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Mineral processing in Australia : progress and potential

by

R.N. Collin

~~LIMITED DISTRIBUTION~~

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FOREWORD

This Record has been prepared for internal use in BMR, for limited distribution only, and is not intended to be available to the public. It does not contain confidential information, or deal directly with policy, but it does make some points which could be regarded as debatable. It makes no recommendations, as it is primarily a compendium of information on the economic aspects of mineral processing, excluding the energy minerals (petroleum, coal and uranium). It does not cover manufacturing, which in the case of metals is defined as any stage subsequent to the production of refinery shapes.

The Record's aims are to :

(1) describe the economic characteristics of mineral processing;

(2) indicate the difficulties in making economic studies of the industry;

(3) outline the practical limits of development;

(4) suggest opportunities for further processing;

(5) stimulate interest and research in the subject; and

(6) assist BMR officers in the preparation of relevant reports.

This Record is not a statement of the policy position on mineral processing of BMR or of any other organisation. Some of the statements in the text, while believed to be true, would require an impractical research effort if they were to be substantiated in detail.

This project was initiated within the former Department of National Resources.

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SUMMARY

A comparison is made between the situation of the mineral processing industry in 1967 and that in 1976. Modern trends in environmental and energy pressures are mentioned, and a survey made of the scale of some Australian processing plants. The problems in determining export prices (in this account, 'determining' means finding out what it actually is), and potential income from an expansion of processing, are studied. An assessment is made of the possibilities for additional mineral processing, in the light of the prospects for exports of metals and processed minerals.

INTRODUCTION

In a paper 'Mineral Processing in Australia' in the Australian Mineral Industry Quarterly Review, Volume 22, Number 1, September 1969, the authors (L.C. Noakes, J. Ward, Z. Kalix) outlined the mineral processing position in 1967. The purpose of this present paper is to update the earlier account, and to indicate some of the restraints and possibilities for further expansion of processing. It does not make a detailed examination of individual processing proposals. The energy minerals (such as coal, petroleum and uranium) and the steel industry have been excluded, to keep the subject to a manageable size.

The period of rapid development of mining and processing characteristic of the 1960's, ended in 1971-73, whereupon the current economic recession reduced development to a low level. Apart from a brief boom in 1974, it has been a period of depressed demand and low prices for most metals and minerals, and of unfavourable financial conditions. In view of the current relative stability, now is an appropriate time to survey the position and examine future possibilities.

At the time of writing the latest complete statistics are those for 1975 and 1976, but the figures for 1976 for overseas trade are sometimes misleading because the onset of the economic recession made them unrepresentative of the long-term trend.

Most documents on minerals are written on an individual commodity basis, which obscures the pervasive economic and technological pressures and principles that affect mining and processing as a whole. Since one of the main objectives of this paper is to bring out these general influences, the paper is arranged primarily under headings relating to concepts and ideas, and only secondarily are commodity sub-headings used.

With such a broad subject it is not possible to give a comprehensive and detailed coverage, but sufficient detail is included to indicate firstly those areas where further study of possibilities for expansion of mineral processing may be worthwhile, and secondly to show up some of the problems involved in making economic studies of the industry.

As in the 1969 paper of Noakes and others the 'processing index' is the percentage of production which is processed domestically, or which is exported in processed forms (PP1 = production processing index; EP1 = export processing index). Generally with metals, processing is defined as any treatment that changes the chemical state or purity of the metal; it excludes ore benefication or pelletising, but iron ore pelletising is covered in this Record. The Australian Mineral Industry Annual Review, gives the processing index for the years since 1967.

GOVERNMENT POLICIES

It is important to understand the structure of government in Australia, and the constitutional powers and responsibilities each of the three levels have in relation to the mining and processing industries. The Federal Government covers export controls, foreign ownership, and off-shore matters beyond the 3-mile zone. It has no direct control over the State Governments, which administer mining tenements and royalties, and which have overriding powers over local government. Local government, which includes city, shire, and harbour authorities, administers building permits, roads, water supply, and land-rates.

Australian Governments have always sought higher levels of domestic processing of minerals, and legislation granting special mining leases for large projects has sometimes included provisions for more processing. For example, in the agreement covering bauxite mining at Weipa, the State has set a lower royalty on bauxite processed in Queensland. The royalty per tonne payable on bauxite mined at Weipa is 50 cents when treated in Queensland and $1 when not treated. Over 11 million tonnes are mined annually at Weipa, and royalties exceed $7 million. At Gove royalties are 20 cents for treated, and 30 cents for untreated bauxite exports. Mining lease agreements sometimes require a feasibility study of further processing, and may restrict prospective plant locations to within the State. This is unfortunate, as in the national interest it would be desirable for processing to be done at the economically optimum site in Australia.

Government policies to encourage processing include, in some special instances, the prohibition of the export of unprocessed material. The best-known case is mineral sands (rutile, etc.) of which Australia is the dominant world supplier, where only separated sands may be exported. Although this is only a low level of processing, it probably doubles the export value and employment of the industry.

The objectives of these polices include maximising employment, revenue, and national economic strength. The multiplier effect of the processing industries upon the supply and service industries meeting their needs, and upon the regional economy is generally recognised. The by-products of processing, such as smelter gases, can form the basis of further valuable productive enterprises.

Other government actions to assist processing have included tax concessions, and facilitating the provision of capital, fuel, and electric power and other infrastructure such as housing, harbours, water supply, roads, and railways. The Export Incentive schemes do not apply to minerals, though there have been suggestions that they should be used to assist the troubled phosphate and salt industries. These forms of assistance are not often provided, and, particularly during boom periods governments have been more concerned with raising revenue from mining by way of licenses, royalties, rail freight rates, and export levies. Technical co-operation from government geologists, cartographers, and scientific organisations has probably been the most effective form of assistance given. Apparently there has never been a comprehensive statement of government policy on mineral processing, and it is of interest that the Prime Minister wrote to the State Premiers in March 1978 seeking co-operation in formulating a suitable policy framework to guide and encourage processing prospects and to facilitate desirable forms of development.

Generally, mining and mineral processing has received less government assistance than farming, or the tariff-protected manufacturing sectors of the economy. The mineral industries are probably smaller, as a result, than would be desirable according to economic criteria. There are some economists who suspect that the mining and metallurgical industries are undersized, by comparison for example with the pastoral industry which is over-expanded, to the detriment of the Australian national ecology and stability of the economy. Apparently, an overall study has never been made of the optimum size, range, and structure of the Australian mineral processing industry, based on the size of the Australian economy and its resource base.

Historically, State Governments have long been engaged in mining, particularly in quarrying and coal-mining, initially for roads and railways, and more recently for power generation. The Federal Government has engaged in mineral processing for defence reasons, particularly during and in the immediate aftermath of war. The Commonwealth Oil Refineries (Altona), Australian Aluminium Production Commission (Bell Bay), Dorset Tin Dredge, Glen Davis oil shale and Rum Jungle uranium, are examples, but only two of these have survived and they have long passed from government ownership. It is the policy of the present Federal Government to avoid participation in mineral processing, but uranium enrichment could be an exception.

In some ways the Constitution hampers mining administration. The States, if they want a share of the revenue, usually have to charge a royalty which may lead to the permanent loss of deep low-grade ore. The Federal Government has to impose uniform levies, whereas the situations of individual mines are often very different.

EXPORT CONTROLS

The main power constitutionally available to the Federal Government, apart from taxation, which can be used for directing the mining and mineral processing industries, is the control of overseas trade. As mentioned earlier, export controls are used to enforce some processing of mineral sands. In the past they have been imposed in times of shortage to safeguard domestic supplies of metals, and to protect the economy from temporary excessive price rises. The iron ore embargo, intended to conserve resources, is best known for inhibiting exploration. Export controls are also applied to commodities like gold and uranium which have special importance, and to trade with certain countries, like Rhodesia, where there are political considerations.

In December 1972 all minerals were placed under export control, to ensure that they were sold for the best prices. It was the export control power which forced cessation of sand-mining on Fraser Island for environmental reasons. The necessity for an export license is an effective means for enforcing company ownership requirements, and for enforcing commodity agreements, such as the International Tin Agreement. It is possible that export controls could be used in future to raise the level of processing of export minerals. It is not easy to administer in detail export controls on minerals passing through the many ports around Australia, since shipments are often made at short notice; as delays are intolerably costly, blanket approvals are often necessary. Nevertheless, the objectives of the control are achieved.

Because of Australian self-sufficiency and efficient production, import controls have been little used with metals and minerals, but were effective in protecting the aluminium industry in the early stages, and in the past have been part of domestic marketing arrangements of subsidised commodities, such as fertiliser.

EXPLORATION

As the obvious surface occurrences of valuable minerals, yet to be discovered, become scarcer, so too is the traditional lone prospector gradually passing into history, though he will continue to have a diminishing role in exploration for many years to come. The gold-rush tradition was of the lucky individual who chanced upon a 'bonanza' discovery, which he sold for a fortune to the highest bidder, usually a company, since he lacked the ability to develop the mine. As the value of the prospect was based on near-surface indications only, it was often a case of 'take the money and run', but if the extent of the mineral deposit was clearer, for example with an iron ore deposit, it was sometimes possible to negotiate an over-riding royalty. Before World War I, major prospects often came under the control of London-based companies, which had an interest in a smelter. This pattern was an important influence upon the structure of the mineral processing industry.

Most recent major discoveries of minerals in Australia have been made by a group of companies, after costly and painstaking field investigations over a long period, using advanced methods to locate deposits below the surface. The discovery is usually developed by the group, using overseas capital, since Australian companies often cannot raise their share of the funds required.

Circumstances are, however, changing as costs mount and discoveries become harder to make. Already much exploration in Australia is funded by companies which are not directly involved in mining, and there are some foreign governmental organisations which are exploring with the intention of having an equity in the development of any discoveries, but not of engaging directly in mining. These organisations function mainly with the aim of ensuring a secure supply of vital raw materials for their own national economies. Agencies of some communist governments are already exploring in some foreign countries, but not yet in Australia. World-wide about 55 percent of capital expenditure on mining is for the replacement of exhausted ore bodies. In Australia exploration is cheaper, but development more expensive, than in most countries. It is a matter of mobilising 'risk capital' from a variety of sources, with a view to maintaining exploration at a high level, while safeguarding Australian control and national interests.

Governments in Australia usually do not explore for minerals, but the States sometimes undertake limited programs. Currently South Australia is drilling for gas reserves in the Cooper Basin. The Federal Labor Government had the Australian Atomic Energy Commission prospect for uranium, and sought to form the Petroleum and Minerals Authority to undertake exploration and development. Rewards for mineral discovery go back at least 145 years, to when Hargreaves claimed the reward for the first discovery of gold. Governments may also hold up exploration, a present example being the off-shore search for petroleum in Queensland.

Exploration requires a different type of employee and organisation from that appropriate for an established mining concern, and it should be regarded as a separate industry. 'Proving up' a known deposit should not be regarded as exploration. A case can be made for introducing special exploration-company legislation, that would provide effective incentives, particularly for those minerals given priority in the national interest, while allowing governments control over development. It is generally accepted that the discoverer deserves to be amply rewarded, but it is unlikely in future that he will be permitted to decide alone on the development of major deposits. A point here is that the government may require some processing to be done, as a condition of development.

INTEGRATION

Although private enterprise can be expected to undertake mineral processing only when it is profitable, this does not mean in the case of an integrated multinational corporation that the profit need be taken locally, since it can be taken at any stage in the chain of processing. Thus, Queensland Alumina Limited operates on a non-profit basis, processing bauxite into alumina for which the participating companies pay a toll charge. The Taxation Commissioner levies income on the theoretical basis of a net profit being earned at a certain rate of interest on the total funds invested in QAL. The massive investment over the years, resulting in staged expansion such that the alumina plant has now become the largest in the world, is a clear indication that the consortium has found it profitable, despite the low nominal profit.

Other companies may decide to integrate forwards or backwards either to make their commercial position more secure, or for tax purposes, or to diversify their product range, or because they have surplus funds to invest. An example is the chloride process developed in the United States for manufacturing titanium dioxide white pigment from rutile. The companies concerned have taken over some of the leading Australian rutile producers to safeguard their supplies of raw material, since when rutile production has appeared to be relatively unprofitable.

The proposal by Mount Isa Mines to establish an electrolytic zinc refinery at Townsville would be a forward integration. Sometimes the processing industry lives on when the mine has been worked out. The non-ferrous metal semi-fabricating firm, Metal Manufactures, had its origin with the copper mines and smelters at Kuridala, near Cloncurry, which closed after World War I. Similarly The Broken Hill Proprietary Company and BH South have survived the closure of their original mines at Broken Hill. The survival of the company is therefore a reason for undertaking mineral processing.

Stability and predictability are important attributes of government policy, particularly for a company planning a new development, though very few mineral projects have been stopped by governments. Sand mining at Fraser Island is an exceptional case. Most mines with adequate reserves, and most mineral processing plants, close because of a lack of demand for their product, or because costs have overtaken the price of their product.

There is a danger that some mining enterprises, particularly a foreign-owned mine that exports unprocessed raw materials to its parent, can remain isolated from Australian industry. One has only to study the history of companies such as BHP, ICIANZ, EZ, CSR, ACI, or Thiess to realise the important part that mining has played in the development of Australian industry. Apart from the advantages for financing exploration, and for stabilising the inevitable booms and depressions of mining, there seems to be a cross-stimulation between the mining, manufacturing, and construction sectors which keeps a company management energetic and able to make the most of opportunities for development. Mineral processing is often the technological link which enables this integration of the industrial structure.

Despite limited success in the past, the less populous States are always seeking conspicuous industrial progress, and since multinational firms usually have better access to finance, technology and expertise, the States tend to give Australian ownership a lower priority than does the Federal government. The recent allocation of coal areas by Queensland to foreign companies without calling for tenders is an example of this tendency.

ENVIRONMENTAL RESTRAINTS

In recent years the protection of the environment from the effects of mining and processing has received much popular attention, and companies now have less freedom than formerly. The choice of sites for the new alumina plants in the Perth area is an example of this. Because of environmental objections, the companies concerned were not permitted to establish their works at the locations originally chosen. Recent W.A. legislation provides for limits on bauxite and alumina production. Port facilities have been particularly vulnerable to such pressures. Also, there have been suggestions that highly industrialised and densely populated countries, like Japan and Britain, should avoid smelting and processing plants likely to contaminate their congested surroundings, and that encouragement should be given to the re-location of such potentially obnoxious industries to countries like Australia, where there is plenty of space, and less hazard to the community. Since pollution is equally impermissable in Australia, the cost to the company of environmental protection would be much the same for new plants. It may be noted that most old smelters in Europe are located on densely populated coalfields, whereas elsewhere in the world smelters are often closer to mines in lightly populated areas.

Some old smelters in the USA have closed down because of environmental considerations, but there have been minimal closures for these reasons in Europe and Japan, even when the survival of the plants concerned has required protection from imports. Such closures as have occurred have been related to the availability of raw materials, obsolescence, fallen demand, or rising costs of fuel and power. Environmental pressures for moving processing to Australia may only effectively apply to new plants, and in the long term. Theoretically Australia could search for obsolescent plants in Europe and Japan and negotiate to have the old plant closed down and replaced by a new efficient plant in Australia but this is not really practical. A government-to-government agreement may be necessary to ensure security of the commodity flow, particularly if it is not part of an integrated company structure.

OVERSUPPLY

During the past decade, some nations have 'nationalised' certain mining and smelting industries, notably copper. They have also increased the proportion of output that is processed locally. When faced with declining demand the governments have been more reluctant than the former companies to cut back on employment, output, and foreign exchange earnings. Some US producers tended to maintain production from their domestic mines and smelters, and cut their foreign subsidiaries more severely. Under the new conditions, with no recovery in world prices, and increased competition with processed exports, the smaller high-cost copper-exporting companies, including some in Australia, have been disadvantaged. The world stockpile of refined copper is now about 2 million tonnes, its highest level ever, and is still growing. In the meantime, the industrialised nations are importing copper at bargain prices, which was not the intention when the mines were nationalised, and there are now poor prospects for opening new copper mines in Australia. Other metals, notably lead and zinc, are also suffering low prices and oversupply, but, being privately owned and therefore capable of more flexible management, will probably recover sooner than copper, and be in a better position to increase output when this is eventually required. International efforts to control production, and the prices of metals (except for partial success with tin), have been largely ineffective.

DECENTRALISATION

Mining and mineral processing have contributed more than any other factor to bringing about decentralised development in Australia, and the encouragement of further processing would be one of the most effective policies for decentralisation. The tax incentives given to mineral exploration and the development of mines often do not extend to processing, which is regarded as manufacturing, despite its frequently isolated location. Processing usually makes more claim than mining upon the social infrastructure, because it leads to a much larger town, requiring a higher level of amenities and a wider range of facilities. In northern Australia infrastructure is costly, and less government assistance is given with housing, power, and water supply, etc. than to corresponding industries near capital cities. A comparison of Weipa, which is predominantly a bauxite mining and exporting town, and Gove, which is mainly a bauxite mining and processing and alumina exporting town, illustrates the difference in population and social infrastructure. The larger workforce associated with processing increases the economic and social consequences of strikes, but the larger, mature mining towns in Australia have a good record for stable industrial relations.

It is reasonable to expect the mining company to pay for a small town to service the mine, and for other infrastructure, if the mine is expected to be highly profitable, or to have only a short life. The 'closed' company town is undesirable as it has problems, both socially and with outsiders who expect to be able to behave as in a normal 'open' town. There is a strong case for government assistance with the larger town associated with a processing plant, located at a port site with potential for permanency as a centre for other industries. Gladstone is an example. The question is complicated by some international competition among governments to "grab" the processing industry, by offering more government incentives and assistance with infrastructure. Often the cost of a new railway and port can be passed on in the price of the exported mineral to the foreign customer, but when a considerable part of the output is to be sold domestically (for example phosphate rock or gas), then there is a case for some assistance with infrastructure to reduce costs to the Australian consumer.

MARKETING

Processed commodities usually have protective tariff barriers to overcome in foreign markets, and are harder to sell than raw materials. Concentrates face few tariffs and are usually sold on long-term contracts, being exported in bulk through the nearest port to relatively few purchasers who normally also supply any necessary shipping. These overseas purchasers frequently possess the special technology needed to utilise complex or refractory concentrates, from various sources, and they have the advantage of the economies of scale, that accompany a large output.

By contrast, there is a multitude of buyers of refined or semi-fabricated metal. Metal is frequently sold on a one-year contract, or less, often in relatively small tonnages and in many countries, making it necessary to use liner transport from the main ports. In times of economic stringency countries tend to maintain imports of concentrates, but to cut back on imports of metals that compete with local producers, A metal producer is more independent than a concentrates producer, but faces a more competitive and dispersed market, and needs more finance and a sophisticated selling organisation.

It is often difficult to penetrate overseas markets because of cartel arrangements, and because the greater elasticity of demand for imports, combined with intense competition, usually leads to prices below those in domestic markets.

The small size of the Australian market has militated against the establishment of local processing industries, particularly when advanced technology is involved in metal production.

ENERGY FOR PROCESSING

The supply of mineral fuels is not covered in this paper, but over 20 percent of the energy used in Australia is for mining and mineral processing. It seems probable that this requirement will grow sharply because most of the prospective major mineral developments, apart from natural gas and phosphate, are energy intensive. As older mines go deeper, more energy is used.

Proposals for expanding energy intensive processing have included the production of electrolytic zinc, copper, caustic soda, and aluminium, as well as new plants for iron and steel, nickel, and enriched uranium. There has been a long-term trend for lower and lower grade ores to be mined, but these require more energy for concentration, and the increasing cost of energy may now cause this trend to flatten out.

Apart from Tasmania, our hydroelectricity resources are limited, but fortunately Australia is well endowed with coal and gas in some localities, and conditions generally are favourable for economic energy production. They are probably at least as good as those facing our major competitive mineral producers in Canada, Russia, Africa, and Latin America, which often have severe fuel and land transport problems. Nevertheless, the provision of energy at a competitive cost is one of the most important factors in fixing the extent of feasible mineral processing in Australia. While it is not true at present, in the long term our major export markets may run short of energy, and become anxious to shift energy-intensive stages in processing to Australia.

An indication of the energy demand for processing minerals, that could be regarded as potentially transferable from overseas to Australia, may be gained by relating the amounts of energy required to convert ore into one tonne of the metal or compound sought, with the quantities of minerals needing further processing, that are exported from Australia, as in Table 1.

Table 1. Energy required for mineral processing

Metal or compound	Energy required to produce one short ton (10^6Btu)
Aluminium	244
Copper	112
Iron (steel slabs)	24
Lead	27
Manganese (ferroalloy)	52
Nickel (electrolytic)	144
Phosphate (phosphoric acid)	11
(phosphorus)	172
Titanium (pigment)	86
(metal)	408
Zinc	65

Source: 'Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing' by Battelle Columbus Laboratories for the U.S. Bureau of Mines, 1975.

Note: A black steaming coal yields about 24 x 10^6 Btu/tonne; thus, the production of one tonne of aluminium would consume the energy contained in about 10 tonnes of coal.

The figures for metals relate to the production of refined ingot equivalent. It would be misleading to simply multiply raw material exports by the foregoing energy figures, because it would be unreal to contemplate transferring many of these industries to Australia. Allowing for the tonnages involved, the table indicates that the main energy requirements are for the manufacture of iron and steel, aluminium, ferro-alloys, zinc, titanium pigment, phosphate and copper. The extent to which energy-starved nations will accept that further expansion in the energy-intensive stages of these industries is to be located in Australia, is probably the measure for the likely growth of Australian mineral processing.

SCALE OF PROCESSING

The concept of minimum economic size does not apply to the production and processing of minerals with the same directness as it does in most manufacturing, where plants are usually located near major industrial centres and where costs tend to be similar. Mines can be located anywhere, from the Arctic to tropical jungles or from the Pacific Islands to Western Europe, where the circumstances are so different that it is almost impossible to specify general economic parameters. Provided a mine is sufficiently rich to be profitable, it can be almost any size, and if a mine meets the minimum requirements for access, grade, reserves, and suitability of ore for treatment, its commercial viability is usually determined by transport, infrastructure, or loan capital costs. Exploration which led to the discovery of the mine is a 'sunk' cost.

Although the economics of a processing plant are greatly influenced by the location of the ore supply, it is possible to make a broad assessment of the optimal scale under Australian conditions. We need to look at the size of existing plants to see whether they might be competitive on the export market, and to see if some small mines could send their output to a central plant operating on an optimal scale, and thereby expand the processing industry.

Most large mining enterprises are vertically integrated, and profits can be arbitrarily allocated through the enterprise, which might result in a rich mine supporting relatively unprofitable processing. The company may prefer this arrangement because of the security and independence resulting from a broader product range, and wider access to markets.

Each stage of processing has its own individual economics, and particular attention should be given to the stage requiring the largest scale of operation, because that is likely to determine what throughput is necessary to give viability to an integrated processing industry, as well as being an indication of the capital outlay required to establish the enterprise. For example, in the aluminium industry, the extraction of alumina from bauxite must be on a larger scale to be economic than the other stages, like the mining of bauxite, smelting, or semi-fabricating.

In broad terms there are two types of enterprise, (1) those with open-cut, high-grade ore, and large-scale processing, such as is found in the steel, aluminium, phosphate, and salt industries, and (2) those with low-grade ore and a valuable product, like copper, lead, zinc, and uranium. The first category has the major expenditure for the processing plant, while in the second category the mine is the more expensive.

It is possible to indicate the approximate scale and cost of establishing certain mining and processing enterprises under Australian conditions, using conventional plant, provided it is understood that the figures could be very different in other circumstances. The only up-to-date published figures (Table 2) relate to constructing new metals projects in North America in 1975. These figures are for new enterprises under modern conditions, and it should be noted that the economics of old long-established mines, and to a lesser extent processing plants which have been largely amortised, are quite different. Such old establishments survive in Europe and Japan and sometimes operate on a scale that would be too small to be commercially viable in Australia for a new plant.

The capital costs can be obscured by the use of 'tied loans' which tend to inflate the total. Multinational groups particularly sometimes lease plant, even buildings and furnaces, often from affiliated companies, possibly overseas, to obtain advantages with taxation, customs and currency controls. Such leasing has greatly reduced the nominal capital investment in some open cut mines. The proportion of capital costs in the operating costs of mines has been steadily rising and now averages about 55 percent, and can be as high as 70 percent for large open cut mines.

The capital cost of processing plant in Australia is higher than in Japan or the USA. Although the difference is difficult to quantify, it can apparently be as much as 30 percent. Labour and transport costs are also higher in Australia than in most countries, but it is not practical to generalise about material or energy costs.

The information in Table 2 is from a paper presented to the American Institute of Chemical Engineers in 1976 by Mr I. MacGregor of AMAX Engineering and Management Services Company. The capital investment requirements cover all stages from mining to the production of primary metal: (thus they exclude exploration).

Table 2 Costs of constructing metals projects in North America in 1975

	Annual capacity (short tons)	Required investment (US$ million)
Aluminium	500 000	1200
Copper	100 000	600
Iron Ore Pellets	10 000 000	800
Nickel	30 000	480
Lead	100 000	140
Zinc	50 000	80

Assuming that processing plants have the same life, and that, operating on the scales indicated in Table 2, they should be capable of competing on export markets under normal marketing conditions, it is interesting to compare these figures with the capacities of existing Australian processing plants. The annual capacities shown are regarded in this chapter as an indication of the minimum economic size of plant, but this is subject to several qualifications. If there are valuable by-products, cheap energy or materials, transport savings, and other cost advantages the real minimum economic size would be smaller.

Aluminium

The size postulated (500 000 tons/year) appears high when compared with existing local smelters (Table 3).

Table 3. Aluminium smelters - annual capacities 1977 (tonnes)

Location	Present	Planned
Bell Bay	93 000	112 000
Point Henry	91 500	-
Kurri Kurri	45 360	67 900
Bluff (NZ)	150 000	220 000
Gladstone	Nil	320 000

According to a 1975 report of the Industries Assistance Commission, the relatively small size of Australian aluminium smelters placed them at a 15 percent cost disadvantage in that year compared with major overseas export smelters. The difficulty will be lessened as further expansion occurs and in any case other factors, particularly alumina and power costs, are as important. It is significant that Comalco has said that the proposed Gladstone smelter, where alumina and power should be cheap, will be export-competitive when of 320 000 tonnes capacity. Its main problems will be access to markets overseas, and competition from older pre-inflation smelters established when capital costs were much lower.

All Australian alumina plants now in operation have annual capacities exceeding 1 million tonnes, and are among the lowest-cost in the world. The mining of bauxite is clearly above economic size, but the rolling and extruding phases receive tariff protection, probably because of their small scale of operation.

Copper

The Mount Isa smelter and Townsville refinery with a capacity of 155 000 tonnes a year are well above the 100 000 tons quoted, and are generally acknowledged as being modern and efficient, though their distance from the main population centres entails additional costs. The rather small flash smelter at Tennant Creek (25 000 tonnes/year of blister copper will be viable given satisfactory recovery of bismuth and an improved market for copper. Savings in transport costs as a result of hauling metal in place of concentrates, will also assist in making the smelter profitable. The Mount Morgan flash smelter (14 000 tonnes/year of copper) is viable under normal conditions because of gold co-production. Experience has led to plant modifications that have raised efficiency to a high level.

The Port Kembla smelter (35 000 tonnes/year) and refinery (tankhouse 60 000 tonnes/year) is well below the 100 000 ton capacity listed although in the early part of this century it was one of the larger copper plants in the world. Its commercial viability is assisted by amortised plant, tolled refining, and by a considerable secondary copper refining business. The problem is to obtain a sufficient and secure intake of copper concentrates at a competitive price to justify expansion to 100 000 tons. Unfortunately it is more profitable for copper mines to export concentrates than to export metal, mainly because of overseas tariffs. It would not pay to import concentrates for smelting and refining at Port Kembla, as the local market for metal is already adequately provided for, and tariffs overseas inhibit the import of refined metal and semi-fabricated products. Next year the new Woodlawn mine will be exporting 16 000 tonnes of copper in concentrates, probably through Port Kembla and mainly to its parent companies' smelters in America.

When the demand and prices for copper improve, a number of new copper mines will be developed in South Australia and Western Australia. There have been suggestions that smelters should be established in those States to treat these concentrates. It seems that, apart from a minimum throughput of 100 000 tons of copper/year, some common ownership of the mines, smelter, and refinery, as well as a secure export market for the metal, would be essential to make local processing feasible. This would be a long-term development, if economic criteria alone determine the course of events.

Iron ore pellets

The US figure of 10 million short tons/year is based on an industry which is primarily engaged in beneficiating low-grade ore, and making the resulting fine material into pellets suitable for feeding a blast-furnace. In Australia, where high-grade iron ore is plentiful, most pelletising (Table 4) has a different basis, and therefore different economic parameters.

Table 4. Iron ore pelletising - annual capacities 1977 (million tonnes)

Location	Capacity
Port Latta	2.5
Whyalla	1.5
Dampier	3
Cape Lambert	5

The Port Latta plant in Tasmania resembles the US situation, as it depends on beneficiating a relatively low-scale magnetite ore, and has been given a higher price by Japan, to help it survive.

The plant at Whyalla was established to treat fine ore from Iron Prince and Iron Baron, which was unsuitable for sintering. Use of feed product from the new magnetite plant was to increase the capacity from 1.5 to 2.3 million tonnes per year; the plant, which uses fuel oil to reduce haematite to magnetite, commenced production in February 1975 but since November 1975 has been closed indefinitely, ostensibly because of reduced demand. The Port Latta and Whyalla plants use about 1 percent of imported Wyoming bentonite for pelletising.

Similarly at Dampier the pelletising plant was constructed to make use of by-product fines at a time when the fines had only a limited market.

At Cape Lambert, pelletising is done to remove volatiles and give a mechanically stronger lump more suitable for blast-furnaces. There were plans to expand all these plants to more economic capacities, but the increased price of fuel oil has made pelletising expensive.

The Japanese have found sintering now more attractive than pelletising, and recently completed a 5-million-tonnes/year sintering plant, employing 600, at a cost of about $200 million, in the Philippines. The plant was originally to be in Autralia, but greater government assistance was available in the Philippines. It also provides extensive storage facilities which cushion the Japanese mills from interruptions in the flow of ore, caused by industrial disputes and cyclones. Its operation has reduced the demand for Australian pellets, and the Dampier and Cape Lambert plants may have to close temporarily. The value of the various stockpiles of materials held by the Japanese steel industry currently exceeds $3 billion; the Japanese Government has given financial assistance with stockpiling. This policy has been influenced by the excessive trade surplus of Japan.

When natural gas becomes available in the Pilbara there could be a further expansion of pelletising, and possibly the establishment of sintering and reduction plants.

Nickel

Both Australian nickel-producing groups compare well with the 30 000 tons/year criterion. The Kwinana refinery, Kalgoorlie smelter, and Kambalda mine have an integrated metal capacity of 30 000 tonnes/year.

The existing furnace at Kalgoorlie, with a capacity of 320 000 tonnes of concentrate/year, is being replaced by a new 450 000-tonne furance. The capacity may eventually be raised further by the addition of oxygen.

The lateritic mine at Greenvale and refinery at Yabulu near

Townsville have a capacity of 25 000 tonnes of nickel/year, but the refinery is a new and complex plant, and has taken some time to reach an economic recovery rate. A serious problem is that the refinery is one of the largest single users of fuel oil in Australia, and the price of oil has increased greatly since the refinery was designed.

Lead

Both the Port Pirie (230 000 tonnes/year) and Mount Isa (150 000 tonnes/year) lead smelters are well above the 100 000-ton minimum. The Cockle Creek smelter (near Newcastle) uses another process and smelts a combined lead-zinc-silver concentrate giving 70 000 tonnes of zinc/year and 28 000 tonnes of silver-lead bullion/year. Mount Isa and Cockle Creek do not produce refined lead, but export a silver-lead bullion, as they lack facilities for separating and refining silver.

Zinc. The Risdon (220 000 tonnes/year) and Cockle Creek (70 000 tonnes/year) plants are both larger than the 50 000 tons postulated. The Port Pirie zinc refinery (45 000 tonnes/year) is a special case, as it is an adjunct to a process for removing zinc from old lead slag by fuming. Since the zinc concentrates now exported have a metal content of about 200 000 tonnes annually, there is scope for additional zinc refining in Australia.

Summary on scale. Although it is not possible to give precise figures of general application for a minimum economic size for most mineral processing plants, a comparison with the sizes given for new US plants indicates that Australian metallic ore processing plants are above the minimum economic size, with a few exceptions which have prospects for expansion and improvement. If the Export Incentives Scheme were applied to exports of refined copper and aluminium it could be one means of stimulating expansion in critical areas, but the production and marketing of multinationals is complex and any move would have to be carefully considered. Their general efficiency is shown by the fact that most compete successfully on export markets and are exposed to import competition. Nearly all were established when Australia had unrestricted access to the British market, and they use the more readily available technologies. In the event of Australia attempting to establish new primary metallurgical industries, such as the production of antimony, bismuth, magnesium, titanium, or tungsten metals, the situation would be more obscure, since less information is available on their technology, economics, and markets.

EXPORT PRICES AND VALUES

The selling price of the output of the various mineral processing industries is, of course, a vital factor in the development of the firm, the industry, and the national economy. It is also essential information for any economic study of the industry, but it is difficult to determine selling prices. By 'determine' is meant 'find out what it really is'. Since most Australian production in this category is exported, the export values recorded in Overseas Trade Statistics are a useful indication of these prices, but prices and values are often very different.

As a result of representations by the industry, certain export figures are not published by the Federal Government. No details are published of exports of bauxite, manganese ore, beneficiated ilmenite, or liquefied petroleum gas. With alumina and nickel exports no details of destinations or State of origin are published, and only the total value for nickel is disclosed.

Export values are, however, stated in some State and Northern Territory publications and are calculated by multiplying tonnages by a nominal value/tonne. The nominal values were recently revised (Table 5)

Table 5. Nominal values/tonne of exported bauxite and alumina

Bauxite	Up to 30-6-76	After 1-7-76
Bauxite	$4	$9
Alumina	$60	$80

The revision in values was made after consultation between the State Mines Departments. In Western Australia the value of alumina shipments to Japan and Victoria was increased in State publications from $66 tn 1974-75 to $82 per tonne in 1975-76. It is interesting to note that the Ministers of the International Bauxite Association agreed in December 1977 that the base price for bauxite sold to North America will be US$24/tonne.

Table 6 shows nominal values for manganese used by The Department of the Northern Territory.

Table 6. Nominal values/tonne of exported manganese

	As to 30-6-76	After 1-7-76
Lump ore	$22	$45
Fines	$12	$45

The installation of a fines sintering plant at Bell Bay would be a factor in the new value for manganese fines. These figures are well below quotations on US commodity exchanges. A better indication of the real prices may be gained from details of manganese supply contracts published in Japan, where the price in 1976 was US$58 to $63/tonne for high-grade lump ore.

The foregoing arbitrary values bear no direct relation to selling prices or production costs. In the absence of other statistics, they are sometimes quoted by people who probably do not fully appreciate their real nature.

Most Australian overseas trade statistics are collected on a fiscal year basis, because of the dominance of the Treasury over the statistical services. The seasonal influence of farm incomes in southern Australia was a factor in the original decision to end the fiscal year on 30 June. It is out of step with the mainstream of international statistics, which are on a calendar year basis. Accordingly, BMR adjusts the trade figures to a calendar year basis for use in its publications, making them compatible with world-wide mineral statistics.

A further anomaly is that Australian trade statistics are collected on a 'free on board' (f.o.b.) basis, apparently as a result of past commercial pressures, whereas the modern international code requires import statistics to be on a 'cost, insurance, freight' (c.i.f.) basis.

Officially exports are valued at the Australian f.o.b. port of shipment equivalent of the actual price at which the goods were sold. During 1937-76 the value for duty as required by Customs was the actual money price paid for the goods. In 1976 import valuations were changed to the Brussels Definition of Value, which is the open market price. Closer study of the situation gives little confidence that these official requirements are effectively applied in practice in the overseas trade in Australian minerals and metals, probably because most are duty-free.

It is possible to compare the adjusted Australian statistics of the values of exports to Japan with Japanese statistics of the values of imports, since both are metric and compiled under the Brussells Classification. Information in Table 7 was obtained from the Japanese Embassy, Canberra; imports are c.i.f. for the year ending 31 December 1975. It would have been slightly better to have used Japanese statistics for the year ended 31 January 1976 to allow for shipping time, but since the figures shown are average unit values obtained by dividing the total value by the total quantity, the differences are not important. Yen were converted at the average rate for 1975, which was Y388.8 = $A1.00. The value of yen has risen to about Y250 = $A1.00 (April 1978) but the prices received for most Australian minerals have not risen to the same extent.

Since the USA is usually their main export market, the Japanese often prefer to write both their export and import contracts in US dollars, as an insurance against changes in exchange rates. This could restrict the Australian use of currency devaluation as a tool of economic management.

The difference between the Australian and Japanese average values is mainly due to ocean freight charges, but there are several other factors. In some cases the commodity might be consigned through a subsidiary trading company, which may adjust prices, and in any case transactions between affiliates are often only nominal. Sometimes the insurance replacement value is entered. Some consignments were imported into Japan for processing (for a toll charge) in Japanese plants, and then re-exported. Multinational organisations are in a position to make more advantageous financial arrangements than can purely Australian firms.

Too much weight should not be placed on the precise amounts because they are not strictly comparable. The Australian and Japanese tonnages differ because of overlap with adjacent years and because of diversion of cargoes to other markets. The values also vary with grades, and as a result of the timing of rewriting long-term contract prices in inflationary circumstances.

Table 7. Average unit values of Australian mineral exports to Japan, year ending 31 December 1975 ($A/tonne)

Commodity	Australian exports (f.o.b.)	Japanese imports (c.i.f.)	Japanese tariff
Alumina	64	73	
Aluminium	589	621	56
Bauxite	4	10	
Asbestos	195	188	
Clay	34	75	
Copper concentrates	222	231	
Copper blister	1294	1388	
Copper refined	922	952	39
Iron ore	9	12	
Iron, pig	100	102	4
Lead concentrates	153	174	
Manganese concentrates	22	37	3
Nickel refined	3317	3250	423
Nickel concentrates	353	286	
Nickel matte	2729	2163	281
Phosphate rock	31	41	
Salt	4	11	
Silica sand	5	13	
Talc	28	44	
Tantalum concentrates	10 670	11 067	
Titanium sands	37	61	
Tungsten concentrates	5306	5141	412
Zinc concentrates	157	166	
Zinc slabs	598	674	
Zirconium concentrates	157	193	

It is of interest to compare the values in the table with the average prices for metals on the domestic market in 1975 (Table 8).

Table 8. Average metal prices in Australia, 1975 ($A/tonne)

Aluminium	723
Copper, refined	951
Iron, pig	105
Nickel, refined	3483
Zinc, refined	627

Where the Japanese values are lower than the Australian export values, the explanation probably lies in the marketing and financial strategies of the firms concerned, at that time.

There are many qualifications to the tariff rates shown, which should not be taken as applying at other times. Those applying to refined copper and zinc were changed in later years, and vary depending on prices. Some of the rates shown are 'temporary', and duty-free quotas may apply in some cases. Where no tariff is shown, there is in general no duty paid, but it should not be assumed that there is free access to the Japanese market, as there are various protective arrangements. For example, all salt imports are a State monopoly.

The purpose of Table 7 is to convey an appreciation of the cost of importing minerals and metals from an Australian port into the buyer's factory in Japan, because this is often the buyer's most important consideration when deciding on his source of supply. Internal handling costs in Japan are additional. The total cost to the buyer in Japan can be quite different from the prices quoted on international markets, such as the London Metal Exchange. It is not easy to determine the selling price of Australian minerals and metals, for use in economic studies. The Japanese have been criticised for stimulating too many sources of mineral supply, and encouraging over-capacity. When the inevitable recession comes there is a "price-squeeze" leading in some cases to a financial "rescues", with changes in mine ownership. In the past, unlike those in Europe and America, Japanese smelters lacked the financial strength to venture into foreign mining.

INCOME FROM ADDITIONAL PROCESSING

Additional local processing of minerals and metals exported from Australia is often advocated as a means of increasing export earnings and Gross Domestic Product. Attempts to quantify these potential additional earnings encounter the great complexity of the problem, particularly determining present export prices and world prices for metals. Some of these complications are outlined below.

Lead concentrates and blister copper are sold at a higher equivalent metal price than refined metals, because of the precious metals present. Silver occurs in a multiplicity of ores, thereby increasing concentrate prices. Although importers do not usually pay for the sulphur content of concentrates, perhaps it would be reasonable to expect them to do so, because generally overseas the sulphur is recovered for making sulphuric acid, but may be wasted in Australia. Some tin concentrates are sold at a discount because of their refractory nature. The cost of converting a concentrate to metal varies greatly, and is for example, two or three times more for zinc than it is for lead.

Japan has been a notable copper producer in the past, with a strong tradition and well-developed skills. The industry has effective protection, resulting in a high domestic price for refined copper. Most Japanese exports of copper are in the form of electronic and other manufactures, where the extra cost of Japanese copper is a very minor factor. With a growing domestic demand, Japan has become the world's third-largest smelter and refiner of copper. Japanese smelters have come to seek imports of concentrates widely, and, since the refined metal is sold at the high internal price, are able to offer high prices to Australian mines. As a result the price difference in Australia between concentrates and refined copper is too small to cover the cost of smelting and refining in Australia. The inflated prices for concentrates are not directly related to the Japanese tariff on refined copper (which varies with prices), because they are also dependent on shipping costs, and on the supply and demand situation. Furthermore, the concentrate price is comparable, not immediately with the present price for metal, but with the expected metal price in a few months' time, when the concentrates will have been processed into refined copper and placed on the market.

The published financial reports of companies lack the detail necessary to make analysis possible of their prices and material flows, but this could change if the UN Commission on Trans-national Corporations succeeds in influencing national legislation to widen disclosure of company accounts.

Examination of the differential between the Australian export values of concentrates, and of refined metals, as shown in the Australian statistics for exports of copper, lead, tin, and zinc reveals wide and erratic variations. The metal prices are loosely consistent with prevailing metal prices overseas, and it is the concentrate values which seem to make it impossible to derive a quantitative function for the pricing differential, even when allowance is made for price trends, grades, and precious metal contents. The explanation may lie in the toll charges for smelting and refining as well as in the concentrate contract terms, both of which are less sensitive to price variation, than in the price of metal. Both usually vary directly with metal prices, but have a smaller amplitude. Toll charges tend to rise when concentrates are scarce. Furthermore long-term contracts, spot purchases, and transactions within integrated companies might not be on strictly commercial terms. For example, a smelter running short of supply may make a spot purchase of concentrates at high prices in an emergency, to maintain output of metal and sulphuric acid, in order to avoid a failure of output which could cause widespread loss and disruption to dependent industries.

When making an economic study of the mineral processing and metal industries in Australia, it is difficult to decide on which metal prices to use, particularly for additional production. The most widely known prices are those of the London Metal Exchange, but this is a 'terminal' market, where, as a last resort, metal can always be bought and sold. LME prices are usually about the lowest in the world when supplies are adequate, but when there are shortages prices can rise spectacularly for brief periods, far above prices ruling elsewhere. The LME is a sensitive leading indicator of the balance of supply and demand for copper, tin, lead, zinc, and silver in western Europe. Most LME transactions are forward, and are made to protect dealers and consumers against future variations in prices and supply; they usually do not lead to the physical transfer of metal. (The premium paid for delivery in (say) three months' time, as compared with delivery now is called a 'contango'. The reverse of contango is 'backwardation'). The 'nationalisation' of metal production in certain African and South American countries has undermined the LME to some extent. There are gold markets in London and Zurich, and silver markets in London, New York, and Chicago.

In the United States there are two main series of metal prices, one being the "US producer" price, and the other being that of the New York Commodity Exchange, which broadly follows the trends of the

LME. US price levels reflect US tariffs. The US Producer Price is set by the "price leader" of the producing companies, and is usually promptly followed by the other producers. In 1977 the nickel price leader (INCO) ceased issuing prices, because of chaotic discounting caused by the chronic over-supply situation. The NYC Exchange (Comex) prices are averaged and published as 'MW prices' in Metals Week in New York.

Japanese prices are normally related to US prices. London and New York Exchange prices are quoted on dealer to dealer transactions, whereas the sales to consumers are often at a discount price. Most trade in minerals and metals is under long-term contract, usually a year for refined metal, longer for concentrates. Contract prices, which are often related to LME prices, are in US dollars, and are privately negotiated. Some Australian export sales are made on LME prices averaged over a period such as 30 days. Sales to affiliated companies abroad are probably made at "transfer prices" in some cases.

Generally the posted Australian prices are loosely related to the LME price, plus the cost of transport from London. Thus Australian lead and zinc are normally cheaper in London than in Australia. Since it is impractical to follow all the variations of the volatile LME prices, there have been a few times when astute merchants have imported cheaper metal into Australia. These opportunities are recorded in import statistics, but were short-lived. Most metals in refinery shapes can be imported duty-free. Aluminium, which is not traded on the LME, has received greater protection from imports and been more subject to price control than the other common metals.

With the formation of the European Economic Community, a need emerged for European metal prices, to replace the former individual national prices. In an effort to record the price at which zinc is actually sold by smelters and refineries, the Metal Bulletin magazine in London each week telephones European zinc producers and publishes the result as the "European Producers Price". There has been some trouble recently with unpublicised discounts, caused by the surplus of zinc. As would be expected in the current situation, the LME price is below the EPP.

In Australia the Trade Practices Commission has ruled that the Australian price of zinc should vary in accordance with the EPP.

Thus, when the Australian dollar was devalued the local price of zinc rose correspondingly. It should be noted that it is not the Australian price of zinc that is set by the EPP, but only the variations in that price.

International prices of metals vary more widely than those of other commodities, because there are no real substitutes for metals in many uses, resulting in an inelastic demand. This is accentuated commonly by the fact that the cost of the metal is only a small proportion of the price of the finished article, for example the tin coating on a can of food, or the tungsten element in an electric lamp. Thus the LME price of tungsten has increased in the past ten years from US$45 to US$186/tonne unit (one hundredth of a tonne of 65% WO_3). Similarly, in the past ten years the Penang price of standard-grade tin has risen from M$ $565 to M$ 1770/per pikul (133⅓ lbs). Most metals have fallen in price in recent years.

Metals take longer to adjust to changes in demand than most commodities, because of the lengthy and expensive process of discovering and developing a mine, particularly of the "older" metals (copper, tin, lead, zinc, silver). To stabilise prices large stockpiles would be necessary, and these would be enormously expensive. For most metals over the last century the trend line for the real price, expressed in constant value terms, is one of slow decline. Factors of scarcity and distance have been more than offset by improvements in efficiency and technology, particularly in exploration and the working of lower-grade ores. The long term trend in world consumption of these "older" metals is an annual growth of only about 3 per cent, which makes it difficult to introduce a major new mine or smelter without disruptive effects upon prices and the industry structure.

Professor Lacey of Townville has said that 50 percent of the total mining costs arise from direct and indirect taxes. It would be interesting to compare this percentage with other primary industries such as farming. In economic theory, if not in practice, the appropriate point for tax incidence in metal mining and processing would be at a late stage in the chain of production, such as semi-fabrication, because then the tax burden would be shared to some extent by the various stages of production. If the tax is levied when the ore is removed from the ground, it will raise the "cut-off" grade, which is the minimum grade which can be mined profitably, to a level that will result in much of the lower-grade ore being left behind in the ground, probably for ever. This usually happens when minerals are exported unprocessed, causing wastage of an otherwise valuable national resource. Mines are highly obvious sources of wealth, and the immediate needs for government revenue invariably have precedence over long-term interests. Australian mining history is rife with examples of mines which have been "high-graded" for a quick profit and then abandoned, leaving behind most of the lower-grade ore. This can almost never by retrieved later, except when it is close to the surface and can be mined from an open pit. While it is impractical to instruct a company how it should work its mine, a more flexible taxation policy could reduce the waste of valuable minerals, and encourage more processing.

Australian prices quoted for metals cover smaller spot purchases, and are not the prices for large regular customers; they are not directly related to production costs, nor are they the prices that would be received for increased local production. Australia already has export surpluses of the economically important metals, and any additional production would have to be exported.

Furthermore, it is not easy to know to what extent any mineral will be eventually processed. Only a small proportion of some ores, e.g. titanium, are converted to metal. Some bauxite exports are not processed into aluminium - they are used for abrasives, refractories, ceramics, and chemicals. Other bauxite, sold for less than $10/tonne, is converted into highly manufactured goods, like foil, which is worth several thousand dollars/tonne. It is necessary to decide what to include in an estimate of potential processing income, and what is a realistic ambition in developing the industry.

With most metals it is more convenient and economical to locate rolling mills and the like close to the main markets. It would therefore be logical for Australia to aim, in the long term, to process metals for export, only up to the refinery shapes stage. Besides avoiding some protective tariffs, the reduction in energy needs and pollution in heavily populated areas, also favours this industrial structure. Semi-fabrication is usually a highly competitive business where production must be closely tailored to demand, thereby minimising stocks and optimising customer service. Nevertheless, Australia should be able to obtain a share of the supply of semi-fabricated metal to some of the smaller export markets, which do not have a well developed local semi-fabricating industry.

The following notes, on a selected list of minerals and metals which are currently produced, processed, and exported from Australia, indicate in very broad terms the potential for economic gain from further processing in 1975. Estimates are indicated by (e), and it should be remembered that 1975 prices apply in the following discussion.

The money figures should only be regarded as indicating relative values, because prices vary erratically and may have little similarity to present day prices. Lags behind the monetary inflation rate are common with the long-term contract prices used for bulk concentrates, while spot metal prices can change rapidly. Some values given for transactions between subsidiary companies, and for two-way deals in which prices of exports and imports are offset, probably should be regarded with some reservation.

Aluminium

If all bauxite exported were converted to alumina for export its value would increase from $50 million (e) to about $228 million. If all bauxite and alumina exported were converted to aluminium, the value of aluminium metal exports would be approximately $2146 million, but this would be partly offset by massive imports of caustic soda, petroleum coke, cryolite, fluoride, lithium carbonate and other plant requirements, including fuel and capital.

Copper

If the concentrates exported in 1975 were converted to refined metal their value would increase from $38 million to only about $40 million, because of the artificially inflated price in Japan for concentrates. It is difficult to estimate the financial effect of refining locally the current exports of blister copper, since the blister fetches a higher price than refined wire bars because of its gold content (which varies). In 1976 the unit value of copper in concentrates was slightly higher than the unit value of refined copper exports.

Lead

The situation is complicated by the silver content (see below) of the exported lead concentrates and bullion. In 1975, concentrates valued at $16 million with a lead content of 39 797 tonnes were exported. If the concentrates had been smelted and refined in Australia, the value of the lead would have been only $13 million (e), excluding the silver, which was estimated as 80 tonnes worth $9 million. Similarly, exports of lead bullion were 143 785 tonnes, valued at $73 million; and if the lead in this had been extracted and exported as refined lead, it would have been worth only about $45 million (e).

Manganese

The 1 711 000 tonnes of manganese ore exported in 1975 was probably sold at a price of about $60 (e)/tonne, which could be compared with the ferromanganese price of about $300/tonne (e). This, however, is only one of the uses of manganese ore.

Nickel

The nickel position is complex because of the various forms exported. These include concentrates, sintered oxides, sulphides, matte, metal powder, and briquettes. In 1975 exports of concentrates containing 5000 tonnes(e) of nickel were valued at $10.6 million, and if this were converted to refined metal briquettes it would be worth about $17 million. If Australia produced refined nickel for fabrication the return would be even higher.

Silver

Several mines in Australia have been worked mainly for silver, the last being the Lady Hampden, in NSW, which closed in 1976. No silver ore, as such, is currently mined in Autralia, all silver being produced as a valuable constituent of lead-zinc, copper, gold, and nickel ores. If the silver present in all ores exported in 1975 had been produced separately as refined silver it would have had a value of about $13 million(e). It is assumed that the 143 785 tonnes of lead bullion exported contained 0.2% Ag (or 2 kg/tonne) and that silver in 1975 was worth $110/kg. Since the bullion received a premium of $188/tonne over refined lead, the margin to cover removing and refining the silver was about $32/tonne of bullion. Thus there would have been a potential gain in export income of about $4 million if the desilvering had been done in Australia. Since the cost of smelting and refining silver from ore is normally about 5 percent of the price of silver, the $32 margin may be inflated, and not all recoverable as potential export income. Most bullion exports are to affiliated companies, and the values entered in the export statistics may be behind the rate of price increase.

Tin

Since the smelting of tin is only a minor part of the cost of production, the potential gain from processing the exported concentrates is limited. Exports of concentrates in 1975 were worth $4372/tonne of tin content, compared with refined tin at $4970/tonne. The tin content of the concentrates was 4521 tonnes, indicating a potential increase of less than $3 million in export income. Since 1975 the price of tin has doubled, but smelting charges have not risen accordingly. Although it might be difficult to compete against the large Malaysian smelters, which use cheaper labour, tin metal can be sold to a very wide range of consumers and, in any case, prices are influenced to some extent by the International Tin Council.

Zinc

From the official statistics for overseas trade the average f.o.b. value for exports of zinc concentrates in 1975 was $290/tonne of contained zinc, while the corresponding return for refined zinc was $557, which indicates that there would be an increase in earnings of $47 million if the 177 418 tonnes of zinc in concentrates now exported were processed in Australia. In 1976 the value of zinc in concentrate exports was $281 per tonne and for refined zinc $605, indicating an increase in earnings of $76 million if the 235,310 tonnes of exported concentrates had been processed in Australia. There would be an additional gain from the sulphur content, if it could be used for sulphuric acid. These values should be regarded with some reservation, as the cost of smelting would account for only a out half of the difference between concentrate and metal prices. In the USA in 1975 the toll for smelting and refining zinc varied from $90 to $150/ton. Belgian smelters in 1974 charged 40.5 percent of the payable zinc metal value for smelting Canadian concentrates, similar to those from Broken Hill. It appears that the concentrates were sold cheaply, possibly because they were shipped to affiliated companies.

Summary on Additional Income

It would be meaningless to attempt to total the potential of the foregoing eight metals. A similar exercise with iron ore would show a potential for billions of dollars, although it is unreal to suggest that the Japanese steel industry should be relocated in Australia. What the figures do show is that there is considerable scope for gaining additional export income in the future by expansion of the local processing of bauxite, zinc, and silver, if such processing proves feasible. An important consideration is the increase in external payments for imports arising out of the construction and operation of these new processing plants, particularly with bauxite processing.

TRANSPORT

Historically, mining has had a profound influence upon transport facilities in Australia, particularly during the Gold Rush period, when it led to the building of roads and railways and the establishment of ports. In more recent times the relatively high revenue from mining traffic on the railways from Broken Hill, Mount Isa, Kalgoorlie, and from coal-mining centres has been used to offset losses on uneconomic branch lines and on commuter services in the State capitals. Mining companies have also had to provide the capital for most of the new railway mileage constructed in Australia during the past 20 years.

With low-value bulk cargoes like coal, iron ore, bauxite, and salt, the cost of transport is a large component of the delivered price. While Australian-registered ships would probably be too costly to use, the potential for economic gain from transporting such commodities overseas in Australian shipping is probably larger than that from any further processing that might be feasible before export. Processed materials have a smaller weight than concentrates, but this does not ensure that their shipping costs are lower than for unprocessed commodities. Thus the equivalent weight of bauxite is four times, and alumina twice as heavy as aluminium ingot, but unlike bauxite and alumina, ingots cannot be simply bulk handled for transportation. Metals such as copper rod, pig iron, and lead bullion, require specialised heavy handling equipment, if large quantities of metal are to be moved efficiently. Some materials need protection from the weather, and others like silver, require special security. Also, the very high cost of coastal freights around Australia hampers local processing.

During the past two decades improvements in bulk handling have tended to favour the shipment of concentrates, rather than metal, but since 1973 the sharp increase in oil fuel prices has had the reverse influence.

DEFENCE

The supply of metals and materials derived from minerals has traditionally received a high priority for defence planning. The aluminium industry was initiated in Australia as a result of wartime needs, and the processing of most of the industrially important metals has been stimulated as a result of defence considerations. Although the current defence situation is very different from the experience at times in the past, similar pressures to remedy deficiencies in the supply of critical commodities for defence industries are possible. Examples might be tungsten wire, fabricated nickel, titanium metal, magnesium, and certain ferro-alloys. Nevertheless, Australia is already one of the most fortunate nations in its indigenous supply of metals and minerals.

OWNERSHIP

Participation of the multinational companies has provided technology, capital (including risk capital for exploration), market security, and managerial expertise, which have facilitated the establishment and expansion of processing. All markets have established suppliers, who are usually well entrenched. To survive the setbacks sometimes encountered with exports, metal producers need a secure share of the domestic market, or access to a "tied" market overseas.

Some foreign processors may regard the ownership of Australian mines merely as a means of securing a source of cheap raw materials, and have no interest in developing local processing. Such mines are usually operated on a low profit basis to minimise taxation and wage demands, but they are provided by the parent company with any technology, capital, and managerial expertise necessary for efficient performance. A minority interest in a mine can be valuable to the foreign processor, provided it gives him a seat on the board of directors. This serves as a "window" on his raw materials supply, helping to ensure that he receives his imports at the lowest commercially feasible price. Several major Japanese importers hold minority interests in Australian mines. British groups often hold a majority interest in Australian mines, but leave the management in Australian hands. American firms tend to seek full control.

Mining is normally more profitable than processing, and if a mining company extends its activities into further processing, it tends to lower the average rate of return on total invested capital. The risks involved in establishing a mine are a major factor in making higher returns necessary.

With many non-ferrous metals the capital requirements lessen as one moves away from mining through the higher stages of processing. Taking copper as an example, the capital cost of discovering and developing a major mine is very large, whereas the outlay for a smelter is less, though still a major investment. The cost of an electrolytic refinery is smaller again, and a fabricating plant, that would probably include wire drawing, tube extrusion and sheet rolling, is still less costly. Thus entry to the industry becomes easier, and therefore more competitive, towards the semi-fabricated metal stage.

Despite this, some mines have been easily taken over by processors, because in times of low metal prices, processors tend to maintain their toll charges, and pass the burden of the low price back to the mine, forcing it into a position where it is vulnerable to takeover. Not all smelters operate on a toll basis; some buy concentrates, but these smelters are often units in an integrated organisation, which can spread its risks.

According to "Australian Business Profitability 1975-76" published by P.A. Consulting Services Pty. Ltd., the percent returns on shareholders' funds after tax and interest were as follows:-

Industry	1973-74	1974-75	1975-76
Mining - nonferrous	17.4	17.7	8.5
" ferrous	6.3	8.4	10.1
" coal	3.5	14.4	14.7
Primary metal	8.0	8.0	5.2
All industries	9.8	8.8	9.6

These rates may be compared with the current long-term bond rate of about 8.5 percent. They show that a non-ferrous mine integrating with a primary smelter would probably be lowering the return on its shareholders' funds. It may also be noted that mining and processing are less profitable than most Australian industry. The publicity given by the media to the spectacular profits made during short-lived booms gives the public a misleading impression of the mining industry as a whole. The copper-boom profits of Bougainville and Mount Isa in 1973-74, and the coal-boom profits of Utah in 1975-77 are examples.

Foreign processors often make developmental loans to mines, on condition that they receive the exported concentrates. It has been argued that such loans stabilise the industry, since the foreigner will then be less inclined to cut prices and orders too far, in case interest payments might be jeopardised.

In view of the economic necessity for modern processing plants to be relatively large and costly, it appears that the days of small mines with their own independent smelter are virtually over. Consortia, similar to those in the Australian aluminium industry, will probably be the basis for future large scale mining and processing industries. These involve difficult questions of taxation, export prices, and foreign control.

INTERNATIONAL

The rapid development of the Australian mining industry, and for that matter, the ability of Japan to provide to some extent an alternative market for Australian farm produce to that lost in Britain as a result of the European Economic Community's protective policies, have been made possible by the prosperity and industrial growth of Japan. Japan's growth would have been significantly delayed and stunted if Australia had restricted the supply of raw materials to Japan by insisting on exporting only processed material. The gain to Australia from processing these materials domestically would probably be much smaller than the total benefit obtained from the expansion of overall trade opportunities with Japan, particularly from farm produce, and as a result of the availability of lower-cost Japanese goods. Altogether about half of Australian exports to Japan in 1975, worth $2658 million, were of mineral origin; and when items such as coal, iron ore, petroleum, opal, asbestos, silica, talc, salt, and various metals, for which there is little reasonable prospect of export in more processed form are excluded, the remaining minerals amount to approximately $167 million, or only about 6 percent of the total. It would not be to the advantage of Australia to pursue an intransigent policy on this 6 percent if it jeopardised the great bulk of our exports to Japan, because in the long term there are alternative suppliers of these raw materials available to Japan. Nevertheless, there is good reason to keep up an appropriate pressure for the export of more highly processed commodities, whenever the opportunity arises. Although there are still opportunities for further expansion of exports to Japan, it is evident that the rate of Japanese growth is declining.

Australia may be in a better position in future to foster increased local processing in certain commodities, where fuel, energy, and pollution costs are important. Government assistance to domestic production is usually in the form of tariff protection, but this is of course inappropriate for export industries, where export incentives, tax exemptions and provision of infrastructure are more effective forms of assistance. Unfortunately in the foreseeable future Australia is unlikely to have continuing free access to any major export markets for refined metals.

The formation of the European Economic Community, which is the largest market for metals and minerals, has restricted opportunities for Australian processing industries. Formerly there was free access to the British and some other markets, but there is now often a tariff barrier against processed commodities. Stimulated by the protective tariff, five new zinc plants have been built in the EEC, making it self-sufficient in slab zinc. Holland used to import zinc metal cheaply as it lacked a domestic zinc industry, but as a result of joining the EEC found it was paying a high price for zinc. When the CRA group participated in the new Budel zinc refinery, one of the incentives given by the Dutch government was electricity at only half the cost of power available in Australia. The new refinery amounts a transfer of the industry, or at least part of its growth potential, from Australia.

Some EEC members have processing industries that were earlier based on colonial mines, and which have highly developed technical and marketing organisations, and are integrated into the national industrial structure. These plants are usually largely amortised, had have low capital costs. If they are reasonably competitive commercially, it is unreal to expect that they can be closed down willingly, to make room in the market for new processing plants located close to foreign mines.

This is especially true when there are other sources of raw minerals available, as is the case with bauxite, salt, iron ore, or phosphate. When there are few sources of concentrates, as for example with tin or nickel, the mining country is in a stronger position to secure the processing industry, If the metal faces a steadily growing demand, as with aluminium, it is easier to establish new processing facilities than if demand is relatively static, as with lead.

The encouragement of prospecting, and of small mines, is an important element of any mining policy. Some small mines have led to the establishment of major mining enterprises. Small mines, particularly if they are of limited potential life or have access to a smelter, cannot justify the construction of their own processing plant. Their owners are sometimes reluctant to sell ore to a local competitor for processing, and often the foreign buyer will offer a higher price for concentrates, and even financial assistance. For example, RB Mining Pty Ltd is now 25 percent owned by European companies which provided most of the money needed to increase mine production of tungsten concentrates, of which they are now the main purchasers. The export of concentrates can give a quick cash flow, which is vital to the survival of many small enterprises.

Most of the larger developing countries have ambitions to establish their own mineral and metal processing industries, even though they lack mine production, one reason being to save foreign exchange. There have been suggestions, for example, that Australian mining companies should establish a lead-zinc smelter in India, thereby securing a potentially large and valuable market for concentrates, which could be produced from undeveloped deposits in Australia.

Because of the high costs, labour problems, and hazard of cyclones in northern Australia, and the relative lack of assistance with infrastructure and taxation, some consortia have recently established processing facilities in underdeveloped locations, where imported Australian material is treated and then exported to markets in industrialised countries. Examples are the Euralumina plant in Sardinia, and the new iron ore treatment works in the Philippines, where there is also a proposal for an alumina refinery based on Weipa bauxite.

These losses to Australia of processing capacity should be regarded as long-term, as it is virtually impossible to change the organisation of the industry once the overseas plants have been established.

If Australia were to restrict raw material supplies to these "off-shore" plants, which are not Australian controlled, they could soon change to alternative sources of raw materials and remain as competitors. Furthermore, the Japanese demand for metals is flattening out, and there may not be sufficient growth to support new processing centres.

In recent years there has been a growing movement by the exporters of minerals and metals to come together in commodity groups, often under the United Nations, to stabilise prices more to their satisfaction. Their policies tend to favour processing locally, and not in the industrialised countries. Australia, because it is a major exporter of a wide range of minerals and metals, is a member of most of these commodity groups, but has pursued a moderating influence upon the policies of the groups.

During the next twenty years the most important economic development in the neighbourhood of Australia will probably be the industrialisation of China. Japan is in the best position to supply the production plant and technical equipment essential for such a program, and China will need exports to pay for these high-priority imports. These exports will include some minerals, such as coal and salt, which will compete with Australian commodities, thereby limiting prices and our share of the Japanese market. If the Chinese are short of foreign exchange, the competition may not be on a normal commercial basis. There will also be opportunities for supplying China with minerals and metals in which it is deficient. Currently China imports a proportion of its copper, aluminium, lead, and zinc supply, but the pattern could change when the application of modern exploration techniques discovers new deposits, such as porphyry copper, which are at present unknown in China. This potential market is worthy of study, particularly if Chinese co-operation is forthcoming, in the light of the recently announced new economic Plan.

Some figures which help to keep the non-ferrous metals industry in perspective were given by Mr Michael West in his address entitled "The Changing Pattern of Processing Facilities" before a United Nations meeting in Ankara in April 1976. World non-ferrous metal production in 1974 was valued at US$48 billion or about 1 percent of the Gross World

Product. The developing countries were responsible for 38 percent of this metal production, and their exports overall were worth about 70 percent of the value of the equivalent refined metal. Of total non-fuel mineral and metal exports from the developing countries, ranked by value, copper was 45 percent, aluminium 11 percent, tin 10 percent and diamonds 5 percent. The developed countries, by contrast, have their main mineral exports in the form of iron ore and coal. Australia has a peculiar pattern of mineral exports which combines aspects of both. Minerals have continued as a fairly constant proportion of world trade over past years, while farm products have declined and manufactured goods including primary metals have increased in importance.

It is not really possible to increase the extent of Australian processing without disturbing the existing international flows of mineral commodities. The processing possibilities with the "older" metals - zinc, silver, lead, tin, and copper - can only be realised by changing the present trade pattern because there is only very limited scope for increases in worldwide consumption, and exports of these metals. Some other Australian mineral exports, such as coal, iron ore, manganese, and salt are not promising candidates for large-scale local processing and export. There are only two important metals with a strong growth in demand which could accommodate new processing plants - aluminium and uranium. Any opportunity for processing more bauxite can only be as part of an internationally integrated project, where the decisions will be made by the multinational group, after comparing the attractions of Australia with alternative processing sites. Uranium is a possibility if the processing can be established in Australia before the international commodity flow becomes too ossified and large vested interests build up to oppose change. When changing a long-term commodity flow it is not only the foreign company which is affected, but also the national governments (and in some cases international organisations) which can have invested millions of dollars in securing the processing industry for their own economy. There could be serious consequences for dependent industries, and for social conditions. Before placing these foreign interests in jeopardy, it would be wise to consider what retaliation might be taken against Australian trade and other interests. It is unlikely to be a matter which would be initiated by private industry, and any major change would involve governments.

PROSPECTS FOR MINERAL PROCESSING

The minerals and metals covered in the 1969 paper of Noakes, Ward and Kalix were: bauxite, lead, iron ore, ilmenite, monazite, tin, tungsten, manganese, zircon, copper, zinc, nickel, salt, rutile.

There have been many new developments since 1969 and new possibilities for mineral processing have arisen. The following additional minerals and metals are also covered here: antimony, arsenic, asbestos, barium, bismuth, cadmium, cobalt, fluorine, magnesium, phosphate, silver,

These "new" items have been chosen because they may indicate scope for further processing. In many cases it is not practicable to calculate processing indexes.

Minerals which Australia does not produce on an important scale, such as chromium, diamonds, graphite, mercury, platinum, and potash, are not covered here, though the processing of imported raw materials could be a possibility for some. There is always the possibility that economic deposits of these minerals may yet be discovered and developed in Australia.

Technology

Since technical problems and deficiencies are probably the least publicised aspects of companies, their importance is not generally appreciated by the public, or by non-technical writers such as journalists or economists. Industrial development has been hindered in some directions by lack of access to technology, but firms are normally reluctant to discuss such matters. Their technological limitations make Australian mining concerns vulnerable to foreign domination.

Most of the primary metallurgy and mineral processing now in Australia is of the more readily available kind, though there are exceptions, for example, in the aluminium and nickel industries. Many mines have unsolved processing problems, particularly with recovery rates, and some ores of lead, tin, and zinc cannot be processed here; some forms of aluminium, copper, and nickel are not made in Australia, as well as many metallic compounds.

If Australia moves into producing the less common metals like antimony, bismuth, magnesium, manganese, sodium, titanium, and tungsten, the acquisition of the necessary technology will be increasingly difficult and expensive and, probably, restrictive.

Inevitably there will be new developments in the technologies of exploration, mining, and processing, leading to structural changes in some sections of the industry. Although some of these developments are unforeseeable, some can be predicted, such as the mining and processing of nodules from the ocean floor. This could have a drastic effect upon land-based production of cobalt, nickel, copper, and manganese, and in the longer term, Australia might undertake the local processing of nodules.

Aluminium

Between 1967 and 1976 Australian bauxite production has increased about sixfold to over 24 million tonnes/year, while alumina output has expanded more than sevenfold to over 6 million tonnes/year. By contrast the corresponding figures for aluminium have little more than doubled to 232 000 tonnes. Apart from the closure of the small alumina plant at Bell Bay and the enlargement of the alumina plants at Gladstone and Kwinana, and extensions to the smelters at Bell Bay and Point Henry, this disparity reflects the establishment of the new Gove and Pinjarra alumina refineries and the Kurri Kurri smelter.

During the 1967-76 period the processing indexes for bauxite rose from 52 to 71 for production, and from 43 to 73 for export. For alumina the indices declined from 21 to 7 for production, and from 3.3 to 2 for export. The Alwest alumina project at Worsley and the Alcoa refinery at Wagerup, both of which are expected to start up about 1981-82, will further raise the bauxite export processing index and lower both alumina indexes. The establishment of a bauxite mine or alumina plant can only occur as part of a vertically integrated expansion. There is also some horizontal integration in that the Worsley and Wagerup alumina plants are major users of natural gas and are necessary to justify a pipeline from the Northwest Shelf.

The small Australian market limits the expansion of processing for local consumption. There are a few forms of aluminium not yet produced in Australia, but they are not significant in an economic sense.

The figures indicate the comparatively limited export markets for highly processed material, such as metal. Few countries have tariff barriers against bauxite, but its low unit value makes it relatively unattractive as a source of profits. The participation of the large multinational aluminium companies has secured export outlets for alumina, something Australian companies could not have achieved alone, as there is no market for alumina. Australia is now such a large supplier, with about one-third of world bauxite production, that the size of the world demand for alumina is becoming an important limiting factor. With the completion of the Alwest project, all six major producers of aluminium in North America and Western Europe will have participated financially in Australian plants, which are supplying them with alumina. There is still some scope for developing new markets for alumina exports, especially to the smaller smelters, and possibly to Communist countries, but expansion will be slower than in the past.

There have been several proposals for establishing new alumina plants adjacent to known bauxite deposits in Australia. The best known are at Mitchell Plateau (by AMAX at North Kimberley, WA), Muchea (by Pacminex at Darling Range, WA), and in Cape York peninsula, Queensland, at Aurukun (by Billiton), Weipa (by Comalco), and Mapoon (by Alcan). It seems unlikely that these will be developed for some years, because of cost increases. Billiton, which is a mining subsidiary of Shell, in March 1978 announced that it had joined the Alwest consortium. This is expected to delay the development of Aurukun for several years. When the demand for alumina grows to the point when new suppliers are essential, the Australian proposals will be compared with alternatives in the Caribbean, Brazil, Africa, and Asia. The Comalco proposal to process Weipa bauxite in the Philippines would also be considered. Since plant costs would be similar, and as operational labour needs are fairly small, it will probably be the cost of infrastructure to the operator which will determine which proposal receives priority, but low interest loans and tax privileges could be important. It would amount to an international auction to "buy" the processing industry.

It may be necessary for smaller organisations with less access to finance and technology, to form a consortium to undertake a project, and for the government to provide sufficient assistance with infrastructure to make the project as attractive as alumina projects in other countries.

Most developed countries tend to be self-sufficient in aluminium metal, and they import metal only to overcome temporary shortages. It is not commercially possible to build an aluminium metal export industry on such an ephemeral demand, and more secure markets are essential before an export oriented smelter is feasible. In many small countries there is usually a semi-fabricating plant financially tied to one of the multinational aluminium companies. Therefore, not only is the market for refinery shape metal often inaccessible, but there are also protective tariffs against semi-fabricated aluminium. Commonly in smaller countries the local market may not support more than one extruder or roller of aluminium.

Despite this, there are several influences favouring increased processing in Australia. The problem of the disposal of red mud from alumina manufacture, and the effect of higher fuel prices in the major developed countries on the generation of power for aluminium smelting, are tending to favour the location of the industry in Australia rather than in congested industrialised cities abroad. Historically, the aluminium industry passes through cycles of development, and there are signs that the low point of the current cycle is now past. The Australian aluminium industry has now developed to the point where it is showing interest in expansion overseas, and thereby securing export markets for Australian bauxite and alumina. Although the Gladstone aluminium smelter project is in abeyance, Comalco has stated that it will proceed when economic conditions improve.

If the International Bauxite Association is successful in raising export prices for bauxite, this would probably favour alumina production in the country where bauxite is mined, as it would allow access to cheaper bauxite. Some bauxite-producing countries, notably Jamaica, have "nationalised" their alumina industry, and it is thought that this will result in the major North American aluminium producers favouring Australia when future expansion plans are considered.

In the shorter term, the better mineral processing possibilities may lie in the provision of materials for the aluminium industry, specifically caustic soda, aluminium fluoride, and synthetic cryolite. These are covered under "Salt" and "Fluorine" elsewhere in this paper. The main material used for the electrodes of aluminium furnaces is petroleum coke, which is all imported. Imports in 1975-76 amounted to 98 404 tonnes valued at $7 239 000, and have been rising. It seems possible that the establishment of a petroleum coking industry in Australia might be commercially viable, particularly if the New Zealand market could also be secured, and if the Gladstone smelter project proceeds.

Antimony

Although Australia is a substantial producer of antimony (2 205 tonnes in 1975), there is little local processing of antimony ores, apart from some antimonial lead production at Port Pirie, based on antimony contained in Broken Hill lead concentrates. Further processing of antimony for local requirements has limited potential because average annual imports amount to only about 200 tonnes of metal. Quelar Chemicals, in Queensland, plans to initiate the small-scale production of refined metal, and this should cover about half of Australian requirements. Imports of antimony oxide are estimated as approaching 300 tonnes/year, and could possibly indicate an opportunity for local manufacture, particularly as its use as a flame retardant is increasing.

Arsenic

For about 25 years Australia has imported practically all arsenic requirements, which usually amount to about 1 000 tonnes of trioxide and a few hundred tonnes of pentoxide annually.

Copper arsenate is now produced at Townsville by Copper Refineries Pty Ltd, and considerable amounts of arsenical wastes were buried regularly at Port Pirie, although some of these are now being used. There are gold mines with arsenical ores at Costerfield (Vic.) and Beaconsfield (Tas.), which would expand production if the price of gold were sufficient. Tasmanian tin ores in some cases have considerable arsenic content. Some old tailings dumps, notably at Wiluna, are potential sources of arsenic.

It may be worthwhile investigating the technical and economic possibilities for extracting and processing arsenic from domestic sources, as it is expected that world supplies will be reduced in the near future. The recent steep price rise may make it feasible to recover some of the arsenic now lost in some Australian mining and smelting enterprises.

Asbestos

The establishment of the large Woodsreef asbestos mine has changed the pattern of supply of asbestos to Australian industry, particularly for the production of asbestos cement. Australia both imports and exports asbestos, and it appears that the long-term pattern has not yet beeen stabilised. In the near future, Australia could achieve a favourable balance of trade in asbestos, when the Woodsreef mine achieves full output, but it will still be necessary to import certain, mainly long-fibre, grades of asbestos.

Imports of manufactured asbestos products have recently been running at a rate of up to $10 million/year, but production of these is not regarded as mineral processing. At present over 60 percent of Woodsreef output is exported. There have been promising prospecting results at Baryulgil, where it seems likely that a new asbestos mine may be located.

Since the Woodsreef mine would have a life of only 12 years if full production were maintained, it is important that a new asbestos mine be developed, if Autralia is to avoid becoming dependent on imported asbestos.

Asbestos processing involves serious industrial health hazards unless proper precautions are taken, and the cost of these is important in the economics of the industry.

Most of the asbestos used in the Western World is mined in Quebec, where a radical Provincial Government was recently elected. This government has a policy of taking over the asbestos mines from the five US firms that now own them, in the way that the Province of Saskatchewan has taken over the potash mines. Its policy is to raise health standards in the mines, keep the profits in Quebec, and increase the local processing of asbestos above the present 3-percent level. Since the bulk of Australian imports are chrysotile fibre from Canada, if this policy is carried through it could have important repercussions for the Australian asbestos industry, as there are only limited alternative sources of asbestos - in Russia and southern Africa.

Barium

Output of barite in Australia could be expanded if there were markets available. The demand for drilling muds has dominated the industry in recent years. It is expected that the current recession in drilling will be not much alleviated over the eext three years, and that barite consumption will remain at about 4500 tonnes/year. If development drilling takes place on the Northwest Shelf, it will create a considerable demand for barite, and during such drilling local production of barite could be stimulated, particularly from deposits in northwestern Australia.

The extent to which local requirements of barium compounds are met from Australian raw materials is not clear. In 1975-76 imports of barium and strontium oxides, peroxides, and hydroxides totalled 16 402 tonnes valued at $2 295 000, while imports of other barium compounds usually are around 3000 tonnes annually. A study of the industry might bring to light opportunities for further processing of local barite.

Bismuth

The temporary closure of the Tennant Creek copper smelter and certain associated mines has reduced the availability of bismuth, which is recovered as a flue dust, although bismuth is still produced in gold concentrates. Nevertheless, Australia is potentially the world's largest producer, and retains a stockpile of bismuth-containing dust.

The question arises as to whethr this material should be smelted, or otherwise processed, in Australia. Peko-Wallsend is conducting research into methods of converting the dust into bullion containing 90% bismuth. Broken Hill Associated Smelters has a pilot plant operating to remove bismuth from lead.

When mine production of bismuth recovers, there will be a good case for smelting and refining bismuth in Australia, as it is likely that production will exceed 1 000 tonnes/year, or more than 20 percent of present world output. Established overseas producers, smelters, and refiners of bismuth may not welcome the intrusion.

Cadmium

Since cadmium is a by-product of zinc mining and refining, the main opportunity for further cadmium processing depends on the domestic processing of those zinc concentrates which are now exported. These mainly have two origins - Broken Hill concentrates exported to south Wales and to Holland, and Mount Isa concentrates exported to Japan. In addition, there are several prospective new zinc mines which will come into production when economic conditions are more favourable.

Mine production of cadmium is about 1600 tonnes/year, of which about one-third is refined locally, most of the remainder being exported in zinc concentrates. Domestic consumption of cadmium was 133 tonnes in 1975, mostly as pigments.

Provided the cadmium content is recovered and not exported as sludge, the construction of an electrolytic zinc plant at Townsville would greatly improve the processing indexes for cadmium, as it would halve the current export of zinc concentrates.

Clays

The clay mining and processing industries constitute a special case, because of the wide range of prices for the products, and the often highly specialised requirements of the users. In 1976 Australia imported 62 487 tonnes of clays valued at $3 million, about half being bentonite from Wyoming, which is used for oil drilling and for pelletising iron ore in Tasmania and South Australia. Australian bentonites are often unable to meet the users specifications, or are too expensive because of high domestic freight costs.

In the past, the Australian market for special clays has been too limited to make domestic production commercially attractive, and exploration and research into the resources and the technology of local clays has been rather neglected. Some Australian users were tied by company affiliations to overseas sources of special clays. In recent years, English clay producers have established clay processing plants near Ballarat, Melbourne, Newcastle, and in Western Australia, which now supply a range of clays for the ceramics, refractories, foundry, paint, paper, rubber, and plastics industries. Nevertheless, there appear to be further worthwhile opportunities in the clay industry for the smaller firm with the necessary specialist technology.

Cobalt

As the statistics for exports of cobalt concentrates, metal and compounds are not available, it is not possible to calculate reliable processing indices. In 1976 mine production was 3250 tonnes of metal content, but it is known that much of this is not recovered.

Cobalt oxide is produced at Risdon (about 30 tonnes/year), but imports in 1976-77 amounted to 6 tonnes valued at $104 000. Cobalt metal is not produced in Autralia, and imports in 1976-77 of cobalt metal (including powder) amounted to nearly about 19 tonnes valued at $240 000. In addition 111 tonnes of cobalt sulphate valued at $385 000 were imported in the same year.

This indicates that there is a significant domestic market for cobalt, but whether it is large enough to make a local cobalt processing industry feasible is unknown, as is the export potential for these materials. Australia exports about 500 tonnes of contained cobalt annually from Yabulu and Kwinana, in the form of mixed cobalt and nickel sulphides, which could possibly be processed to replace some of these imports, and there could be additional cobalt recoverable from Mount Isa and other mines.

Copper

There has been only limited change in the processing indexes for copper in the past decade, although production has more than doubled. The production processing index has risen from 81 to 84, and the export processing index from 54 to 66. The processing capacity was affected by the closure of the Mount Lyell smelter and the temporary shut-down of the Tennant Creek smelter, but this was offset by expansion at Mount Isa and Townsville and increased production at Mount Morgan following installation of a new smelter.

Copper output peaked in 1974, and since then a sharp fall in prices, and rising costs, have forced several small mines to close (i.e., those which have produced less than 2000 tonnes in the past 20 years). Some of the medium-sized copper mines at Tennant Creek and in South Australia have also been temporarily closed, while at Cobar and Mount Lyell production has been curtailed, with a consequent cut in Australian exports of blister and concentrates, as compared with 1974. In the long term, provided known prospects in NSW, SA, and WA develop successfully, there could be scope for new processing capacity in those States, because of the high interstate freight costs. Another possibility would be the processing in Australia of concentrates or blister from New Guinea and the Pacific Islands, but there would be severe competition from foreign processors for these materials. There also appears to be potential for initiating the local manufacture of copper powder and flake, now all imported.

Some delay in the recovery of copper prices could be expected as a result of changes in the policies of some major exporters. In the past the companies promptly reduced production to match a fall in demand, but with the mines and smelters in Chile and Zambia now under national administration, production and employment are being maintained. The resulting large stocks of copper bear heavily upon the current world market, and there have been moves by copper exporters through the United Nations to stabilise prices, so far without success.

Fluorine

No fluorspar has been mined in Australia since Leighton Mining NL closed their Pine Mountain workings in 1974, when they were unable to compete with low-cost imports. Although deposits are known at Speewah Valley and Meentheena in Western Australia, at Mount Garnet in Queensland, and at Jinka Plains 300 km east of Alice Springs, none is likely to be developed in the short term because of their remoteness, and the availability of competitively priced imports. There will also be a potential by-product source of fluoride when Queensland rock phosphate is used for fertiliser manufacture.

Imports of fluorspar exceeded 36 000 tonnes in 1976, when more than 3500 tonnes of aluminium fluoride worth over $1.3 million, and 2449 tonnes of synthetic cryolite valued at $688 000 were also imported, as well as a wide range of fluo-chemicals, including about 700 tonnes of fluocarbons.

These facts indicate that there is scope for developing economic mine production of fluorspar in Australia, and that there is a growing but dispersed local market of considerable size for fluorine compounds. The fluoride requirements of the New Zealand aluminium industry should also be noted. A closer study of the possibilities for mining and processing of fluorspar appears justified, particularly as there may be a need for a co-ordinated policy, affecting the mining and overseas trade in fluorides, as well as the fertiliser and aluminium industries.

If uranium processing is developed in Australia beyond the "yellowcake" stage, it would require a substantial tonnage of fluorite. To convert uranium oxide into hexafluoride for export would take an equal tonnage of fluorspar, and requirements could reach 5000 tonnes in 1980 and 15 000 tonnes in 1985.

Iron Ore

Although steel production in Australia during the period from 1967 to 1976 increased only from 6.2 to 7.8 million tonnes, the output and export of iron ore grew from 17 million and 9 million tonnes in 1967, to 93 million and 81 million tonnes respectively in 1976. As a consequence, the production processing index fell from 47 in 1965 to 12 in 1976, while the export processing index rose from 3 to 4 in the same period.

This massive iron ore export was made possible by the remarkable expansion of the Japanese steel industry, which has now levelled off as a result of the worldwide economic downturn. Capital expenditure in iron-ore mining has been reduced, following the lack of growth in demand. Cliffs and Hamersley have implemented expansions after concluding arrangements for future iron ore deliveries to Japan. Cliffs have added 4 million tonnes annual capacity at a cost of $65 million, while Hamersley are constructing a new concentrator at Mount Tom Price which will raise capacity by 11 million tonnes/year. Newman plans to expand capacity to 46 million tonnes/year by 1980, by beneficiating low-grade ore.

Numerous development proposals for iron ore have been publicly mentioned, and although none has yet eventuated, some are expected to proceed when conditions are more favourable. They include the development by BHP of the Deepdale deposit, and a new pelletising plant at Cape Lambert. The establishment of new iron ore mines has ceased for the present, in the absence of new export contracts, and because inflation has increased capital costs excessively. This is relevant to the Marandoo and Goldworthy's Area C proposals. Increased output can be achieved more cheaply by expanding existing mines, and it is clear that the period of rapid expansion of iron ore demand is past.

Processing of iron ore employs more labour than mining, and makes greater demands for infrastructure, which is becoming very expensive, particularly in the Pilbara. The recent steep rise in the price of fuel oil has spoiled the economics of pelletising iron ore, and increased pellet production may have to wait until natural gas is available. This is probably also true of proposals for the manufacture of metallised agglomerates. The establishment of a large new steelworks near Perth has been deferred.

The new additions of ferromanganese and ferrosilicon furnaces at Bell Bay could be regarded as involving the processing of iron ore, but they will have only a slight effect upon the processing indexes.

Lead and Zinc

Although lead and zinc are usually co-products, the more complex technology for processing zinc causes distinct differences in their processing indexes. The industry has been relatively static for some years, as shown in the following figures:

		1967	1976
Lead	- Production processing index	81	90
	Export processing index	73	92
Zinc	- Production processing index	54	60
	Export processing index	40	41

The main export of unprocessed lead is from two sources - the copper-bearing lead concentrates from Tasmania, and lead concentrates from the New Broken Hill Consolidated Mine. There is, nevertheless, some unused lead smelting capacity in Australia. The Russian Kivcet lead smelting process may be used in new plant. The export of lead bullion from Mount Isa is mentioned under "Silver". When weather conditions make it impossible to operate the Mount Isa smelter without excessive atmospheric pollution, there is a build-up of lead concentrates, leading to exports of lead concentrates in some years. A new high stack is being built to alleviate this problem.

The zinc production processing index in 1975 was abnormally low because poor demand led to the stockpiling of concentrates. Broken Hill concentrates have been traditionally exported to a smelter in south Wales, while more recently large quantities have been exported to a new affiliated electrolytic zinc refinery at Budel in the Netherlands.

There is an Imperial Smelting Furnace process used in south Wales, which is rather inflexible in output, unlike the electrolytic plant which can match the demands of the market more readily. The other main export of zinc concentrates is from Mount Isa, mainly for refining in Japan, and eventual sale of the metal in the United States. The project to establish an electrolytic zinc refinery to treat these concentrates at Townsville has been temporarily deferred. Most zinc refineries are owned by groups which also own zinc mines, and in times of recession maintain production from their own mines and cut purchases of outside concentrates. This is a consideration in the relationship between Risdon and Mount Isa, and a reason for Mount Isa planning the Townsville refinery. Similarly the construction of a zinc fuming plant at Mount Isa, to recover zinc from lead smelter slag, has also been delayed. When the Townsville zinc refinery was under consideration MIM was rebuffed by the government when it sought assistance. Its largest shareholder ASARCO thereupon decided to invest in a new zinc refinery at Stephensport, Kentucky. It is uncertain whether there is still scope for a refinery at Townsville. The Beltana mine in South Australia produces a zinc silicate ore which is not suitable for treatment in existing Australian plants. The Woodlawn mine near Canberra is the only important new zinc mine being developed at present. It will probably export concentrates.

While the export of zinc concentrates rather than refined metal means receiving about $47 million less in export income, as previously mentioned, it is more difficult to sell metal, and the metal market is less stable.

Some countries in the past have placed high export taxes on ores and concentrates with the aim of increasing local processing, but as far as is known such measures have never been successful in expanding processing, and have been subsequently largely abandoned. If such an export tax were imposed in Australia upon, say, zinc concentrates the immediate result would be that the importers in Holland and Wales would switch to alternative suppliers, probably in Canada. Meanwhile, Australia would suffer the disruption of the closure of the weaker zinc mines, while overseas funds for mineral exploration would be transferred elsewhere. Retaliation by the EEC against Australian exports of farm products could be expected. A more rational move would be to give MIM whatever assistance was needed to bring forward its project to establish a zinc refinery at

Townsville, but this would involve the politically impossible provision of public funds to a large mining company.

In Mexico the export tax on zinc is as follows:-

Refined metal	0.50 percent
Impure bars	1.79 "
Concentrates	1.92 "
Ore	2.35 "

The rates are too low to have much effect upon the industry, and can be regarded as equivalent to a royalty. In Australia there are some instances (such as bauxite in Queensland) where differential royalties are levied to encourage processing.

The effectiveness of these export taxes for restructuring the mining, processing and fabricating industries is a subject deserving closer study. In theory, if the main exporters of concentrates acted in collusion they could force domestic processing, but this would not happen in reality because the ownership of most of the larger exporting mines is located in the USA and EEC.

In the long term, new lead-zinc-silver mines at Hilton, Lady Loretta, Elura, Que River, Sorby Hills, and McArthur River are awaiting more favourable economic circumstances for development, and when they eventually commence operation, the processing pattern of the industry could change. The potential output of some of these new mines is so large that it would be of world significance. The usual course is for a mine to start with exporting concentrates, and at a later stage with increasing financial strength, for the company to extend into smelting and refining, and eventually into fabricating.

The only regular significant imports of lead are in the form of fuel additives, including tetra-ethyl lead, which amount to about 20 000 tonnes, with a lead content of 6000 tonnes, and valued at $20 million annually. There was a plan by ICIANZ to manufacture these anti-knock petrol additives in Sydney, but it has not been implemented. Environmental pressure for a lower lead content in petrol has reduced imports recently. Nevertheless, since it is impractical at present to do without tetra-ethyl lead there appear to be good economic reasons for replacing this import by local manufacture, if it is feasible. It would provide a secure market for a considerable tonnage of Australian lead, and could enable the establishment of a new industry for extracting bromine from salt bitterns. Bromine is used in making lead anti-knock additives.

Magnesium

Although Australia produced 589 087 tonnes of dolomite and 28 156 tonnes of magnesite in 1976, it also imported large quantities of magnesium-related goods, particularly magnesium oxide (4812 tonnes, with an additional 440 tonnes of electrically fused oxide in 1976) and magnesite bricks (8339 tonnes valued at $2 930 000 in 1975-76). The purer magnesium oxide is derived from sea water, and it seems possible that the local demand is approaching a volume that could support such an indutry, perhaps near Port Augusta where the sea water is relatively concentrated and bitterns are available.

While there are export opportunities for developing Australian magnesite, the immediate question is whether more calcining, dead-burning, and fusing of magnesium oxide could be undertaken in Australia. Allied to this is the possibility of making more of our needs of magnesite and chrome-magnesite refractory bricks. There appears to have been an increasing tendency to substitute imports for local bricks.

Imports of magnesium chloride in 1975-76 were 611 tonnes and in 1976-77 were 400 tonnes. There is a very large potential source of magnesium chloride in the bitterns of the solar salt industry.

Magnesium metal is not made in Australia, and imports were 1205 tonnes in 1975 and 1529 tonnes in 1976. The smallr producers, such as France, Canada, and Italy, have outputs of 5 to 7 thousand tonnes annually. Assuming that this is about the minimum economic scale of production, it indicates that, in the absence of secure large export markets, Australia would probably be an inadequate base for a viable magnesium metal industry, but this could change if new local uses of magnesium were developed.

Manganese

In the nine years since 1967, annual mine output has quadrupled to 2 154 000 tonnes, but ferromanganese production has declined from 59 069 to 57 069 tonnes. Hence the production processing index has fallen from 38 to 6 percent, with the Export Index remaining near zero. This reflects the growth of manganese ore exports to the Japanese steel industry, and the rather static domestic situation, where an obsolete ferroalloy plant at Newcastle was closed. Recently, additional new plant has been installed at Bell Bay, which will make Australia more than self-sufficient in ferromanganese, silicomanganese and ferrosilicon. A new sintering machine will enable the more efficient use of manganese fines. The new capacity for high-carbon ferromanganese exceeds present domestic steel-making requirements. Therefore, some ferromanganese may be available for export in the immediate future.

The export potential for ferromanganese to overseas steelworks is rather limited, because most developed countries make their own ferro-manganese from imported ore. Because Australia imported 1070 tonnes of manganese dioxide in 1976-77, there appears to be possibly scope for electrolytic production of manganese dioxide, as over 1000 tonnes/year are used for dry cell manufacture. Between 3 and 4 thousand tonnes of impure manganese dioxide a year is produced as a by-product of electrolytic zinc refining at Risdon, but it is unsuitable for dry cells or ferro-manganese and is used instead for making fertiliser and chemicals.

Australia also imports over a 1000 tonnes/year of manganese metal, mainly in the form of powder and flakes.

Mineral Sands

Monazite: Rare earth compounds were produced at Port Pirie in 1969-72 but since then monazite has not been processed in Australia. One of the largest readily accessible resources of thorium and rare earths is the tailings pond at Mary Kathleen uranium mine. In 1971 MKU Limited, which is an affiliate of Rare Earth Products Limited in Britain, constructed a pilot plant which successfully recovered rare earth concentrates using a solvent extraction process on the barren liquor from which uranium had been extracted. The project, for the production of 4000 tonnes/year of rare earth oxides, appears to be in abeyance. Prices have improved recently, despite the world surplus of monazite, but until a more substantial market for rare earth appears, there is no prospect of further monazite processing in Australia. There is a possibility that thorium may be used as a complementary fuel with uranium, and as a nuclear fuel in high-temperature reactors.

Zircon: Although Australia is the world's major source of zircon, with a mine output of 420185 tonnes in 1976, there is still little processing of the material locally. Associated Minerals Consolidated Limited has established an opacifier plant near Brisbane, and is investigating joint venture proposals for the oversea processing of Australian zircon, and for the production in Australia of zirconia and related products using a plasma arc furnace.

Zirconium metal production apparently requires to be on a 300 tonnes/year basis at least, to be economic. Australian demand for the metal is negligible, but it is likely that nuclear applications will become important in the future.

Titanium: Rutile mining has maintained a fairly steady rate of output (389750 tonnes in 1976) and export in recent years, while the extent of local processing has continued to be minimal. Since the Australian market for titanium dioxide pigments is adequately catered for by the two existing sulphate plants using ilmenite, the construction of a chloride process plant to make titanium dioxide from rutile would be of dubious economic value, but is attractive as it reduces pollution. Unlike the sulphate process, the chloride plants do not have to dump thousands of tonnes of ferrous sulphate and sulphuric acid effluent. The prospects for exporting titanium dioxide pigments are not promising, as all major markets overseas have tariff-protected domestic production. World trade in other titanium compounds, and in titanium metal, is relatively small. There have been suggestions that titanium tetrachloride could be exported for pigment and metal production, but freight costs for such a corrosive chemical would be high and there is as yet no overseas demand for tetrachloride.

Ilmenite production and exports have increased from 552951 tons and 390468 tons in 1967 to 959203 tonnes and 964686 tonnes respectively in 1975, while domestic titanium dioxide pigment output has risen commensurately. These figures reflect the considerable expansion of ilmenite mining in Western Australia. The processing indices have decreased slightly, because exports of concentrates have grown more rapidly than local pigment output.

Progress has been made with processes to convert ilmenite to synthetic rutile, and though in 1976 only 70 000 tons was processed, all for export, Western Titanium has plans to double this output. It is expected that beneficiation of ilmenite to rutile will continue to expand, as the chlorination of beneficiated ilmenite avoids the serious environmental problems caused by the disposal of the waste ferrous effluent produced when manufacturing pigment from ilmenite. This effluent is in effect transferred from the pigment plant to the beneficiation plant, which is probably in a better position for its disposal. Some beneficiation processes avoid the effluent problem by producing easily disposable iron oxide waste.

Nickel

There have been major developments in the Australian nickel industry since the previously mentioned paper on processing, with the nickel content of mine output rising from 2094 tons in 1967 to 82532 tonnes in 1976 and the PPI changing from nil to 95 and the EPI from nil to 95. These figures are calculated on nickel concentrate output, and not on mine production, which would give a figure about 2 or 3 lower. The opening of new mines and a smelter in the Kalgoorlie area as well as the refinery at Kwinana, have transformed the industry in Western Australia. The establishment of the Greenvale lateritic mine, with an ammonia-leach plant at Yabulu has been equally important. There have been several proposed new nickel mines, but the only one currently being developed is at Agnew, and the Kalgoorlie smelter is to be enlarged to convert the Agnew concentrates to matte. The current recession in the industry has forced the closure of some nickel mines, and it could be a few years before further large-scale projects are undertaken.

Although the PPI and EPI are now high, there is still some scope for increased local processing. This is indicated by imports in 1976 of nickel metal valued at $18.5 million. This comprises forms of nickel such as sheet, wire, and alloys, not made in Australia. The establishment of an electrolytic nickel refinery would be a logical development. Other imports which might be replaced by local substitutes are nickel oxide, sulphate, and chloride, as well as ferronickel. Ferronickel is made from lateritic nickel concentrate with an electric furnace. In the long term, it is possible that a ferronickel plant could be located near Townsville using Greenvale ore. Mixed nickel and cobalt sulphides now exported could probably be processed to meet local requirements for nickel compounds. One of the main forms in which nickel is imported is stainless steel, of which Australia imports about 40 percent of its requirements, mainly from Japan.

Phosphate

Up to the present, practically all phosphate rock used in Australia has been imported, but now for the first time large tonnages of local rock phosphate have become available for export from North Queensland and for local industries.

There is a worldwide trend towards the use of more concentrated phosphate fertilisers than the traditional superphosphate, and except in some sulphur-deficient areas, it is likely that triple superphosphate and ammonium phosphate will eventually largely replace it in Australia. These require phosphoric acid as an intermediate, and it would be logical to make this near the phosphate mine from lower-grade rock using sulphuric acid from smelter gases at Mount Isa. This would save transport costs, and the phosphoric acid could be transported by pipeline or in tankers. A side benefit would be a major reduction in imports of sulphur. In some sulphur-deficient areas agricultural gypsum would be an alternative source of sulphur.

The manufacture of elemental phosphorus in an electric furnace is another possibility. Imports of phosphorus in 1976-77 were 2305 tonnes valued at $2 573 000, apparently mainly for detergent manufacture. The Japanese have found that the Queensland rock phosphate is well suited for electric furnace feed for making elemental phosphorus.

Salt

There have been great changes in the Australian salt industry since 1967 when salt production was only 714 444 tons, primarily for local needs. In 1976, output of crude salt was 5.6 million tonnes, of which 4.26 million tonnes was exported, mainly to Japan. On the other hand, the Australian processing of salt has changed little, apart from some increases in capacity, with the result that the PPI is now down from 88 to 16. The gradual development of Australian exports of sodium compounds, such as caustic soda, has increased the EPI from 2.7 to 12.9.

Since Australia continues to import liquid caustic soda for alumina production (caustic soda imported for this purpose was valued at nearly $48 million in 1976-77) there have been several proposals for the local large-scale manufacture of liquid caustic soda. The difficulty is the disposal of the co-product chlorine. A proposal for a plant at Redcliffs near Port Augusta, SA, using the chlorine for petrochemicals, has been deferred. Except for the replacement of imported caustic soda, there appears to be little scope for increased processing of salt in Australia. Australian costs for producing sodium compounds are rather high because of the small scale of production, making exports uncompetitive. Although it may eventually be possible to replace imports of sodium metal, sodium sulphite, sodium sulphate, and sodium cyanide with local production, the total imports of sodium compounds each year, other than caustic soda for alumina, amount to only about $5 million.

There is also the possibility of finding a commercial deposit of trona (sodium carbonate), which can be causticised with lime and used in the alumina industry, replacing caustic soda imports.

Silver

Only 23 percent of the silver exported from Australia is in the form of refined silver, the remainder being in lead bullion; lead, zinc, and copper concentrates; blister-copper; and in various slags, mattes and residues. This highlights not only the scope for further processing of silver, but also the variety of materials of which it is a constituent.

The major possibility would be the establishment of desilvering plants, probably at Townsville and Cockle Creek, to process lead bullion. As a result of Britain entering the European Economic Community, Mount Isa Mines has apparently decided not to build a new desilvering plant at Townsville, which would have employed about 60 men, but to enlarge its existing plant at Northfleet, near London, to handle the additional silver that will come from the new Hilton mine. Since the Australian market for silver is already catered for by the Port Pirie plant, which exports more than half of its production, any increased production would have to be exported. By exporting silver in the form of bullion the high freights attaching to shipments of precious metal are avoided.

Although this helps to secure the European market for Australian silver, it means less metal is available for sales in Asia and elsewhere.

Tin

Mine production of tin has nearly doubled during the past 10 years, but the basic position of processing has changed little. With an increasing proportion of lode tin production, the sole Australian primary tin smelter, in Sydney, has been smelting lower-grade concentrates, and this has restricted refined tin output, because the smelter was designed for high-grade alluvial tin concentrates. It has been announced that $500 000 is being spent on installing Russian machine drossing and vacuum equipment, to facilitate the processing of lower-grade concentrates. The smelter supplies the Australian market, which is mainly for tinplate and solder.

Between 1967 and 1975 the PPI fell from 66 to 53 while the EPI rose from 1.8 to 41. There were special influences, including export quotas imposed by the International Tin Council, arising from the economic recession in 1975 which temporarily affected the indexes.

Imports of tin metal usually amount to about 50 to 60 tonnes/year of lower-grade ingot used for solder, and about 40 tons of powder, foil, and semi-fabricated forms. It is uncertain whether the local production of tin powder or foil would be economic. There are also imports of tin oxide, stannic chloride, and tinned plate, as well as any secondary metal recovered, to be included in any national balance-sheet of tin supplies.

Exports of tin in concentrates to Malaysia and the United Kingdom account for about 40 percent of mine output, and these include some of the lower-grade and more refractory ores requiring special processing. Renison Limited has been investigating the feasibility of establishing a second smelter or processing plant.

Tungsten

Although the mine output of tungsten concentrates has increased during the period under review from 1676 tons to 3398 tonnes, the processing situation has remained unchanged at nil, apart from about 80 tonnes/year used for making tungsten carbide.

Tungsten prices are notoriously volatile, and influence production.

The prospects for further local processing are limited by the small Australian market, which imports only about 12 tonnes/year of tungsten metal, including wire. The possibility of substituting locally manufactured tungsten for these imports probably deserves investigation, because of its defence significance. During World War II, when tungsten wire was scarce, it was produced on an experimental scale in a Government Factory at Footscray. Ferrotungsten alloys are also imported, but are not recorded separately.

Of the world consumption of tungsten, ferrotungsten accounts for 10 percent, tungsten metal for 15 percent, tungsten carbide for 65 percent, and chemicals and other uses for the remaining 10 percent. It is believed that this pattern is reflected in Australia, but all local consumption of Australian tungsten is for carbide, with a small amount being used in alloy steels made from tungsten-bearing residues from the carbide plant.

CONCLUSIONS

From this brief description of Australian mineral processing it is possible to select a list of those minerals which could perhaps, become candidates for further processing; the minerals are listed, in the order of previous reference, in Table 9.

Table 9. Summary of Mineral Processing Prospects

	Short-term (5 years)	Middle-term (5 to 10 years)	Long-term (over 10 years)
Bauxite	Alwest alumina* Wagerup alumina*	various alumina proposals*	
Aluminium	Gladstone smelter*		
Antimony		Oxide	
Arsenic		Oxide	
Asbestos			Fabrication
Bismuth		Smelter	
Cadmium		Zinc by-product	
Chromium		Ferrochrome	
Cobalt		Metal & sulphate	
Copper		Powder & flake	New smelters*
Fluorine		Cryolite	
Iron	Concentrators* Pelletising*	Metallised agglomerates	New steelworks*
Lead		Desilvering	New mines and smelters
Zinc	MIM fuming and* electrolytic refining*		

	Short-term (5 years)	Middle-term (5 to 10 years)	Long-term (over 10 years)
Magnesium		Extraction from seawater; oxide & refractories	Metal
Manganese		Electrolytic oxide Low-carbon ferromanganese	Metal
Zircon		Oxide	
Ilmenite	Synthetic rutile	Chloride process pigment	Metal
Nickel	Smelter expansion	Electrolytic metal	ferronickel, fabrication
Phosphate	Beneficiation	Phosphoric acid*	Phosphorus
Salt	Caustic soda*		
Silver		Desilvering lead	
Tin	Smelter (Tasmanian ore)		Powder, foil
Tungsten		Ferrotungsten	Metal

Those marked * are the more important projects, in economic terms.

It is emphasised that none of the middle or long-term prospects listed above are real projects. The fact that they have not been undertaken already is good evidence that they have not been commercially attractive, and may not be feasible. Except for the short-term projects, they require much more research before they could merit Government support. The purpose here is merely to point out the possibilities deserving closer investigation.

When evaluating the various possibilities the following criteria are relevant:

processing indexes
technical practicality
economic feasibility
market access
industrial significance
national policy

An examination of overseas trade in the particular commodity and its related products is usually a guide to the potential of the domestic market.

It is as well to keep in perspective the relative importance of mining to the Australian economy. Mining contributes between 3 and 4 percent of the Gross Domestic Product, and employs only about 75 000 persons, out of a total workforce of more than 6 million. Most employment in mineral processing is included in manufacturing statistics. A mining boom alone could not solve the current unemployment, but mining is highly significant because of the many dependent economic activities and its high export earnings.

There would be certain effects upon the Australian economy as a whole if the mineral processing industries underwent a major expansion. While this is not the place for a detailed economic study, some indication of the main implications is relevant.

Firstly, other things being equal, further processing would tend to raise the international value of the Australian dollar, as a result of the increased export income from more highly processed exports. This would hinder other exports, particularly of farm produce, and would disadvantage manufacturers who would have more severe competition from cheaper imports.

Secondly, since large-scale mineral processing is capital intensive, its demand upon the domestic capital supply would leave less capital available for other projects, and might lead to higher interest rates. This would particularly disadvantage other growing capital intensive industries, such as petroleum, if they could not make good the deficiency by drawing capital from overseas. The inflow of foreign capital would be encouraged by the higher interest rates mentioned above.

Besides capital, all production requires labour. When a capital-intensive industry, such as mineral processing, is expanded, then compared with most alternative investment opportunities there is a relative decrease in the long-term demand for labour. In theory this might depress wages, but under Australian conditions this is unlikely to occur, because the economy is not static, and there are other factors such as unemployment, immigration, the shortage of skilled workers, and the industrial relations circumstances, which affect the result.

The tertiary industries, such as finance, education, government, etc., would be largely unaffected by the expansion of mineral processing, although they would share in the general advantages of an expanded economy.

Some industries would benefit, particularly mining, energy, transportation, construction, and chemicals, because they would service the new processing plants.

It should not be assumed that the establishment of more mines and processing plants necessarily results in a total increase in national employment and production. Thus the development of Pilbara iron ore exports, while showing impressive economic progress locally in Western Australia might well be off-set by falls in employment and profitability, mainly elsewhere in Australia, in, for example, exporting farm produce, and in manufacturing clothing and cars. Historically, the growth in export revenue from minerals has largely compensated for the decline in Australian export earnings from wool and food.

To obtain a clearer understanding of the relative importance and nature of the various influences upon the Australian economy that would derive from an expansion of mineral processing, it would be best to formulate a computer-oriented model of the economy. This would enable a study of the effects of any proposed expansion upon other industries and upon the economy generally. t might also lead to some measure of the priority that should be given to mineral processing, as compared with other options for developing the economy and improving welfare.

During the current worldwide economic recession the development of new mines has almost come to a standstill. When the economy recovers it is expected that shortages of some minerals and metals with emerge, leading to a boom in their prices. This would eventually enable an expansion in Australian processing capacity, particularly if interest rates fall. If this happens, a change in the economics of the industry in favour of Australia is foreseen in the medium term.

The main immediate obstacle to further processing in Australia lies in the protection given the smelters and refineries in Japan, Europe, and America, which prevents access by Australian refined metals to adequate and remunerative markets.

Except perhaps for the Soviet Union, all countries are deficient in some minerals, and have no alternative to importing their requirements of these metals and energy minerals. Since, except for crude oil, diamonds, and potash, Australia produces surpluses of nearly all the important minerals, metals, and fuels, it is in a strong trading position, provided its mineral exports have been processed to a stage where they are saleable in most markets, and not just to a few overseas smelters.

The processing of minerals, despite the constraints mentioned, is one of the most promising fields for industrial expansion in Australia because it takes advantage of the natural resources, and is well suited to the available labour, capital, and technology.