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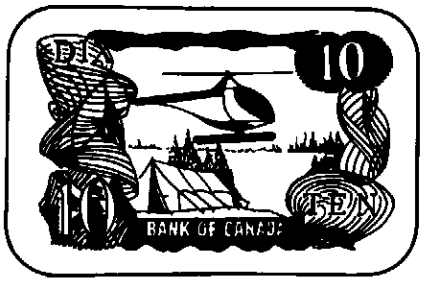

Success in Mineral Exploration: Confidence in Prosperity

Based on the Second Joubin-James Lecture, University of Toronto, March 1, 1983

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Introduction

The single most critical requirement for successful mineral exploration is the chain of confidence linking financial investors and Boards of Directors to the scientists and field operators. Every person in that chain must believe that his efforts will make a difference to prosperity, in a personal, professional or national framework. How much prosperity does the minerals industry create? How confident are we that our efforts in earth science research and mineral exploration will contribute to prosperity?

The early mineral discoveries in Australia and Canada resulted from the observations of pioneer settlers and explorers, but today the search for new mineral deposits is a sophisticated application of science and technology. This scientific form of mineral exploration is research, involving all aspects of geology, as well as physics, chemistry, mathematics and computer science, to solve the problems of the origin of mineral deposits and the detection of concealed ore through observations and measurements at the surface. It is concerned with the search for environments in which minerals and metals have been concentrated and the location of economic accumulations within those environments. Geological science has played an increasing role over the past fifty years in the discovery of new deposits in Australia.

Discovery and Prosperity

We strive to make discoveries in the hope that we will contribute to prosperity and the deeper this belief, the stronger is the motivation to succeed. We thus need to understand the magnitude of the impact of mineral discoveries on prosperity in our society to strengthen our conviction that to strive and succeed in this difficult, costly and risky business of mineral exploration is worthwhile.

It may appear unnecessary to argue that prosperity and the wealth and leisure prosperity make possible are good things. There is, however, a strong tradition that holds the contrary view, i.e., that wealth, of itself, does not bring contentment. It is, however, a fact that many of our leading contemporary critics of wealth live in fairly comfortable circumstances. Criticism of wealth and of the ambition to be wealthy rarely come from those who live in poorer circumstances and who desire the opportunity to rise from their state of poverty.

The virtues of increasing wealth in a society are many:

it offers increasing opportunities for the economic betterment of poorer people;
it can make domestic, political and social peace and stability easier to achieve;
it provides strong incentives for securing international peace; and
it enables people to participate in new and diverse scientific, cultural, creative and recreational activities.

Most people agree that the minerals industry had a major influence on the past prosperity and industrial growth of our countries. The impact of mining on the Australian nation has been well documented by G. Blainey in his book *The rush that never ended* (Blainey, 1963). The fabulous gold discoveries in south-eastern Australia between 1850 and 1910 brought great prosperity and a surge of immigrants to the young Australian nation. In ten years, from 1851 to 1860, Australia produced nearly 25 million ounces of gold, worth $12 billion in today's monetary terms, and the revival of world commerce in the 1850s owed much to this new wealth from the goldfields of Australia and California. Spectacular discoveries of gold in the Kalgoorlie region in Western Australia in the 1890s helped relieve the hardship of drought and economic depression which struck the Australian economy at that time (Blainey, 1963).

The Colony of South Australia was struggling until rich copper deposits were discovered between 1842 and 1860. The bonanza Broken Hill silver-lead-zinc deposits were discovered in 1883 and with other discoveries of copper, lead, zinc and tin made a substantial contribution to Australia's prosperity. During the last century and until 1914 Australia had the highest average standard of living in the world, as measured by Gross Domestic Product per head of population (Fig. 1).

Profits from the mines in turn had a major impact on Australia's industrial development. Facilities to produce steel, smelt lead, refine zinc, fabricate metals, make paper and build aircrafts were established with the financial surpluses produced by the mining operations at Broken Hill. These were times of relatively low company tax and low royalty payments. As a result, profits were large but they were reinvested in Australia's industrial development and thus benefited the whole nation and future generations. Profits were also reinvested in mineral exploration and mineral development, which led to the discovery and de-

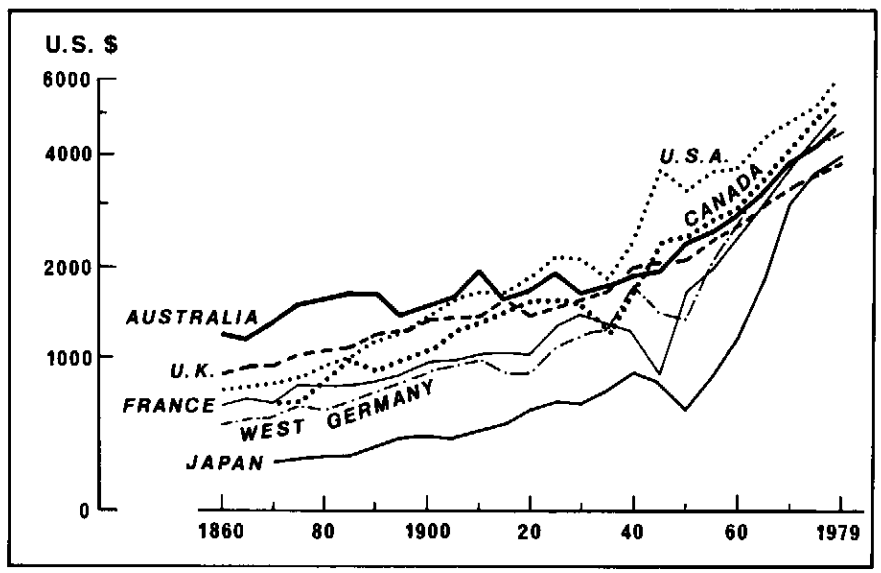

Figure 1 *Gross domestic product per head of population (1970 prices)*

velopment of bauxite, iron ore, oil and gas and the establishment of two great integrated aluminum industries.

Australia's minerals industry helped the nation to withstand the enormous pressures of two world wars. It brought increased self-sufficiency in minerals and metals, effective decentralization, new processing facilities, new and expanded manufacturing facilities and management skills, greater population and greatly increased employment. It continues to play a major part in strengthening the nation's balance of payments and it provides very substantial new sources of revenue to the government. Canada's history goes back further than Australia's and its prosperity also has been closely linked with the development of efficient primary industries, especially mining.

The importance of the minerals industry, i.e., mining in its broadest sense, to Canada's and Australia's present prosperity is not generally appreciated or understood. It is therefore instructive to look in a more quantitative way at the prosperity which the industry in fact creates. *Gross Domestic Product* (G.D.P.), *employment* and *value added* are the measures of economic benefits to society which will be used.

The contribution of "mining" (the production of all minerals including coal and petroleum) to GDP and employment in 1979 is supposedly given in government statistics, figures which are presented in Table I. But mining's significance is understated by these statistics, for the statisticians define "mining" as simply the production of ores and mineral concentrates, i.e., mining is counted, mineral concentration is counted but smelting and refining are not counted, even when such operations are located close to mines and totally dependent on the mines for their survival.

We can get a little closer to the truth by studying the statistician's breakdown of manufacturing according to *value added* (Table II). In 1979, 24 percent of Australia's manufacturing output and 14 percent of Canada's manufacturing output was directly related to the processing of minerals. Thus mining, including mineral processing, did not produce only 5 percent of Australia's GDP but 10 percent, and in Canada, the mining industry produced 9 percent of GDP, not 6 percent (Fig. 2). Note that much of this mineral processing would probably not be carried out in Canada or Australia if the minerals were not produced there. These figures are not perfect and one can argue about the steel industry but it is quite foolish to exclude from the mining industry the workers in a smelter at Noranda or Sudbury, or an alumina plant or nickel refinery in Australia.

Table I.

	% GDP		% LABOUR FORCES	
	Australia	**Canada**	**Australia**	**Canada**
Manufacturing*	21	22	19.6	19.8
Utilities	3	4	3.3	1.1
Construction	7	6	7.3	6.4
Agriculture & Forestry, etc.	7	4	6.3	5.5
Mining	5	6	1.5	1.5
Total New Wealth	43	42	38	34.3
Services	57	58	62	65.7

Sources
1. Year Book Australia and Stats. Canada: 13-201
2. The Labour Force Australia and Stats. Canada: 71-001

* See Table II for breakdown of Manufacturing

Table II. *Value Added by Manufacturing*

	$ MILLIONS			
	Australia		**Canada**	
Basic Metals (Smelting, Refining, etc.)	2,358	(10.6%)	4,915	(8.1%)
Coal, Petroleum & Mineral-Dependent Chemical Industries	1,899	(8.5%)	1,460	(2.4%)
Processing Other Non-Metal Minerals	1,089	(4.9%)	2,148	(3.5%)
Total Mineral Related Manufacturing	5,346	(24.0%)	8,523	(14.0%)
Other Manufacturing	16,884	(76.0%)	52,100	(86.0%)
Total Manufacturing	22,230		60,623	

Sources:
1. Year Book Australia 1981
2. Statistics Canada 31-203

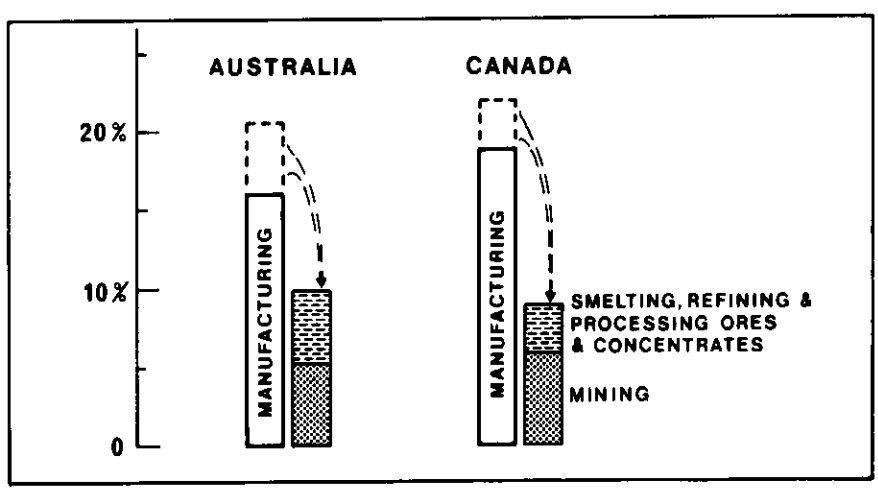

Figure 2 *Mining and manufacturing: contribution to gross domestic product 1979*

Another economic reality is that increases in national prosperity depend on the creation of *new wealth,* not on the expansion of service industries. In 1979, 43 percent of Australia's GDP ($101 billion) and 42 percent of Canada's GDP ($240 billion) was *new wealth* created from basic resources by the "growers", "miners" and "makers" (Table I). The minerals industry, including the mineral processing component of manufacturing, together contribute 23 percent of all the new wealth created in Australia and 21 percent of all new wealth created in Canada. Moreover, in Australia the relative contribution of the minerals industry is increasing while manufacturing declines.

The employment generated by the minerals industry is also understated in our national accounts. This has promoted the fallacy that miners may be productive but they are too few to have an impact on employment. In 1979, 70,000 persons were employed in "mining" in Australia and 115,000 in Canada. But, in Australia and in Canada a further 200,000 persons were employed in mineral processing. Therefore, total employment in mining and mineral processing was three to four times greater than the number arrived at by the statisticians' narrow definition of mining. Moreover, the people who provide services to the "growers", "miners" and "makers" exist in the ratio of 1.6:1 in Australia and 1.9:1 in Canada (Table I). It follows that in 1979, of a workforce of 6.4 million and 11 million respectively, 700,000 Australians and 900,000 Canadians depended on the existence of the minerals industry for their employment. In Australia the figures are substantially higher today; the statistics available for 1981 indicate that the number of jobs dependent on the minerals industry had risen to one million.

The impact of minerals production is felt in the economy beyond those manufacturing industries directly involved in the processing of minerals and the refinement and fabrication of metals. For example, the manufacture of transport equipment (rail, freight cars), minerals processing equipment and other heavy engineering works depend to a large extent on the mining and petroleum industries for their markets, which adds a further dimension to the impact on national prosperity of the "miners" and "oilers".

The Exploration Investment

There will always be the adventurous and the gamblers who will search for the hidden treasure of a mineral deposit regardless of the odds, but the minerals industry is too important to the prosperity of our countries for its survival to be left to chance. We need to do everything possible to ensure that mineral exploration is a worthwhile financial investment and that all of those involved become more aware of the real nature of the mining cycle from this point of view. Certainly, if politicians and their advisors understood this better there would be far more chance of rational policy decisions which affect the industry.

The investment in mining does not start at the development stage; it starts at the exploration stage at which time there is not only a long period of cash expenditure, but a high risk of total loss through failure to make an economic discovery (Fig. 3). The average cost to the Australian mining industry of each economic discovery during 1955 to 1978 was $38 million in 1980 monetary terms, and the investor must be prepared to spend two to three times this amount to have a 90 percent probability of making at least one economic discovery. This massive high-risk investment which must precede discoveries is forgotten by our politicians and the men and women who form the public opinion to which our politicians react.

For investment in mineral exploration to be rational from the point of view of a financial investor, as distinct from a gambler, the expected value of that investment in financial terms at the commencement of exploration needs to be positive (i.e., the net present value [NPV] of the expected cash flows must be positive) and the rate of return (ROR) on the investment must be substantially greater than the current interest rate in order to preserve the value of the money invested and reward the investor for the very substantial risk that is being taken that all may be lost through failure to make an economic discovery.

Method of Analysis. Two assumptions are necessary to assess the economics of present and future exploration. First, we must assume that the deposits to be found will resemble, in economic terms, those which have been found in the past. Secondly, we must assume that the cost of making a future discovery will be similar to the cost in the past.

A study of the economics of Australian exploration has been carried out by Western Mining Corporation in collaboration with Professor Brian Mackenzie of Queen's University and Professor Michel Bilodeau of McGill University following the method presented in Figure 4. The investment characteristics of the six different geological environments listed in Table III were assessed, and the data presented in Figure 4 were examined for any significant changes in the cost of discovery or the economic characteristics of discoveries during the period studied (Mackenzie and Bilodeau, 1982). A twenty-four year period, from 1955 to 1978, was used, during which $1600 million was spent in 1980 monetary terms on exploration for gold, copper, lead, zinc, tin and tungsten. The economic characteristics of the discoveries made were assessed in terms of 1980 capital and operating costs, and 43 of the 100 discoveries made during the period were shown to be economic under today's conditions. An annual exploration budget was set to distribute the average discovery cost of

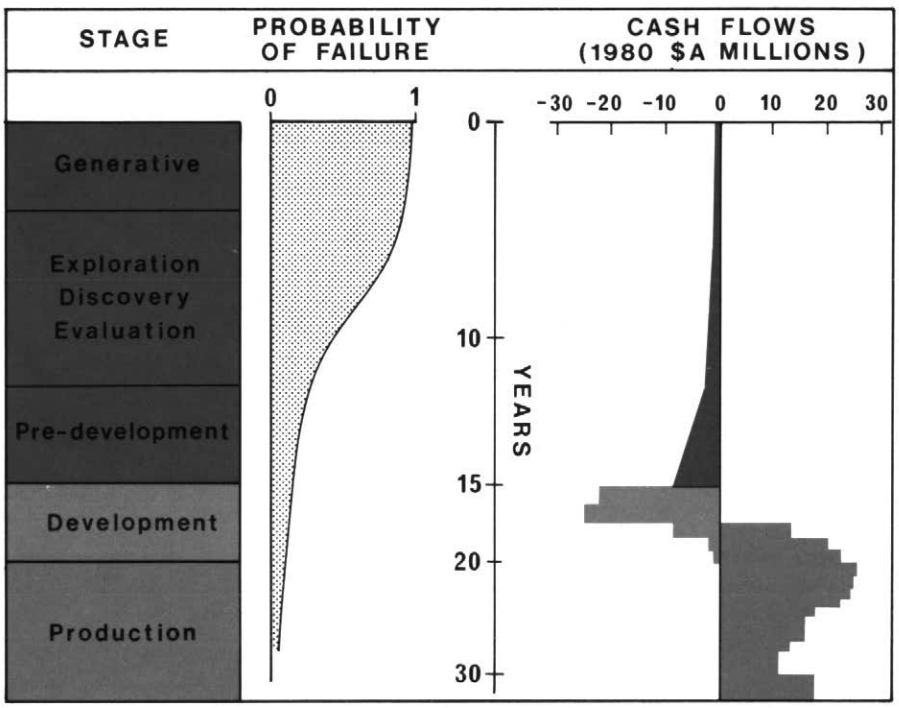

Figure 3 *The mining cycle*

$38 million over time. $2.5 million per annum was considered an optimum budget for efficient exploration by any one autonomous unit, although financial studies at $1.5 million and $4.0 million per annum were also carried out.

Results of the Analysis. The results of the study are not such as to encourage the rational investor. The average cash flows are shown in Figure 5 and the financial results on a before-tax basis are shown in Table IV. Over the past twenty-four years it has cost, on average, $38 million in 1980 monetary terms to find an economic metal deposit in Australia. The dollar values in Table IV are net present values (N.P.V) at the commencement of exploration, using a 10 percent discount rate. Although the average "expected value" of each exploration investment by the industry is positive ($4 million), the rate of return of 11 percent before tax is low for such a high-risk investment.

What is wrong? First, exploration in Australia is generally difficult and costly so that the expenditure and time required, on average, to make a discovery is too great. Secondly, the financial returns (gross revenue—costs) from production are too small even without taxation. The study has clearly demonstrated how costly it will be, based on past experience and average performance, to replace the orebodies on which our present vital minerals industry depends for its survival. *On average,* mineral exploration has not been an attractive financial investment in Australia for a quarter of a century.

The results of exploration in Canada are more favourable (B. Mackenzie, personal communication), largely due to more effective airborne geophysical surveys in base metals exploration, lower capital and operating costs and better commodity prices in terms of Canadian dollars. However, this is no reason for Canadians to be complacent, for the period of relatively low-cost discoveries in Canada is probably over.

Even when the financial returns from the average performance of an exploration industry are unsatisfactory, as has been the case in Australia, there is still reason for optimism. It is possible for an exploration team to have a performance well above average, as in the case of Western Mining Corporation (WMC), for whom exploration in Australia has been a very sound investment indeed. WMC spent 7 percent of the exploration funds during the 24-year study period and discovered 19 percent of the economic discoveries (by mineral fields), including by far the largest deposit, i.e., the giant Olympic Dam copper-uranium-gold deposit.

Assessed on the same basis as the total industry, but with its discoveries grouped

Table III. *Environments Studied*

LODE GOLD		
NICKEL SULPHIDES		
ARCHEAN BASE METALS	PRECAMBRIAN BASE METALS	BASE METALS
PROTEROZOIC BASE METALS		
PALEOZOIC BASE METALS		
LODE TIN—TUNGSTEN		

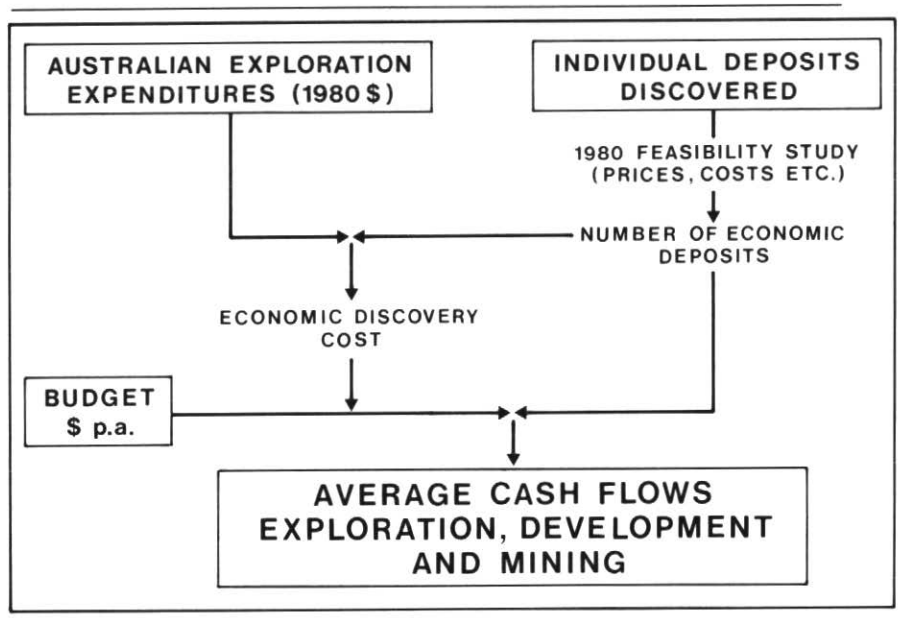

Figure 4 *The exploration investment: method of analysis*

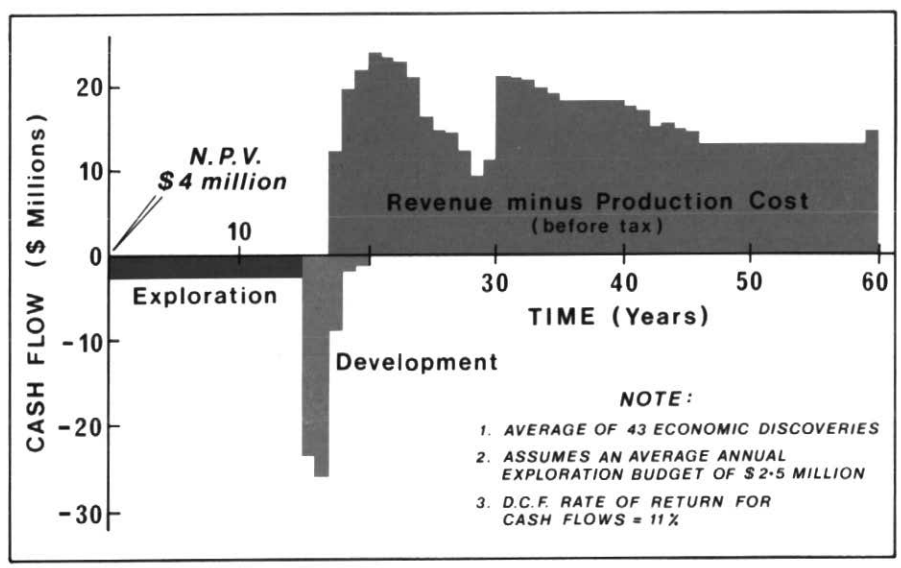

Figure 5 *Financial returns—metal exploration, Australia 1955-1978*

into mineral fields to reflect most accurately the situation in the Kambalda region, WMC's exploration investment between 1955 and 1978 shows an expected value of $35 million (industry average = $4 million) and a rate of return of 17 percent before tax (industry average 11 percent; Table V and Fig. 6). This assessment of WMC's performance *excludes* the financial benefits of the giant Olympic Dam deposit, although this deposit was considered in calculating the financial returns for the total industry (Table IV and Fig. 5). When WMC's performance is removed from the industry average, the results are very discouraging (Table V and Fig. 7), for the expected value of an exploration investment is negative ($-12 million) for other companies when taken as a group, and the rate of return is only 7 percent.

What is the difference? It is a matter of confidence: confidence in oneself and one's understanding of the science we are applying and the value of science; mutual confidence up and down the organizational structure, and confidence that what we are doing will create prosperity and is therefore worthwhile.

One "spin-off" from these financial assessments is a quantitative means of comparing mineral endowment and exploration performance in terms which have economic reality. For example, we can compare the number and revenue characteristics of base metal discoveries made in Canada and Australia over a given period, as a similar study of base metal exploration in Canada from 1946 to 1977 has been completed (Mackenzie and Woodall, 1984).

Canadian exploration has been far more successful than exploration in Australia. Between 1946 and 1977, 100 economic base metal discoveries were made in Canada from $2000 million of expenditure, *versus* 16 discoveries from $1000 million of expenditure in Australia. Australian discoveries have, however, better revenue characteristics, i.e., they have been larger or of better grade. This raises the question as to whether there is a fundamental difference in mineral endowment between the two countries, i.e., in the number, size and grade of the base metal deposits in the two countries. The figures probably reflect the more effective Canadian exploration, especially, I suggest, more effective geophysical exploration rather than any significant difference in mineral endowment. It is very difficult to find medium to small deposits under the complex weathered zone which blankets most of Australia. A clue can be found by comparing the discoveries made in the Appalachian region of Canada and those made in similar Paleozoic rocks of Eastern Australia. The results are very similar. Why? I suggest it is because the weathered zone has been largely removed from the Paleozoic of Australia so that exploration in both environments has been equally effective.

Between Geological Science and Prosperity

The prosperity generated by the minerals industry cannot be sustained without new discoveries to replace existing deposits. The techniques of discovery, the financial incentives for discovery and the technologies of resource use must all constantly improve if the minerals industry is to be a sustainable industry—sustained, moreover, by its own profits.

We have the expertise to make discoveries, but impediments to exploration and the profitable development of discoveries must be reduced. Land must be available for exploration for long periods of time and finance is needed for mineral exploration and development. The key to this finance is a minerals industry in which the level of profit compensates for the high risks of each step between the decision to explore and mineral production.

Because of Canada's and Australia's bountiful mineral endowments and small populations, the bulk of our mineral production must be exported at internationally competitive prices, and thus our wages, taxation and exchange rate policies must be sensitive to international economic realities.

We need also to remember that large sections of the international trade in minerals (58 percent of the nickel market and 63 percent of the copper market) are influenced by production and pricing policies of centrally-planned economies, such as the U.S.S.R. and Third World countries.

Table IV. *Financial Assessment of Australian Exploration 1955–1978*

Total Expenditure	$ 1618 million
No. of Economic Discoveries	43
Average Expenditure per Discovery	$ 38 million
NPV of Average Exploration Expenditure*	$ 19 million
NPV of Average Return from Development*	$ 23 million
∴ Expected value at start of exploration*	$ 4 million
D.C.F. Rate of Return	11 %

NPV = Net Present Value at start of exploration assuming 10% discount rate

Table V. *Comparative Financial Assessment of Exploration 1955–1978*

	ANALYSIS BY INDIVIDUAL DEPOSITS		ANALYSIS BY MINERAL FIELDS
	WMC	Other Companies	WMC
Total exploration expenditure ($ Million)	112	1506	112
No. of Economic Discoveries	15	28	5
Expenditure per discovery ($ Million)	8	54	22
Years per discovery (Per $2.5 million annual budget)	3	22	9
NPV of exploration expenditure ($ Million)	7	22	14
NPV of return from development ($ Million)	33*	10	51*
∴ Expected value at start of exploration ($ Million)	26*	−12	35*
D.C.F. Rate or Return	23%*	7%	17%*

* Olympic Dam excluded.

In these countries profitability as it applies in our society and market-forces may not determine production levels, as the national economies may be heavily dependent on the sale of a single mineral commodity to provide foreign exchange or sustain employment.

The price of mineral commodities in Canadian and Australian dollars is vital to the health of our respective industries. Historically, the price of most mineral commodities in constant dollar terms has been declining, demanding ever-increasing efficiencies in production. Moreover, mineral commodity prices are highly cyclical and it is essential that those who wish to comment on the profitability of the minerals industry recognize that profit today may quickly change to loss tomorrow, and high, retained profits today may be essential to survival tomorrow. As Mr. B.W. Gilbert of Kidd Creek Mines reported recently in "The Northern Miner" (February 10, 1983):

> "high, marginal tax rates imposed during good times is unfair to a cyclical industry that must use profits accrued in the good times to expand and to help weather the type of severe recession currently being experienced."

When a government takes an excessive share of the revenue of the minerals industry it reduces profits, which in turn chokes exploration and may force the development of otherwise profitable discoveries to be deferred. Governments must seek to match community expectations with reality and ensure that in solving short-term political problems the future of the minerals industry and the well-being of everyone in our countries is not put at risk.

The recent history of low profits and punitive government imposts on the Australian mining industry has deterred the rational investor to the long-term detriment of its mineral exploration. If this situation is allowed to continue, it will be to the long-term detriment of the minerals industry and ultimately to the detriment of the whole of Australian society. The minerals industry in Canada has had similar unpleasant and unhelpful experiences in dealing with governments, sandwiched, as is the Australian industry, between provincial and federal politicians.

If society takes a punitive or covetous attitude toward the profits and rewards in the minerals industry, and in its ignorance imagines that the industry operates in a risk-free environment, we can say good-bye to vigorous minerals exploration and mineral development and the efficient industrial growth which new mineral discoveries bring and the prosperity which follows.

The mining cycle now rarely begins with an ore deposit and thus the minerals industry does not consist only of development and production. The full cycle includes exploration and each cycle of mineral exploration, mineral discovery and mineral development leads to production spans of 10 to 20 years for the average company. Within an industry which operates on such a long time-scale, in which profits may come only 10 to 20 years after a decision was made to risk funding in earth science research or in mineral exploration, the crippling effects of excessively high wages, exchange rates and taxation are slow to appear. But appear they ulti-

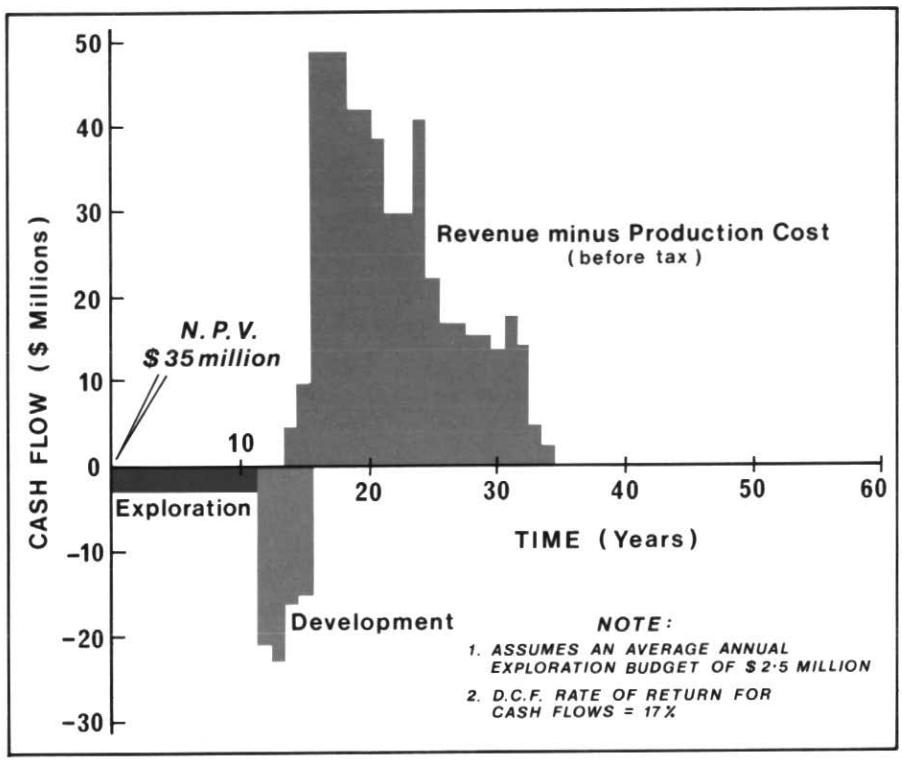

Figure 6 *Financial returns—Western Mining Corporation Limited1955-1978: Analysis by mineral field with Olympic Dam excluded*

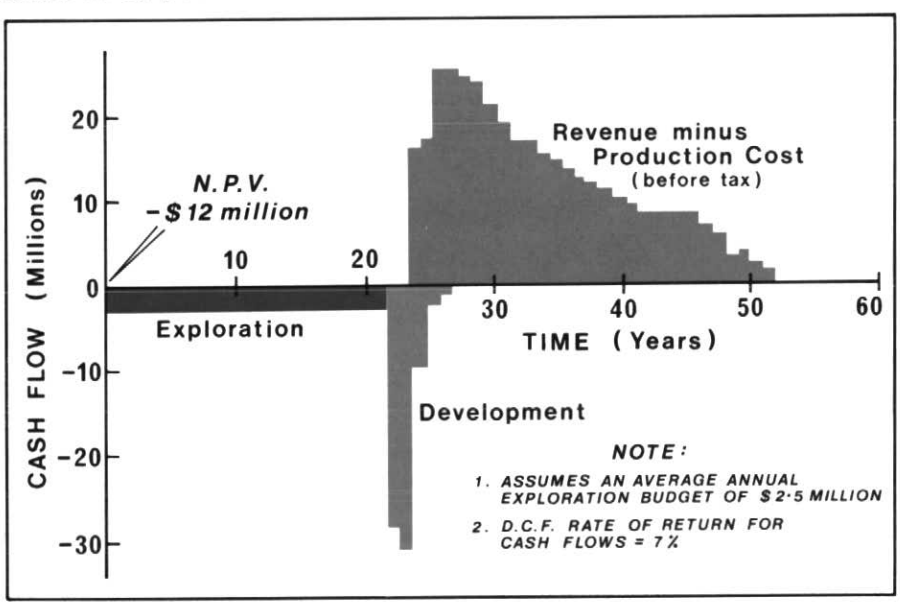

Figure 7 *Financial returns—metal exploration, Australia 1955-1978 excluding Western Mining Corporation Limited.*

mately will, to our nations' ultimate disadvantage, if we ignore the facts and the early warning signs.

What are the early warning signs? The profitability of our minerals industries has declined alarmingly. A study of 86 Australian mining companies has shown that their return on total assets before tax and interest fell from 7.9 percent in 1979-80 to 4.0 percent in 1980-81. Australian industry overall, however, showed a return of 10.5 percent in 1980-81. The return on shareholders' funds, after tax and interest, for those same 86 companies fell from 7.2 percent to 3.3 percent over the same period (PA Australia, 1981; Fig. 8).

This serious decline in the profitability of the mining industry was registered before the worst effects of the present world recession were felt. The situation is now even more serious. It is thus not surprising to find that discoveries are being made but not developed, and more serious still that exploration is being curtailed.

The next generation of mineral deposits on which survival of our minerals industries and national prosperity will depend are not lying out there like apples on a tree, ripe for picking when we need them. They have to be discovered, and in Australia risk capital of the order of $38 million is needed, on average, to discover a significant ore deposit. But where are the investors? Australians gamble hundreds of millions of dollars on horse racing, lotteries and poker machines and are encouraged to do so by the media and governments, but they are reluctant to invest in the very industry responsible for part of the surplus income they have with which to gamble. How ironic that these same Australians protest when people from other countries invest in our minerals industry or when mineral discoveries and developments are made by non-Australians who are prepared to risk their savings by financing mineral exploration in Australia. There is the same problem in Canada. We certainly need to encourage Australians and Canadians to invest in mineral exploration and mineral development and to make it easier and more profitable for them to do so.

It seems that the public is suspicious of the motives of the minerals industry, and unconvinced of its importance and its need for adequate financial rewards. Is it simply a reflection of the frailty of human nature that we think only of ourselves and of our generation? Perhaps it is also because most people don't understand the real financial character of the minerals industry, in which each cycle does not commence at the start of mine development but at the commencement of a long period of high-risk financial investment in exploration. The average citizen only hears about the industry when there has been a new discovery or new development or when a company makes an occasional high profit.

There are several popular myths in the minds of affluent, city-dwelling Australians and Canadians, those who make and administer our laws included. One such myth I have already mentioned is the belief that orebodies are easy to find. Another myth is that the mining industry, in general, is a highly profitable industry. Yet one more myth is that mineral development will automatically satisfy people's lust for more and more social benefits from less and less effort. We must show people the truth and convince them of the truth.

Our minerals industries urgently need the support of the media to help people, including politicians, understand the real nature of the industry and its importance to our nations. Perhaps if the industry had the coverage and expert reportage from which sport benefits it would not be so misunderstood, regarded with such suspicion, or so dependent on foreign investment.

Growing urban affluence has led many Australians and, perhaps, Canadians to believe that we should stop exploration and mineral development. But, from the same quarters there is a growing expectation of more benefits from mining by way of higher wages, greater taxation of the industry and high exchange rates which make imports and foreign holidays inex-

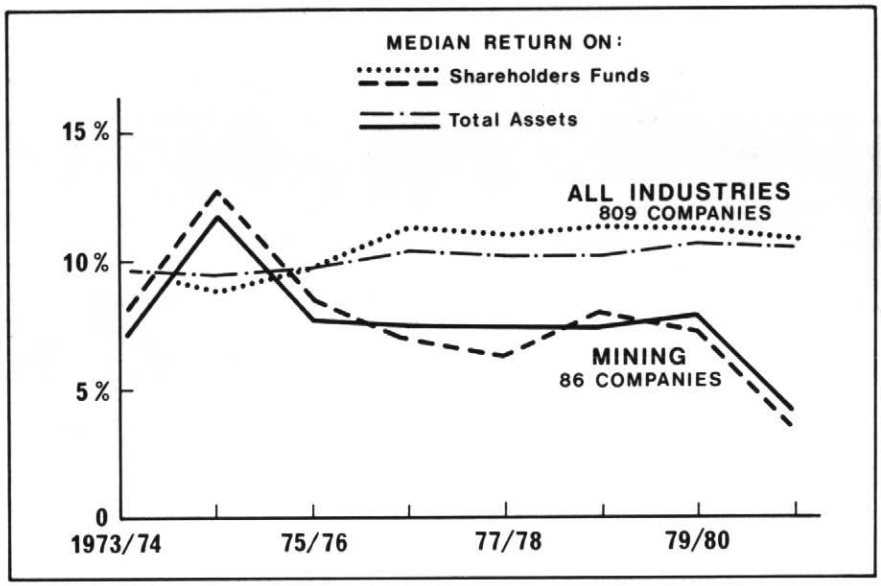

Figure 8 *Return on shareholders' funds and total assets: Australian Mining Industry*

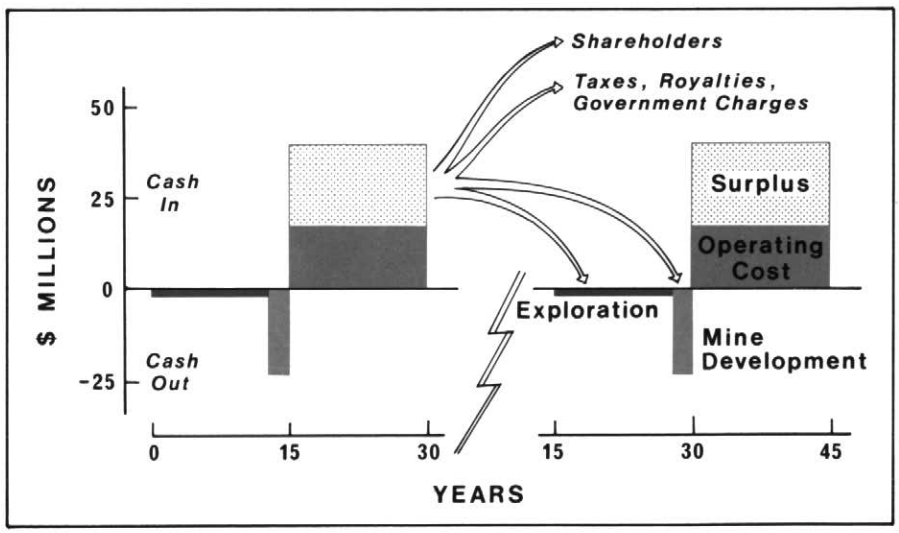

Figure 9 *A sustainable mining industry: internally funded exploration development*

pensive. The minerals industry is being asked to satisfy an unreasonable demand for social benefits and ease of living. Meanwhile, mineral developments are delayed and at the same time the industry is being deprived of the high profits it needs and the risk capital it needs to finance the mineral exploration and development on which the industry's survival depends.

As creditable as many community expectations are, there is a danger that the present generation will, in its greed and affluence, consume so much of our minerals-based prosperity in this generation that we will "break the chain" of mineral exploration—mineral development—mineral production, as depicted in Figure 9, and leave as our heritage a crippled minerals industry.

It is thus not enough to work together to improve the cost effectiveness of mineral exploration. If we are to be confident of future prosperity we must convince society that it is in danger of devouring the "seed corn" which rightfully belongs to our children. The seed corn is the profit from mining today which is needed to finance scientific research and mineral exploration, seeds which we should be sowing now in sufficient number in order that the next generation of Australians and Canadians may also have a profitable minerals harvest and also enjoy prosperity.

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