REHABILITATION OF HISTORIC MINEWORKINGS IN EUROPE

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ABSTRACT

Europe was the focus for the early development of mining on an industrial scale which is evidenced by the numerous examples of historic sites where extraction has been continuous for 2,500 years and in some instances, for as long as 3,500 years. These historic mining areas have seen recent interest in the redevelopment of extraction operations as well as increasing environmental pressure for appropriate closure and rehabilitation of old workings. Major historic mining areas such as the Iberian Pyrite Belt, South West England and Northern Greece have seen much activity with regard to both redevelopment and rehabilitation during the last ten years.

The problems arising from closure and abandonment of historic workings are primarily those of establishing an appropriate engineering environmental approach to meet standards. Mining development on sites associated with historic mining operations also raises questions of liability. Both closure and redevelopment issues relate not only to mine site contamination and the safety and stability of tailings disposal facilities, but often more importantly to the control and treatment of minewater. The liabilities associated with mine site decontamination and tailings disposal stabilisation (both from an engineering and an environmental perspective) are transitory i.e. they have potentially a finite cost and time scale for implementation of rehabilitation measures. Minewater can pose a longer term problem which commences once the groundwater regime is impacted by mineworkings and may continue ad infinitum.

The liabilities associated with mine closure, regardless of whether the workings are recent or historic, are complex as in many cases direct responsibility for the site and mine ownership are ill-defined. Current European legislation takes a very strict approach to liability for pollution and contamination and therefore clean-up standards imposed upon such sites often take no account of site history or of antecedent environmental conditions. The strict liability approach may thus impose on mine owner and regulator alike an inappropriate clean-up strategy and a cost burden out of proportion to the potential long term environmental risk.

This paper reviews the implications of historic mining activity on new mineral extraction projects across Europe and identifies the problems of environmentally appropriate mine closure. The case for a more pragmatic approach to mine site clean-up is proposed, together with a revised approach to assessing the real environmental implications of some of Europe's "dirtiest" mining areas and the risk that these sites truly represent. A new acronym, BACCUS, is proposed which presents opportunities to developer and regulator alike to address the issue of closure to the benefit of mining industry and the environment.

INTRODUCTION

The focus for much of the early industrial scale mining was Europe with many of the innovations, particularly in mineral processing, being developed in Greece and the Mediterranean region. The focus for much of this early mining activity lies in a broad band across southern Europe from Greece to the Iberian peninsular with outliers such as the south west of the UK. Some of these sites are of great antiquity with continuous extraction and processing on many sites for more than 3,000 years.

With improvements in exploration, extraction and processing technologies these historic mining areas are once again the focus of attention and localities such as the Iberian peninsular and Greece are currently under consideration for the development of modern mining projects. Mine projects in this region are being advanced in parallel with those in less developed areas of the world, but there are significant differences between the process of permitting new mines in greenfield and brownfield sites. These differences relate primarily to the history of the site and the extent to which there has been historic disturbance and hence potential longer term environmental impact.

Modern mining requires the development of a bankable feasibility document which will include the results of both engineering and environmental studies of the orebody proposed mine and the site. This documentation will be required prior to implementation in order to obtain both project funding and government authorisation for the development. Inevitably the associated permitting requires the production of an Environmental Impact Assessment, together with appropriate engineered mitigating measures and in addition a closure plan.

For a "greenfield" site post closure conditions can be readily defined against which to measure the post abandonment rehabilitation objectives. On a "brownfield" site where there has been historic mining of some longevity, pre-existing conditions will be difficult, if not impossible, to define. Such a mine project particularly when viewed in the context of increasingly stringent legislation with respect to environmental performance post closure, poses significant technical and permitting difficulties for both developer and permitter alike. Further, the long term liabilities associated with such a development also make a mining project potentially fraught with environmental problems and potential long term risks.

This paper reviews the development of new European mining projects on or adjacent to historic extraction sites. The implications of the lack of pre existing environmental data on closure objectives is considered. The paper concludes by proposing a pragmatic approach to the definition of post closure conditions for adoption by developer and permitter alike to enable appropriate abandonment of mines on historic sites.

HISTORICAL MINING CONTEXT

Mining on an industrial scale, using semi modern mineral processing techniques, commenced in the western world between 2500 and 3000 years ago. Sites such as Lavrion in Greece, which provided much of the wealth for the Athenian city state around 450 BC, can still be visited and evidence of comparatively advanced processing techniques seen. These sites which were often themselves developments of previous, often prehistoric, workings, indicate the longevity of extraction and processing in many parts of Europe and the Mediterranean which can extend continuously for 4000 years. There are many sites in southern Europe and the UK where this historic mining has left a significant environmental legacy. Sites such as Lavrion in Greece, Aljustrel in Portugal, Almagrera in Spain and the Carnon Valley in the UK are some of the known and documented sites. These and other sites are also of sufficient antiquity that their archaeological value may out weight the liabilities associated with contamination and dereliction.

South America and Mexico were established producers of precious metals in the 16th Century following the Spanish conquest. In comparison, development of metal mining in Australia and the American continent for instance commenced on an industrial scale in the mid 19th Century and expanded rapidly thereafter. In Africa metal extraction increased in production from around the 19th Century as the potential mineral wealth of these countries was discovered but has seen the major developments during this century.

The current world production for copper shows the American continent as the major producer which reflects the change in the geographical centre for mining. It is interesting to note, that Cornwall provided more than 50% of the world's industrial copper requirement in 1865 but that by the mid 1870s Cornish mining, defeated by the heavy costs of dewatering, was already in decline due to cheaper concentrate derived primarily from S America and Australia. With its decline, however, the Cornish exported their extraction and processing technology around the world hastening the development of mines in the new mining regions.

In the past 20 – 30 years there has been renewed interest in some of the world's historic mining areas, notably UK (Cornwall and Wales), Greece, Italy (Sardinia), Spain and Portugal. These areas which were originally exploited in the pre Christian era on an industrial scale, particularly by the Romans, have been worked on a semi continuous basis throughout the intervening period.

The recent advances in exploration techniques, combined with more efficient extraction and processing technologies, have made these areas of renewed interest. In addition these mines have been of particular interest to America and Australian mining houses faced with much in country pressure from regulators and environmental/anti mining pressure groups. Parts of Europe, where mining has a different social and cultural image, have been seen as more favourable climates for new developments. At the same time it has been noted that investment at existing mining operations on such sites has often been inadequate and that new financing and management practices can restore the fortunes of the operations, bringing benefits at both community and corporate level. However, there are potential liabilities associated with inward investment into such mines and particularly associated with, and post, mine closure.

POTENTIAL LIABILITIES ASSOCIATED WITH HISTORIC WORKINGS

A number of modern mines have been developed on historic sites and on others, bankable studies have been prepared with the projects yet to be implemented. These projects have a common requirement to address the financial impact of historic site disturbance. Potential sources of contamination associated with historic mining activity can include old workings, waste rock stockpiles, ore residues, tailings ponds and in addition there may be old process buildings and in some cases minewater discharges and treatment lagoons. These facets represent a potential liability for the incoming investor, for despite contractual agreements which may apparently exclude historical liabilities, it has frequently been the case that the incumbent operator bears ultimate responsibility by association. Such liabilities can relate to all aspects of previous mine activity and an investing company entering into a contract on such a site needs to ensure that the advice of an experienced engineering/environmental group is available before accepting the conditions.

The potential liabilities at closure together with the associated risk and timescale are summarised qualitatively below.

	Liability Timescale	Cost Implications	
		Short Term	Long Term
Mine site	Short Term	Low – Medium	Low
Mine buildings	Short Term	Minimal	Zero
Waste rock dump	Short – Medium	Medium	Very low
Ore stockpiles	Short	Minimal – Medium	Very low
Tailings dam	Medium to Long	Potentially high one off	Low – Medium
Minewater	Long Term	Medium	Low – medium but potentially infinite

Table 1. Qualitative assessment of historic mine liabilities.

Old workings present problems of ground stability and human safety requiring capping and structural support, though lack of adequate historical plans may prolong such activities. Historic ore and waste rock stockpiles are finite in quantity and have generally reached quasi stability through age, and in terms of closure, remediation and maintenance criteria can be readily defined. Where stockpiles contain pyritic material however, ensuring geochemical and geotechnical stability and establishing treatment for potential acid rock drainage may be a longer term liability. Tailings dams pose a different problem, the initial cost of closure may be high entailing stabilising measures both to the confining wall and tailings surface. Subsequent capping and/or dewatering together with seepage water treatment may be a much longer term prospect. Costs, however, within an appropriate closure scheme should be limited once the rehabilitation work is completed and the vegetation cover stabilised. Long term inspection/auditing is likely to remain a requirement however.

Minewater poses a different problem being potentially of infinite life, where extraction has resulted in groundwater conditions which determine that there will be long term discharges to surface. Where this occurs and the water quality exceeds environmental limits long term treatment may be a requirement in order to meet agreed or permitted standards. Although this may be a limited cost during mine operation, on closure the liability could remain, potentially ad infinitum, and represent a significant long term cost as at Wheal Jane (Cambridge et al., 1996).

These sites present a potential operational cost in minimising future liability and in complying with permitting requirements. At closure the potential costs can also be significant due, not only to the abandonment of the mine infrastructure, but to often widespread contamination within and downstream of the site. Table 2 shows typical data for background levels for selected metals from a number of historic mine sites. The metals selected for inclusion in the table are EU list I and II metals and are those for which closure objective levels would be conditioned.

Such data pose a major potential problem for regulator and operator alike, namely the identification of appropriate clean up standards, even to the extent of identifying neutral or no deterioration conditions.

MINE CLOSURE

Depressed metal prices have recently had three important effects, the dramatic slowdown of new mine projects, the increased interest in existing European mine sites and an increase in the rate of mine closures. The latter is of particular significance as many of the mines approaching decommissioning over the next five to ten years are likely to include old operations many of which pre date the current requirements for closure planning. Such mine sites include those in the former Soviet Union, the former Eastern Bloc and Western Europe. Of these, a significant number are likely to include workings of some antiquity, with a continuous operational history of three to five hundred years or more.

In addition, the Mining Industry in North America and Australia has been affected by events such as Aznalcóllar and by adverse publicity against proposed mine development. This has led to increased pressure on the already hard pressed

		Pb	Zn	As	Cd	Hg	Cu
Carnon Valley, UK (Paspaliaris et al. 1999)	Soil mg/kg	130	150	447	3	<0.5	188
	Surface water µg/l	22-37	3854-8943	<10-48	49-62	0.4-0.5	2689-4833
	Groundwater µg/l	<10-66	57-42115	<10-12571	<1-351	<0.2-1.2	<20-17680
Lavrion, Greece (Stavrakis et al., 1994)	Soils mg/µg	1180-23780	740-70000	120-14800	5-485	5-728	36-1540

Table 2. Typical background levels for historic mine sites.

finances of mining companies and further enhanced the environmental profile of new and old mining projects alike. These developments have led to a noticeable increase in exploration activity in Europe which has already focused attention on historical mining areas.

The closure of a modern mine on a greenfield site and a similar development in an historic extraction region pose very different problems in terms of permitting and clean up standard.

Mine closure (Greenfield Site)

When mines threatened with closure are relatively modern and have been developed on a greenfield site, the operator is more likely to be in compliance with current best practice, a closure plan in place and the mine being engineered towards closure, regardless of how far in the future this may be. In addition such mines will, it is hoped, be operating a policy of compliance with discharge standards within the framework of European Directives or other International Standards as appropriate. It is also likely that the mine will hold a database of background/baseline data against which to measure post closure performance.

Performance during the operational phase will have been assessed by the local or national regulating agency and in the best operations there will have been internal audits to ensure compliance with company policy and externally regulated quality standards. For such operations, the concept of BATNEEC will either have been adopted or prescribed resulting in an inexorable, environmentally appropriate, move from mine development through operation to closure, abandonment and remediation over a defined period. This closure and rehabilitation will hopefully be targeted towards existing neutral conditions i.e. no deterioration, or to other international/local legislative requirements. Compliance with such closure requirements has increasingly been the subject of bonding at the permitting stage. This is seen by the authorities as a means of ensuring that appropriate provision has been made for initiating and monitoring closure performance. Relatively recent European examples of bonding can be found in Ireland and Portugal where closure plans have had to be lodged with relevant authorities and proof that appropriate financial arrangements have been made provided.

Mines which pre date such rigorous permitting procedures, say the Zambian copper industry, operate in the same mode and still need to develop closure strategies, however, for such sites baseline conditions may not be readily defined from existing site data. It is, however, often possible to extrapolate from local environmental conditions and thus to define local data which may permit the application of a "no deterioration", national or such other standard for closure as may be required (Short et al.).

Mine closure (Historic/Brownfield)

In Europe mining companies have increasingly been involved with projects which are based on, integrated with, or associated with historic workings of significant antiquity. These mine workings bring additional problems and challenges which are not encountered in more modern developments. Such mines still have to operate within an existing framework of standards for environmental compliance despite their antiquity.

The mining areas of Southern Greece and South West England are well documented and present excellent examples of the associated environmental problems. For such historic mines baseline data is absent and pre existing conditions can only be inferred from anecdotal evidence. In the present environmental permitting climate such evidence is unlikely to meet the increasingly stringent requirements of legislators with regard to environmental performance and closure criteria. Therefore, though anecdotal information may be useful in postulating the precedent conditions, it will not provide a firm baseline data set against which closure, or even against which the minimum criteria of no deterioration on abandonment, can be measured.

Of particular pertinence is that continuous mining over many centuries may have resulted in permanent alteration of the local environment including evolvement of metal tolerant flora and fauna. There is increasing evidence of the incidence of metal tolerance at a number of old mine sites, resulting in some locations, in a unique ecology. This factor would clearly affect the definition of environmental baseline conditions against which a legislator would wish to measure no deterioration and define closure performance criteria. There is much evidence to support the evolvement of metal tolerant ecosystems as exemplified in

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the UK in Falmouth Bay (Cambridge, 1997)) and by the development of metal tolerant grass species, i.e. Merlin (Bradshaw). There are likely to be similar examples from elsewhere in Europe.

Wheal Jane is of particular importance due to the opportunity afforded by the minewater project to study the environmental significance of more than 3000 years of continuous mining in the Carnon River catchment. The more or less continuous discharge of mining waste from Wheal Jane and associated mining operations over much of this period has caused measurable environmental changes on both macro and micro level. The result has been described by a number of authors as resulting in unique habitats and metal tolerant species downstream. Where such mining induced environmental changes have occurred, minewater discharges, post modern mine closure, have to be viewed in relation to the potential impact on unique habitat rather than compliance with a directive. This is not seen as a means by which mining companies can opt out of compliance due to historical discharge, but rather one of ensuring appropriate standards are applied and enforced.

Mine closure - A pragmatic approach

For such sites the mining industry and regulators alike are posed with a conundrum. How is the mining industry to derive appropriate environmental standards for closure and, in particular, how can the often idealistic quality levels and standards increasingly imposed under a prescriptive approach to mine closure be achieved and, in the case outlined above, can such operations be closed without impacting, potentially to their detriment, on the local environment?

What is required is an approach which ensures that the impact of mining is minimised and public confidence in the industry as a whole, particularly in the light of recent occurrences, is enhanced. It is encouraging to note that many mining houses themselves recognise that improved environmental performance leads to improved process recovery and profitability. However, imposing historical liabilities on modern mining companies together with responsibility for apparent historical environmental degradation may not be appropriate. An Australian mining company can hardly be held to be directly responsible for historic tailings deposits produced as a result of silver production during the 4th and 5th Century BC in Southern Europe. However, should modern workings on the same site destabilise these tailings then liabilities may be shared.

BACCUS

A less prescriptive approach is required which is more appropriate and rational but still achieves sound environmental performance. This pragmatic (a word in common use in most modern European languages) acronym embodies the spirit of the approach proposed for adoption by regulators and planners alike to provide guidance in establishing closure criteria and an appropriate response to mine site clean up of historically affected locations. Mining companies and regulators alike would adopt a Best Appropriate Clean Up Strategy (BACUS) to ensure that appropriate mitigating measures are included during abandonment. This approach would then lead to the development of the Best Appropriate Cost-effective Clean Up Standard (BACCUS) i.e. closure criteria that best befit the location. This approach enables environmental performance on abandonment to be balanced against the potential impact on existing habitats/ecosystems to achieve appropriate closure criteria (Figure 1).

The intention of BACCUS is to define mine closure requirements, and on some sites mine discharge consents, in terms of existing (historic) conditions rather than adopting a global non site specific EU directive or international standard. The requirement for undertaking an environmental baseline study and impact assessment remains the same. Once the historical impact on the habitats/ecosystems has been proved, the mitigating measures are engineered either towards no deterioration, i.e. no change to existing conditions, or to reduce/negate potentially harmful impacts. On closure the same criteria would apply i.e. any permanent environmental changes which are not seen as detrimental would be retained, thus preserving potentially unique habitats. The latter criteria (i.e. not detrimental) is considered to be of importance as there may be historic sites where maintaining the status quo is potentially harmful and engineered measures to mitigate those effects may be necessary. Thus each closure plan must be treated on the basis of establishment of baseline conditions, impact assessment and criteria adopted to suit the local conditions and location.

The examples shown in Table 3 indicate sites where positive and negative impacts have been identified.

CONCLUSIONS

Mining remains the primary source of metals for maintaining global industrial development, and is also one of the most heavily regulated industries worldwide. Currently the

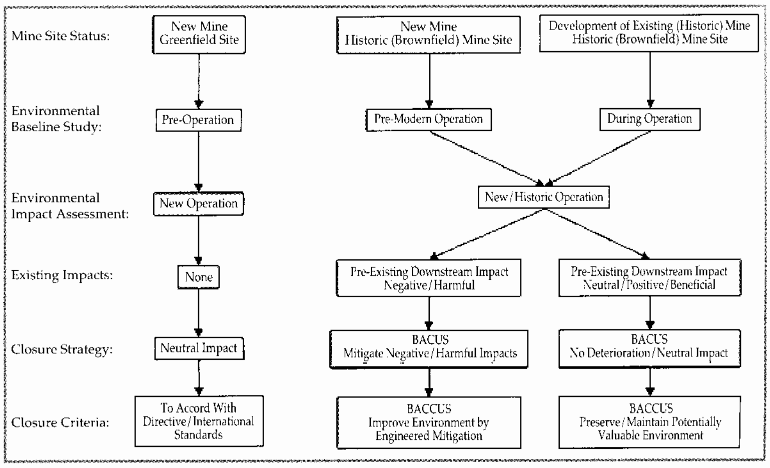

Figure 1.

Site	Location	Source	Pre Closure Impact	Potential Impact
Wheal Jane	Cornwall, UK	Acid minewater	Metal tolerant marine invertebrate [Unique Habitat]	Destruction of Unique Habitat if Directive adopted
Lavrion	Greece	Lead rich tailings	High Pb dust levels, significant impact on human health	Improvement in local human health if mitigation engineered
Parc Mine	N Wales	Lead rich mine waste	Metal tolerant grasses developed but impact off site via erosion	Site restored with varieties developed from unique local species
Aljustrel	Portugal	Acid and mine drainage	Dispersion of acid discharge and fish kills during seasonal flooding	Prevention of downstream impacts by ARD control

Table 3. Environmental impacts associated with historic workings.

mining industry is under pressure from increasingly stringent regulations and adverse publicity, particularly in North America and Australia. This has led to renewed interest in some of the older mining areas which may, for cultural reasons, be amenable to development and which due to improvements in extraction technology have re-emerged as viable prospects. Historic mining sites, however, are often associated with a long term contamination problem which must be appropriately addressed if the existing European mining industry is to develop and thrive.

The residual contamination associated with historic mine sites and the means by which recent mining operations at the same location may be economically and safely closed need to be addressed. The global adoption of EU or other directives to establish closure criteria is not always appropriate and a less prescriptive approach, which moreover may be more environmentally sound, is recommended. A new acronym is proposed which epitomises this pragmatic approach and enables mining company and regulator alike to retain existing modified habitats or mitigate harmful effects without blind acceptance of directives which would be to the detriment of all. Best Appropriate Clean Up Strategy (BACUS) leading to Best Appropriate Cost-effective Clean Up Standard (BACCUS) which establish appropriate closure criteria meets this requirement. The proposed acronym BACCUS has a satisfying ring to it and is held to be particularly appropriate in the light of the conjectured link between good red wine and mining in Southern Europe.

There are a number of mine rehabilitation studies currently underway which focus on the ancient mining areas of Europe. It is hoped that the results of these studies will assist by providing data to substantiate the BACCUS principle. The studies currently in hand involve potentially some of the heaviest contaminated mine sites in the western world and should permit the development of environmental data sets and lead to the scientific justification for this approach, particularly with respect to Regulation. This data may also indicate that more flexibility in closure performance criteria will be beneficial not only to industrial development but also to the environment itself. In the meantime, the BACCUS approach can provide guidance both to regulator and practitioner alike, and lead to pragmatic solutions to the problems associated with rehabilitation of historic mine sites.

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