

Accounting for Increasing Mine Wastes in the Australian Mining Industry

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Abstract

The mining industry in many countries around the world is often the single largest producer of solid wastes, sometimes orders of magnitude higher than other forms solid waste (eg. municipal). Over the past century, a considerable portion of the mining industry has shifted to large-scale open cut mining techniques, which invariably requires the removal of significant quantities of waste rock (overburden). This is also coupled with a general trend of declining ore grades for most commodities, meaning higher quantities of ore need to be processed to produce a given unit metal or mineral. In the long-term, in terms of sustainability, it will be the balance of the environmental, social and economic costs of increasingly large-scale mining versus the efficiency of recycling and demand for metals and minerals. This paper presents the results of a detailed compilation and assessment of the current trends in the Australian mining industry, namely bauxite, coal, copper, iron ore, lead-zinc-silver, gold, nickel and uranium. The results for the amount of ore milled, declining ore grades and the increasing mine wastes are presented for each of these specific commodities. Overall, it can be seen that there are clear trends towards lower grades and increasing open cut mining and waste rock production, though not all of this data is publicly reported in a consistent manner. From a sustainability perspective, this has a number of important consequences, including energy use, water consumption and rehabilitation, among others. The data presented in this paper can be used to guide life cycle assessments as well as broader sustainability assessments. The issue of mine waste is growing and provides a number of opportunities for innovative waste disposal and other engineering solutions within the context of sustainable solid waste management frameworks.

Keywords: sustainable mining, waste rock, overburden, ore grades, mine wastes

1. Introduction

The debate over the environmental (and social) impacts of mining is indeed old, dating from ancient times through to Agricola in 1556 (Agricola, 1556) and the most recent international conferences and global summits on sustainable development. The principal change over the past two centuries has been the increasing and now global scale of modern mining. The most enduring legacy of modern mining is the solid waste

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remaining after closure of a project : tailings and waste rock/overburden. Given that grades are generally declining and large-scale open cut mining is now widely used, the cumulative solid waste legacy of mining is becoming more substantive every year. In terms of sustainable development and “life cycle analysis”, it is critical to have accurate data on these trends to facilitate better accounting of environmental costs, especially when compared to alternatives such as secondary supply (recycling). This paper presents the results of a detailed study of the Australian mining industry (Mudd, 2005b), within the context of the debate on sustainable mining, in order to provide a rational basis for strategic assessments of the quantities of solid wastes now produced by mining and metallurgical industries. The key trends in Australian mining are discussed with respect to future environmental costs/risks and the need to more thoroughly report and account for these costs/risks.

2. Methodology

The methodology is based on the detailed analysis and compilation of available reports and publications series, of which there are several with pertinent data. A full description of the methodology is found within Mudd (2005b), and is briefly presented below. The following reports or publications series were used to compile the master data sets :

- Annual Mineral Industry Review (annual series 1948-1987) (BMR, various);
- BMR 1964 Production & Trade Study (Kalix et al., 1966);
- NSW Coal Industry Profile (annual series) (eg. (NSWDMR, various-a);
- QLD Coal Industry Review (annual series) (eg. (QNRM, various);
- State Department of Mines Annual Reports, Statistical Reviews and Industry Reports (eg. (NSWDMR, various-b, NSWDM, various) and other state equivalents);
- ABARE, Australian Mineral Statistics quarterly journal (ABARE, various-a);
- ABARE, Australian Commodities Statistics (annual series) (ABARE, various-b);
- Mining company Annual and Environment Reports (eg. (BHPB, various);
- Data courtesy of Barlow-Jonker Pty Ltd (coal consultants);
- Australian Aluminium Council, industry statistical data (AAC, 2004);
- McGraw Hills’ ‘The Mineral Industry : Its Statistics, Technology and Trade’ (annual series 1892-1940) (Anonymous, various);
- Register of Australian Mining (annual series 1978-2004) (RIU, various);
- Australian Uranium Production and Resources (Mudd, 2005a);
- Australian Mines Handbook (annual series 1980-2004) (LP and Minmet, various);
- Jobson’s Mining Year Book (annual series 1984-2004) (Riddell, various);
- Many historical books, reports and miscellaneous sources.

The data within these publications is not always consistent. In general, the following rules or principles were adopted to ensure consistency :

- company data takes precedence over other sources;
- calendar year was adopted where possible, otherwise financial year data was applied in the year it was reported (eg. 1987/88 would be recorded in 1988);
- assayed ore grade was sought, with yield data corrected for recovery (where known);
- all data was converted to SI units (this was a key issue for earlier pre-SI data);
- alluvial mining has generally not been included;

- co-product or by-product mines with significant production have been incorporated into each specific commodity (eg. a Cu-Au mine would be included in both sectors);
- where sources conflicted, the data considered closest to or most consistent with a company source was adopted (requiring some degree of judgement).

Thus a master data set for most major mineral commodities mined and milled in Australia was derived, covering nearly two centuries for certain commodities.

3. Results: Ore Milled, Grades and Waste Rock

The master data sets are given by Mudd (2005b), and generally represents >90% of the production for that commodity (often close to 100%). Some data sets remain incomplete as certain data is not publicly reported by the mining company or compiled by a state or other agency (eg. waste rock). The data does represent nearly the entire quantity of ore milled and grade (or yield), with variable results for overburden/waste rock.

The results for ore grades for gold, nickel, copper, uranium and lead-zinc-silver are shown in Figures 1 to 2. The results for the quantity of ore milled for gold, nickel, copper, uranium and lead-zinc-silver is shown in Figure 3. The results for bauxite, iron ore and coal production, including the extent of open cut coal mining (black only and black+brown), is shown in Figure 4. The results for reported waste rock production for gold, copper and uranium and the extent of open cut mining for nickel, copper, uranium and lead-zinc-silver is shown in Figure 5. Due to the large number of gold mines and the often combined use of open cut and underground mining it has not been possible to quantify the extent of open cut mining for gold, though the extent of data for waste rock suggests at least of the order of 50%. There is virtually no waste rock data reported for nickel, lead-zinc-silver, iron ore or bauxite mining, with only a small number of waste:ore ratios available for some years and not the historical record of such data. There is only limited and recent data available for overburden in coal mining, but due to this short history of data it has not been included within the graphs below.

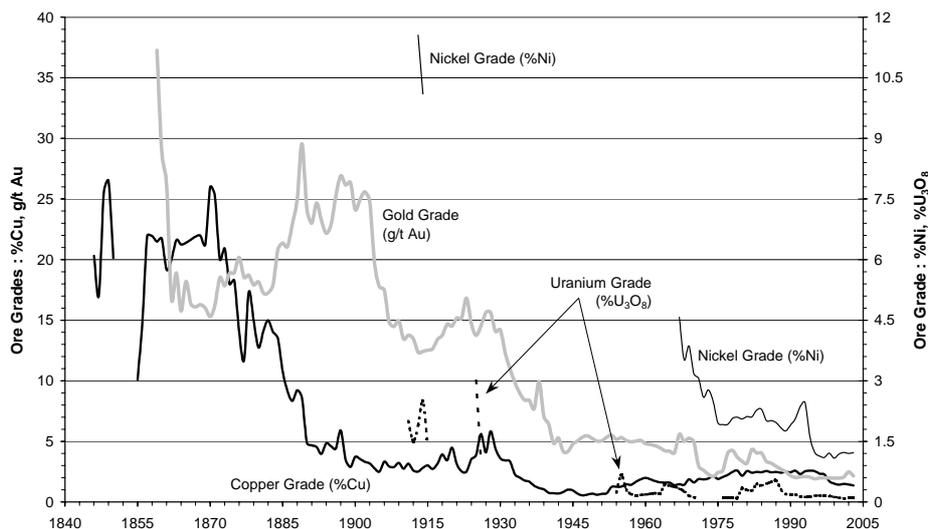


Figure 1. Australian Average Ore Grades Over Time : Copper, Gold, Nickel and Uranium

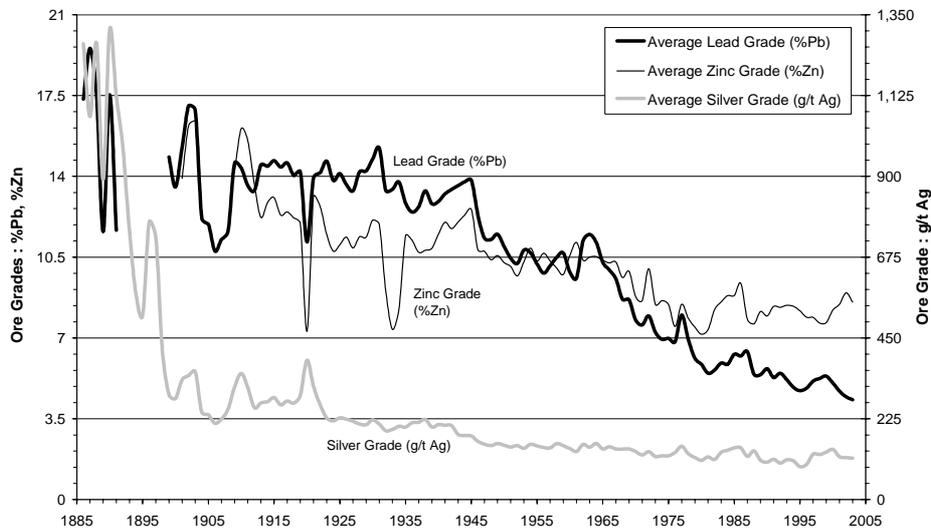


Figure 2. Australian Average Ore Grades Over Time : Lead-Zinc-Silver

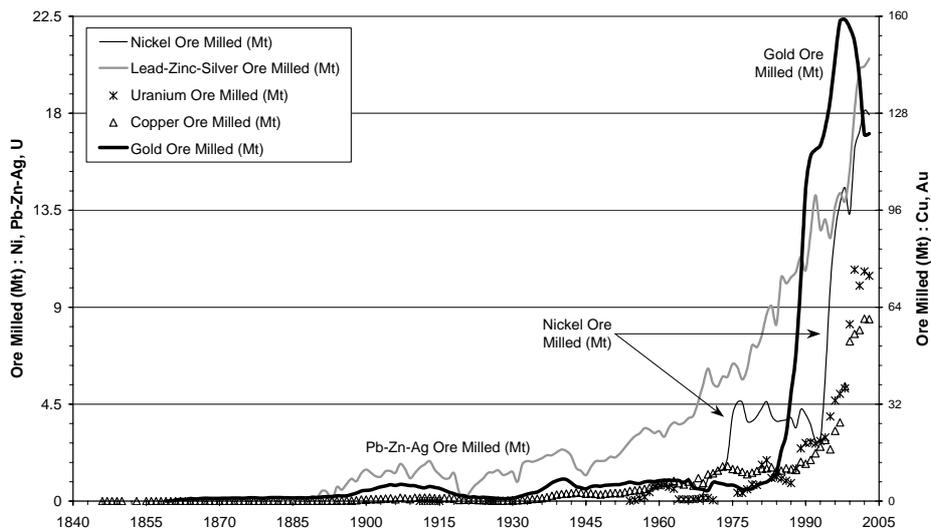


Figure 3. Australian Ore Milled Over Time : Nickel, Lead-Zinc-Silver, Uranium, Copper & Gold

For open cut black mining in Queensland, 1992/93 saw 76.92 Mt of saleable coal mined (about 95 Mt raw) with the creation of 645.5 Mm³ overburden. For 2002/03, open cut mining produced 160.35 Mt raw black coal with 1,016 Mm³ overburden. For New South Wales, 1994/95 saw 59.08 Mt of raw coal mined with the creation of 261.0 Mm³ overburden. In Victoria, about 66 Mt of brown coal is mined per year with around 15 Mm³ overburden produced.

Where there is no data for waste rock, the extent of open cut mining and the ore milled can be used as a surrogate to approximate waste rock production. For example, iron ore and bauxite uses open cut mining (100%) with waste:ore ratios of the order of 2:1.

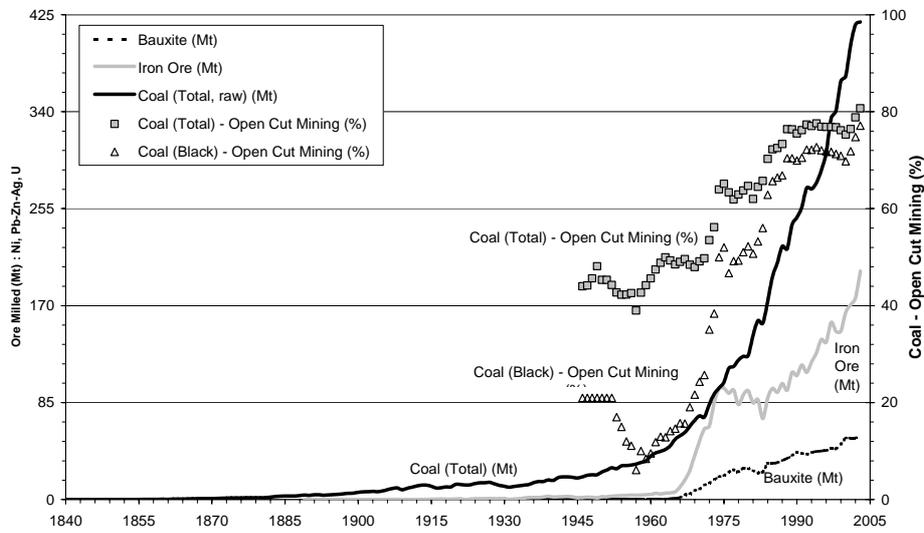


Figure 4. Australian Bulk Commodities : Bauxite, Iron Ore, Coal & Open Cut Coal Mining

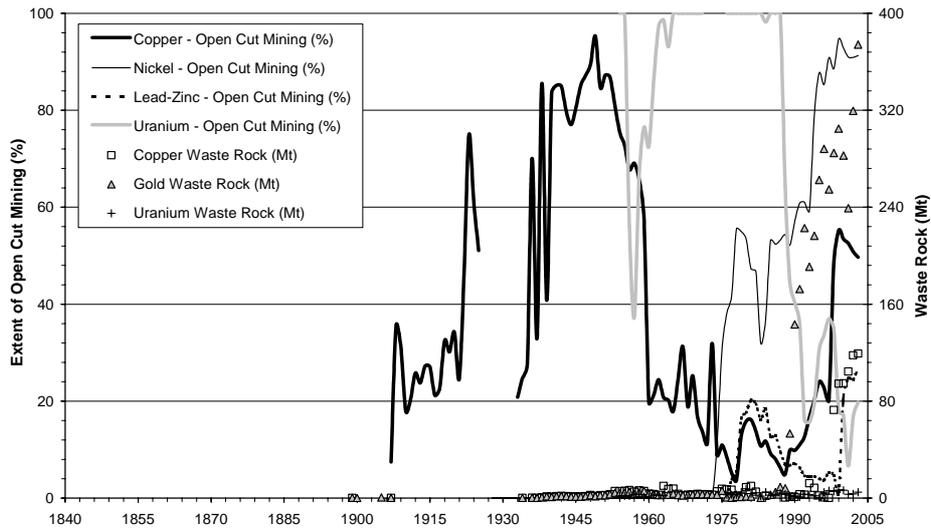


Figure 5. Australian Open Cut Mining & Waste Rock : Copper, Nickel, Lead-Zinc-Silver, Uranium & Gold

4. Discussion and Analysis

4.1 General

The Australian mining industry has clearly been successful in discovering and developing new mineral resources (a trend which could arguably also be demonstrated globally). This has occurred throughout the 20th century due to increasing demand, new technology and cheap, abundant energy (especially hydrocarbons) facilitating profitable exploitation of larger and lower grade ore resources, particularly using open cut mines.

4.2 Ore Grades

The trends of ore grades over time for gold, nickel, copper, uranium and lead-zinc-silver are, in general, declining. For some commodities, such as gold and copper, a considerable portion of data prior to 1950 is yield as opposed to assay grade, suggesting that the declining trend is slightly greater than shown in the figures. The rate of the decline in ore grade is somewhat variable, although there appears to be no reasonable basis to expect any significant long-term increase in the immediate future. There is very little long-term data available on iron ore and bauxite grades though there is some evidence for a slight decrease over recent decades.

4.3 Ore Milled

The trends of ore milled or produced over time are, in general, rapidly increasing. For most commodities, with perhaps the exception of gold, it is expected that the rate of milling will continue to increase significantly for some time as both existing projects expand and new projects are developed (primarily for export markets). At present there appears to be sufficient known economic resources, often with substantial sub-economic (or lesser quantified) resources, suggesting no resource shortage for the foreseeable century (though continuing expansion will place pressure on this situation).

4.4 Open Cut Mining

The use of open cut mining greatly accelerated during the 20th century, as evident in Figure 5. For some commodities, such as copper-gold, the early mines of Mt Lyell and Mt Morgan led the introduction of large scale open cut mining in Australia prior to 1950. From the mid-1950s the Mt Isa and CSA projects led copper to shift to underground mining. For most commodities, with uranium being the exception, there is a clear trend over the past three decades towards the use of open cut mining in preference to underground mining. It is expected that this trend will continue, though some key factors that will influence this trend in the future include the often deeper nature of new mineral discoveries (eg. Prominent Hill), the ratio of waste rock to economic ore, environmental regulation and the cost of liquid fuels (especially diesel).

4.5 Overburden/Waste Rock

The trends of overburden or waste rock are readily apparent in Figure 5. Although the extent of waste rock production is not fully reported by numerous mining companies or state agencies, the compiled data clearly shows the significant nature of the quantities involved, especially compared to the quantity of ore milled. For example, for gold and copper, there is significantly more waste rock produced than ore milled, while for others such as uranium the waste rock is of approximately the same extent. Unfortunately, for nickel, lead-zinc-silver, iron ore and bauxite there is virtually no data available on waste rock production over time, despite the almost complete use of open cut mining. For coal mining, the data is incomplete but shows the substantial quantities of overburden already excavated annually. Given the scale of overburden/waste rock produced by the Australian mining industry, it is imperative that mining companies report this data clearly and consistently to facilitate better accounting of the production of minerals.

Environmentally, it is the rapidly increasing quantities of solid wastes produced which is becoming an acute factor in the future sustainability of the resources sector, especially the challenge of ensuring long-term successful rehabilitation of such volumes of wastes.

4.6 Summary of Key Trends and Ratios

A compilation of the extent of mining-milling required to produce key mineral commodities in Australia over time is shown in Table 1. All data is calculated using a 5-year average centred on the year noted to minimise the effect of annual variability.

Table 1. 5-Year Average Annual Production Trends Over Time.^a

	Units ^b	1850	1875	1900	1925	1950	1975	2000
Coal	Mt/year	0.06	1.42	6.27	14.33	24.32	105.00	378.66
Iron Ore	Mt/year			0.02	0.75	2.29	93.75	161.33
Bauxite	Mt/year				0.001	0.007	21.75	50.93
Copper	t ore/t Cu	3.3	6.0	31.0	25.5	151.3	48.8	65.7
Copper	Mt WR/year			0.29		2.45	6.05	96.84
Uranium	t ore/t U ₃ O ₈				50		909	873
Uranium	Mt WR/year						2.75	5.10
Nickel	t ore/t Ni						45.2	84.6
Gold	t ore/t Au		52,990	39,318	66,273	191,394	371,766	479,126
Gold	Mt WR/year			0.25		2.44	2.56	286.22
Lead	t ore/t Pb			6.6	7.2	9.2	13.9	20.2
Zinc	t ore/t Zn			6.6	9.0	9.8	12.1	12.2
Silver	t ore/t Ag			2,995	4,478	6,630	7,770	7,882

^a For some years the averages are based on <5 years data available. ^b WR is waste rock.

It is clear that most mineral commodities are experiencing exponential growth though there is generally insufficient publicly available data to ascertain the true extent of solid wastes produced by the Australian mining industry. This is especially true for waste rock. Overall, the total solid wastes (ore plus waste) mined per unit mineral are generally increasing along with higher production. This leads to some key future environmental risks : (i) potentially higher energy and water requirements per unit mineral production; and (ii) rehabilitation uncertainties (eg. acid mine drainage, structural collapse, etc). In order to address these risks within a sustainability framework, it is clear that a more detailed account of mining and milling needs to be reported to facilitate this type of analysis.

5. Conclusions

The mineral industries are a substantial producer of solid wastes, including both tailings and overburden/waste rock. For most mineral commodities in Australia, the average ore grade is gradually declining over time (eg. lead-zinc), or more rapidly for some (eg. gold, nickel). This trend has also been accompanied by a shift towards large-scale open cut mining, particularly over the last 25 years of the 20th century, with a consequent significant increase in the overburden/waste rock produced. The latter, however, remains poorly reported by mining companies and the industry as a whole. From a sustainability perspective, it is imperative that true accounts of mine wastes be properly reported which include overburden/waste rock. Although it has not been possible to analyse the energy and water usage of the major commodities of the Australian mining industry, thereby giving the energy and water costs per unit mineral production, this is planned for the future. By combining true mining and milling accounts with

environmental data, more accurate and realistic estimates/analyses of life cycle costs and comparisons to secondary/recycled materials can be undertaken, thereby leading to more informed judgements about the sustainability of raw mineral production.

Acknowledgements

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