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# Resolving the Conflict between Mining and Sustainability

**David A. C. Manning**
School of Civil Engineering & Geosciences, Newcastle University,
Newcastle upon Tyne, NE1 7RU, UK.

Corresponding Author's E-mail: David.Manning@newcastle.ac.uk
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**Abstract**

Mining is essential for human health and prosperity, and is increasing as the global population grows. The need for minerals appears to conflict with what is commonly understood as 'sustainability', as geological resources are non-renewable on a human timescale. However, the Brundtland definition of sustainability includes the concept of 'needs', implying that there has to be a balanced approach that considers poverty alleviation. It identifies the three pillars of sustainability: economic, social and environmental.

In the UK, mining has a legacy extending back over 6000 years. The approach taken to sustainability will be illustrated by 3 examples from northern England. In the 18$^{th}$ and 19$^{th}$ centuries, the London Lead Company was directed by members of the Religious Society of Friends, and had social sustainability as a high priority, building a village with facilities to promote physical, mental and spiritual health amongst the mining community. The legacy of this company's mining operations on river water pollution is currently a major problem, reflecting its lack of knowledge of geochemistry. Potash mining started in North Yorkshire in the 1960s, and now there are plans for a new potash mine within the North York Moors National Park. Over 1 km deep, the new mine is planned to be as invisible as possible. Open pit coal mining takes place as part of a construction operation in city centre Newcastle, and in nearby rural locations. Operators take great care to minimize their impact on local populations, adapting equipment and making sure operations are timed to minimize disturbance.

In the UK, one key characteristic of a successful mining operation is that it engages in dialogue with the local community. It is important to involve the community right from the start of planning a mine, even before its location has been finalized. Operators typically have a community fund, and this can be approached by local people to pay for resources that benefit the community, such as sports equipment and facilities. Mining companies need to have a clear plan for restoration, with dates, and some take the opportunity to plan major works of public art as a way of enriching the community with a legacy that can generate income through tourism.

**Keywords** : mining, sustainability, lead, zinc, fluorspar, potash, coal, community

## Introduction

Mining is essential to maintain human life and well-being. Analyses of global mineral production, excluding fuels, show that there is a close correlation between the amounts of mineral that are mined and GDP [1], corresponding approximately to 1 tonne of mined product per person per year. This figure includes all mineral

products, and so takes into account construction materials as well as industrial minerals, fertilizer raw materials and metals. The true figure for the amount of material mined is of course much higher, as many products are separated from mined material leaving a mineral residue or waste.

The concept of sustainable development was defined in the landmark 'Brundtland Report' [2]. It led to the widely adopted definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Importantly, the Brundtand Report goes on to state: "It contains within it two key concepts: the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs".

Sustainable development can be judged in the context of the three pillars - social, economic and environmental sustainability [3]. These can, in principle, be used in an assessment of the sustainability of any development. When applied to mining and the exploitation of mineral resources, there are a number of issues that need to be considered [4, 5] including those relating to the long time scale required to produce a mineral deposit through geological processes. Cowell et al. [4] give a detailed overview of the assessment of the sustainability of mining, where a number of different viewpoints give rise to differing outcomes. Again presenting an Australian perspective, Giurco and Cooper [6] reconsider the sustainability of mining from a number of points of view, and comment that recycling and changing raw material use tend to have been neglected in overall sustainability assessments.

Petrie [5] describes the importance of considering the entire value chain for mineral production, and comments on the importance of educating consumers. Drawing on different geographical perspectives, Amezaga et al. [7] address the issue of the sustainability of mining, focusing on the conflict that arises with the associated use of water resources which are needed for mining and which can be seriously contaminated by mining activity, making them unfit for other uses such as drinking water and irrigation (drinking water, irrigation etc).

Detailed specific assessments have been carried out on individual mining systems. For example, Mudd [8] investigated the Australian mining industry, analyzing trends in production and resource use until 2008. This period shows a rapid rise in mine production and at the same time a reduction in the grade of ore being mined, which leads to more waste and greater processing costs (energy and money). Mudd [8] also highlights the consequences of the trend to move away from underground towards open pit mining, which generates much greater volumes of 'waste' through the removal of overburden.

Mudd's assessment [8] addresses mined commodities that include metal ores, diamonds and coal. The production of aggregates for construction is volumetrically one of the most significant mining operations in terms of the volume of material produced, and the number of mineral workings - because of the need to produce aggregates close to their market given their low value and high transport costs [9]. Very few academic studies have addressed the production of construction materials in the context of sustainability of a mining operation. One example concerns the supplies of aggregates to Brazil's metropolitan areas [10, 11], although these two papers focus on the requirement for aggregate resources and the need for strategic land planning to ensure supply that is sufficient to meet the needs of construction.

The translation of the principles of sustainability to practice in the mining industry depends on action that is often reflected through the adoption of corporate social responsibility (CSR) management as a key part of a business strategy [12]. In their survey of CSR practices in Spain (Catalonia), Vintro et al. [12] show that those companies that adopt a strong CSR policy report a better competitive position, highlighting the importance of sustainability for the 'bottom line', thus

improving the financial sustainability of a mining venture.

In the context of the sustainable development of mineral resources, much depends on the practical steps that can be taking by a mining company to minimize the negative aspects of mining. The United Kingdom has a history of mining extending back to prehistoric times [13] and so there is abundant scope for observing the long term effects of mining. This paper presents a brief overview of some examples of mining activity in northern England, using these to illustrate individual approaches to sustainability, and to show how these have changed over a period of 300 years.

*Mining and the three pillars of sustainability*

As already described, sustainable development can be considered in the context of social economic and environmental sustainability. When considering mining, these three issues relate very closely. The bottom line for a mining venture is that it has to be economically sustainable; in other words, a mine needs to make enough money by production from known reserves [14] in order to repay the costs of the capital used to start the mine, and to repay the operating costs, including processing, environmental protection and planned restoration on closure. If economic sustainability is not possible, there may be no financial provision for post closure restoration, and environmental protection schemes and protocols may not be funded.

Social sustainability is also vital for a mining operation to succeed. First, in ideal circumstances, a mine can only be developed with the consent of the people affected by its development. In some countries, the planning process enables this to be achieved through consensus, but if governance structures are weak or do not function then this might not be achieved. Secondly, social sustainability includes the benefits that come from employment through primary employment within the mining operation itself, and also through the secondary employment of suppliers of goods and services to the mine and those who work there. Social sustainability extends beyond the life of a mine, as consideration needs to be given to the future prospects of a community that supported the mine, once it has closed.

Environmental sustainability requires a long timescale, like social sustainability. The immediate environmental impact of a mine can be considered in the planning stage, in the context of current knowledge, and appropriate mitigation measures can be adopted. But there is a legacy of mining activity from earlier days, when mitigation was not a concern, and there is the possibility that environmental harm might come from impacts that are unknown at the time of mine planning. The issue of time, from a historical perspective, is in fact critical in any assessment of the sustainability of a mining operation. In addition to societal changes that might, or might not, relate to the mining operation directly, changes in our understanding of environmental science might lead to unexpected problems. Only history can judge whether or not a mining operation has been sustainable. And as every operation must come to an end, its sustainability has to be seen in the context of the overall sustainable development of its host society.

*Case studies*

To illustrate how the principles of sustainability, according to the three pillars (environmental, economic and social), can be applied to mining, a number of examples have been drawn from mining operations in northern England (Figure 1). These are 1) the London Lead Company, which had a history of over 200 years production of lead from the North Pennine Orefield, 2) the development of two potash operations in Yorkshire, one that started in 1969 and the second that is currently (2013) at the planning stage, and 3) the surface mining of coal in urban Newcastle and nearby rural areas, where mining takes place in communities used to a long history of mining. Judgments of success are made on a qualitative basis. It is important to use the internet when considering the examples given, especially as this tool provides a way of investigating an operation from the perspective of the general public, and of how a company might present its interests, ethos and approach to its operations.

*The London Lead Company*

In the early18th century, lead mining in the Carboniferous rocks of England and Wales was a difficult task, requiring miners (and their families) to suffer appalling living conditions. The work often took place at remote and inhospitable locations, so miners lived in what would now be called hostels close to the place of work while the families lived in villages sometimes many kilometers away.

The London Lead Company started in 1692 and was taken over in 1705 by members of the Religious Society of Friends, or Quakers [15]. The company closed in 1905. As the Quakers were a nonconformist movement, individuals were banned from holding public office and so many made their living through industry. The London Lead Company supplied significant proportions of the United Kingdom's lead production, covering all aspects of the operation from mining to smelting and refining. As a religious group, the Quakers have always had a strong commitment to social justice, and so took great pains to ensure that the living conditions of the miners and their families were improved. One lasting legacy of this in the North Pennine Orefield is the village of Nenthead, which was built by the company at the site of one of its major mining and processing operations. The village provided good accommodation, and a wider range of amenities including chapels (the miners were not required to become Quakers). Public health was improved by the provision of a safe supply of clean drinking water.

*Potash in north Yorkshire*

In 1969, work started on developing a potash mine at Boulby in north Yorkshire, following the discovery of sylvite during exploration for oil in the 1930s [16]. With a depth of 1100 m, this is the deepest mine in Europe, with over 1000 km of tunnels extending under the North Sea. In 2013, plans are being developed by York Potash Ltd. part of Sirius Minerals, for a second potash mine near Whitby, about 20 km from Boulby, to produce polyhalite from a similar depth. Both operations are in the North Yorkshire Moors National Park. Current information about each can be obtained from www.iclfertilizer.com/Fertilizers/ClevelandPotash and http://yorkpotash.co.uk, respectively.

Boulby potash mine and the York Potash project were conceived at different times. Boulby mine was designed in the 1960s, and although largely hidden from view from the south, much of the operation is above ground, with surface head gear and processing plant as well as the mine offices and other facilities (Figure 2). Ore is taken from the mine to Teesside by train, a distance of around 20 km.

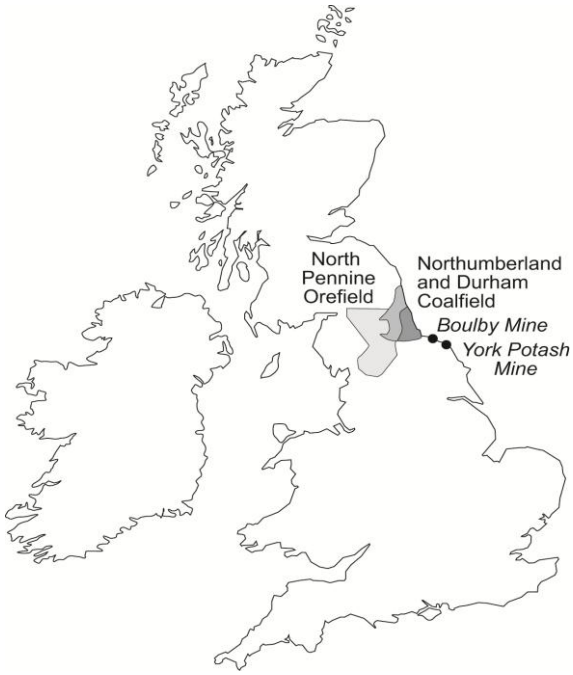



**Figure 1** Location of case studies from Northern England. The Northumberland and Durham coalfields are divided into exposed (light grey) and concealed (dark grey).

**Figure 2** Boulby mine from the north-east.

Plans for the new mine, near the town of Whitby, are at an advanced stage. The location of this mine is sensitive, given its location and the importance of tourism for the local economy. The plan is for the mine to have as low an impact as possible. Surface buildings will be minimal. Headgear and other plant associated with the mining operation will be underground, and ore will be taken by an underground conveyor

to Teesside for processing and shipping, a distance of about 40 km (Figure 3).

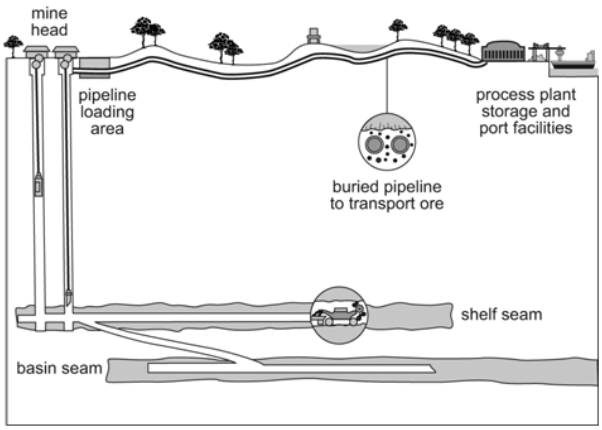



**Figure 3** Conceptual cross section of the York Potashmine, Whitby, North Yorkshire (based on http://yorkpotash.co.uk).

*Coal in Newcastle and Northumberland*

Newcastle upon Tyne is famous for coal, which has been produced for perhaps as much as 2000 years. The peak of production was in the late 19th and the 20th centuries, largely from underground mines throughout the exposed and concealed coalfields (Figure 1).

The coalfield is characterized by 'pit villages', which were built so that miners could live close to the collieries. Ashington, a significant town, became known as 'the biggest pit village in the world'.

During the second half of the 20th century, underground mining ceased, and surface mining became more important as a source of coal. Surface mining took place predominantly in rural areas, with restoration to agricultural land. In rural Northumberland, the scale of mining was substantial, with individual open pit operations occupying several $km^2$ of land. Landscapes restored in the 1970s and 1980s are characterized by a lack of mature trees, and field boundaries marked by fences and hedges with relatively little plant diversity.

In the 21st century, demand for coal continues (especially as the coals of Northumberland have a low sulfur content). Mining takes place in communities where great care has to be taken, partly because of the proximity of workings to housing, and partly because communities may be weary of mining, especially if an open pit operation is proposed for land that has already had an open pit in living memory (for example, to mine coal deeper than previous open pits).

Two examples show how mining can be achieved in sensitive areas. Newcastle Science Central is located in the heart of Newcastle city centre; at this location, coal was removed to a depth of 20 m in order to stabilize ground that had many old and uncharted underground workings, prior to development of a high quality inner city location. The Shotton surface mine is on the northern edge of the city, close to Cramlington, a town with a large population, and is between the two main transport arteries that link eastern England with Scotland.

Newcastle Science Central is a 10 ha site, with housing accommodation on 3 sides and the city centre on the fourth (Figure 4). The process of mining involved dividing the site into a series of 'cuts' to remove coal down to the planned depth. As soon as one cut was completed, overburden from the next was used to fill the void. Individual cuts were small and intensely mined with a dense population of mobile plant (Figure 5). This means that the site moved rapidly, removing approximately 30-40,000 tons of coal within a period of about 9 months. During planning and operation of the site, local residents and other interested parties were engaged in frequent consultation, to ensure that they know what was planned to happen, and had the opportunity to influence those plans. Care has been taken to avoid noise during the night, and lorry movements taking coal away from the site are restricted to specific times. Importantly, residents know that mining at the site will come to an end as quickly as possible, so that construction can begin.

**Figure 4** Newcastle Science Central site, before mining.

**Figure 5** Infilling a cut from which coal has been extracted, Newcastle Science Central.

The Shotton surface mine is worked by Banks Mining, (www.banksgroup.co.uk), a company that has a long history of successful community engagement when planning its mining operations. The 300 ha site lies between the East Coast Main Line, which is the railway line between London and Edinburgh, and the A1, which is the main highway between these two capital cities. It is close to a densely populated area, and within an area of agricultural and park land.

Banks Mining has a track record of innovation that minimizes the environmental impact of their mining operations. Any new project involves dialogue with local communities at a very early stage, so that local people are aware of what is planned and have the opportunity to shape those plans. The mining operation is an important source of employment locally, and (like other mining companies) there is a separate trust fund that community groups can approach to seek funding for specific projects to improve community life.

Two major concerns are noise and dust. In both cases, Banks have modified mobile plant to reduce each nuisance (www.mininginstitute.org.uk /papers/dust_suppression.html). Trucks and excavators have been fitted with additional acoustic insulation and improved exhaust silences, to reduce engine noise and broad band reversing alarms have replaced the traditional bleeping alarms that can cause widespread community annoyance (Figure 6). Plant that handles coal and overburden has been fitted with water sprays, so that airborne dust is prevented at source from being generated (Figure 7). These modifications are supplemented by regular dampening of roadways and stockpiles, and by a rigorous programme of environmental monitoring.


**Figure 6** Modification of mobile plant to reduce noise; Shotton surface mine. Photographs courtesy of Banks Mining.

These modifications are supplemented by regular dampening of roadways and stockpiles, and by a rigorous programme of environmental monitoring.

Once mining is completed, the land is restored to an agreed use. In addition to agricultural land, new uses can be created. At Shotton, carefully selected rock, clay and soils from the adjacent mine has already been used to create 'Northumberlandia', the largest female form on Earth (Figure 8), sculpted by Charles Jencks. Northumberlandia is a landmark visible from the railway and the road links between England and Scotland, as well as from the air. It adds to the tourism industry in the region, thus contributing to the local community through income generation that will be sustained once the mining operation is complete.

**Figure 7** Dust control by modification of excavating plant and spraying; Shotton surface mine. Photographs courtesy of Banks Mining.

*Progress towards the goals of sustainability*

The three examples given above demonstrate different approaches to sustainability that reflects the times in which they were conceived. Table 1 uses a traffic light approach, based on a subjective judgement, that allows different cases to be compared. In the context of social and economic sustainability, the London Lead Company can be judged as a success. After all, the company survived for over 200 years, so financial sustainability was not a short-term problem. In terms of social sustainability, the village of Nenthead still exists, and although society has changed since the early 20th century, the legacy of the mining operation still generates business for the community as it is now a tourist asset, in the heart of the North Pennine Geopark.

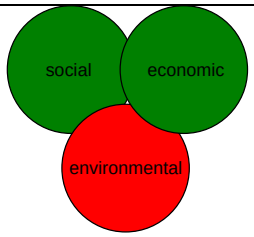
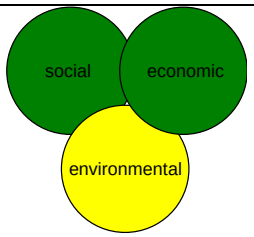
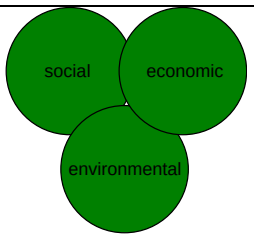
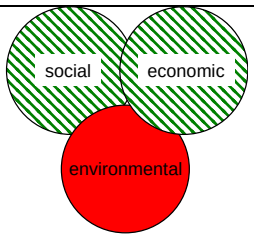
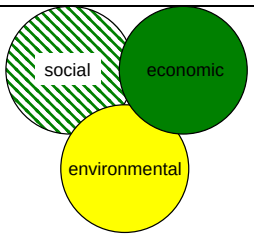
In contrast, the activities of the London Lead Company (and others working in the same ore field), have failed to achieve environmental sustainability, largely through ignorance of the environmental consequences of mining. In particular, there is a long history of polluted mine waters draining from the old workings. These can be in the form of acid mine drainage [17],

**Figure 8** 'Northumberlandia', part of the land restoration associated with Shotton surface mine. Photograph courtesy of Banks Mining.

and as a diffuse flux of contaminant metals that has recently been found to be the major source of heavy metal pollutants in the Tyne river system [18, 19]. There is no way in which pollution on this scale could have been anticipated by the directors of the London Lead Company when it was in operation.

Potash mining in the North York Moors National Park has visual and transport impacts as the dominant environmental factors (assuming that dust and noise are controlled; chemical pollution derived from geological sources is a minor consideration). When Boulby Mine was planned, in the 1960s, the visual impact of the mine was not as great an issue as it would be 50 years later, and so the new mine planned by York Potash is proposed to be all but invisible, with almost all key infrastructure underground, and limited car parking on site. From the point of view of long-term economic sustainability, potash mining in this area can be judged to be a success, with large reserves of an ore that is in demand. While the new mine near Whitby is in the planning stage, the existing mine at Boulby is expanding, with significant investment so that production can be increased and continued for a further 40 years. This substantial investment leads to social sustainability, with around 1000 high quality jobs already associated directly with mining and a similar number to come through the new mine, and a much larger number of jobs in businesses that supply and support the operations.

**Table 1 Summary assessment, on a qualitative basis, of the sustainability of mining operations in Northeast England over the past 200 years.**

| Example | Key issues | Sustainability assessment |
|---|---|---|
| London Lead Company, North Pennine orefield | • Business operated for 200 years (1705-1905), improving living conditions and community amenities; legacy of tourism.<br>• Environmental pollution is now a major problem. |  |
| Boulby potash mine | • Operated in a National Park since 1969. Visual impact is main environmental issue, given the location. |  |
| York Potash planned mine | • In a National Park, with much more sensitivity than when Boulby was planned in the 1960s. Special effort taken to hide as much of the mining operation as possible. |  |
| Historic coal mining, Northumberland and Durham coalfields | • Peak production in 19th and 20th centuries, from underground mines, supported large communities. There is now a legacy of environmental pollution and former mining communities. |  |
| 21st century open pit mining, Northumberland and Durham coalfields | • If carried out to a high standard, open pit mining minimizes possible negative impacts on local communities and provides employment. Environmental issues include dust and noise management and site restoration. |  |

**Key:** red indicates the existence of problems that need to be resolved as a legacy of historic mining; yellow indicates issues that are a legacy of historic decisions relating to current operations; green and white indicates that there may be issues (that are manageable) relating to existing communities and their historical experience of mining, and green indicates acceptance, or likely acceptance, of mining in accordance with current regulation. Colours will change with time.

Coal mining in north-east England has seen a change in achievement of the goals of sustainability. The industry has continued for several hundred years, and although individual components have flourished then faded during the life of the coalfield, overall economic sustainability can be demonstrated – but only to a limited extent. There needs to be substantial inward investment at the present time to replace jobs lost as the coalfield has declined. Although it continues to make a very significant contribution to the local economy, the coalfield alone cannot fully sustain the communities that once depended on it for employment and income. In terms of environmental sustainability, there is still a legacy of geochemical pollution from old workings,

predominantly from those that are underground (although some very old surface mines are sources of water contamination). Modern mining operations are able to minimize their environmental impacts, so that the nuisance of mining (vibration, noise, dust, visual impact) can be reduced to an extent that is accepted by local communities. Backfill design minimizes the potential for surface mines to contribute to acid mine drainage. The coal industry makes a significant contribution to social sustainability through community schemes that fund a wide range of programmes that originate from the communities themselves. For example, support of community sports includes rowing; Cambois Rowing Club (www.cambois-rowing.org) was established by coal miners in 1911 and provides the opportunity for teenagers from the post mining community in Ashington to develop an interest in the sport, competing at a national or in some cases international level. Trusts associated with the coal industry provide substantial funding that reflects the value of what the rowing club does, and ensures that it has the equipment and facilities needed to enable youngsters to compete at the highest level (Figure 9).


**Figure 9** Presentation of a new racing boat to Cambois Rowing Club by the Banks Community Fund. Photograph courtesy of Banks Mining.

## Conclusions

When taking a national view, mining is essential for societal sustainability, given society's need for minerals. A qualitative assessment of the environmental, societal and economic sustainability of metal, coal and potash mining in northern England over the last 200 years has shown considerable change with time. Early metal and coal mining activity was sustainable in the sense that it supported communities for many generations, but there is a legacy of environ-mental problems that could not have been foreseen when the original mines were planned. Modern mining is carried out with the consent of the community, and so does as much as possible to minimize the environmental consequences of mining. In coal mining areas, modern surface mining activities contribute to community funds that enable communities to develop, compensating in part for earlier loss of employment as deep mining came to an end.

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