An Assessment of the Sustainability of the Mining Industry in Australia

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ABSTRACT

The mining industry has a long tradition in Australia, but the question of its "sustainability" still remains a vexed and difficult issue. In recent decades, there has been significant improvement in environmental management during operation as well as better efforts at rehabilitation after closure. However, the industry continues to expand significantly as continually growing demand drives the need for new supply. Over time, this has led the mining industry towards lower grade ores and increasingly large scale open cut mining, with subsequent increases in the solid wastes produced. A further issue related to this is known economic resources. This paper will review the history of mineral production in Australia, focusing on the extent of ore grade changes for many key mineral commodities, the known extent of solid wastes produced, the sustainability of reserves versus expanding production rates and the issues of post-mining land use or rehabilitation. For all commodities there is a clear trend of long-term decline in ore grades, even rapid for some (eg. gold), as well as increasing open cut mining and associated waste rock (overburden). In terms of resources, there appears to be increases in resources over time, though some appear to have stabilised while others conversely are increasing significantly. A major challenge in assessing the life span of resources is that of exponentially increasing production. These trends will affect, to some degree, future energy, water and emissions efficiency per unit mineral production – or *sustainability*. This paper presents a unique case study in the sustainability debate on Australian mining.

1. INTRODUCTION

The phrase "sustainable mining" appears to many, at first glance, a classic oxymoron. After all, numerous famous mines have long since closed due to a finite quantity of ore able to be economically (or technologically) mined and processed at that given period of history. Yet in reality, for most mineral commodities, there are mines in operation today that dwarf the productive output of previous generations of mines.

In recent years there has been a renewed debate about mining and its sustainability, due to strong public sentiment on environmental and social issues surrounding mining. This debate is not new and indeed dates back many centuries. Georgius Agricola, German scholar of mining and metallurgy, stated in 1556 that "… the strongest argument of the detractors is that the fields are devastated by mining operations …" (Agricola, 1556:p8). Although Agricola was a passionate supporter of mining in modern society, this remains a key acknowledgement that mining can cause long-lasting environmental-social impacts. The approach to describing what is "sustainable mining" varies considerably, dependent on whether the view is from industry, government or civic groups. Some of the most common issues include declining ore grades, impurities (eg. As), availability of economic resources, economic parity, sharing of risks-benefits, environmental and social impacts, the increasingly large scale of mining, especially major open cuts and the sizeable volumes of waste rock produced. This paper summarises a major study, Mudd (2005), on the history of mineral production in Australia as a basis to assess the key sustainability trends affecting mining.

2. METHODOLOGY

The history of mineral production in Australia is relatively well documented, with various publications and reports containing pertinent data. In brief, the study compiled master annual data sets of the ore mined and milled, assayed ore grade (or yield), mineral production, extent of open cut mining as well as economic resources over time. The commodities covered include coal, bauxite (Al), iron ore (Fe), copper (Cu), gold (Au), lead-zinc-silver (Pb-Zn-Ag), uranium (U or U_3O_8), nickel (Ni) and diamonds (additional minerals are in the main report). The principal data sources included State Department of Mines Annual and Statistical Reports (eg. NSWDM, various), government reports on industry statistics (Kalix *et al*, 1966; ABARE, various; BMR, various), numerous mining company annual reports as well as industry annuals (eg. RIU, various). Additional reports or series were also used for specific commodities. In general, the compiled data sets represent close to 100% of each mineral. The economic resources from 1975-2003 is obtained from GA (various), while earlier data is obtained from various sources (eg. McLeod, 1998; NSWDM, various). A more detailed description of the methodology is given in Mudd (2005).

3. RESULTS

3.1 Mineral Production

The mineral production over time in Australia of black coal, brown coal, Fe ore, bauxite, Cu, Au, Pb-Zn-Ag, Ni, U and diamonds is shown in Figure 1. The key observation (shown as the general trend) is that virtually all minerals have shown near-continuous growth in production, with many exhibiting strong exponential growth (eg. black coal, Fe ore, Cu and Zn).

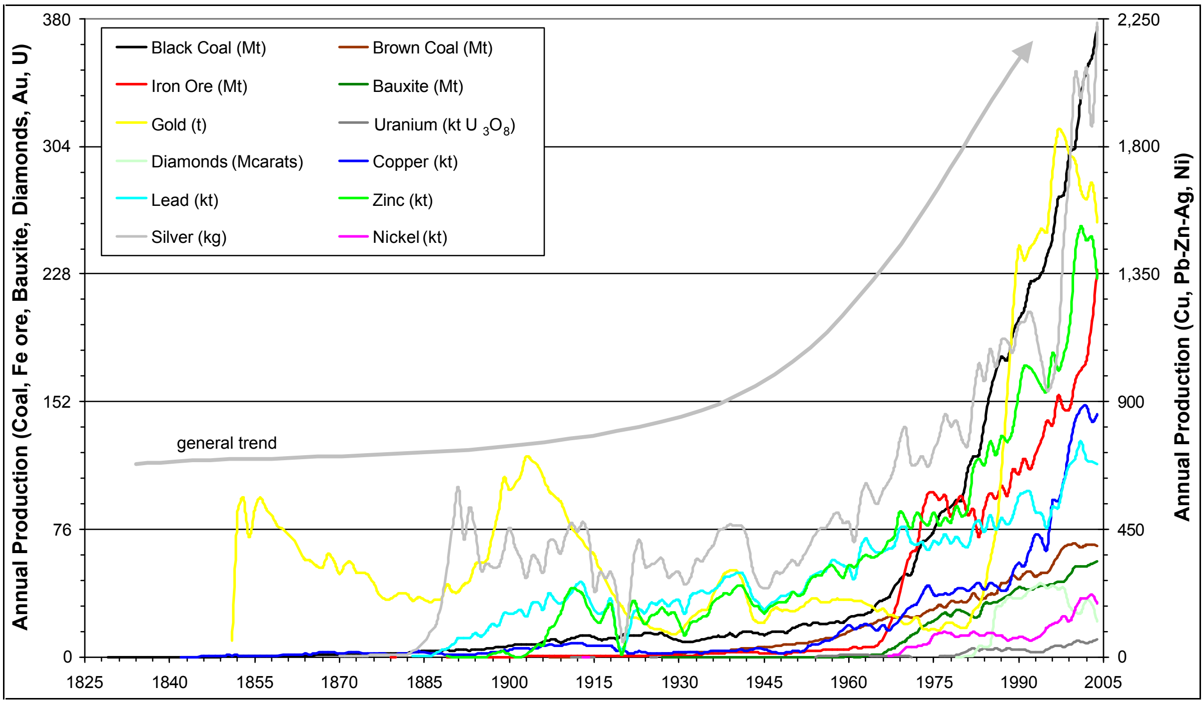

Figure 1. Mineral Production Over Time in Australia (all units in legend)

3.2 Ore Grades

The ore grades over time in Australia for copper, gold, lead, zinc, silver, nickel, diamonds and uranium are shown in Figure 2. The key observation is that most ores are showing long-term declining trends, with many showing a rapid initial drop (eg. Cu, Au, Ag). For some minerals the ore grade is dominated by a small number of mines (eg. U, diamonds). As ore grades continue to decline, the energy required per unit mineral production will increase, sometimes rapidly (eg. Cu). It is unclear whether water use would also follow this pattern.

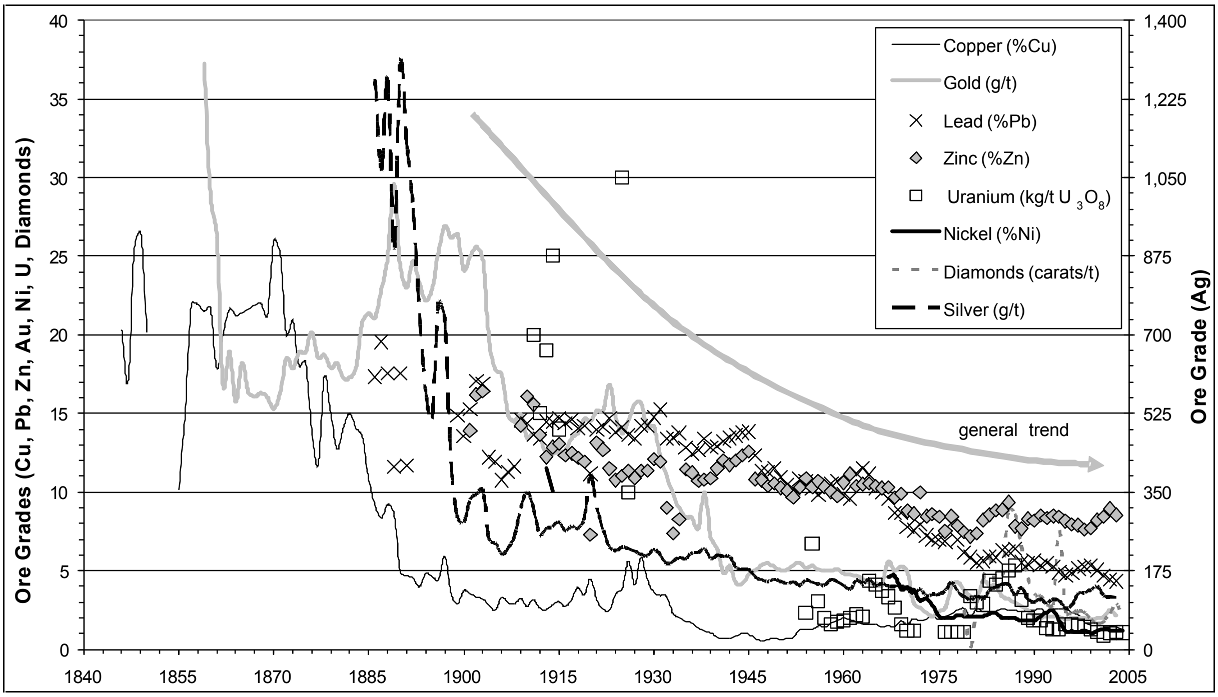

Figure 2. Ore Grades Over Time in Australia (all units in legend)

3.3 Extent of Open Cut Mining

The method for calculating the percentage of open cut mining is based on the percentage of ore derived by open cut from the total ore milled. Although it is possible to use the mineral, for most commodities this difference is negligible. The extent of open cut mining for some minerals, namely black coal, copper, lead-zinc-silver, nickel and uranium, is shown in Figure 3. For some minerals, namely brown coal, iron ore, bauxite and diamonds, they have been almost entirely mined by open cut methods (historically and presently). For gold there is not sufficient data available to ascertain the full extent of open cut mining, though it is considered to be of the order of at least 40% of all ore milled for gold in recent years.

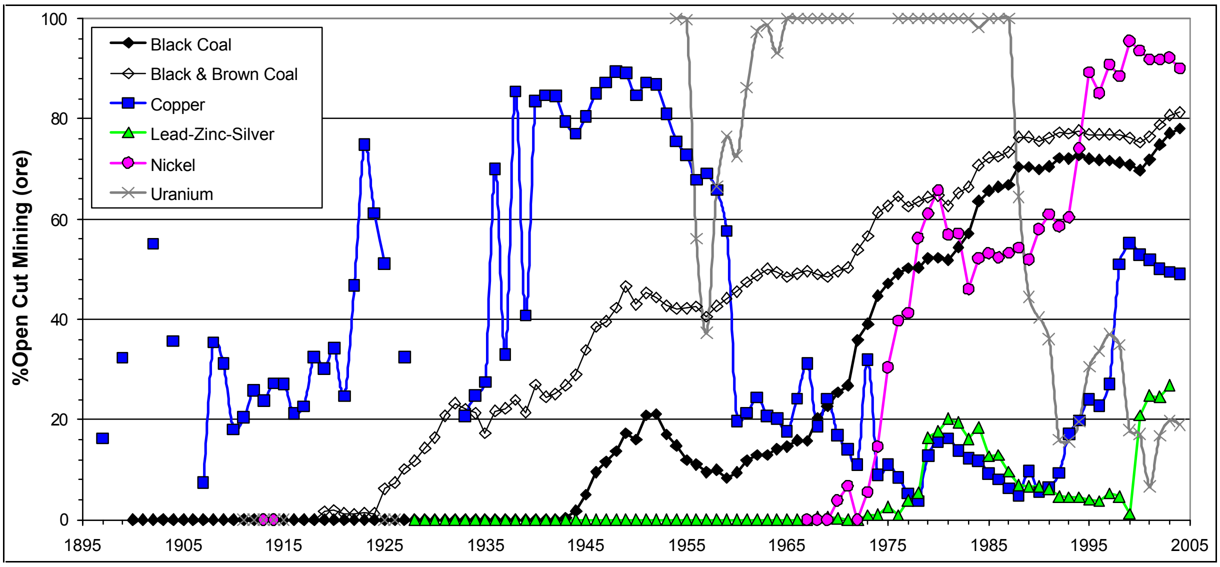

Figure 3. Extent of Open Cut Mining Over Time in Australia (based on %ore)

Overall it can be seen that some commodities are shifting significantly towards the use of large-scale open cut mining, especially coal and nickel. The changes in the various series reflect the opening or closing of major new mines or fields (eg. Mt Lyell, Mt Morgan, Century Zinc, Bowen Basin, Latrobe Valley, Olympic Dam). Based on existing and potential projects, it is most likely that open cut mining will continue to increase in significance for most commodites. This is a critical factor from a sustainability perspective due to the energy required for such operations (especially diesel) and the challenges in rehabilitating large open pits and the associated waste rock (see next section).

3.4 Waste Rock (Overburden)

In general, waste rock is the most poorly reported aspect of mining – despite often being the single largest quantity of solid wastes in mining projects. The available data for waste rock for major minerals is shown in Figure 4. Due to the absence of consistent waste rock data for many mining projects, especially black coal, gold and copper, the data represents a minimum only. The rapid, near-exponential growth in waste rock production over the past two decades is very clear in most commodities.

A key issue to recognise with waste rock is that it can often be the single largest cause of downstream ecological impacts. For some former (or even current) mining projects, such as Mt Lyell, Mt Morgan and Rum Jungle, the greatest pollution loads are generated from acid mine drainage discharging from waste rock, as opposed to just tailings. The increased quantity of waste rock, often deeper and therefore generally less oxidised, not only requires energy and water to extract and manage it but also increased engineering effort during rehabilitation to prevent long-term legacies (eg. Mt Lyell). This may lead to risks of significant future costs if current rehabilitation approaches prove to be inadequate (Harries, 1997). The question of who should be accountable for this long-term risk remains contentious.

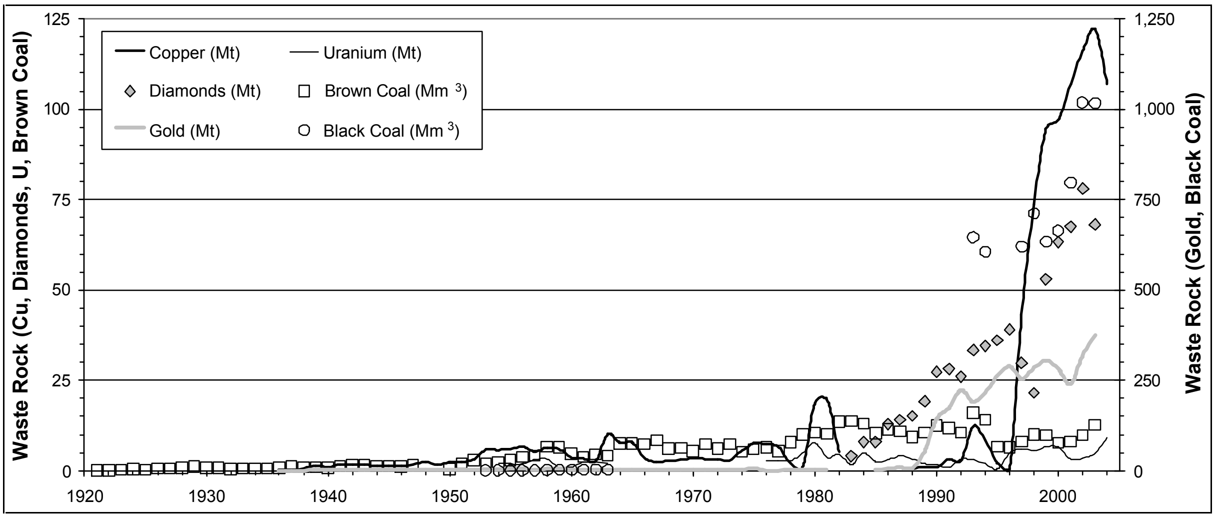

Figure 4. Waste Rock Production Over Time in Australia (as reported; all units in legend)

3.5 Economic Resources

The extent of available mineral resources is often a key issue raised in the debate on sustainable mining. The major factors which have allowed Australia to continually expand production over recent decades are that new resources have been discovered, better technology allowing exploitation of lower grade deposits has been developed (especially for gold), as well as the relatively cheap cost of energy to facilitate open cut mining. The economically demonstrated resources for many minerals are shown in Figure 5.

In general, most economic mineral resources in Australia have grown either steadily (eg. lead) or experienced sudden increases (almost all, eg. iron ore, bauxite, nickel, gold) due to new provinces or mines being discovered or the advent of new technology (gold and nickel are good examples in this regard). Based on the compiled data in Mudd (2005), future production from most resources will not increase average ore grades or quality. For some minerals (eg. coal, iron ore), the true extent of economically (or technologically) recoverable resources remains open to conjecture, though some resources appear to have stabilised.

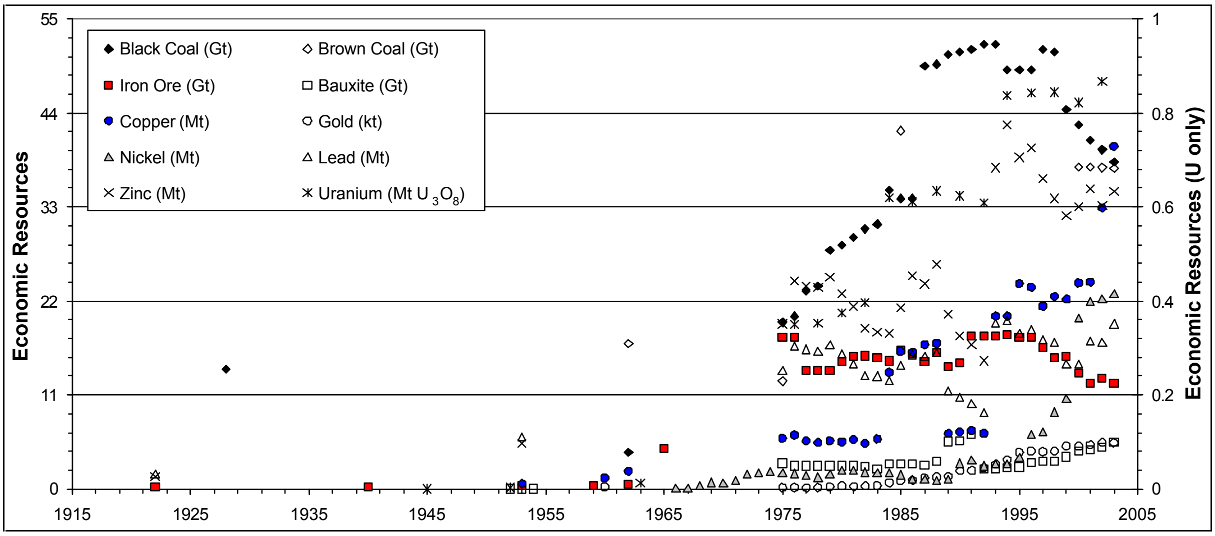

Figure 5. Economic Mineral Resources Over Time in Australia (all units in legend)

3.6 Predicting Production Versus Resources

A key issue often raised in the 'sustainable mining' debate is that of known economic resources versus production. Although there has clearly been exploration success over recent decades, expanding rates of production continue to place pressure on known economic resources. A preliminary analysis of this is shown in Table 1, including both stable production (2003) and allowing for polynomial regressions of increasing production rates.

Table 1. Economic Resources versus Production Rates

Mineral	2003 Resources	2003 Production	Cumulative Production	Production Years Left		R^2 (%)
				Stable	Increasing	
Black Coal	38.3 Gt	357.8 Mt	7,115 Mt	107	37	99.98
Brown Coal	37.5 Gt	66.8 Mt	1,860 Mt	561	90	99.99
Uranium (U_3O_8)	867 kt	8,097 t	133.8 kt	1,071	14	99.82
Iron Ore	12.4 Gt	200 Mt	4,189 Mt	62	23	99.99
Bauxite	5.5 Gt	55.6 Mt	~1,170 Mt	99	36	99.96
Copper	40.1 Mt	830 kt	16.5 Mt	48	30	99.8
Gold	5,382 t	282.5 t	10,557 t	19	10	99.52
Nickel	22.8 Mt	218 kt	~3.1 Mt	105	21	99.98 #
Lead	19.3 Mt	688 kt	~36.2 Mt	28	20	99.98
Zinc	34.8 Mt	1.48 Mt	~41.4 Mt	24	16	99.99

Note : R^2 values derived from statistical regressions of cumulative production using Microsoft Excel. All regressions are based on a 6th order polynomial; # except nickel which is a 5th order polynomial.

3.7 Rehabilitation

A further aspect of mining which needs to be included in any assessment of sustainability is the long-term success of rehabilitation. There is, however, very little systematic data on this aspect. For WA, it is estimated that a total of 165,040 ha has been disturbed by mining while only 36,952 ha has had preliminary rehabilitation to 2003 (Mudd, 2004). In Queensland 73,586 ha has been disturbed with only 20,313 ha having been rehabilitated (to June 1997) (Anderson, 2002). This gap is likely to be similar across Australia.

As noted previously, increasing open cut mining and waste rock production is also placing further environmental pressure on rehabilitation requirements. Although the engineering and regulatory standards are considerably better at present than in the past, there remains concern over long-term effectiveness (eg. Rum Jungle; see Mudd, 2002).

4. DISCUSSION AND CONCLUSION

The future sustainability of the Australian mining industry is facing several key challenges, namely declining ore grades, increasing solid wastes (tailings and waste rock), the rehabilitation gap as well as significant pressure on the extent of mineral resources. Any future exploitation of many of these mineral resources will be dependent on often lower grades or quality, potentially higher impurities and the need for more intensive processing (eg. Fe, Ni). If the steady growth of production is projected into the future, it can be seen that current known resources for will only last a matter of two to four decades (with the exception of brown coal). This pattern will be somewhat tempered by rising resource scarcity, changing economics, technology and socio-environmental issues. When combined, all of these long-term trends have significant implications for future water, energy and emissions efficiency from mineral production (an area of current research). Given these trends, it is clear that the environmental burden of modern mining is increasing and is likely to continue to do so.

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