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MINERAL CONSERVATION IN AUSTRALIA

- A PRELIMINARY ANALYSIS -

by

L.C. Noakes

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SUMMARY

Current emphasis on conservation and the environment has inevitably heightened interest in the future availability of minerals and in the apparent need for mineral conservation. Unfortunately the availability of minerals in the future cannot be objectively determined, and predictions made on the basis of present knowledge appear alarming to those with inadequate knowledge of the many factors involved; figures accepted for existing reserves are mostly minimal and no prediction of the situation in the future can take proper account of additional new resources, rates of increase in demand for minerals, and the effect of prices, substitution, and new technology.

On the other hand problems of the likely availability of minerals in the future demand periodic analysis as knowledge and trends change. The first requirement for such studies is that Australian mineral resources be realistically assessed; indeed the present study can only be termed preliminary because current assessments of resources have been completed for only a few minerals.

However, the situation has been analysed for five minerals in which resources have been recently assessed or for which known reserves are already large, in search of criteria of use in determining relative levels of availability and in gauging the need for mineral conservation. Domestic consumption of many minerals in Australia is small compared with exports and total production; so mineral conservation at this stage needs to be studied against the background of total production.

Figures for apparent life expectancy of reserves, based on assessed reserves and judgments on future rates of production, appear to provide the only feasible guide to future availability of minerals, albeit an unreliable one, particularly in the longer term.

However, it is suggested than an apparent life expectancy of no more than 30 years for currently assessed mineral reserves might well be taken as a threshold for concern on mineral conservation, requiring critical review of future availability. The application of this criterion to the five minerals for which study is currently warranted indicates no present concern in terms of mineral conservation for the three minerals which provide over 60% of our exports - iron ore, coal, and bauxite - but a need for better knowledge of potential resources of zircon and of the titanium minerals.

Similar studies should be extended to other minerals as proper assessments of resources become available, and indeed periodic review of likely future availability of all minerals in Australia seems to be an essential element in any national planning.

INTRODUCTION

Growing emphasis on aspects of conservation together with fast-increasing demand for minerals has inevitably focused attention on both national and world supplies of minerals.

It will never be possible to predict confidently either availability of or demand for minerals for years ahead because ore yet to be found cannot be estimated with any confidence, and demand, although more amenable to estimation, is likely to be controlled by complex factors such as per capita income, population, relative price, substitution, and technology. However, it is relatively easy to produce calculations, principally based on current ore reserves and projected demand, to indicate an alarming situation in which both Australia and the world will soon run out of mineral reserves. The complexities of the situation and the impossibility of quantifying reserves of the future make it difficult to counter these claims convincingly. But objective analysis of the future availability of minerals is urgently called for and this paper presents a preliminary examination of the situation in Australia on data currently available.

Minerals selected are those of most importance in both domestic consumption and export. The ratios of current ore reserves to both domestic consumption and to total production in 1970 (R/P ratios) are determined and the minerals tentatively grouped in accordance with relative levels of apparent reserves on the basis of these ratios; basic figures of these ratios are shown in Table 1.

Each of the selected minerals is then summarily studied in both domestic and world spheres in terms of present production, projected production rates in the future, and known reserves, for the purpose of analysing the need for mineral conservation. Finally, an attempt is made in the Synthesis to establish criteria of use in gauging the need for mineral conservation and to apply them to the group of minerals studied.

GENERAL CONSIDERATIONS

Before attempting some analysis for each mineral it is important to establish the significance of the ore reserve figures used and to discuss a number of other factors. The figures used in Table 1 are factual; but the reserve figures are minimal in that in most cases they represent the summation of tonnages of commercial ore published by mining companies or organisations.

The process of "proving" ore reserves is expensive and represents a large capital investment, so that companies commonly prove ahead of mining only enough ore to establish initial or continued viability; additional large reserves may well be known, but in less detail, for proving in due course and existence of still more ore reasonably suspected. But published reserve figures commonly refer only to measured or indicated ore and thus to only a portion of the existing reserves. Moreover, published ore reserve figures normally include very little, if any, marginal or sub-marginal material which may well become mineable in the future by changes in technology or by increase in price.

Among important factors for consideration are of course the likely levels of world demand for minerals in the future, with due account of prices and substitution, and possible new sources of supply; new sources of supply defy confident prediction and projection of world demand is difficult, particularly more than a decade ahead.

Prediction of trends of mineral consumption is obviously complicated by the likely role of secondary metals in future supplies, costs, and the degree of substitution; in any case the rate of increased consumption of minerals by developing countries is virtually unknown and is subject to a wide range of factors; no projections of increased world demand for minerals could reasonably be based only on predicted population growth. Growth in demand depends more on increases in per capita income than on increase in population alone; so rise in population in developing countries is not likely to be accompanied by pro rata rise in the demand for minerals, for example, unless per capita income rises as well. In fact prediction of exponential growth of demand for or production of minerals is particularly subject to error and seems most likely to err on the high side. Demand for most minerals has always been subject to embarrassing fluctuations reflecting changes in price, tehcnology, and the state of world economies; it is not possible to predict such fluctuations in the future and obviously difficult to decide what exponential rate of growth to assume for the future to allow for these changes. Short-term projections dealing, for example, with five or ten years ahead have proved hazardous enough, and longer term projections are no more than guesses. However, if we attempt to study the future in any detail we are forced to make such projections with as much knowledge and judgment as can be mustered.

On the side of future new supplies, analysts with little or no knowledge of the mineral industry tend to ignore the undoubted but unquantifiable potential of Precambrian shield areas and other mineral provinces in both developed and developing countries, the recognisable potential for new sources of copper, for example in the Middle East and in South America, the potential for copper and nickel in particular in manganese nodules and for copper-lead-zinc in some sediments in the deep ocean. These possibilities cannot be quantified, but certainly need to be taken into consideration in attempting an analysis of mineral supply and demand in future years. Indeed, exploration and metallurgy have combined for more than a century to effectively expand ore reserves for the mineral industry; confidence in this combination rightly remains high in the world today and particularly in countries like Australia.

It was not intended in this preliminary study to make any new analysis of likely future trends in the sonsumption of minerals. Trends for Australia for the decade ahead follow BMR analyses made as a basis for the projection of mineral exports published in the Australian Mineral Industry Review for 1970. They are subject to the hazards already mentioned and indeed will be too high if the Australia Mineral industry does not pick up well, as predicted, in the latter half of this decade.

TABLE 1: RESERVE/PRODUCTION RATIO

Mineral (unit in which measured)	Australia, 1970			Reserve/Production Ratios			
	Reserves ('000 tons)	Total Production ('000 tons)	Domestic Consumption ('000 tons)	Australia 1950	Australia 1960	Australia 1970	World 1970
Very large apparent reserves							
Iron ore (FeO_3)	20 000 000	50 000	9 400	121	83	400+(2 000+)	336
Black Coal (coal)	12 600 000[2]	48 000	25 000	124	100	260 (500)	832
Bauxite (Al_2O_3)	4 500 000	9 100	500±	2 850	850	450(9 000)	144
Nickel (metal)	3 750[2]	31±	4	n.p.	n.p.	120 (900+)	105
Large apparent reserves							
Lead (metal)	17 000[3]	435	34	13	14	40 (500)	26
Copper (metal)	5 000	155	70	19	12	32 (71)	50
Zinc (metal)	28 000[3]	441	105	12	11	63 (265)	20
Manganese (MnO_2)	200 000[4]±	740	122	33	25	270[4]+(1 600)	80
Titanium (metal)	15 900			77	63	79 (700)	116
Rutile (cons)	7 800	365	2				
Illmenite (cons)	50 000	883	85				
Medium-sized apparent reserves							
Zircon (cons)	11 300	390	7	44	39	29(1 600)	26
Tin (metal)	200[2]	9	4	9	21	23 (53)	35

1 Reserve/Domestic Consumption Ratio in brackets
2 Estimated recoverable
3 Includes the Arthur River deposit
4 All grades - % recovery uncertain; have classification under 'large apparent reserves'

However, these predicted growth rates in production are in general significantly lower than those of the last two decades, which have been inflated by initial production from major export-based enterprises, particularly in the 60's after new resources of iron ore, bauxite, coal, nickel, manganese, and tin were discovered. Possible cumulative production and consumption in Australia in the future is plotted against current reserve figures for iron ore, bauxite, black coal, zircon, and titanium (Figures 1-5) because current reserves for these minerals have either been recently assessed (coal, zircon, and titanium) or are large in any case; the graphs also show the rise in known reserves since 1950. Reserves of the other minerals will have to be assessed before similar graphs can become meaningful.

Likely world trends in consumption have been principally based on data published in the 1972 edition of "Mineral Facts and Problems", Bulletin 650 of the United States Bureau of Mines. In arriving at likely world consumption trends and rates of increase, the Bureau of Mines has taken into account the probable supply of secondary metals and the influence of substitutes in analyses which appear to be the best of their kind available, although suggested future consumption rates in developing countries are generally higher than those predicted for developed countries - an assumption that may well be questioned.

For the purpose of this analysis the minerals dealt with have been divided into convenient groups on the basis of current R/P ratios (Table 1). Those with R/P ratios exceeding 100 form a group in which reserves are regarded as "very large"; those with R/P ratios of 30-100 are regarded as having "large reserves" and those with R/P ratios of 15-30 have "medium size reserves". Minerals with R/P ratios of less than 15 would be regarded as having "small" reserves, but none are included in Table 1.

It might be noted that, not by chance, the minerals with very large reserves are principally those forming extensive near-surface and flat-lying deposits where drilling is less costly and interpolation and extrapolation of reserves less hazardous than in the less regular and steeply dipping ore deposits in which copper, lead, and zinc orebodies commonly occur. On the other hand, there is a tendency for the resources of such minerals, although relatively lower, to remain at much the same level as companies annually seek to replace the ore reserves mined. Flat lying orebodies offer better chance of estimating total reserves than do underground orebodies.

Returning to Table 1, it should also be noted at this stage that known supplies of many of the minerals concerned are sufficient for foreseeable domestic consumption in Australia for very long periods, and that any problems in conservation concern exports rather than domestic use; the same point is illustrated by the relationship of current reserves to projected future domestic consumption in Figures 1-5.

However, a number of factors would need careful consideration in any restriction of exports with the conservation of supplies in mind. Economies of scale stemming from large production, based on exports, have doubtless reduced the domestic cost of mineral products and thus assisted the domestic economy and increased our competitiveness in selling both raw and processed products overseas; restriction of exports could therefore increase costs and could vitally affect the viability of some mineral projects. Such a course could also seriously influence trade relations with foreign countries and of course any restriction of mineral exports would need to be considered in the light of incentives for exploration and of the level of overseas funds, to which mineral exports currently make a vital contribution. In general any necessary restriction of exports might best be achieved by seeking to regulate new projects or expansions rather than existing production; and execution of any such policies would require changes in mining administration to allow discoverers or holders of mineral deposits to delay development.

CURRENT SITUATION OF SELECTED MINERALS

MINERALS WITH APPARENT VERY LARGE RESERVES

Iron Ore

Australian situation

Iron ore, our major mineral export, shows current R/P ratios of 2 000 for domestic consumption and 400 for total production; reserves are currently quoted at 20 000 million tons of better than 50% iron, and this estimate is certainly minimal.

BMR projections of iron ore output to 1980 suggest an average annual increase in production of about 7%, totalling about 740 million tons for the ten-year period; continued production at this rate would absorb about 5 000 million tons to the end of the century and in fact presently quoted reserves would accommodate this rate of annual increase of production for about 50 years or alternatively could accommodate an average annual increase in production of about 5% for over 60 years (fig. 1).

World situation

Reserves of iron ore in the world are better known than those for most other metals as a result of a survey conducted by the United Nations and published in 1969; this survey indicated iron ore resources in the world of about 773 000 million tons, including 250 000 million tons of "reserves" and 523 000 million tons of "potential ore". Data on predicted consumption taken from Bulletin 650 of the United States Bureau of Mines suggest that world demand for primary iron is likely to increase at about 1.7% per year up to the year 2000 and that known world reserves should be adequate until well into the 21st century; in fact at this assumed rate of annual increase of consumption the world "reserves" quoted

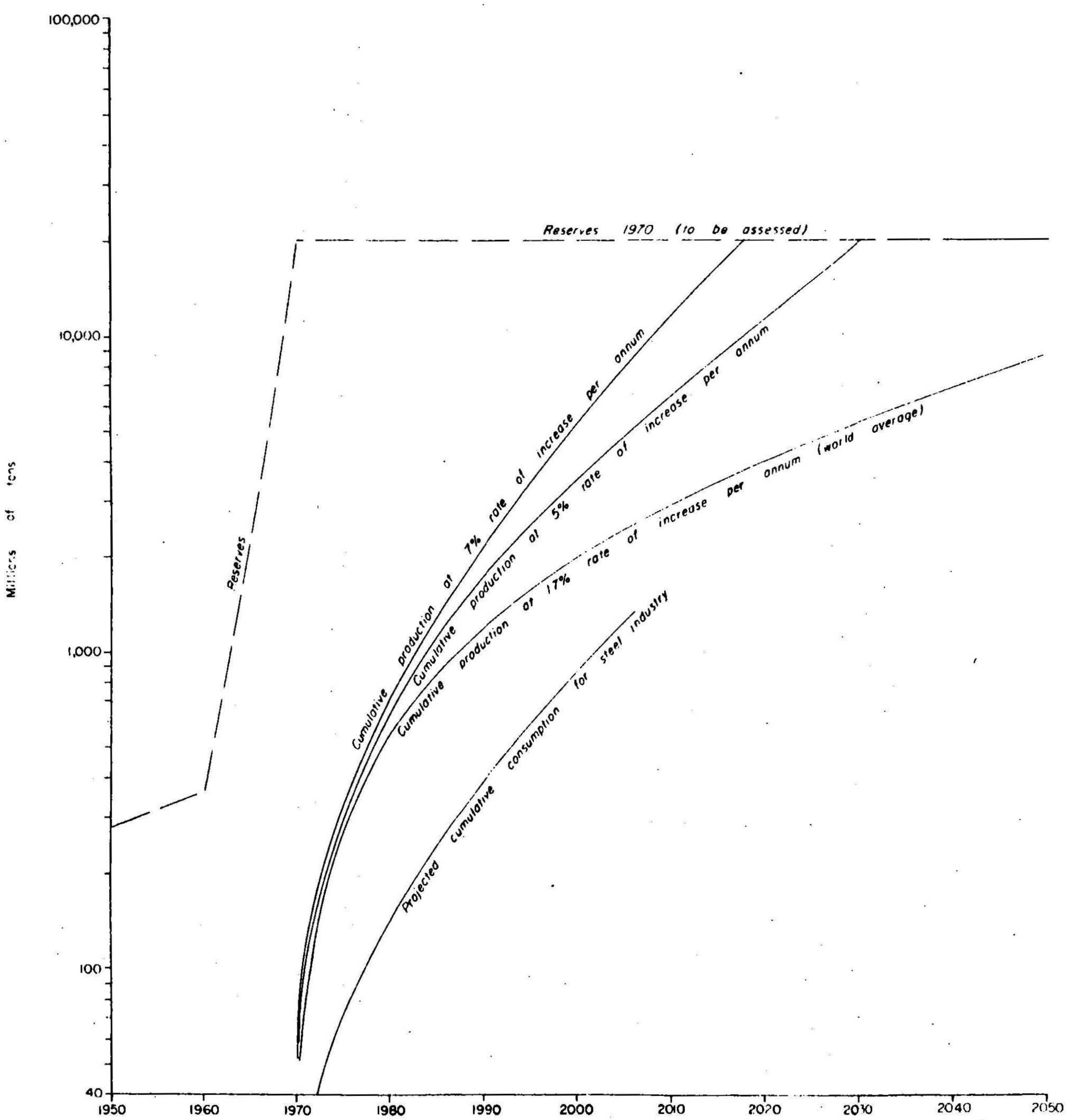

Fig I IRON ORE — AUSTRALIAN RESERVES AND PROJECTED PRODUCTION AND CONSUMPTION

To accompany Record 1972/40

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above would last for about 112 years and use of the potential ore would extend this period to over 170 years.

Discussion

The current assessment of reserves of iron ore in Australia at 20 000 million tons is most conservative even for the high-grade ore with which it deals: it takes no account of huge resources contained in low-grade iron deposits. More realistic figures for both total reserves and the quantities of ore available at various grades are currently being sought. However, some indication of the situation based on the present reserve figures is gien in Figure 1; present reserves would last for 50 years from 1970 if production increased 7% per annum, 60 years at 5% and 120 years at the projected world average increase of 1.7%.

In view of the fact that the present reserve figure is certainly conservative there is no immediate problem of conservation with regard to iron ore, although review is intended when an assessment of iron ore resources in Australia is completed; further discussion will be found in the Synthesis.

Bauxite

Australian situation

Australian reserves of bauxite currently stand at 4 500 million tons at a minimal estimate. Production in 1970 was 9.1 million tons and projections to 1980 suggest an increase in annual production to about 30 million tons, although present over-capacity in the aluminium industry indicates that this suggested annual increase (nearly 12% per annum) may well be somewhat inflated. Such an increase could involve the mining of 176 million tons of bauxite to 1980 and if continued to the end of the century would increase cumulative production since 1970 to 2 700 million tons (Fig. 2).

World situation

World reserves of bauxite quoted in Bulletin 650 of the United States Bureau of Mines and adjusted for current Australian reserves are about 8 350 million tons. Consumption of primary aluminium is expected to rise at the rate of 5-7% for the rest of this century and would absorb about 5 400 million tons of bauxite or over half the presently known world reserves.

However, substantial additions to bauxite reserves will doubtless be made in the next 30 years; for example recent discoveries of deposits in South America, reportedly of the order of 2 000 million tons, are not

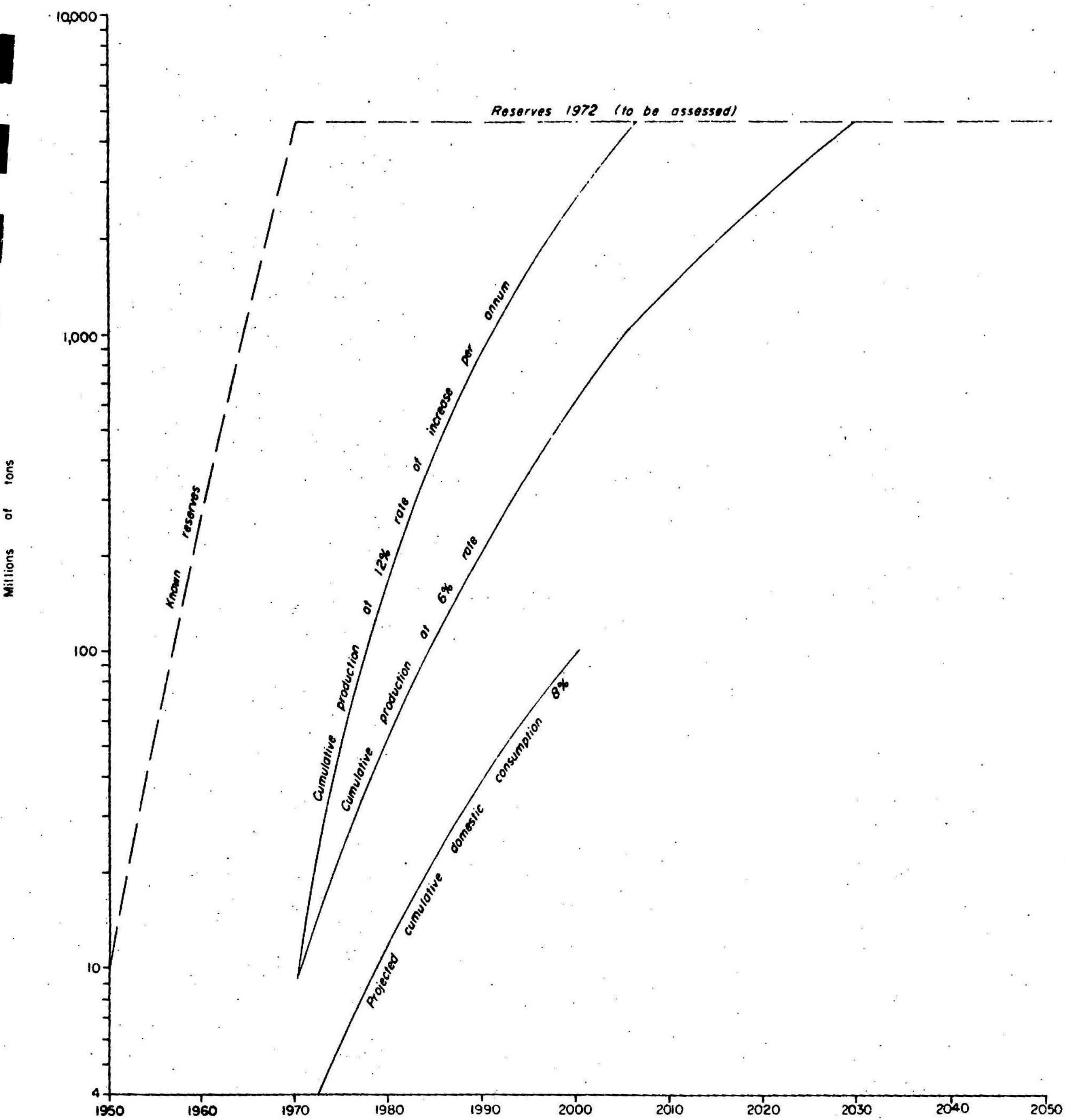

Fig 2 BAUXITE — AUSTRALIAN RESERVES AND PROJECTED PRODUCTION

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yet included in the world reserve figures used above. Processes for producing alumina from non-bauxitic clays and from other aluminous rock like an orthesite, although not likely to become competitive while bauxite is available at the equivalent of present prices, could eventually bring in very large new sources of alumina.

Discussion

World supplies of aluminium in the 21st century would appear to depend on additional discoveries of bauxite and on processes by which clays etc. can be economically used, although known reserves of bauxite should be adequate well beyond the year 2000. The current situation in Australia is satisfactory in that the minimal reserves currently quoted are adequate for planned expansions in the next decade and for the continuation of such an expansion beyond the end of the century. Continued expansion at a rate of 12% per annum does not seem likely and perhaps long term expansion at the rate of 6% per annum would be nearer the mark (fig. 2) but the situation should be regularly reviewed. Further discussion appears in the Synthesis.

Black Coal

Australia situation

Australian current reserves of recoverable black coal have been assessed by BMR as 12 601 million tons, of which 7 117 million tons are coking coals (Mead & de Farranti, 1971*). Our production in 1970 was 48 million tons and projections to 1980 suggest that production will rise to about 83 million tons per year, of which 70% is likely to be coking coal. At this rate of annual increase in production (5.6%) our presently known reserves of all black coal would last somewhat more than 49 years, coking coal being exhausted before the end of that period (see Fig. 3).

World Position

Present world reserves of black coal stand at 1 996 657 million short tons including about 930 000 million short tons of coking coal. The United States Bureau of Mines (Bulletin 650) suggests average annual increase of world consumption of black coal to the year 2000 as 1.7%; using this increase to the end of the century and beyond, present world reserves would last about 165 years. This figure appears inflated because some of this coal is uneconomic to mine under present circumstances because of depth below the surface and other factors but future energy needs may well induce a rise in price and the development of technology required for the utilisation of larger sub-marginal resources of coal both in Australia and overseas.

*Mead, S.F. and de Farranti, R., 1971 - Black coal Resources of Australia. Aust. Miner. Ind. quart. Rev., 23(4), June 1971.

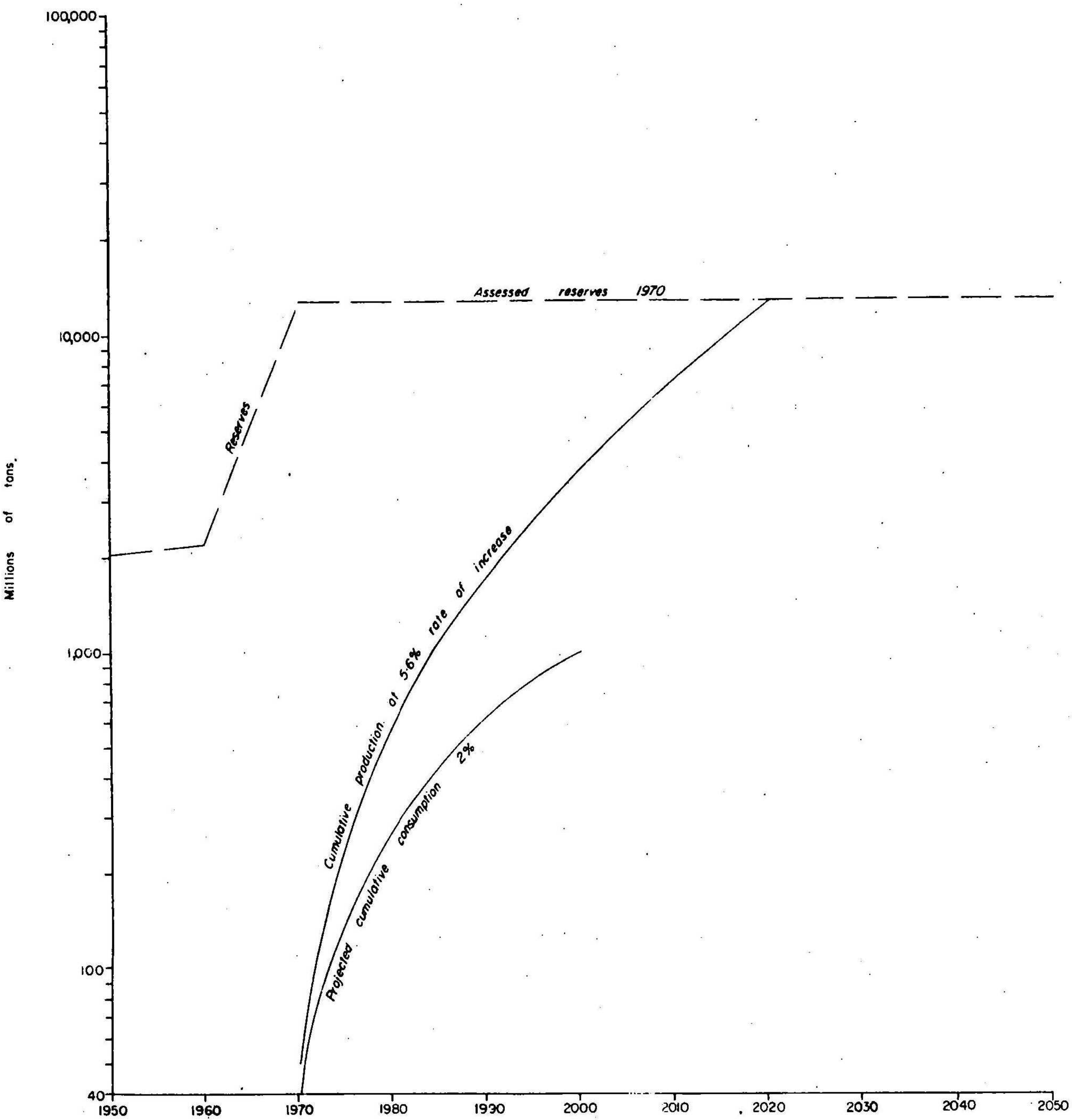

Fig 3 COAL — AUSTRALIAN RESERVES AND PROJECTED PRODUCTION AND CONSUMPTION

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Discussion

No detailed analysis of the black coal situation is appropriate to this report; it is complicated not only because of undiscovered reserves but because of inevitable competition by nuclear energy and by technological changes in iron making which seem likely to reduce greatly the importance and value of coking coal, perhaps before the end of the century. Increases in the real cost of coking coal will accelerate processes of blending or of the production of "form coke" from largely non-coking coals; and moreover it is possible that the blast furnace, the prime user of coking coal, may be phased out as the principal producer of pig iron in the early years of the next century.

Under these circumstances and until there are some clear indications that our current predictions of future coal usage are mistaken, there is little sense in conserving Australian coal for conservation's sake. Current problems are not so much concerned with the quantity of reserves, which doubtless will further expand, as with the need to ensure that adequate supplies of black coal, particularly coking coal, will be available in Australia at minimum prices over the next 30 years when and where they are required to produce iron and steel for a competitive export market.

Nickel

Australian situation

The nickel situation in Australia has changed and is changing rapidly as a result of exploration; current reserves at 3.75 million tons of contained metal are very conservative and do not yet include some of the significant deposits under exploration. Production in 1970 of 31 000 tons of nickel could rise to about 100 000 tons in 1980, although the present restricted market indicates that the figure could well be less.

World position

Present world reserves of nickel are quoted at 67 million long tons by the Bureau of Mines (Bulletin 650), and world production in 1968 of 442 000 long tons is projected to rise at a rate between 2.8 and 4% per annum to the end of the century. Production continuing to rise at a mean rate of 3.4% would absorb current world reserves in about 53 years, but reserves of nickel, particularly of lateritic nickel, are certain to increase very substantially, and manganese nodules from the deep ocean floor promise large supplies of nickel in the future.

Discussions

Australian production at a rate of annual increase of 12% to 1980 would absorb a little over 600 000 tons of the present reserve of 3.75 million tons, but the certainty of additional reserves and the likelihood that the rate of annual increase of production beyond 1980 will be considerably less than 12% per annum suggest that currently planned developments in nickel production in Australia pose no problems in mineral conservation. Assessment of nickel resources in Australia is needed to clarify the situation.

MINERALS WITH LARGE APPARENT RESERVES

Copper

Australian situation

Reserves in Australia are currently quoted at about 5 million tons of metal with R/P ratios of 71 (domestic consumption) and 32 (total production including export). BMR projections to 1981 suggest that the 1970 production of about 155 000 tons of primary metal may rise to about 253 000 tons, an average annual increase of about 5%, absorbing about 2 million tons of current reserves. At continued increase of 5% per annum these reserves would last about 20 years or until 1992.

World Situation

World copper reserves are presently recorded in Bulletin 650 of the United States Bureau of Mines as 308 million tons of metal; with 1970 consumption of primary metal running about 6 million short tons and assuming an average annual increase of demand for primary metal of 4.45%, the mean of a range suggested in Bulletin 650, these recorded reserves would be accounted for in about 27 years.

Discussion

Copper provides a good example of the false impression given by published ore reserve figures both in Australia and in the world at large. New porphyry-copper discoveries in Iran, South America, and other developed countries are not included in world reserves quoted above and no reserves can yet be established for copper eventually available from manganese nodules from the deep ocean basins; moreover known low-grade deposits not included in the present reserves would become reserves with sufficient rise in the real price of copper in the future. However, it should be noted that future increases in the real price of copper would not only bring in additional low-grade resources but would also tend to dampen demand for copper by encouraging substitutes.

Much the same situation applies to Australia, where published reserve figures of about 5 million tons are certainly conservative; more realistic assessment of ore reserves and of potential ore is planned and further analysis of the situation should await this assessment.

Lead

Australian situation

Known reserves of lead in Australia currently total 17 million tons of metal with R/P ratios of 500 (domestic consumption) and 40 (production). BMR projections to 1980 suggest that the 1970 production of 435,000 tons of metal is likely to increase to about 500 000 tons in 1980, absorbing about 4.7 million tons of reserves in that time. Continued production at this suggested rate of annual increase (1.4%) would exhaust presently recorded reserves of 17 million tons of metal in about 31 years from 1970.

World situation

World reserves of lead metal, based on United States Bureau of Mines Bulletin 650 but corrected for Australian reserves, are about 98 million short tons. World consumption of about 3.8 million short tons in 1970 seems likely to rise to about 6.8 million tons in the year 2000 at a suggested rate of annual increase of 2%. However, at this rate of annual increase of world consumption, recorded world reserves would only last about 21 years.

Discussion

The lead situation is uncertain on a number of accounts. Existing reserve figures are probably minimal, particularly outside the U.S.A. and world demand for lead in the next two decades may well rise by less than 2% per annum. On U.S.A. figures for 1968 35% of lead was consumed in storage batteries and 18% in additives to petrol; use as additives should fall and additional use of lead in batteries in uncertain.

There seems little doubt that improvements in technology and new discoveries will prolong the life of reserves at about present prices and should demand support higher real prices for lead, known deposits of lower grade material would greatly increase reserves; however, the quantity of lead in such deposits is not currently known.

A realistic assessment of lead reserves is obviously required in Australia to clarify the situation and to determine the order of new reserves required about the end of the century. It is, of course, well known that large lead producers in Australia like those in Broken Hill have always reported as reserves only "proved" or "blocked out" ore. The current price and prospects for lead do not encourage active exploration for lead alone, but exploration will continue because lead is commonly associated with zinc, for which prospects are more encouraging.

Zinc

Australian situation

Known zinc reserves in Australia presently stand at 28 million tons of metal. BMR projections indicate that production of 441 000 tons of metal in 1970 may well rise to about 600 000 tons in 1980 - an average annual increase of 3% requiring a total of 5.2 million tons of zinc in the ten-year period. If production of zinc continues beyond 1980 at this rate of annual increase presently known reserves of 28 million tons would last about 36 years from 1970.

World situation

Currently recorded world reserves of zinc are about 109 million short tons, based on United States Bureau of Mines Bulletin 650 but with adjustments to include present Australian reserves. World consumption of zinc in 1970 of about 5.4 million tons is likely to rise, according to Bulletin 650, to about 13.04 million tons in the year 2000, at an average annual rate of increase of about 2.9%. However, at this rate of increase in production, presently known world reserves would last about 16 years although doubtless world reserves of ore minable at present prices are certainly larger than those currently recorded.

Discussion

Projected demand for zinc in the world may well require the use of low-grade resources, of new discoveries, or of substitutes like aluminium, plastics, or low alloy steel before the end of the century; and the same applies to Australia probably early in the 21st century.

Current prices and prospects for zinc are sufficiently encouraging to attract exploration but again a realistic assessment of Australian resources is needed for proper analysis of the situation, although not so urgently as for lead; any consideration of conservation would be precipitate before this information becaomes available.

In the longer term, supplies of zinc and lead seem to be assured for considerable periods when it is considered that either new technology or increase in the real price of one or both metals is likely to make available large tonnages of known lower grade material, particularly in U.S.A., and that both developing countries and indeed some deep ocean basins like the Red Sea have deposits of both metals awaiting further exploration and the technology to develop them.

Manganese

Australian situation

Australian reserves of manganese ore are at least 200 million tons of all grades, but data are insufficient at present to reduce reserve figures to manganese content with any confidence. However, in terms of manganese ore, production of 739 000 tons in 1970 may rise to about 2½ million tons in 1980, although there is no present indication of increase beyond that level. On this basis presently known reserves appear likely to last well into the next century.

World situation

World reserves of manganese currently stand at about 700 million short tons of metal and show an R/P ratio of 80. Consumption of about 8.8 million short tons in 1970 is likely to rise to about 21 million short tons in the year 2000 and currently world reserves would cope with this average annual increase in demand of about 3% for some 40 years.

Discussion

World resources of manganese include quantities of low-grade material which would become available should prices or technology or both make them economic. Moreover, manganese nodules, which seem likely to be mined, particularly for the recovery of copper and nickel, provide additional resources of manganese roughly estimated by some to contain from 90 thousand million to 400 thousand million tons of manganese. Supplies of manganese in the forseeable future are therefore fairly well assured.

On the Australian scene, successful beneficiation of some grades of material at Groote Eylandt would increase the usefulness of these resources and the results of current research into these matters is awaited with interest.

There would appear to be no sense in questioning the modest increases in production planned for the next 10 years; both continent and deep ocean basins in the Australian region promise additional supplies. The situation can be further reviewed when an assessment of manganese reserves in Australia has been completed.

Titanium

Ilmenite and rutile, the two major sources of titanium, need to be taken together in considering mineral conservation; except for the use of rutile for welding rods, the two minerals are virtually alternative sources for production of pigment, metal, etc., although rutile, if available at reasonable prices, remains the preferred feed for the production of metal and of high grade pigment.

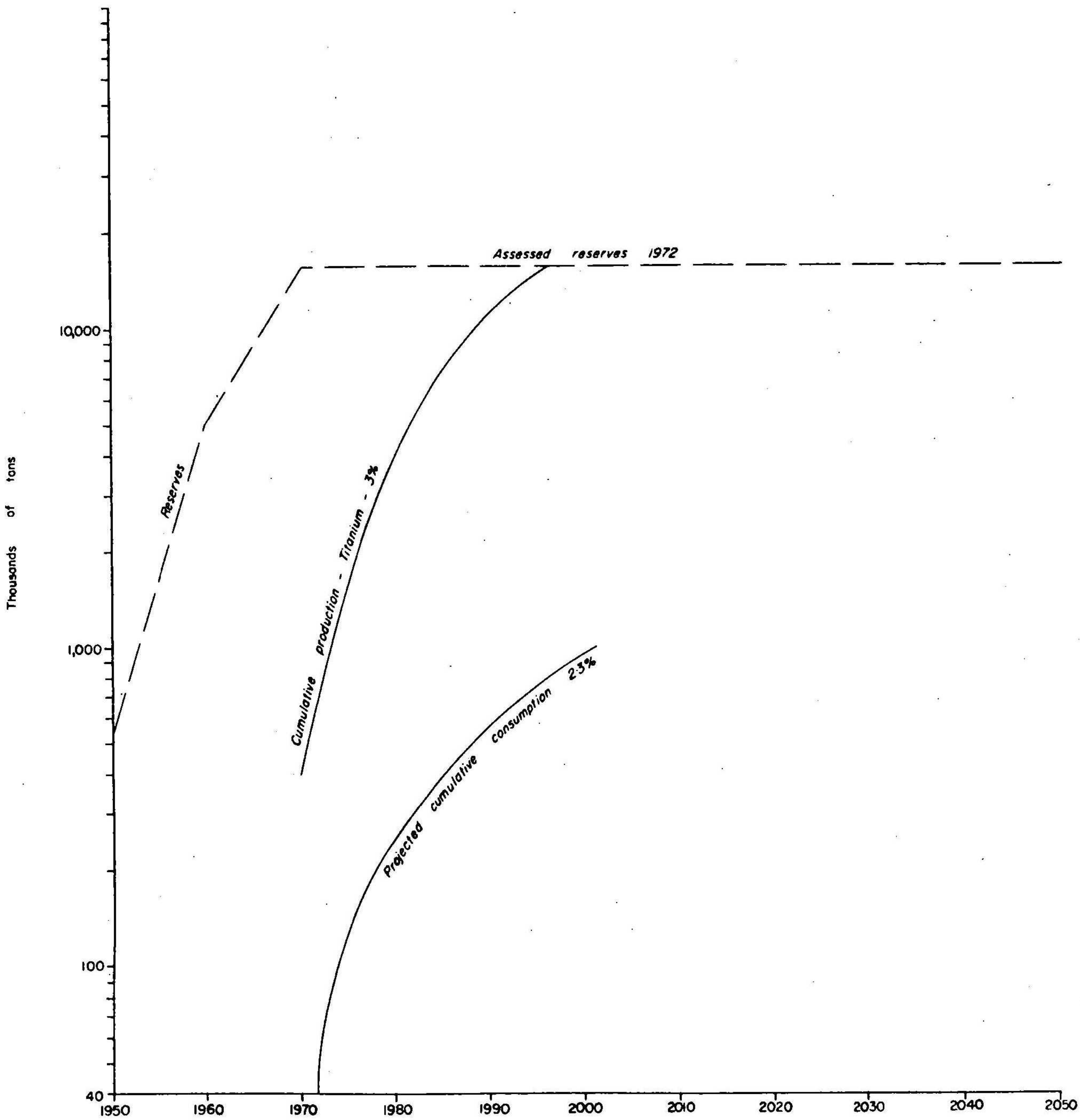

Fig 4 TITANIUM — AUSTRALIAN RESERVES AND PROJECTED PRODUCTION

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However, inevitable shortage of rutile in the future has increased the importance of ilmenite, which is relatively plentiful, and places emphasis on perfecting some of the upgrading processes by which ilmenite provides a product closely approaching rutile in chemical and physical properties. Upgraded ilmenite, which can be confidently expected on future markets, is likely to be priced somewhat below rutile but the two products are obviously likely to control each other's prices, particularly as upgraded ilmenite become more plentiful, suggesting that price increases for rutile are likely to be under tighter control that they have been in the past. In considering rutile and ilmenite together it is convenient, following United States Bureau of Mines Bulletin 650, to accept the titanium content of rutile as 50% and that of ilmenite as 25%.

Australian situation

The current assessment of resources of rutile and ilmenite in Australia indicates the following reserves (Ward, 1972*):

Reserves of Titanium in Australia			Assumed Titanium Content
Rutile	7.8 million tons		3.9 million tons
Ilmenite	48* million tons		12 million tons
		Total	15.9 million tons

These figures include inferred reserves of 0.8 million tons of rutile and 3.8 million tons of ilmenite and also reserves currently "frozen" in the interests of preservation of reserved areas - 1 million tons of rutile and 2.4 million tons of ilmenite. This 'frozen' ore is included in the reserves used in this report because some portion of it may well be recovered. In addition the recent assessment of resources has indicated sub-marginal deposits of about 2.7 million tons of rutile on and offshore and some 20 million tons of ilmenite onshore; these tonnages cannot be regarded as current reserves but could become reserves in the future depending on price, cost, and Technology.

Production in 1970 amounted to 365 000 tons of rutile and 883 000 tons of ilmenite, or, in terms of titanium, about 403 000 tons. BMR projections suggest that rutile production in the 70's will fall somewhat and then rise to about 350 000 in 1980, and that production of ilmenite from Western Australia will increase to about 1 200 000 tons, indicating production of total titanium of the order of 560 000 tons at the end of the decade. On this basis average annual increase in production in terms of titanium would be about 3% and continued increase at this rate would exhaust presently recorded reserves of titanium in about 26 years from 1970 (Fig. 4).

*Ward, J, 1972 "Australian Resources of Mineral Sands" Aust. Miner. Ind. quart. Rev. 25(1), Sept. 1972.
*includes 11 million tons of East Coast ilmenite relatively high in chrome.

In terms of titanium minerals the 10-year period would have withdrawn about 3.2 million tons from rutile reserves (which, with no further increase in annual production, would last another 13 years), and about 10.5 million tons of ilmenite reserves (which would last about another 22 years at the same rate (about 3%) of annual increase in production).

In summary, projected rates of production suggest that currently recorded reserves of titanium are likely to be largely exhausted in little more than 30 years. Known sub-marginal resources, should they become viable, would extend the life of reserves at a continued rate of annual increase of 3% for an additional 10 years.

World situation

According to U.S. Bureau of Mines Bulletin 650, but correcting for Australian reserves, current reserves of titanium stand at about 156 million short tons, including some 6 million short tons from rutile and 150 million short tons from ilmenite. The world R/P ratio for titanium is approximately 116. Consumption in 1970 was about 1.34 million short tons of titanium and by 2000 is likely to rise to 5.3 million short tons, suggesting an average annual increase of consumption of some 4.7%. At this rate of increase in annual consumption presently known world reserves would last about 40 years from 1970.

Discussion

World resources of titanium prinicpally of ilmenite, are undoubtedly very large, and, according to Bulletin 650, accepting increased costs ranging from 5 to 25% above present levels or given improved technology, the United States should be able to provide for titanium needs from domestic resources indefinitely, but mainly from hard rock deposits.

The situation is obviously more favourable than current figures suggest because reserves of rutile and ilmenite in India and Ceylon and of ilmenite in a number of South East Asian countries are very imperfectly unknown.

However, on the basis of a recent assessment of reserves the situation in Australia appears less favourable in that current reserves of both ilmenite and rutile, both derived from beanch sand deposits from which production is cheaper than from hard rock sources, seem likely to be exhausted in less than 30 years at projected rates of production and export. However, further discussion on this matter appears in the Synthesis.

MINERALS WITH MEDIUM SIZED APPARENT RESERVES

Tin

Australian situation

Currently recorded reserves of tin metal in Australia total about 200 000 tons with R/P ratios of 53 (domestic consumption) and 23 (production). Production in 1970 was 8 700 tons of tin, and BMR projections currently suggest that although production will rise mid-term, output of tin is likely to be much the same at the end of the decade. In any case, market prospects indicate that only small expansions of tin production are likely, so that our recorded reserves are likely to last about 20 years.

World situation

World reserves of tin are currently recorded as 6.5 million tons. World consumption of about 185 000 tons in 1970 is likely to rise to about 288 000 tons per year by the year 2000, an average annual increase of about 1.5%. At this rate of annual increase world reserves would last about 28 years.

Discussion

In reviewing the tin situation both in Australia and overseas it should be noted that present reserves are certainly greater than those recorded, with significant quantities of potential ore known and with new deposits, particularly offshore in South East Asia, under exploration. Moreoever, increasing attention is being extended to better recovery of both primary and secondary tin and, because of the cost of the metal, industry is gradually reducing tin requirements per unit product in tin plate. Prospective markets for tin provide little incentive for exploration for those not already involved in tin production, but any increased demand for tin in the future would probably have the effect of stepping up exploration and discovery. the BMR assessment of tin resources in Australia, which should be completed this year, has already indicated additions to currently recorded reserves and significant tonnages of potential ores which either technology or increased real price for the metal would make available. Further consideration of the situation should await the completion of the current assessment of resources.

Zircon

Australian production and reserves of zircon are of course closely linked with those of titanium minerals, as zircon is a co-product of beach sand mining for rutile on the east coast and in King Island and an important by-product of ilmenite mining in Western Australia.

Australian situation

Reserves of zircon have been recently assessed (Ward, 1972) at 11.3 million tons, most of which is associated with rutile in east coast deposits, and at Ennabba, Western Australia. BMR projections suggest that production of 390 000 tons in 1970 will fall marginally in the 70's before gradually rising to about 450 000 tons in 1980. Production at these rates to 1980 is likely to involve about 3.7 million tons of reserves, and beyond 1980 production of zircon of this order could continue as a co-product of rutile for some 14 years, eventually declining when by-production with

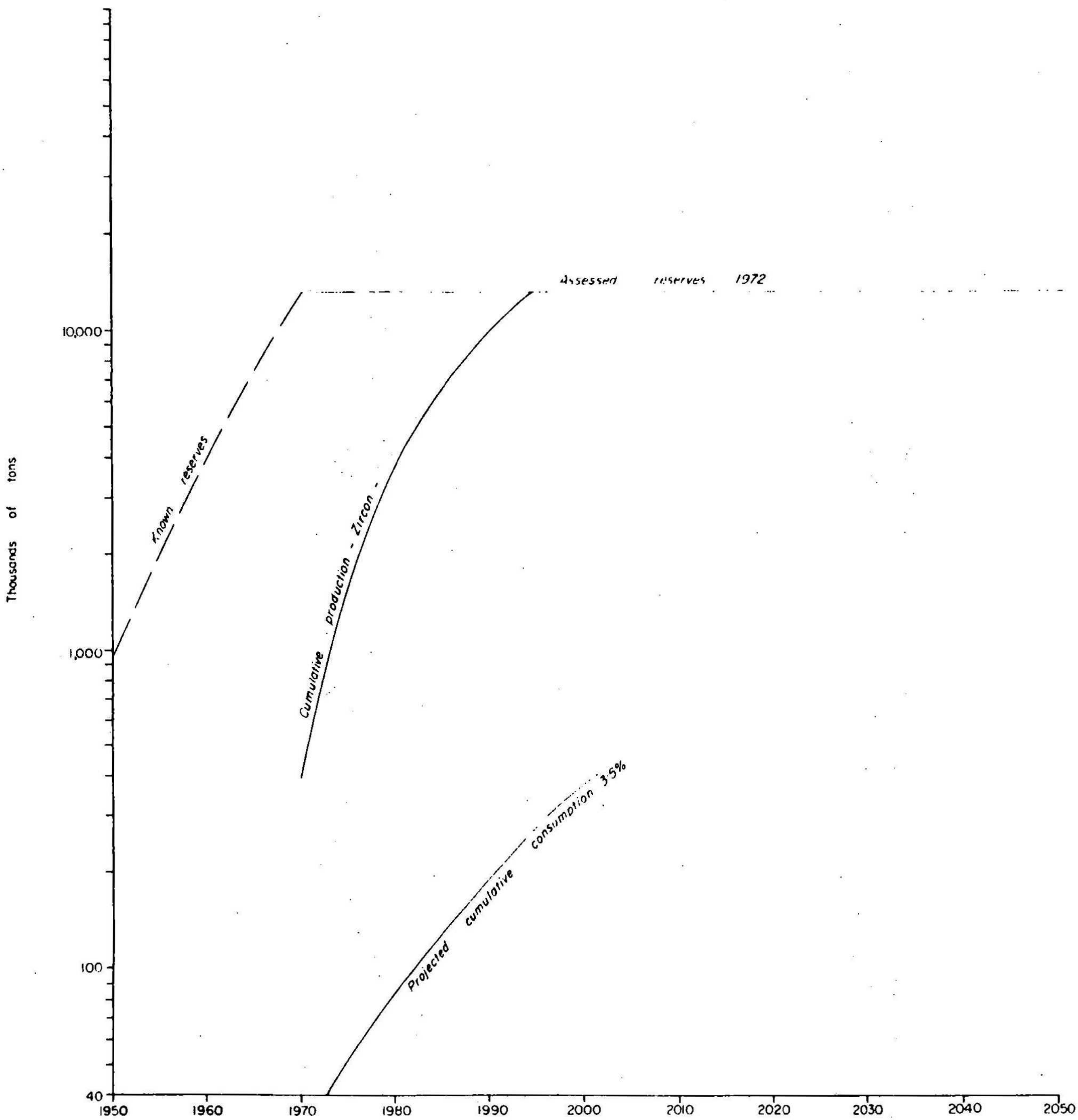

Fig 5 ZIRCON — AUSTRALIAN RESERVES AND PROJECTED PRODUCTION

To accompany Record 1972/40

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ilmenite becomes the main source (Fig. 5). Known sub-marginal resources of zircon are about 4.7 million tons, which, should they become viable, would extend the life of reserves by some 10 years.

World situation

Known world reserves of zircon based on U.S. Bureau of Mines Bulletin 650, but adjusted for current Australian reserves, stand at about 37.7 million short tons, the equivalent of about 18.9 million short tons of zirconium. World production in 1970 in terms of zirconium was about 346 000 short tons indicating an R/P ratio of 76. Consumption of primary zirconium is likely to increase to about 460 000 short tons in the year 2000, indicating an average annual increase in consumption of 2%; continued increase of consumption at this rate would exhaust known world reserves in about 47 years.

Discussion

World needs for zirconium seem to be assured for the rest of this century and beyond by known reserves, and large quantities of currently sub-marginal material would be available, particularly in the United States, if the real price of zircon rises.

As for titanium, and based on recent assessment of zircon resources, the Australian situation seems less favourable in that known reserves in Australia appear to be restricted yet are currently providing the bulk of world supply; existing reserves seem likely to be exhausted in less than 30 years on current projected rates of production and export and known sub-marginal resources, should they become viable, would add about another 10 years. However, the matter is further discussed in the Synthesis.

SYNTHESIS

This preliminary analysis emphasises the need for realistic assessment of Australian mineral resources to provide as sound a basis as possible for regularly examining mineral conservation in Australia. The many unknowns in projecting future mineral demand and availability call for careful collection and consideration of data to avoid the unnecessary problems which would stem from any unwarranted or precipitated restriction of output.

Although resources of a number of important minerals have still to be assessed, assessments have been recently completed for coal, titanium, and zircon; two other minerals, iron ore and bauxite, already have large known reserves, so that it is legitimate to analyse the data from this group of minerals in search of criteria of use in establishing levels of supply of minerals and in gauging the need for mineral conservation. Further study of the other minerals included in this report - nickel, lead, zinc, manganese, and tin - is better postponed until realistic assessment of resources is available; known reserves of all of these minerals promise life expectancies of at least 20 years, but further analysis must await realistic reserve figures.

Returning to the group of minerals worthy of present study, criteria for gauging the need for mineral conservation should first be sought and then applied in situation analyses for each of the minerals.

CRITERIA IN MINERAL CONSERVATION

Basic or derived data of possible use in gauging conservation needs include the R/P ratios and the apparent life expectancy of reserves on the basis of reserve figures and the production rates assumed for the future. These figures for the minerals concerned are as follows:

	R/P Ratio	Apparent Life Expectancy of Reserves in 1970
Iron Ore	400	50
Bauxite	450	36
Coal	260	50
Titanium	39	26
Zircon	29	24

R/P ratios have limited significance because they refer strictly to one point of time; however, they are based on firm figures with no subjective judgments involved, and a series of R/P ratios for a number of minerals over the years would at least indicate whether the reserve position relative to annual production is improving or becoming worse. Ratios for minerals from 1950 to 1970 given in Table 1 have notably increased for most materials except titanium and zircon but would have been more significant had mineral reserves been realistically assessed; such a series of R/P ratios based on assessed reserves should be useful in the future. However, R/P ratios with no link with the future can remain only a general guide to apparent availability of minerals in the years ahead.

Figures for the apparent life expectancy of known reserves, where these have been realistically assessed, are subject to many obvious reservations; they relate only to the 'known' portion of resources and are subjective in that projected rates of increase in production and the effects of improved, technology, re-cycling and substitution are largely matters of judgement. However, at present these figures are probably the most practical guide we have.

Figures for the apparent life expectancy of reserves will change with time, knowledge of reserves, and judgement of future demand; but at any one time apparent life expectancy for a number of minerals will normally provide a range - in the case of the minerals studied here from 50 to 24 years.

If we seek to use such figures as a guide it is necessary to decide at what point on the scale we become concerned in terms of mineral conservation. An apparent life expectancy of 10 years would obviously cause concern as programs of exploration for, and development and production of, new resources may well take more than 10 years to provide results. Indeed an apparent life expectancy of 20 years would in general provide little comfort and would suggest undue reliance on good fortune. On the other hand, apparent life expectancies toward the other end of the scale, say above 30 years, can only be regarded as possible minimum figures, boviously subject to many changes in the future stemming from additional discoveries, new technology, price and changes in mineral usage and substition; it would seem very unwise to base any decisions on apparent life expectancy of reserves of this order.

It is suggested therefore than an apparent life expectancy of presently known reserves of about 30 years could well be regarded as the threshold of concern in the field of mineral conservation and the point at which at least a critical review of the situation is desirable. Such a review may not call for immediate action, but it might indicate the need for a basic prospecting program or for research into treatment, mining, or substitution in which Government might well need to play a major role.

Mineral Conservation in Australia

This suggested threshold to concern about mineral conservation may now be applied to the group of minerals which have known very large reserves or for which reserves have been recently assessed.

The minerals providing over 60% of our exports - iron ore, coal, and bauxite - lie beyond the threshold and this appear to warrant no immediate concern. The situation for iron ore and coal appears satisfactory, with apparent life expectancy of reserves at 50 years, but bauxite at 36 years is worthy of note; it should be remembered that reserves of bauxite have not yet been properly assessed and that as mentioned previously the projected increase in annual production beyond 1980 of 12% is probably excessive.

However, both titanium and zircon at 26 and 24 years respectively fall within the threshold of concern and therefore warrant special review.

Rutile, ilmenite, and zircon have much in common as regards occurrence in Australia and may be discussed together. They are all currently derived from beach sand deposits from which production is cheaper than from hard rock sources, so that unless prospects for additional low-cost reserves are favourable, export of current reserves at rates likely to exhaust them in 20 to 30 years should be reviewed in relation to the future of Australian industry. A number of factors need to be taken into account. Concern for the level of known reserves mainly stems from the fact that these beach sand deposits have been found in a restricted environment, in areas where occurrences seem to be fairly well explored; some offshore resources exist but their size is only vaguely known and apparent grade does not encourage confidence in early development.

On the other hand, the recent and unexpected discovery of deposits at Eneabba emphasises the point that much fundamental consideration of possible provenance and concentration of detrital minerals away from known detrital provenances remains to be done.

Apart from possible new deposits on land, sub-marginal resources include about 2.7 million tons of rutile, 20 million tons of ilmenite, and 4.7 million tons of zircon; some of the rutile and zircon occurs offshore, where commercial mining remains a challenge, but the extent of these marine resources is not known. Furthermore, we have little knowledge as yet of our possible reserves of hard-rock ilmenite, which currently provides most of the world's reserves of titanium.

Another facet of mineral conservation is possible restriction of production and exports. As regards titanium there might be a tendency to single out rutile for conservation as the higher grade ore in apparent short supply. However, except in the case of any newly discovered deposits in remote areas, such a course would present difficulties in that most of the known ore reserves are now low-grade, requiring high throughput and economies of scale for viability; and most are situated in coastal areas where land use and conservation issues are critical, so that delays in mining could well lead to permanent loss of reserves. Mineral conservation, if required, could probably be best affected by controlling the development of new discoveries or the exploitation of presently known sub-marginal deposits as and when they become viable and possibly by encouraging in the future the processing of ilmenite to the upgraded product and this seeking to decrease the level of export of raw concentrates.

However, the situation is somewhat different for zircon in terms of price. The main use of zircon continues to be in foundries as shell moulding material, but increases in price would gradually phase zircon out of this field, except for special uses, in favour of less costly substitutes. Shortage of zircon and consequent rise in price would virtually reserve zircon for uses for which the mineral is best suited - for example zirconia for ceramic and refractory applications and the metal zirconium - where cost of the raw material becomes relatively insignificant. In such circumstances world demand for zircon would tend to fall, and even after main reserves of zircon in Australia, associated with rutile, had been largely exhausted, an adequate supply of zircon for Australian consumption could well be provided as a by-product from continued ilmenite mining.

The review of these minerals therefore suggests that there is need to widen the search for additional resources based on the fundamental consideration of provenance, transport, and concentration of detrital heavy minerals in Australia; such a fundamental investigation aimed at better knowledge of the potential for additional supplies is very necessary before considering other possible channels of mineral conservation, principally the restriction of output and exports. Moreover, added emphasis falls on those reserves currently frozen in the interests of preservation along the eastern seaboard; on present knowledge of reserves, Australia can ill afford to loose these deposits.

Finally, the suggested program of investigation for these minerals might include the following items:

(i) Fundamental investigation of provenances of beach sand deposits in Australia and the application of these and other considerations to the search for additional deposits in Australia and in Australia waters

(ii) Detailed review of offshore deposits and of problems of development and mining

(iii) Assessment of possible hard-rock sources of titanium, particularly ilmenite, in Australia

(iv) Review of occurrences and possible recovery of titanium associated with red muds produced by alumina refineries in Australia.

CONCLUSIONS

This preliminary analysis of mineral conservation in Australia has led to a number of conclusions. It is patent that the situation can only be analysed realistically for these minerals for which existing resources in Australia have been properly established; the lack of proper resource assessments for iron ore, bauxite, tin, copper, lead, zinc, and manganese is the principal reason why this present study cannot be other than a preliminary one, to be expanded as resource assessments become available.

Study of minerals for which recent resource assessments are available (coal, titanium, and zircon), together with iron ore and bauxite for which known reserves are already large, suggests that the apparent life expectancy of reserves, based on existing reserves and projected future rates of production, provides the only feasible criterion for gauging need for mineral conservation, although, because of the several unknown factors involved, the credibility of such figures becomes less and less as the period of prediction in the future becomes longer. However, it is suggested that an apparent life expectancy of existing reserves of 30 years might well represent the threshold for concern about mineral conservation and require at least some critical review of the situation.

Application of these criterion to the five minerals analysed indicates no present concern about iron ore, coal, and bauxite - the three minerals which provide over 60% of Australia's mineral exports - but suggests need for critical review of our resources of zircon and titanium minerals and for a program designed to better determine potential resources of these minerals.

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