

Minerals sustainability, emerging economies, the developing world, and the ‘truth’ behind the rhetoric

Michael G. Petterson

British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK; mgp@bgs.ac.uk

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Abstract. This paper reviews the principles and applications of sustainable development as applied to minerals (sustainable minerals). The key pillars of sustainable minerals are well known and include economic, community, environmental, and political considerations. The ideal solution is one that finds a balance between community benefit, economic development, profit, and minimal negative environmental and political impacts. This is, of course, fine in theory but in the ‘real world’ difficult to achieve. From a geoscience perspective this paper argues that non-private sector geoscientists have a crucial role to play in developing the sustainable minerals paradigm to an intellectually mature and usable form. The geoscience approach includes re-interpreting the rich legacy of geoscience data and acquisition of new data (geological mapping, 3 and 4D modelling, geophysical and geochemical information) and contextualizing this information with socio-economic and environmental data (e.g. ethnicity, social mix, wealth indicators, environmental sensitivity indicators) to assist with strategic and localized decision-making, maximizing benefits, and minimizing adverse impacts. This approach also involves modelling the full lifecycle of minerals, mines, mineral commodities, and mineral-bearing land in an attempt to quantify benefits and disbenefits of mineral extraction. One crucial key element of a sustainable minerals approach is a mix between ‘hard’ science and social science and genuine inclusion and consultation with stakeholders, especially impacted communities. As geoscientists we are in a position to explain clearly the benefits of mineral development to society and the disbenefits of ‘nimbyism’ (e.g. exporting problems to countries less able to manage mineral extraction) and promote a ‘custodianship’ ethos of mineral development that is the only way to realizing the key principle of sustainability, i.e. leaving the planet in a state that our grandchildren can enjoy.

Key words: sustainable development, minerals, geoscience, copper, coal, aggregates, developed and developing world.

INTRODUCTION

The sustainable development paradigm was given birth in 1987 by the Brundtland report of the World Commission on the Environment and Development, which first coined the definition that sustainable development meant meeting the needs of the present without compromising the needs of future generations. Who could disagree with such a high-aspirational, religious-like sentiment? But who could apply such a sentiment in real-world practical terms? Surely, non-renewable mineral resource development follows the laws of cause and effect: in simple terms, extraction and usage of resources today will inevitably mean a reduction of resources tomorrow (and yet, paradoxically, it is living resources such as fish etc. that struggle to be ‘sustainable’). Sustainable development is a widely discussed but in reality little understood conceptual platform or paradigm that offers an intellectual and practical basis for mineral development with a heart and socio-environmental conscience. However, to demonstrate real-world benefits it must be seen to be

clearly applied, with tangible benefits, to real problems, real situations, and real people.

There is concern that the term ‘sustainable development’ is being hijacked and used as a politically convenient ‘sound bite’ by a wide range of interest groups with disparate but self-centred agendas. Over-usage of any term across a broad range of subjects and at a relatively shallow intellectual level runs the risk of killing the creative essence of the concept itself. The sustainable development ‘label’ has become over-used and possibly tired and somewhat dated. Fresh thinking and new exciting applications are needed to re-energize this area. We, as responsible world citizens and geoscientists must ensure that our specific application of the sustainable development paradigm works in a manner that leads to better practices, particularly with respect to mineral and energy resources. As part of the world geoscientific community we have a responsibility to encourage a custodianship ethos towards mineral and energy resources that maximizes resource usage and recycling, minimizes waste production, is kind to the

physical environment, ensures that local communities and economies receive widespread and long-lasting benefits, and deals with our responsibilities towards mineral production within our sphere of influence without unnecessarily exporting problems elsewhere.

One of the most practical beneficial applications of sustainable mineral development involves reinterpreting our legacy of geoscientific information and knowledge and setting alongside a range of other contextual datasets (national parks, city development areas, environmental, social and wealth indicators, etc.) to assist with medium- and longer-term land and mineral use in a strategically planned and prioritized manner. In this way decisions can be made that are supported by clear and transparent information and argument. We must also learn from past unwise mining practices and their related negative environmental, economic, and social impacts. We must encourage and lobby for mining extraction best-practice for the future. One key advance is in modelling the lifecycle of minerals, mineral-bearing land, and mining community-impacts from a grass-roots exploration stage to a post-mine stage. Real engagement with (including active listening!) a range of communities affected by natural resource development is fundamental. Developing customized local, national, and international minerals and planning policies for the benefit of all mineral stakeholders is an aspirational outcome of our cumulative study and engagement. These approaches must acknowledge that the world has an ever-growing need for minerals, which underpins a wide range of economic benefits and should aim to move mineral development forward in a consensual, strategic manner.

The greatest danger in any application of sustainability is complacency and cynicism. This leads to outcomes such as paying lip-service, using sustainability as a 'gloss' to make companies look good and improve their image, and developing so-called sustainability policies that are, in reality, vacuous. Sustainability relies on a dynamic balance between economics, society, environment, and politics. To a large degree economics takes care of itself as shareholders and profit drive this. Environmental concerns are, in the main, seriously attended to in most of the mining industry and this fight has largely been won (with some continuing notable exceptions). Politics is always a 'wild card' as it moves at the mercy of political winds and vested interests: it must be taken into account and managed but can rarely be directly controlled. The society challenge has not always been seriously addressed, is a particularly complex issue that is difficult and time-consuming to solve, and can be inappropriately acted upon. It is in the area of social engagement where I believe non-industry geoscientists, in particular working at universities, geological surveys, and

other public institutions, can make real contributions as they are seen by the general public to have fewer vested economic interests, possess bona fide expertise, and act impartially. I therefore suggest it is a challenge to all of us to explain to society the need and benefits of mineral resources and the imperative of wise custodianship of these resources. The only real test of mineral sustainability is the lasting transfer of mineral-generated wealth from the mine to the people in one form or another – more sophisticated and widely accepted modelling is needed in this area to demonstrate clearly benefits and disbenefits.

Global sustainability has become even more complicated with the advent of the new economic tigers personified at the moment as China, India, Brazil, and the like. The current climate change debate clearly crystallizes the conundrums: how can a high-consuming Western world who have had it good for so long preach to an aspiring Eastern and Southern world with any real credibility (e.g. Dasgupta 2002)? It just cannot and it is deluded if it thinks it can. China is fuelling exceptionally high raw material demand and is a key driver for the commodity super-cycle in which we find ourselves at the moment. There will be no turning back. In China and India hundreds of millions of people will attain a lifestyle that will be ever-more demanding of mineral and energy resources, and history teaches once such a lifestyle is attained, people are very reluctant to drop living standards. Geoscientists have a heavy burden of responsibility to engage with the global community and develop ever more sophisticated and customized raw material custodianship methodologies through the sustainability paradigm or something better that springs from this.

We also have a responsibility to focus on the poorest world. Europe produces a large mineral footprint and largely relies on commodities extracted from a global market. It has a responsibility to the poorest and by definition most vulnerable part of the world in particular. It is in this world where we often find examples of least-sustainable mineral development practices and the presence of the 'resource curse' that distorts local markets, fuels wars, and creates misery. Perhaps the real test of sustainability is here: mineral development in this part of the world more than anywhere else should tangibly improve quality of life in the longer term. If it does not, it has failed the sustainability test and heads should hang in shame.

The core challenge is: can sustainable development offer a real way forward or be used merely as public relations gloss with little genuine inner-meaning? For this test to be truly successful motivation must be added to intellectual analysis, systems development, and the ever-growing arrays of high-quality data our modern digital world can produce. If the motivation for mineral

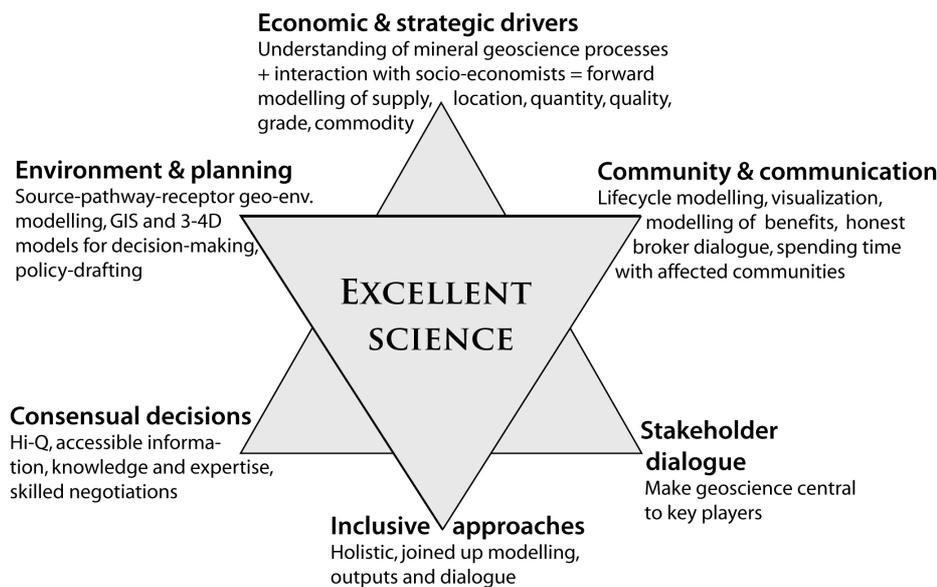


Fig. 1. Conceptual model of a 'sustainable minerals approach' for geoscientists.

development is profit and profit alone, then there is little chance of new sustainability approaches succeeding.

Figure 1 summarizes the key tenets of real sustainability for the geoscientist: excellent science at the heart of a dynamic process involving inclusive management and engagement, stakeholder identification, decision-making, community, economics, and environment.

This paper will present practical examples of the application of sustainable mineral development in the developing and developed world and focus on issues such as how geoscience can underpin policy and planning, how the geoscientific community can encourage best-practice, and will give examples of good and not-so-good mining practice.

A THEORETICAL FOUNDATION: WHAT IS MEANT BY 'SUSTAINABLE MINERALS'

As mentioned above, the sustainable development paradigm was introduced in 1987 by the Brundtland report of the World Commission on the Environment and Development. More recently (2002) the Global Mining Initiative (GMI) published a 440-page report entitled *Breaking New Ground: Mining, Minerals and Sustainable Development* (IIED 2002). This report was possibly the most mature body of work to date relating to the concept of 'sustainable minerals' and crystallizes three years of worldwide study, consultation, and analysis undertaken by the London-based International Institute for Environ-

ment and Development. The report summarizes current ideas, thinking, and methodologies across a wide range of themes from the need for minerals to the impact on local and global communities. The impact of this report is only just beginning but already provides a more substantial knowledge and information base than previously existed. Important milestones such as the GMI have assisted the drafting of this strategy document.

In the context of minerals sustainable development is clearly not a way of making a finite non-renewable resource infinite and 100% renewable. It is more about developing a range of methodologies for maximizing and sustaining the economic, environmental, and social benefits and minimizing the negative impacts which accrue from mineral development.

A deeper and more refined definition of sustainable minerals must recognize that the sustainable development paradigm is a dynamic network and interplay of ideas, concepts, and evolving thinking. The key idea is that an optimal balance is arrived at between the three fundamental thematic areas of concern: economics, environment, and community. Sustainable minerals must find a consensual way forward which: a) generates sufficient minerals-oriented wealth to attract capitalist-oriented private-sector industries; b) makes it essential that mining companies operate to the highest environmental standards, thus protecting the physical environment; and c) develops methodologies and approaches which maximize lasting benefits to communities at local, regional, and national levels. Approaches to be adopted should encourage:

- maximizing resource usage and recycling;
- minimizing waste production;
- minimal negative impacts on the physical environment;
- local communities and economies to receive widespread and long-lasting benefits;
- an increased sense of responsibility towards mineral production within our sphere of influence without unnecessarily exporting problems elsewhere.

The most beneficial application of sustainable mineral development involves:

- reinterpreting and modelling our legacy of geo-scientific information and knowledge to assist with medium- and longer-term land and resource use in a strategically planned manner. These data must be ‘contextualized’ by combining the data with a range of social and environmental indicators;
- learning from the unwise mining practices of the past and their related negative environmental, economic, and social impacts;
- encouraging mining best-practice for the future; mining will be judged through the eyes of a critical world by worst, not best practice. It is in all our interests to raise the level of the lowest quality practice as high as we can;
- modelling the lifecycle of minerals, mineral-bearing land and mining communities from a grass-roots exploration stage to a post-mine stage;
- consulting with and listening to a range of communities affected by mineral development;
- developing local, national, and international minerals and planning policies for the benefit of all mineral stakeholders (local communities, local and national economies, mining companies, etc.).

Before developing this concept further it is useful to analyse a range of drivers which have led to the current debate relating to sustainable minerals.

TRADITIONAL VIEW OF THE LINKS BETWEEN MINERALS AND ECONOMIC DEVELOPMENT

Historically, those countries that were the first to industrialize in the ‘modern era’ (e.g. Western Europe and North America) underwent a series of major changes in social and economic structure: this was the time of the Industrial Revolution during the 19th century. The industrial revolution was a key driver in changing economic function from agricultural- to manufacturing-dominated and had a major impact on demography by increasing population numbers and settlement habits, e.g. from relatively low density rural-based villages to high density urban centres.

These changes led to increasing consumption in mineral commodities, particularly coal, iron ore, non-ferrous metals (e.g. copper), limestone, ceramic quality clay, brick clay and railway aggregate. Increasing mineral materials demand was fuelled by manufacturing industry raw material requirements, rapid urban development, and a strategic requirement to develop modern transport systems (e.g. railways).

For example (Fig. 2), the average annual growth rate in world copper production during the 19th and 20th centuries was 6% and 4% respectively, with significant peaks in the last decades of both centuries as many parts of the world were ‘wired’ for electricity and the internet (and related electronic technologies), respectively (Greg Chapman, pers. comm. and the BGS annual publication *World Mineral Statistics*). British coal and pig iron production increased from 10 and zero million tonnes per annum (Mta) respectively in 1770 to 25 and 1.5 Mta respectively in 1850, to a peak of 300 and 10 Mta respectively in 1910, a growth rate for coal up to 1913 of ca 4% per annum (Kernot 1993). Similarly, in more recent times British crushed rock aggregate demand increased from 12 Mta in 1900 to around 80–90 Mta from the 1960s onwards (BGS 2002b) as Britain developed its modern road highway system (responding in turn to the increasing purchasing power of individuals who could afford expensive items such as private motor cars).

Minerals played a large part in this classical economic evolutionary model, not only by providing essential raw materials but by generating capital assets which could be transferred to a myriad of requirements by rapidly

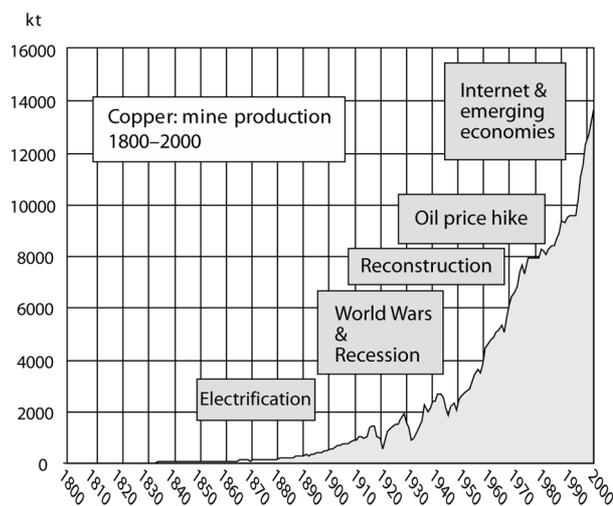


Fig. 2. Copper consumption can be used as a proxy for a wide range of mineral and energy consumption trends. Key points include that pre-1860 global consumption was insignificant, that consumption has rarely declined (only in times of global large scale war), and that the rate of consumption growth is largely dependent on economic and social wealth.

growing industrial nation states. For example, as ‘western’ style nation states developed, the role of governments in wealth redistribution also grew to the point where many states now have fiscal responsibilities for a wide range of infrastructure and social welfare programmes: these government programmes must ultimately have a funding source and a nation must produce a sufficient level of wealth to sustain these programmes.

Mineral-derived wealth is one source of capital asset which can get the economic ball rolling and many of today’s developed states (e.g. USA, Canada, Australia, UK, Spain) have undoubtedly benefited from mineral-generated wealth at various stages during their economic development. Furthermore, there was an almost unquestioning belief amongst most of the population of industrial nations that mineral development was an intrinsically ‘good’ phenomenon as they could directly relate to the connection between mining and wealth generation: for example, many received their wages from mining-related activities.

CHANGING ATTITUDES TOWARDS MINERAL DEVELOPMENT

The 20th century saw the increasing globalization of industrial-based economies with many nations in Asia, South America, and oil-rich North Africa developing industrial-based economies and experiencing their individual industrial revolutions. This impacted on the older industrial economies of Western Europe and North America as stiff competition led to the demise of traditional industries, such as ship-building in some areas in Europe and the creation of the same industries in Asia and Eastern Europe. The growth in world industrial economies had similar impacts to those described above for Europe and North America: increasing populations and urban populations; infrastructure development; increasing consumerism and consequent increasing demands for materials and minerals.

Mature western economies are now moving towards ‘post-industrial’ economies that are less reliant on primary and manufacturing industries and are moving towards a service economy dominated by activities, such as financial services. This change in social and economic function has mirrored attitudes towards mining, from an unquestioning acceptance of mining during the ‘industrial-manufacturing’ eras of mature economies to an anti-mining or begrudging acceptance stance in many modern post-industrial societies (e.g. much of present-day Western Europe).

Service-based economies inevitably lead to a lower proportion of a country’s population being involved in manufacturing and/or mining activities. It becomes

increasingly difficult for such a population to see the links between quality of life on the one hand and minerals on the other. Most people will not even be aware that the house they live in, the road they drive on, and the car they drive in are almost entirely made from mineral-based products. Even if they are cognisant of this fact, they may not be concerned about it. However, there is now a developing consciousness with respect to the physical environment and climate change and an association in peoples’ minds between mining, minerals, and environmental degradation. Many proposals for mineral development and mining now have a very hard time within the planning bureaucracies of the western world with many proposals being turned down. For example, Scotland turned down applications in the 1990s for the opening of a baryte mine in the Scottish Highlands and a hard rock aggregate super-quarry in the Hebrides in spite of the fact there were proven reserves, markets, local unemployment, and viable mining/quarrying plans. There is almost an unwritten imperative to turn down mining applications in many areas unless incontrovertible evidence of very significant short-term economic benefits is presented. However, the indigenous demand for minerals remains in the very same countries who turn down mining planning applications. These countries look to the world market to supply them with the minerals they require for their standard of life. As more and more developed countries adopt anti-mining planning strategies, this will inevitably mean that they will look to the less developed world for mineral supplies. A British example used to illustrate this change is given below.

Coal mining in northern England: the rise and fall of a mining industry and consequent change in societal attitude to mining

The Northumbrian (Northumbria = Northumberland and Durham counties of northern England, see Fig. 3) and Yorkshire coalfields were the largest coalfields in Britain, with a history dating back at least to the 13th and 14th centuries. Earlier mining operations were predominantly small-scale opencast, drift and ball and pillar workings owned by a range of local landowners, including Christian monasteries. The modern ‘coal age’ (from a British perspective) began around 1765, peaked in 1913 (when 165 000 miners were employed in 310 collieries in County Durham alone) and continuing in a small way to the present day. In 1945 some 231 Northumbrian mines were in operation, employing over 100 000 men (Kernot 1993). This compared with a national UK picture in 1945 of 1299 mines and 720 000 miners. Each mine employed an average of 554 miners (Kernot 1993). In 2001 only 8500 deep coal miners were left working at fifteen active deep mines (BGS 2002b). The number of

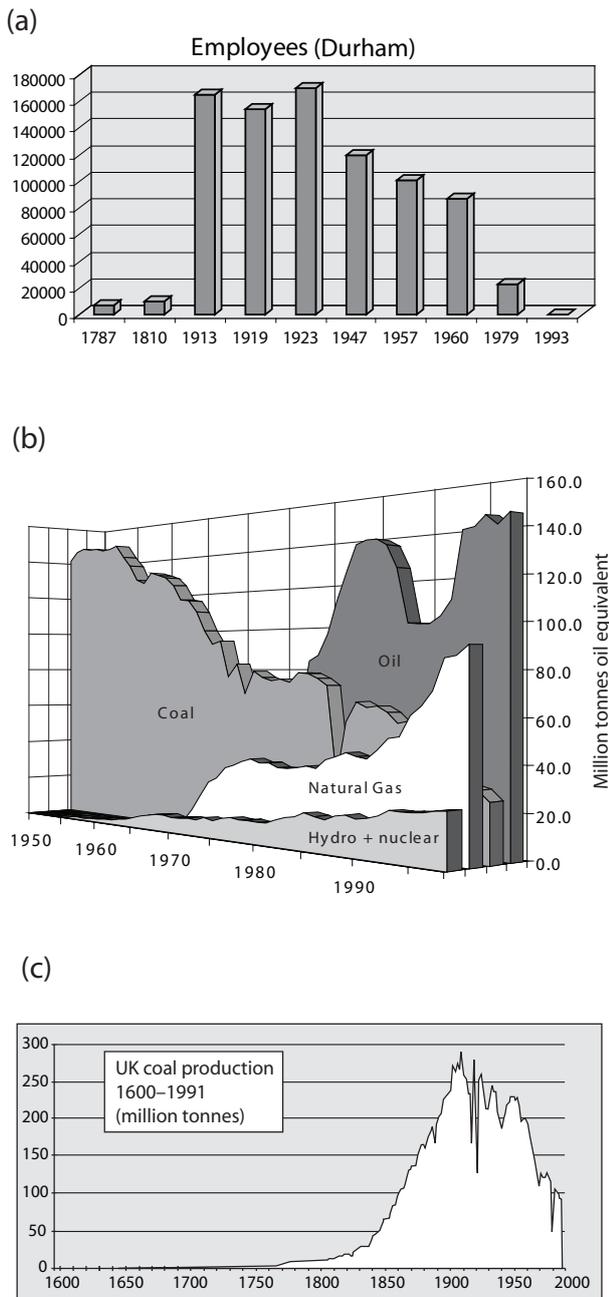


Fig. 3. (a) Changes in the number of Durham miners (Northern England coalfield). (b), (c) The rise and fall of coal production in Britain with peak production in 1913; the demise of coal has led to the rise in the consumption in oil, natural gas, and nuclear energy (figures after BGS and Kernot 1993).

Northumbrian and UK miners fell dramatically from 1960 onwards, losing around half its working population by the late 1970s; the work force was decimated after the tragic 1985 miners strike which led to major confrontations between miners, mining communities, and the government and police.

As with other coalfields in Britain, the demise of the Northumbrian coalfield has led to far-reaching changes in communities, local economies, and attitudes. The typical Northumbrian coal mining village owed its *raison d'être* to mining: it most probably did not even exist prior to the opening of the mine. The physical appearance of most Northumbrian mining villages is quite similar, with, typically, several rows of back-to-back style terraced houses, shops, churches, mining welfare clubs, public houses, garden allotments and of course, the mine itself with its characteristic mine-head winding gear. These communities were typically tightly-knit with an ethos of self-help and mutual assistance. The livelihood of individuals and their families in Northumbrian coal mining villages, the welfare of the local economy and service industries relied ultimately on the mine for their survival. It was obvious to people why mining was required: they burned coal for heating their homes, and saw their pay packets at the end of every week.

The closure of the mines occurred over a 30-year period (1960 to 1990) for most of the Northumbrian coalfield. During the early phase of closure men were redeployed from one mine to another, but ultimately there were few mines left in which to be redeployed and major redundancies ensued. Many of the redundant men possessed skills that were only really useful to the coal-mining industry, whilst others with generic skills, such as electrical expertise, found it easier to find work in other non-mining industries. The British Government attempted to regenerate the coalfield region through a series of programmes and schemes designed to attract inward industrial investment and improve transport infrastructure. These schemes have had a range of success. Some areas of the Northumbrian coalfield (e.g. those close to main roads) have moved on to some extent and left their coal-mining heritage behind. Other areas, such as in east Durham, remain areas of high unemployment; mining villages left without a mine and looking to the future with uncertain eyes.

Even in this region with such a long mining heritage there is little sympathy for new mining developments. Most requests for opencast mines are turned down and quarry companies have to work hard to obtain extensions to current mineral-permitted areas. The younger and newer populations of this proud mining region have little or no connection with the region's mining past and are just as likely to resist mining developments which, in their eyes, threaten the local landscape or their quality of life. They look to 'other areas or other countries' to supply the minerals their lifestyles demand. This historic example is a clear example of 'unsustainable minerals'; i.e. mineral extraction that helped in the economic growth of the country (Britain) has not left a lasting economic benefit in the region the mineral was extracted – it has failed the key sustainability test of transforming mineral-generated wealth into lasting economic wealth.

DEMONSTRABLE DEMAND FOR MINERALS AND DEMAND VARIATION

There is little doubt that there is real demand on a global scale for minerals. The global copper production (Fig. 2) clearly demonstrates this. Prior to 1850 the world demand for copper was infinitesimally small compared to present-day production (ca 14 Mta). Copper production became significant in the second half of the 19th century and really took off as the industrialized world became 'wired-up' for electrical energy transmission to individual homes and businesses, growing at 6% per annum between 1880 and 1910. A lower growth rate of 2.4% per annum in copper production between ca 1910 and 1950 was the consequence of global war and economic recessions: however, there still remained an overall growth in production. The post-World War II boom of ca 1950–1973 was reflected in an annual growth rate of 4.8%, which fed reconstruction in the countries devastated by war and increasing industrialization, globalization, and infrastructure development in areas such as Asia, Eastern Europe, and South America. The oil price rises and recessions (in some parts of the world) of the latter part of the 1970s and 1980s resulted in the lowest annual growth rate in copper production (1.2%) for over a hundred years. Finally, the last decade or so has experienced a 5.5% rapid annual growth rate in copper production as the world has wired up a second time for the internet and related electronics applications, and fed enormous infrastructure growth in China, India, and elsewhere.

Of course, there is no guarantee that a commodity will always be required: the Stone Age did not end through an end in stone supply! Even 'King' copper may one day 'die' as material substitutes for copper are found in the future. Lead is a commodity that illustrates the point. Lead was a high-demand commodity in the 18th, 19th, and earlier 20th centuries with a myriad of applications (including piping and guttering, petrol additives, paints, etc.). Demand for lead and primary lead in particular fell markedly during the latter part of the 20th century as the health risks associated with lead digestion became better understood and recycling technologies developed. There remains a market for lead, although this is a restricted one compared to its former glory days. Other commodities (such as palladium and tantalum) become increasingly popular as new products and markets develop (such as catalytic converters and mobile telephones) that require their input. The minerals market is dynamic and variable, with a range of complex economic and market factors acting as drivers one way or the other. Recent trends in the gypsum market illustrate how complex the picture can become. Gypsum is largely produced through primary mining and is used for products such as plaster and plaster-board. Global environmental

pressure on electrical power stations (particularly coal-powered ones) and metal smelter plants has reduced atmospheric sulphur dioxide emissions from the 1970s onwards. This has resulted in some cases in a reduction in coal-fired power stations but also in a new technology which uses powdered limestone in power station furnaces to be used as a chemical sponge for SO₂. Resulting chemical reactions produce a new source of gypsum (desulphogypsum), which now has a place in the market place, substituting for primary mined gypsum for some end-products. So, interestingly, global environmental awareness resulted in new government policy that impacted most directly on the electricity generation industry and indirectly on the minerals industry. This was probably not foreseen in the earlier phases of government policy drafting.

Thus I would argue that although the demand market for minerals will never be static, it will most likely always be present in one form or another. History teaches us that in broad terms the demand for minerals has grown along with world economic development. The world now demands a broader range in mineral commodities than ever before. Demand for individual commodities will rise and fall, driven by changing markets, new technologies, changing lifestyles, and environmental pressures. Demand for mineral commodities, as with all material things, is disproportionate on a world scale. For example, in a 77 year lifetime the average American and West European consumes ca 550 and 380 t of fuel and 620 and 600 t of aggregate, respectively, whilst an average Ethiopian, Bangladeshi or Nepali will consume less than 4–5 t of these commodities (BGS 2002a; Fig. 4). It will always be the case that the richer world will consume proportionately more than the poor world. However again, this will be a dynamic, constantly changing phenomenon as national and regional economies rise and fall (e.g. the current rise of China).

There is also an increasing trend in maximizing materials efficiency and even, some argue, 'dematerializing'. These trends are and will increasingly result in more efficient and economic usage of mineral resources. They could, for example, lead to a much more restrictive commodity grade versus end-use approach where the appropriate (rather than the superior) commodity grade is used for a specific end-use. For example, lower-quality grades of aggregate could be used for fill purposes than is presently the case. This is particularly relevant for many materials which are produced through recycling processes, as these processes can often down-grade commodities, particularly non-metallic commodities. Recycling and secondary usage of materials is a key element of sustainable development. However, there are always market drivers that can prevent this 'grade-matching' occurring in specific markets. Similarly, infrastructure developments will be increasingly planned

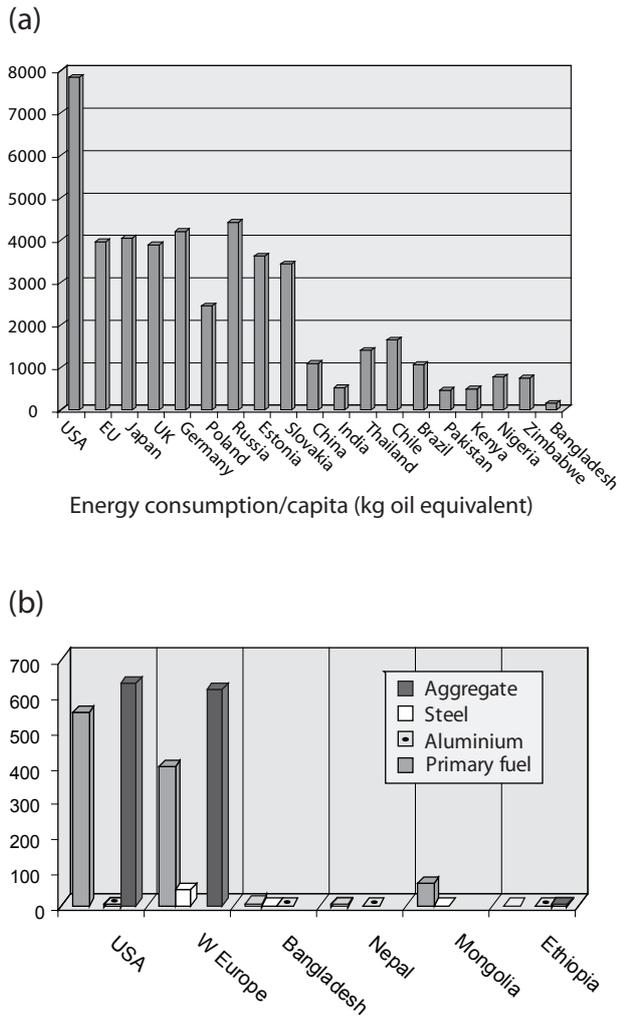


Fig. 4. Uneven consumption in terms of energy (a) and materials (b) in rich and poor countries across the world.

on the basis of using lower quantities of mineral commodities. For example, the design of housing estates makes a significant impact on material volume requirements. Architects and planners are increasingly encouraged to minimize materials usage when they design housing estate road and sewerage networks.

Recent studies have shown that countries such as the UK may become ‘decoupled’ from materials with respect to economic development. These studies argue that economic development and growth does not necessarily lead to a proportionate increase in materials usage as new technologies and economic-social policy development leads to increasing materials usage and efficiency (Bringezu & Schutz 2001).

The most notable change in recent times has been the rise of new economic giants such as China, whose exports alone have increased almost exponentially (Fig. 5). On 8 November 2007 it was announced by the



Fig. 5. The growth of exports from China as an indicator of the rise of a new economic giant (along with India and other countries) (after *The Economist*).

world press (e.g. BBC website news) that the Chinese petrochemical giant *PetroChina* has now become the largest company in the world and is worth twice as much as its closest rival *ExxonMobil*. Furthermore, China owns five of the top 10 world companies at the current time (November 2007). China’s extremely rapid economic growth has fuelled demand in metals, raw materials, and energy supplied across the globe. For example, China sources much of its iron ore from Western Australia and South America and is extremely active across the world in mining investments. Most recently China has adopted an aggressive ‘aid’ policy in sub-Saharan Africa, investing heavily in places such as the Democratic Republic of Congo in an effort to secure raw materials and metals for decades to come. This economic growth has not led to dematerialization in any shape or form. Figure 2 demonstrates the impact of the new economic giants such as China on the rate of consumption of copper – currently the rate of consumption of copper is higher than ever before. Gold has recently broken the US\$800 per ounce mark (November 2007) and oil is currently attracting record prices: all symptoms of very high global demand, fuelled at least in part by the rise of new economic giants.

THE DARKER FACE OF MINING

There is little doubt that some of the current negative perceptions linked to the minerals industry are rooted in a range of bad mining practices: from pollution to negative landscape impacts, from threats to local ecosystems to causes of community and political unrest. Unwise mining practices will hit the world headlines much more readily than good mining practices and to this extent progress with positive image building will always be handicapped by the existence of poor mining practice. There is also a huge legacy of mining, which has left a negative impact on the landscape and barely-surviving communities across the globe.

Large opencast mines

The largest-scale opencast mining operations on earth are related to porphyry copper extraction in the Western Americas. These mining activities produce gargantuan open pits, which have been left behind by past operations or will be left behind by current mining operations. The Chuquicamata mine in Chile, for example, will produce at least 11.4 billion tonnes of 0.75% grade copper ore by the time it closes and has produced arguably (in competition with Bingham Copper Mine Utah, USA, which measures some 3.7 km in diameter by 0.76 km deep) the largest man-made hole in the ground measuring 4.5 × 3.5 km wide and 0.8 km deep. Other large open pits include Bisbee, Arizona, USA, which produced several billion tonnes of copper and gold ore during a ninety-year lifetime ending in the 1970s. Bisbee's Lavender pit (some 250 m deep) is considered an eyesore by some and a tourist/heritage attraction by others – although it is marketed as a major state tourist attraction. There are many other porphyry copper mining giants (e.g. Morenci and Mission-Pima, Arizona, Escondida, Chile and Cananea, Mexico), which will ultimately leave large landscape footprints, within an arid West American montane environment. In wetter climates these mine legacies would pose difficult challenges relating to acid mine drainage and the resultant impact on local ecosystems: for example, the relatively tiny pool of water which stands within the floor of the Bisbee Lavender pit has a pH around 2. There does, of course, exist today a range of remediation technologies which can reduce the negative environmental footprint of mines. Responsible mine operations of today and tomorrow will undertake stringent, post-mine environmental rehabilitation. However, the key point is that the modern mining industry cannot afford to remediate the mining-related environmental legacy of the past (this responsibility has been inherited largely by governments) and that society must accept that its need for copper currently entails the production of kilometre-scale human-engineered craters, which will remain as unfilled holes in the ground.

Ghost towns

There are many examples of 'ghost towns', which sprang up in previously uninhabited areas in response to mineral prospectors attracted to perceived bonanza mineral deposits. Communities developed around subsequent mines, which ended up as ephemeral settlements whose sole function was to service the mine. If the town failed to develop a diversified economy, then it was unlikely to survive many months or years beyond the lifetime of the mine.

An example of such a mining township can be found in Argentiera, NW Sardinia, Italy, where a small town-

ship developed around a silver mining function. Mining in the area dates back to classical Roman times and ultimately Argentiera became the largest silver producer on the island. The township is located in a relatively remote peninsula and failed to develop a non-mine economic base. Mining ended in 1963. Today the township barely survives. There are a few residents but the area is characterized by many hectares of unremediated mining land, open and abandoned mine shafts, dilapidated mine buildings and miners quarters, and a rather depressing, neglected atmosphere. Similar mining townships in SW Sardinia, such as Iglesias (related mainly to Pb–Zn mining), have coped rather better and have developed at least a tourist and mining heritage-based local economy which post-dates mining.

The mining townships of the north Pennines in northern England are another good example of communities left 'hanging' once mining has ceased. This area of England is relatively remote and climatically inhospitable. It was largely unpopulated before mining developed but the discovery of lead (and also fluorspar, baryte, silver, and zinc) encouraged large numbers of miners to the region from the 18th century. Many of these miners worked in appalling conditions and lived a mixed subsistence-based mining-agricultural existence (miners' wives tended small holdings on very poor agricultural land on upland moors, e.g. Forbes et al. 1996). Numerous remote mining towns developed (e.g. Alston, Nenthead, Killhope, Allenheads, Carrshield, Rookhope) which flourished during the 18th and 19th centuries, whilst the industry boomed but fell on hard times due to slumps in the lead price during the 1870s and increasing international competition from countries such as the USA and Australia. The area subsequently depopulated, some towns and villages became abandoned (e.g. Coalcleugh village in Northumberland), whilst others survived largely through agriculture and service industries. More recently the area has been reinventing itself as a tourism-mining heritage region. In a similar mould the coal mining districts of Britain have all had to adapt to a rapid closure of their industry (see above).

Tailings dam failures

Omai, Guyana

The open pit gold mine at Omai in Guyana, owned predominantly by Canadian companies Cambior Inc and Golden Star Ltd, began its mining life in the 1880s and had produced 115 000 oz of gold by 1911. Modern mining began in 1993 and produced 251 000 oz of gold in 1994. In August 1995 the main section of the tailings dam failed, releasing enriched tailing slurry and spillages into the Essequibo River. Press reports at the time (Roberts 1995) claimed that up to 3.4 million cubic metres of cyanide-rich effluent were released over a

five-day period and that the sampled river water contained 25–30 ppm cyanide (WHO safe limit for cyanide concentration in water is 0.07 ppm). It is difficult to assess the full impact of this tailings dam spillage and it is fortunate that the spillage eventually entered the large, high-volume, and fast-flowing Essequibo River. The small Omai Creek, which leads from the Omai Mine Site to the Essequibo River, was mostly affected and the Essequibo itself was affected downstream of the cyanide spill entry point over a length of ca 45–130 km (op. cit.). *Mining Journal*, 6/9/96 (OGM 1996) quotes that the spillage event was under control within five days and an ensuing Guyanese Government Commission of Enquiry agreed a range of actions which closed down mining for a period of 5–6 months and partly led to more stringent operational methods (although these were already being planned) with respect to tailing pond and dam design and effluent treatment (for example, discharges into the Essequibo River will contain <1.5 ppm cyanide which is rapidly diluted).

Los Frailes, Aznacollar, Spain

On 25 April 1998 a tailings dam failure of the Boliden-owned Los Frailes lead-zinc mine at Aznacollar, close to Seville, Spain, released 4–5 million cubic metres of tailings slurries into the Rio Agrio, a tributary of the Rio Guadiamar. This incident impacted on several thousand hectares of farmland and threatened the UN world Heritage designated Donana National Park. The incident received a large amount of ‘bad press’ particularly within Europe. Boliden announced the closure of Los Frailes on 20 September 2001 and the consequent redundancies of 425 employees (Coleman & Perales 1998 and references to *El Pais* reports therein).

Baia Borsa, Romania

Melting snow and torrential rain broke a tailings dam at Baia Borsa mine, some 350 km northwest of Bucharest in Romania in early 2000, releasing large volumes of lead-, zinc-, and cyanide-rich tailings into the Vaser River, which ultimately flows into the River Danube and consequently through several European nation states. The plume of pollution killed a range of aquatic and sub-aerial fauna and rendered large amounts of drinking water un-potable for a significant period of time. The incident underlines the fact that mine-related incidents can impact on more than one political region or state (Anonymous 2000).

Riverine tailings disposal

Ok Tedi is a world-class copper-gold orebody and mine located at Mount Fubilan in the Star Mountain Highlands of Papua New Guinea (PNG) close to the Irian

Jaya border. Mining production began in 1987, and in 1998 export sales from the mine made up almost 20% of PNG’s total exports.

Ok Tedi has always attracted a degree of controversy due to its tailing disposal policy: mine tailings are disposed by river. Environmental problems result from the discharge of 85 million tonnes of waste rock per year into the Fly River System. Problems include river turbidity, increased sedimentation and bedload, a decreased river gradient, bank overflow and flooding, and negative impacts on the local ecosystem (see www.oktedi.com/environment/impacts.htm 1999, 2002). In September 2001 BHP-Billiton divested itself of a 52% share in the mine. The mine is now predominantly owned by PNG-based companies and the PNG Government. Over 90% of the workers at Ok Tedi are PNG nationals. Residents and villagers affected by the mine within the Fly River System have been compensated through a number of agreements between the mine operators and the local community.

Community–government–company interactions

Panguna, Bougainville, Papua New Guinea

Panguna is one of the darker episodes in recent mining history. Essentially it records a serious breakdown in relations between a local community, a mining company, and a national government. As such it is an excellent example of unsustainable development and remains a lesson to this day as it remains unresolved. As with most complex issues the root cause or causes of the problem are manifold, and it is beyond the scope of this paper to explore these.

Bougainville is the most easterly island province of PNG and borders the island nation state of Solomon Islands. It has an ethnic and linguistic identity of its own, as do many provinces of PNG, a land of over 700 languages. Bougainville provided PNG with its first large-scale modern mine (a porphyry copper mine) after CRA (Conzinc Rio-Tinto Australia) were granted a prospecting licence to explore the Panguna area. The resulting mine began commercial operations in 1972 and was operated by Bougainville Copper Limited (BCL – a joint venture between Broken Hill Corporation and Conzinc Rio Tinto, more recently 54% Rio Tinto, 19% PNG Government, 27% public shareholders). The mine disposed its tailings into the Jaba River, which impacted on the whole valley. The mine was highly valuable to the PNG government as a source of hard currency and foreign capital earnings. In May 1987 a more radical leadership took over the Panguna Landowners Association (PLA), which included Francis Ona and Pepetua Sereo. The PLA demanded back-compensation of US\$10 billion, which they claimed was a more realistic community compensation payment than

the much lower local agreements which had been in place since the mine's inception: there was a widespread feeling amongst the community that they had been unfairly treated and taken advantage of by both company and national government. The PLA leadership were instrumental in setting up the Bougainville Resistance Army (BRA) in 1988 who forcibly closed the mine (in late 1988/early 1989) using explosives stolen from the mine itself. Mine operations were officially closed in May 1989. The mine has never reopened and a Civil War has ensued, which has embroiled aspirations for Bougainvillian self-determination, has displaced up to 60 000 people, led to much loss of life, and political and economic instability, which remains to the present day. On 1 May 2001 Rio Tinto announced its intention to sell Panguna mine (McIntosh 1990; Lipscomb et al. 1998).

Suriname

In 1995 an incident at Nieuw Koffiekamp in the interior bush-lands of Suriname between the descendants of runaway African slaves (the Maroons) and the mining company Golden Star led to the temporary cessation of exploration activities related to the Gross Rosebel gold deposit. The Maroons have a long history of undertaking small-scale gold mining in the area as part of their traditional economic way of life. A six-year bush war between the Maroons and Government troops ended in 1992. Golden Star were granted prospecting rights over the Gross Rosebel concession but found it increasingly difficult to work alongside the small-scale local miners. Eventually they requested that small-scale miners ceased operating within their prospecting licences, which led to intense local resentment amongst a community comprising 19 bush villages. The Surinamese Government continued to attempt to address the problem of accommodating the interests of the large-scale formal mining and the small-scale informal mining sectors – this of course is an issue of worldwide significance (Healy 1997). More recently agreements have finally been reached.

A FORWARDS LOOK

In spite of the examples of bad practice given above, it is apparent that there has been a consciousness shift towards sustainable development practices in mining during the past 10–20 years. This movement has not occurred uniformly across the industry at a uniform rate, but in broad terms the industry accepts that it is current good business practice to follow sustainable development principles as much as possible. There are many examples of good practice and some are given below.

The move towards sustainable minerals does not just involve industry of course. There are many players including government and government agencies, non-government agencies (NGOs), consumers, social scientists and scientists, communities, and others. Various strategies are gradually evolving with the overall objective of developing a consensual way forwards for mineral development. This section concentrates on a few examples of this approach.

The lighter face of mining

Lihir, Papua New Guinea

The history of Panguna in Bougainville (see above) is one example of what can develop if consensual and fair approaches to mineral development are not achieved. The worst case scenario is that a complete breakdown in trust and relations occurs between communities, the mining company, and government, and this ultimately leads to conflict. There are, however, many examples of the achievement of harmonious relationships between the major stakeholders.

The case example of the development of Lihir gold mine is a case study in sustainable approaches to community participation in developing a mine. The account below is a summary of an article published in March 1996, in *Mining Environmental Management* (LMC 1996).

Lihir gold mine has been developed in a remote island (Niolam), which is part of the four-island Lihir Group that itself forms part of the Taba-Feni island group, New Ireland Province, northeast of the main island of PNG and New Britain. The PNG constitution states that mineral ownership is in the hands of the nation state, but customary landowners view mineral resources as part of their traditional lifestyle. The extreme remoteness of Lihir, its small size (only a few kilometres in diameter), and the traditional way of life meant that even a medium-scale mine development would have an enormous impact on the Lihirian people. It was vital that this impact was explained to the population as fully and comprehensively as possible before mining began.

Lihir was discovered in 1982 and at the time the Lihir Group had a population of 7000 people, of whom 5500 lived on Niolam. Prior to the discovery of Lihir there was very little infrastructure development and the population were involved in traditional subsistence agriculture with some involvement in cash crop farming (cocoa, copra, and chillies). The population lived in small hamlets.

In March 1995 the PNG government granted a Special Mining lease to the Lihir Management Corporation (LMC) who were a subsidiary of Rio Tinto Zinc. A total of 1800 people were involved in the construction of the mine and 1200 in the subsequent mine operations.

As early as 1984 the need for socio-economic studies was recognized and in 1986 the New Ireland Provincial Government commissioned a full study into the potential social and economic impacts of a gold mine at Lihir. A further study was commissioned in 1988 by the Provincial and National governments and the company partners entitled *The Social and Economic Impact of a Gold Mine in Lihir*. Community relations and consultations became part of an ongoing process of dialogue after the publication of the 1988 report. An intensive land investigation study identified and surveyed the land required for the mine and established that the land was owned by 6 Lihirian clans or tribal groups, 18 sub-clans, and 750 individuals. Landowners were represented by a co-operative called the Lihir Mining Area Landowners Association and the Nimamar Development Authority. Lihirian landowners set out their terms for compensation, emphasizing that this should not be limited to physical resource losses or damages but should be more comprehensive and sustainable. A key feature was the establishment of a sustainable trust fund to allow for the post-mining period. Royalties of 2% of gold production were agreed to be split 50:50 between Lihirians and New Ireland Province. The Lihirian royalty is split along the following lines: 56% to the Nimamar Development Authority and 40% to the Landowners, some of which is set aside for future generations. There were other specific financial agreements between the company, the landowners, and Provincial and National governments.

The LMC attempted to cement community relations from a very early stage through a variety of methods. One method was to support and fund infrastructure projects designed to improve quality of life. Projects included the development of water supplies, school, church, medical facilities and buildings, health programmes such as malaria mitigation, sports facilities, scholarships, and work-related skills training and development. Almost 80 Lihirian companies (involving activities such as earth-moving, security, retail businesses) were set up by 1996. Gender issues were taken very seriously and a range of programmes have been developed, which focus on women in a way that is appropriate for Lihirian society, operating within Lihirian societal values. Work was provided for women as far as local custom would allow and support was provided for women with respect to managing societal change, family health, education, nutrition, and other matters.

Unlike Panguna, Lihir remains an active mine and continues to work alongside and with the local community. This is a testament to the strenuous efforts and vision of people who invested time, money, ideas, and energy into an ongoing programme, designed to involve the community as far as possible in mineral development.

There will inevitably be problems, and the change in Lihirian society has been dramatic and traumatic. It will be interesting to see how successful this business and social experiment is in the longer term and how much of an example Lihir will be for future mine developments.

Environmental Impact Assessment Law in Austria

In 2000 the Austrian government introduced a new Environmental Impact Assessment Law (EIAL), which is designed to provide a basis for approving developments such as mines and quarries. One particular key aspect of the law included a 'democratization' process whereby all plans and information are made available to the key stakeholders, particularly the communities most closely affected by a mine or quarry. The democratization process includes the holding of a number of public meetings that give all key stakeholders the opportunity to present facts and viewpoints and engage in dialogue. Any proposal must present alternative options to the main project proposal and be specific about the lifetime of the project.

To date only one hard rock quarry project has tested the efficacy of Austria's EIAL. The project involves an extension to an existing diabase quarry in the Austrian Alps close to Salzburg. The quarry company presented detailed plans regarding the scale of operations, visual and environmental impact, post-quarrying plans, and economic benefits of the quarry, as well as presenting a number of alternative options. The company put together an 'expert' team who managed and presided over a series of public meetings where they attempted to justify the project proposal to planners, local authorities, and interested members of the community. The meetings were very well attended and people were given the opportunity to consider at least 50 different quarry designs and 10 transportation strategies. This presented a range of management challenges, not least how to present information in a way that is readily understandable by a broad group of people. The positive benefits included allowing grass-roots decision-making to take place and giving communities a sense of ownership in decisions. The proposal was approved, and this is certainly an example of a definitively consensual methodology for approving mineral development. The down side includes the cost of the whole process, the time taken, and the level of bureaucracy involved (Obendorfer 2002).

Environmental remediation technology

One of the main factors which helps to give mining a poor image is negative environmental impact. One key issue relates to the production of highly acidic mine

tailings, tailing ponds, acid mine drainage, and land contaminated by acidic mining residual materials, which also contain high concentrations of heavy, often toxic metals. Environmental technology is rapidly developing and is being used to address both the legacy of 200 years and more of less environmentally-friendly mining practices as well as current environmental problems.

An example of a highly effective remediation technology is Bauxsol (McConchie et al. 2002). Bauxsol is essentially a modified red mud which begins life as a residue or 'waste product' when alumina is smelted from bauxite ore. The original red mud which starts life as a highly caustic product with a pH of ca 11 is mixed with seawater to produce bauxsol. Bauxsol has the ability to neutralize highly acidic mine waters and to fix heavy metals within newly formed minerals. It readily reacts with mine waters to produce new and stable minerals, and is also highly insoluble in water and flocculates, allowing separation of the reacted bauxsol if required. Applications of bauxsol have led to the neutralization of tailing ponds with a pH of 2 and the development of an experimental market garden using bauxsol as a soil substrate on top of highly toxic mine tailings.

Developments in environmental technologies such as this provide the mining industry with powerful mining 'clean-up' tools. In order to move mining forwards, it is increasingly important to demonstrate that the mining industry truly cares about post-mine land remediation and environmental management. Every mine should have a full lifecycle model which addresses environmental issues at every stage of mine development. It is, perhaps, particularly important to leave behind a post-mining environmental legacy, which is one to be proud of and one which promotes a high-quality post-mine land usage, whether that be recreational, industrial or agricultural.

The global mining initiative

In response to the increasing awareness of sustainable development issues and negative perceptions associated with the mining industry, the London-based International Institute for Environment and Development was commissioned by a consortium of 40 sponsors (mainly mining companies) to undertake a major study of the key issues related to sustainable minerals. The project was entitled 'Mining, Minerals and Sustainable Development' (MMSD) (IIED 2002) and had a two-year lifetime, reporting in Toronto in May 2002. The project was undertaken by a 'work group' that was charged with executing MMSD at a global level and coordinating regional activities. The work group comprised 26 individuals and numerous other contributors who

collectively undertook the bulk of the research and report drafting. The work group coordinated regional partners in Australia, North America, South America, Western Europe, and Southern Africa and national partners in India, Indonesia, Philippines, Papua New Guinea, Kyrgyzstan, Khakassia, Bolivia, Brazil, Chile, Ecuador, and Peru. Work was quality assured through an independent panel of 25 individuals from key stakeholder groups.

It is beyond the scope of this report to comment extensively on the MMSD/Global Mining Initiative project. However, the project is presented here as evidence of a key change in thinking within the mining industry. The industry acknowledges that the only way forwards is through developing a truly sustainable approach to mining. The MMSD project is evidence of an inclusive approach where all key stakeholders (industry, communities, governments, miners, miners' families, women, ethnic and language groups, and others) are consulted and their views are seriously considered. The report comprises 410 pages of double-column text, which documents issues ranging from sustainable development theory to the need for minerals to communities, access to information, the roles of government and regional perspectives.

Minerals and strategic planning: ball clay mining in Dorset, UK

Setting the context: environmental planning designations vs mineral development

Mineral-related activities at the British Geological Survey (BGS; Bristow et al. 2002) have evolved in recent years from a classical minerals geoscience approach towards a more integrated approach where classical geology and minerals science are combined with 'soft' scientific skills, including economics, planning, and social science. This evolution in activities reflects changing needs of both government and industry who increasingly demand an approach which involves using geoscience to solve problems and address issues rather than only providing technical data advice and interpretation. From 1997 to 2002 the BGS was commissioned by the British Government to examine a specific case area in southern England, which was becoming a microcosm of a generic issue that faces particularly the Western world. The issue is one of land-use priority: should minerals be developed or should the environment and landscape be 'preserved'?

The test area was eastern Dorset, which is some 160 km west of London and includes an Area of Outstanding Natural Beauty (AONB) with rolling hills, picturesque rural landscapes, and ecological niches with

wet and dry lowland heath: a particular type of ecology that is becoming increasingly rare in Western Europe. The area also hosts a range of other environmental planning designations, including Sites of Special Scientific Interest and Ramsar (wetland) sites. Each planning designation restricts development, sometimes to the point where it becomes impossible to engage in certain types of economic activity. In the context of minerals it is possible for mineral reserves to become sterilized as a result of legislation, policy and planning regulation.

Economic and environmental aspects of ball clay mining

Dorset ball clay is a Tertiary stratiform kaolin-rich clay (Fig. 6) that was deposited within lowland fluvial-estuarine delta systems in humid-warm to tropical environments. Some of the highest-quality ball clay deposits in the world are found in Dorset. Ball clay is used for a range of manufactured products, including high-quality white ceramics, sanitary-ware, and coloured floor tiles. The highest-quality ball clays are rich in kaolin and have relatively low levels of silica, illite, titanium, and iron. These clays are used for the highest-value white ceramics industry. Ball clays can be blended with other clays to provide raw materials for a broader range of manufactured end-products.

Ball clay mining has a reasonably long history in the area. Although underground mining has occurred in the

past, the only economically viable method of mining ball clay is by opencast methods. Ball clay opencast mines are usually small- to medium-scale highly mechanized operations with a lifetime of a few years to a few tens of years for each individual mine. The technology is available to fully remediate mine sites, although it may not be possible to return individual sites to an identical pre-mining condition. The UK Government commissioned studies to examine a range of aspects of the local ecosystem and the impact of mining on the ecosystem. These studies concluded that the rural environment is not an original 'natural' environment but is one that has resulted from hundreds of years of agricultural activities. There is a complex relationship between human activities and local ecosystems. What many people now consider 'natural' is not, in fact, a natural equilibrium ecosystem, and the very heathland which is highly valued relies on human intervention activities for its preservation. Various studies have shown that it is possible to recreate heathland environments within areas affected by ball clay mining, although it can take several years or decades before the heathland is fully restored. It may not be possible to recreate certain specific niche environments after mining has ceased.

The BGS was part of a government study, which attempted to place an economic value on the UK ball clay industry. This study concluded that the raw material ball clay was worth ca US\$75 million and this under-



Fig. 6. Ball clay extraction in the Wareham Basin of Dorset, southern England (worth £45M in raw material exports, underpins £9 billion ceramics industry).

pinned a ca US\$14 billion ceramics industry in mainland Europe and the UK. There are alternative sources of ball clay, for example in the Ukraine, but English ball clay currently has a market niche and has a reputation for consistent quality and grade which is not necessarily easily replaced. Ball clay mining has impacted on the local Dorset economy in a positive way by providing jobs directly related to mining, jobs in service sectors (such as transport) which support the mining, and in indirect services through a net increase in earnings within the local population who 'buy-in' services and goods. In general, ball clay mining employs only a few hundred people in the local area.

Using a combination of geoscience and 'soft science' to its maximum advantage

One of the main roles of the BGS in the East Dorset study has been to provide an up-to-date geological assessment of the location, distribution, and grade variation of ball clay resources. This classical geological approach has provided a wide range of data on the stratigraphical and geographical distribution of ball clay and a fundamental understanding of the key geological processes involved in the genesis of the ball clay deposits. Data from geological mapping, borehole logs, and geochemical analysis were synthesized within a modern GIS framework. The GIS is used to produce a range of thematic geological maps which illustrate a range of parameters either individually or in combination. Key parameters, which are of interest in this study, include the location of the various ball clay stratigraphic horizons, depths to the deposits, the geochemical composition and variation in chemistry of the ball clay, and variation in grade.

The geological data were then combined within non-geological data, such as environmental and planning designations, local government administrative boundaries, and infrastructure information within the GIS platform. The ability to compare, contrast analyse, and interpret these data sets within the same GIS environment and in the context of a multidisciplinary skills team including geoscientists, planners, and others adds tremendous value to the whole approach. These integrated, holistic multidisciplinary approaches to problem-solving and decision-making inevitably develop new ways of thinking, new approaches and new methodologies. In the context of ball clay in Dorset, the team and data were assembled with the key objective of presenting a range of policy options, based on high-quality data and expertise to the British Government. Results were presented at a public dissemination seminar whose audience included a range of key stakeholders representing local communities, local and national government, industry, and academia. Results from this and other consultation exercises were incorporated into the final report.

A sustainable minerals synthesis

The key question to be answered in this case is whether it is possible to proceed with consensual ball clay development within an area which contains a range of prescriptive environmental and planning designations. The studies showed that the highest-quality ball clays are located within the Area of Outstanding Natural Beauty, the very area where local government would like to discourage mining activities. The studies also demonstrated that mining is a temporary usage of land and it is possible to remediate mine sites to a high-quality post-mining condition. In economic terms ball clay mining supports a multi-billion dollar multi-national ceramics industry that produces a range of products in demand within the UK home market. There is a net benefit to the UK economy in terms of trade and balance of payments.

This case study is presented here as an example of a possible 'sustainable minerals' methodology, which particularly involves non-industry, public sector geoscientists within a multidisciplinary integrated methodology. Classical geology is a key component of the methodology but is not the exclusive component. Geological data and expertise are combined with other data sets and skills from the fields of planning, economics, and social science to provide an approach that addresses real problems and issues related to sustainable minerals.

The final conclusion to this particular case study has yet to materialize. It is uncertain at the time of writing whether or not ball clay mining in Dorset will be allowed to proceed in the longer term. It is indeed a microcosm of the developed world conundrum: the products of mineral resources are wanted and needed but the will to develop minerals within developed world national boundaries (particularly within smaller highly populated countries) is lacking.

Lifecycle modelling: minerals from 'waste'

One of the major changes in mining psychology over the past few decades has been a realization that the mining process must consider all aspects of the mining lifecycle, from grass-roots exploration to post-mining. One area that is receiving increased consideration is recycling of mining waste materials, which usually end life in spoil-heaps and dried-up tailing lagoons. This 'waste' could actually be considered a resource in some circumstances.

Harrison et al. (2002) report a case study from northern Namibia. The mining township of Uis grew around a tin pegmatite mine at the edge of the Namib desert. At its height in the 1950s and 1960s the town had a population of 3500, which fell to 1500 after the mine closed in 1990. The local economy is currently largely dependent on civil service employment, tourism,

and small-scale tin-tantalum-gem mining. However, the economy has suffered and Uis represents an example where minerals-derived capital has not generated a sustainable local economy.

The mineral waste resource at Uis comprises 75 million tonnes of feldspar, quartz, and mica, which are amenable to separation and beneficiation and could provide raw materials for the manufacture of glass, cosmetics, paint, and plastic. A financial appraisal suggests that although there are no local markets for the resource, it could be exported to South Africa. A capital-intensive large-scale operation is thought to be the most appropriate way forward. Thus recycling may provide a partial solution to the regeneration of the Uis economy.

Development aid and sustainable minerals

Older thinking: mineral development directly impacts on economic development

In the post-colonial era which followed World War II and particularly in the period 1960–1995 the promotion of developing world mineral resources was strongly supported by a range of development aid organizations, particularly governmental aid departments (e.g. the Canadian International Development Agency and the UK's Overseas Aid Administration). These departments funded developed world geological survey organizations to second teams of people on a residential basis to undertake geological and mineral prospectivity assessments, and strengthen the skills base of indigenous geological institutions within recipient developing world countries. The overall rationale was to make developing countries self-sufficient within their public service mines and minerals departments with respect to achieving optimal skills balances and up-to-date geological and mineral-based maps and databases, which were then used to attract inward mineral-related investment.

Many developing countries had (and still have) limited options with respect to wealth generation. Mineral resource-generated wealth is considered to be one option for economic development, and this model has certainly been the case for many developed countries (as discussed above). The basic idea is that mineral-generated wealth provides much needed finances to allow developing world governments to develop their economies and quality of life through infrastructure-building, education, health, and other activities.

This approach brought mixed results. The best examples did indeed build up indigenous skills base capacity within recipient countries and helped to stimulate mining development. However, in other cases it became apparent that the only way of sustaining strengthened institutions was by maintaining aid programmes: once a project came to an end, the indigenous teams that had

been built up in recipient countries were not necessarily affordable by the former recipient country. Individuals moved on to better-paid occupations, or if choices were limited, stayed on within a weakened government department. Mine developments did not always bring lasting benefits to developing countries. Some analysts believed that the approach of sending in residential developed world teams on a residential basis could be construed as 'neo-colonialism' as the teams did not always address the highest priority issues of the recipient countries and residential staff lived in conditions which were very significantly superior to indigenous people. However, in broad terms and in spite of a range of reservations, it can be argued that the policy was successful, particularly in strengthening local skills and institutions in terms of human, physical, and data resources. It is also true that in many cases external funding was essential to the maintenance of capability, and perhaps this was one of the key issues which caused a shift in mineral-related policy during the early to mid-1990s.

Newer thinking: mineral development can positively impact on economic development, but not necessarily

From 1990 many governmental aid departments began to change their policy positions significantly. For example, the UK's Overseas Development Administration (now the Department for International Development or DfID) moved away from funding in-country residential line positions (e.g. government geologist positions within a Developing World Geological Survey) and essentially away from geoscience. Instead, the DfID now prefers to fund residential people who are involved in advising governments at a high level (e.g. economic or education advisers), and in-country technical work is commissioned mainly on a shorter-term non-residential basis.

The priorities of the DfID changed and the new focus became direct poverty alleviation, encouragement of 'good governance', and primary support in education and health. The DfID argued that it was pointless generating mineral-related wealth if mature government structures were not yet developed, which ensured that maximum developmental advantage was made of this wealth. There are examples of squandered wealth and little evidence of a direct link between mining and local or national economic development. Mining also became associated with a negative environmental image and government departments did not necessarily wish to be linked to promoting mining activities. Many developmental economists failed to see the tangible connection between geoscience and development. The net effect of this new thinking has been a much-reduced level of investment in mineral-related aid projects from national departments such as the DfID.

Bodies such as the World Bank and European Union (and some individual countries – e.g. Japan) still fund large geological mapping and mineral prospectivity aid projects, particularly in sub-Saharan Africa. In many of these cases money is loaned to recipient countries at favourable interest rates and the recipient country and funding organization design projects together. Projects are put out to tender and organizations such as national geological survey organizations or private sector consultancies bid for the work. The projects have a similar design to those described above and aim to strengthen indigenous data and knowledge bases through geological mapping and development of information technology capacity, and to build or strengthen institutions. The ultimate aim remains the attraction of mining companies to poor countries. Projects usually last for between 18 months and 4 years after which recipient countries should have attained an elevated and sustainable level of in-country expertise.

More recent thinking amongst developmental economists and social scientists is that a more directed approach is required to achieve true sustainable development through mineral-generated wealth (e.g. IIED 2002). The ideal model requires open and transparent government systems at national, regional, and local scales and in-country mature strategies for using mineral-generated wealth to develop a range of economic activities. Mineral-generated wealth is channelled through planned spending at national, regional, and local levels: funding is split between various levels of government. In this way it is easier for those communities most affected by mining to see a direct benefit link between mining, wealth generation, and quality of life. This new approach is quite different from the old approach of channelling the bulk of funds to central national government and relying on a top-down trickle effect to stimulate economic development. The overall aim is to transfer capital assets from one source to another and one generation to another. In this case mineral wealth becomes embedded within developed skills capacity and infrastructure development, which supports a range of economic activities which are lasting. In theory the wealth of an individual mine is thus transferred to other forms of lasting and sustainable capital assets which remain after mine-closure. Of course, theory is one thing, practice another, but at least levels of awareness and understanding are being raised through this approach, which points an optimistic way forwards.

CONCLUSIONS

This paper has attempted to capture a number of arguments and case studies that demonstrate the sustainable development paradigm can have a real

impact on the global mining and minerals industry and society. The world consciousness has been elevated and the holistic links between mining, environment, and community must be addressed in a strategic and long-term manner. Sustainable minerals are a force that is here to stay and will mould mining practices for many years to come. More importantly perhaps, a deliberate lack of application of the sustainability principles will almost inevitably lead to ill-thought out-mining projects that do not lead to lasting benefits for local people or even the nation undergoing mining.

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Maavarade jätkusuutlikkus, tõusvad majandused, arengumaad ja ilukõne taga olev tõelisus

Michael G. Petterson

On käsitletud jätkusuutliku arengu printsiipe ja rakendusi, nagu neid kasutatakse maavarade puhul. Seal on jätkusuutlikkuse tuntud tugisammasteks majandus, kogukond, keskkond ja poliitilised kaalutlused. Ideaalne lahendus on selline, mis tagab tasakaalu kogukonna kasu, majandusarengu ja tulu ning minimaalse negatiivse keskkonna- ja poliitilise mõju vahel. Selline tasakaal on teoorias võimalik, kuid tegelikkuses raskesti saavutatav. Maateaduste poolelt on artiklis väidetud, et geoloogidel, kes ei kuulu erettevõtete teenistusse, on täita otsustav osa maavarade jätkusuutliku kasutuse paradigma arendamisel intellektuaalselt küpseks ja rakendamiseks sobivaks. Selleks on vaja ümber hinnata geoloogiateaduse rikkalik pärand, mõtestada uued tulemused (kaardistamine, modelleerimine, geofüüsika, geokeemia) ja ühendada see teave sotsiaal-majandusliku ning keskkonnaalase infoga, mis hõlbustaks strateegiliste ja kohalike otsuste tegemist maksimaalseid hüvesid ning minimaalseid kahjusid silmas pidades. Selline käsitlus peaks endas sisaldama ka maavarade, kaevanduste, kaevisse ja mäeeraldise täieliku elutsükli, hindamaks kõiki kaevandamisega kaasnevat kasulikku ning kahjulikke efekte. Jätkusuutlikkuse paradigmas on üheks võtmekomponendiks ka loodusteaduste ja sotsiaalteaduste ühildamine ning eriti kaevanduspiirkondade huvirühmade tõeline kaasamine konsultatsioonidesse. Geoteadlastena on meil võimalik selgitada maavarade kasutamise hüvesid ja kahjusid ning aidata ellu viia jätkusuutliku maavarade kasutamise põhinõuet: säilitada meie planeet elamiskõlblikuna ka tulevikus.