische Kartierungen und geomorphologische Analysen von Veränderungen der physischen Umgebung miteinander kombiniert. Die ökologischen und gesellschaftlichen Veränderungen, die mit der Bergbauindustrie einhergingen, waren tiefgreifend und führten zu Bergbaugebieten mit unverwechselbarem Landschaftscharakter und einem Erbe, das bis heute anhält.

ITALIAN

Metalli, miniere e brughiera: i cambiamenti nel paesaggio minerario del piombo sui Monti Pennini settentrionali nel Regno Unito (1700-1948)

RIASSUNTO: L'intensa attività mineraria aveva già considerevolmente alterato diversi paesaggi collinari e montani fra il XVIII e il XX secolo, cambiando sia la morfologia del sottosuolo, sia l'ambiente in superficie. Questo studio, attraverso un approccio multidisciplinare, vuole arrivare a comprendere lo sviluppo dell'industria mineraria in una prospettiva storica all'interno di un'area di quasi 200 km^2 nella zona settentrionale dei Monti Pennini (UK). Vengono messe a confronto fonti documentarie e cartografia, mappe archeologiche e analisi geomorfologiche che riguardano i cambiamenti dell'ambiente fisico. I cambiamenti dell'ambiente e del paesaggio che hanno accompagnato l'industria mineraria sono stati profondi, e hanno dato luogo a distretti minerari con specifiche caratteristiche paesaggistiche, con un'eredità che permane fino ai nostri giorni.

SPANISH

Metales, minas y páramos: los cambiantes paisajes mineros de plomo de los Peninos Norte, Reino Unido, 1700-1948

RESUMEN: La minería intensiva de metales alteró considerablemente muchos paisajes de las tierras altas británicas entre los siglos XVIII y XX, modificando tanto los ambientes subterráneos como los superficiales. En este estudio, adoptamos un enfoque interdisciplinario para comprender el desarrollo histórico de la industria minera en un área de casi 200 km^2 en los Peninos Norte, Reino Unido. Nuestro enfoque combina documentación escrita y cartografía, mapeo arqueológico y análisis geomorfológico de los cambios en el entorno físico. Los cambios ambientales y sociales que acompañaron a la industria minera fueron profundos y dieron como resultado distritos mineros con un carácter paisajístico distintivo y un legado que persiste hasta el día de hoy.

FRENCH

Métaux, mines et minerais : les paysages changeants des mines de plomb des North Pennines, en Angleterre, 1700-1948

RÉSUMÉ: l'exploitation minière intensive du métal entre les XVIII^e et XX^e siècles a considérablement altéré de nombreux paysages des plateaux britanniques, modifiant les environnements à la fois souterrains et de surface. Dans cette étude, l'approche interdisciplinaire permet d'appréhender le développement historique de l'industrie minière dans une zone de près de 200 km^2 des North Pennines, en Angleterre. Cette approche combine des inventaires documentaires et cartographiques, des cartographies archéologiques, et une analyse géomorphologique des changements de l'environnement physique. Les changements environnementaux et sociétaux qui accompagnent l'industrie minière étaient profonds, créant des districts miniers avec un caractère paysager particulier et un héritage qui persistent encore aujourd'hui.

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