BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

1982/21

PAPERS

PRESENTED AT

PETROLEUM AND MINERALS REVIEW CONFERENCE

1-2 JULY 1982

CANBERRA

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INTRODUCTION

The Petroleum and Minerals Review Conference was held in Canberra on 1 and 2 July 1982. A volume of abstracts was given to all registrants, and this volume of abstracts, reproduced as BMR Record 1982/12, was distributed to the BMR open file centres in all states.

The demand for copies of the papers by both registrants and people who could not attend the Conference has been so great, that the papers, or speakers' expanded notes, have been produced in microfiche form. Not all slides used in the talks are reproduced here.

The microfiche will be issued to all registrants, and may be purchased as either microfiche or hand copy from the Copy Service, Government Printer (Production), P.O. Box 84, Canberra, A.C.T. 2600.

In line with current BMR practice, these papers have not been edited, and it must also be emphasised that, in most instances, they were prepared for oral, not written, presentation.

MINERAL INDUSTRY OVERVIEW AND OUTLOOK

I.R. McLeod

The mineral industry has been an important part of the Australian economy since the middle of the last century, and it now accounts for about 5½% of the GDP and 37% of exports.

This afternoon, I am going to look briefly at the growth of the industry over the last 20 years or so, focussing on the last couple of years, consider some implications of recent events, and have a look at our mineral resource position.

I might add that the paper draws on the work of all the people in BMR's Minerals Branch.

Unless I indicate otherwise, the statistics are for calendar years, which is the world-wide basis for mineral industry statistics. You will find most of them, and a lot more, in the Australian Mineral Industry Quarterly which is in the material you have been given. Data from some of the slides I'll be showing has also been included in this material. Some of the figures I'll be using are a little later than those in the publication.

Until the mid 1960s, the Australian mineral industry was based on six commodities - lead, zinc, copper, silver, gold, and black coal. In 1965, these six made up 64 per cent of the value of mine production, which then was $542M. In 1981, it was about $7600 million.

The industry began to expand rapidly in the mid 1960s.

While production of the traditional six commodities increased, especially coal production, the expansion was accompanied by diversification; mineral sands, iron ore, bauxite, nickel, tin and uranium have been added to the list of major value mine products, and production of many other commodities such as tungsten, manganese, cobalt, and gem stones has increased several fold.

In fact, the traditional six now account for only 44 per cent of the total value of mine production, and black coal makes up nearly two-thirds of that 44 per cent. But an interesting point is that, in terms of annual value of production, construction materials - that is, humble stone, sand and gravel - still rank highly: fourth in 1980, after coal, iron ore and lead.

Australian consumption of minerals has increased also over the last 20 years or so, but much of the additional production has gone to exports.

Exports of all commodities have increased, except in 1981; three, coal, iron ore, and alumina and aluminium, have increased much more rapidly than the others.

The value of exports of mineral primary products increased from $308 million in 1965 to $7 034 million in 1981. In constant dollars, the value of 1981 exports was nearly 7 times the value for 1965. The figures for exports and imports include metals in refined and semi-refined form, so they are not strictly comparable with the figures for mine production.

TABLE 1

PRODUCTION AND EXPORTS 1981

COMMODITY	PRODUCTION TONNES	% EXPORTED
BAUXITE	25.5×10^6	22
BLACK COAL	111.7×10^6	46
COPPER	224.4×10^3	55
GOLD	17.60	42
IRON ORE	84.7×10^6	84
LEAD	393.1×10^3	87
MANGANESE ORE	1409.4×10^3	64
MINERAL SANDS	2.02×10^6	78
NICKEL	74.5×10^3	95(e)
TIN	12.15×10^3	72
ZINC	517.12×10^3	81

TABLE 2

PRIVATE MINERAL EXPLORATION

EXPENDITURE

($ Million)

Sept. '80 - Mar, '81 qtrs	283
June '81 qtr	111
TOTAL 1980-81	434
Sept. '81 - Mar, '82 qtrs	344
June '82 qtr (expected)	119
TOTAL 1981-82 (expected)	463

The pattern of exports has changed also, like the pattern of production. The proportions of lead, zinc and copper of total mineral exports have fallen, and coal, iron ore, and alumina and aluminium have increased.

The pattern of destinations of mineral exports has changed also. The most obvious long term changes are the percentage growth of the Japanese market and fall of the United Kingdom.

The value of imports increased from $305 million in 1965 to $2 372 million in 1981. In constant dollar terms, 1981 imports were 2½ times those of 1965. Crude oil is still the major import item, accounting for 64 per cent of the total in 1965 and 85 per cent in 1981.

To put it another way, in 1965 the values of imports and of exports were about equal.

In 1981, there was a favourable trade balance in minerals of $4.7 billion. (Fig. 1.)

In some ways, the mineral industry has suffered from its very success. It is now very export-dependent, and because of this its health depends on world economic conditions, not just the state of the Australian economy.

Just to illustrate (Table 1), over half the mine production of most of our major commodities is exported, the most export dependent one being nickel, with an estimated 95 per cent of mine production going overseas.

And of course a lot of bauxite eventually goes overseas in the form of alumina or aluminium.

Up to now, I have included petroleum (that is, crude oil and natural gas) in the statistics. From here on I won't be considering these two - I'll leave that to John White, who will be speaking shortly.

Let's look briefly at the extent of mineral processing in Australia. (Fig. 2.)

The PPI, or Production Processing Index, is the percentage of the mineral commodity mined in Australia, that is processed in Australia in some way - such as copper concentrates to blister copper or refined copper, or bauxite to alumina.

The EPI, or Export Processing Index, is the percentage of total exports of a mineral commodity that is exported in processed form - rather than as ore or concentrates. The extent of processing of lead, zinc, copper (all traditional minerals) and tin is high. It is interesting that the level for two newcomers, nickel and aluminium is also high. Nickel processing was initiated so that the company could break into world markets which were held at the time by three or four well established companies. One reason for the high level of processing of bauxite is that the grade of Darling Range bauxite is too low for it to be exported. It must be converted to alumina. And the special mining lease requirements imposed by Governments were also a factor in the establishment of processing facilities for bauxite.

TABLE 5

EXPORTS OF MINERAL PRIMARY PRODUCTS
($ million)

Total, 1980	6 861
excluding coal	5 173
Total, 1981	7 034
excluding coal	4 733

TABLE 6

IMPORTS OF MINERAL PRIMARY PRODUCTS
($ million)

Total, 1980	2 157
excluding petroleum	423
Total, 1981	2 372
excluding petroleum	361

TABLE 7

PROJECTED DEPLETION OF DEMONSTRATED ECONOMIC RESOURCES

COMMODITY	DER (TONNES)	AUST CUMULATIVE PROD 1982-1991 (TONNES)	% DER DEPLETED 1991
IRON ORE	15.5×10^9	1.1×10^9	7
BLACK COAL (recoverable)	29.5×10^9	1.3×10^9	4
BAUXITE	2.7×10^9	382.2×10^6	14
NICKEL	2.2×10^6	1.1×10^6	50
URANIUM	294.0×10^3	92.0×10^3	31
COPPER	5.8×10^6	2.4×10^6	41
LEAD	17.9×10^6	4.8×10^6	27
ZINC	26.6×10^6	6.8×10^6	26
TIN	215.6×10^3	149.6×10^3	69
MINERAL SANDS	65.9×10^6	19.1×10^6	29
CRUDE OIL	$266.8 \times 10^6 m^3$	$257.6 \times 10^6 m^3$	97
NATURAL GAS	$501.2 \times 10^9 m^3$	$231.1 \times 10^9 m^3$	46

The rapid expansion of the late 1960s and early 1970s slowed down in the late 1970s with deterioration of world economic conditions. The index of mineral production was the same in 1980 (the last year for which data is available) as it was in 1979. And probably it actually fell in 1981, although we don't have 1981 final data. The estimated value of mine production in 1981 increased by less than 2% from $7 436M in 1980 to about $7 600 million in 1981. In 1981, the only commodities whose production - that is, the quantity of production - increased to any extent were black coal, uranium and zinc. Black coal production increased, even allowing for industrial problems in the previous year, because of the continued demand for thermal coal, especially in the earlier part of the year. Uranium increased because production began at the Ranger deposit, and zinc increased with the beginning of production at Que River in Tasmania and Teutonic Bore in Western Australia.

At the smelting and refining level, aluminium production increased with increased capacity at all three smelters operating in 1981 - Port Henry, Bell Bay and Kurri Kurri. Refined copper production also increased. On the other hand, mine production of bauxite, copper, iron ore, manganese, rutile, zircon and silver all fell substantially.

We don't have sufficient statistics yet to compare 1982 with 1981. However, it seems safe to say that, on the whole, 1982 won't be any better than 1981. It does seem clear that production of some mineral commodities will be less. These include bauxite, manganese, tungsten, and tin, at least.

On the brighter side, gold production could be 10 per cent or more higher in 1982 than in 1981. Several mines began production in late 1981, and these probably will continue to operate - unless perhaps the gold price goes down even further.

Exports in 1981 reflected the trends in production.

I referred to this downturn earlier on.

The value of exports (Table 5) increased by only 3 per cent - i.e. actually fell in constant dollar terms. If black coal is excluded the value of mineral exports, in fact, fell by 8 per cent in 1981 in current dollar terms.

If we look at the quantities exported in 1981, the only substantial increases were of aluminium, coal and uranium. Coal and uranium I have already referred to. The quantity of aluminium exported in 1980 was unusually low because of large domestic demand, and aluminium exports in 1981 were only a little more than those in 1979.

The quantities of copper and tungsten exported increased slightly, but exports of other major commodities fell, especially iron ore, steel and ferroalloys, mineral sands, salt, and zinc.

The value of imports of mineral commodities in 1981 (Table 6) increased by 10 per cent. This increase was more than accounted for by the increased cost of crude oil imports. If crude oil is excluded, the value of imports fell by 15 per cent in current dollars. The main falls were in gem and industrial diamonds, gold, ingot steel and ferroalloys, and nickel (whose value has changed irregularly over the years). Gold imports were abnormally high in 1980 and imports in 1981 were comparable to those in earlier years.

TABLE 3

AUSTRALIAN METAL PRICES

($A)

ANNUAL AVERAGE

	1979	1980	1981	End of 1981
Aluminium (t)	1161	1502	1501	1370
Copper (t)	1767	1959	1536	1460
Gold (oz)	266	547	407	357
Lead (t)	1031	843	663	650
Nickel (kg)	5.4	6.7	6.6	6.3
Silver (kg)	519	616	299	232
Tin (t)	14517	15441	13363	15028
Zinc (t)	713	713	799	847

TABLE 4

AUSTRALIAN METAL PRICES

($A)

	End 1981	End May 1982
Aluminium	1370	1370
Copper	1460	1440
Gold	357	310
Lead	650	650
Nickel	6.3	6.8
Silver	232	216
Tin	15028	13428
Zinc	847	824

At this time we don't have enough statistics to see any clear trend in 1982 in exports and imports.

Current prices present a pretty dismal picture. It is hard to generalise because of changing currency parities, but broadly, prices of mineral commodities were going up (in current dollars at least) or were relatively stable for the four years to 1980.

In terms of average prices (Table 3), 1980 was a good year. However, 1980 averages were held up by high prices - record prices for some commodities - early in the year, and actual prices for a lot of commodities were on a downward trend by the middle of 1980.

The result of this was that 1981 was rather different to 1980.

These are the averages of the Australian prices, which are also a measure of what exporters would receive, even if their product was priced in other currencies.

There is no published Australian price for nickel. The nickel prices in the table were obtained by doing a straight conversion from US to Australian dollars of the end of the month INCO price.

The prices are per metric tonne except for gold, which is in ounces, and nickel and silver, in kilograms.

If we take average prices for the calendar years, the only major commodities whose price was higher in 1981 than in 1980 were nickel, zinc, coal and iron ore.

I've not shown coal and iron ore in the table. Their pricing arrangements are different to those of most of the other major commodities, and it is difficult to calculate averages. However, contract prices for both were higher in 1981 than in 1980.

Although the quoted nickel prices increased, it is a moot point whether actual prices increased, because there was extensive discounting going on.

The zinc price held up despite weak demand for the metal because of the demand for concentrates by those smelters who do not have captive suppliers.

Despite some excitement in the tin markets, the average Penang tin price in 1981 was just below the 1979 average. In fact, the only major commodities whose average price in 1981 was higher than in 1979 were coal, iron ore, nickel and zinc, plus gold and aluminium.

Averages are rather misleading, however. The price for most commodities trended downwards in 1981.

And 1982 didn't see any improvement (Table 4).

At the end of May, if we leave aside coal and iron ore, whose prices are determined annually, prices of all major commodities except 3 were less than they were at the end of 1981. Two, aluminium and lead, were the same. The nickel price appears to have risen, but this is because of the falling value of the Australian dollar against the US dollar. The quoted producer price didn't change.

And this trend has continued since this slide was prepared.

Today's aluminium price is the same, and tin and gold about the same, as they were a month ago. But the MIM copper price is now $1 260, although this is $20 more than it was yesterday. Lead is down to $600 and EZ's prime western zinc price to $796. And silver is $171 a kilogram.

The fall in prices has lead to a complete turn around in profitability. Mining company profits generally were good in the 1979/80 fiscal year but a lot of these profits were made largely in the first half of the year, that is, in the December 1979 half year.

1980/81 was not nearly so good.

According to the AMIC annual surveys the effective after-tax return on average funds employed by the respondents fell from 14.6% in 1979/80 to 8.5% in 1980/81. Of the respondents who were actual producers, 24% made a loss in 1980/81 compared with 11% in 1979/80.

As you all know, many companies especially in metalliferous mining have reported losses for the December 1981 half. One result has been retrenchments by a number of companies, and other companies are not replacing people who leave.

Another victim of the reduced profitability has been mineral exploration.

This slide (Fig. 3) shows total private expenditure on mineral exploration in current and constant dollars, and private expenditure on other than production leases, which is a measure of the effort put into finding new mineral deposits. In addition, Government expenditure over the years has been roughly 10 per cent of total private expenditure - although it was only 6 per cent in 1980/81. The data are for minerals only, excluding petroleum and oil shale.

As you can see, total private expenditure has increased in the last few years in both current and constant dollar terms. In fact, it doubled in real terms in the five years to June 1981, and several important or potentially important deposits were discovered in this period, including the Taronga tin deposit, Benambra base metals, Parkes copper, and coal in South Australia and Western Australia.

In 1980/81 total private mineral exploration expenditure was $435 million. This was not quite a record in real terms - it was a little less than 1970/71 expenditure.

In the first three-quarters of 1981/82 (Table 2), total private expenditure was $344 million. For the same period of 1980/81, it was $283 million, so expenditure has gone up in real terms.

ABS statistics indicate that expected expenditure in the June quarter just finished would be about $119 million, 17% more than in the previous June quarter.

However, it is unlikely that this figure will be reached.

In fact, the indications are that exploration, especially for metals, is being cut back quite drastically. Some major companies have announced reductions in exploration effort - one is cutting back by 25% in real terms this year and a further 10% next year. Another company has closed down its entire exploration department; and these are not the only ones.

So while total figures for exploration in 1981/82 might look good they certainly do not reflect current exploration levels.

The reason for the cut-backs is that, with low metal prices and high interest rates, companies are looking very hard at all activities which are not producing a cash flow. It seems likely that exploration expenditure and effort will fall as companies complete their work commitments and don't take up new projects.

And exploration probably will continue to fall until mineral commodity prices increase substantially and improved profitability brings a greatly increased cash flow.

However, I believe that expenditure is unlikely to fall to the levels of the early 1970s.

With reduced exploration, there is less chance of finding new ore bodies to replace the resources now being mined.

What effect will this have on Australia's ability to meet long-term demand for its minerals?

This brings us to mineral resources.

BMR has been monitoring Australian resources of minerals for some years, and you will find a table giving our latest estimates in the Australian Mineral Industry Quarterly, Vol. 34 No. 4.

We use the McKelvey classification and in this context the important category is demonstrated economic resources. These are resources in deposits where the tonnage, grade and outlines of the ore body are known well enough to allow mining to be carried out or planned, and which can be economically worked.

There are a number of ways of looking at the adequacy of resources to meet demand. All of them have shortcomings of various kinds and I am not going to go into these.

One approach is to project production of a commodity over say, the next 10 years and see what impact this production has on the total current demonstrated economic resources of the commodity.

Table 7 shows current demonstrated economic resources, the aggregate projected production for the next 10 years and the percentage of current demonstrated economic resources this production accounts for, disregarding treatment losses. The resource totals except for coal, and of course, for crude oil and gas, are for in situ resources. The coal total is for recoverable raw coal.

So what we are saying is that in ten years time, 7 per cent of our current demonstrated economic resources of iron ore will have been mined. That is, 93 per cent of them will still be left. We will still have 96 per cent of our black coal, 86 per cent of our bauxite, and so on.

As you can see, resources of iron ore, bauxite and probably coal are clearly sufficient for many years.

For mineral sands, lead, zinc, and uranium, a quarter to a third of the resources will be extracted in the next 10 years, so resources of these are likely to be adequate into the next century.

Current demonstrated economic resources of nickel and tin will be gone by the end of the century and much of the copper will be mined by then.

However, for tin, at least, there are large inferred resources, that is, resources which have not yet been tested sufficiently to be classed as demonstrated.

And there are large resources of copper, nickel and tin which are not economic at present and which could become economic with some increase in prices relative to costs.

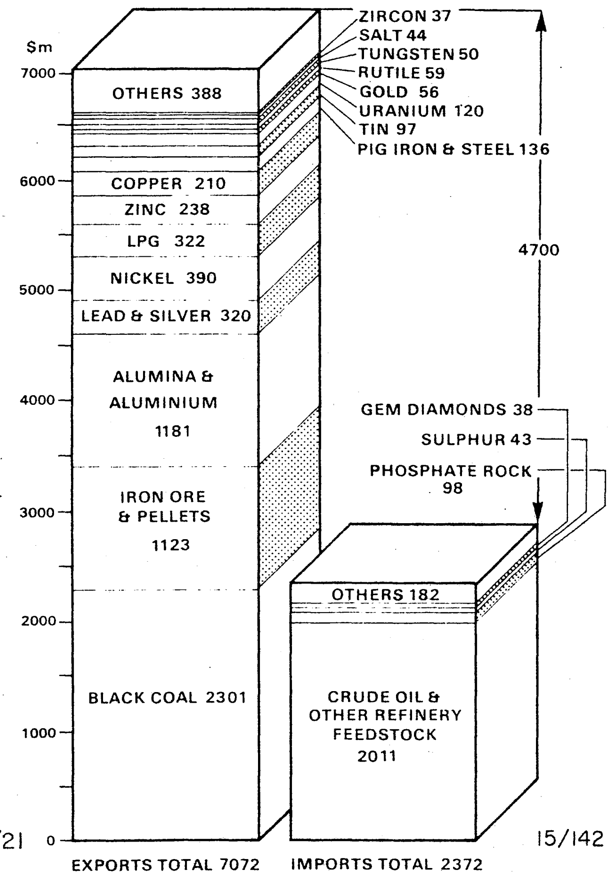
A weakness of this approach is that we are forecasting production but using present demonstrated economic resources - we are assuming there will be no additions to demonstrated economic resources, which history suggests is an unlikely assumption. Of course, if costs go up much more than prices, there may be losses from the demonstrated economic resources because deposits become uneconomic.

So these figures must be regarded as indicative only.

So, although the situation for some commodities needs to be watched, and you will be hearing more about some of these later in this conference, on the whole, our resource situation is not bad in the short to medium term at least.

Clearly, present circumstances in the mineral industry are not good, and they are likely to stay that way until prices increase and interest rates come down, that is, until the world economy improves.

It is not clear when this is going to happen. However, the Australian mineral industry has underlying strengths and provided the present downturn does not last for too long and provided Australian costs do not get out of line with those in other countries the industry will remain well placed to compete in world markets when price increases do occur.



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AUSTRALIAN BALANCE OF TRADE, MINERAL PRODUCTS, 1981

Fig.1

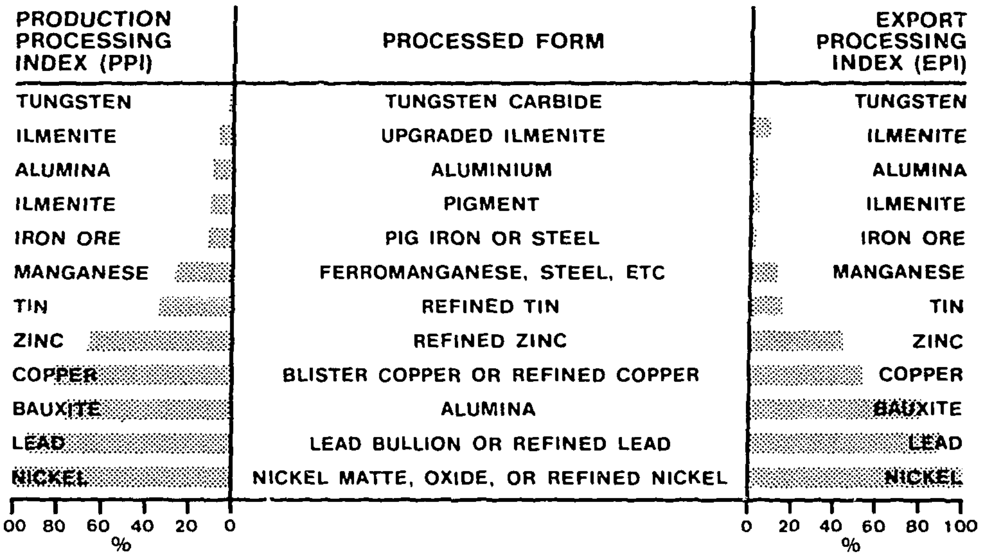

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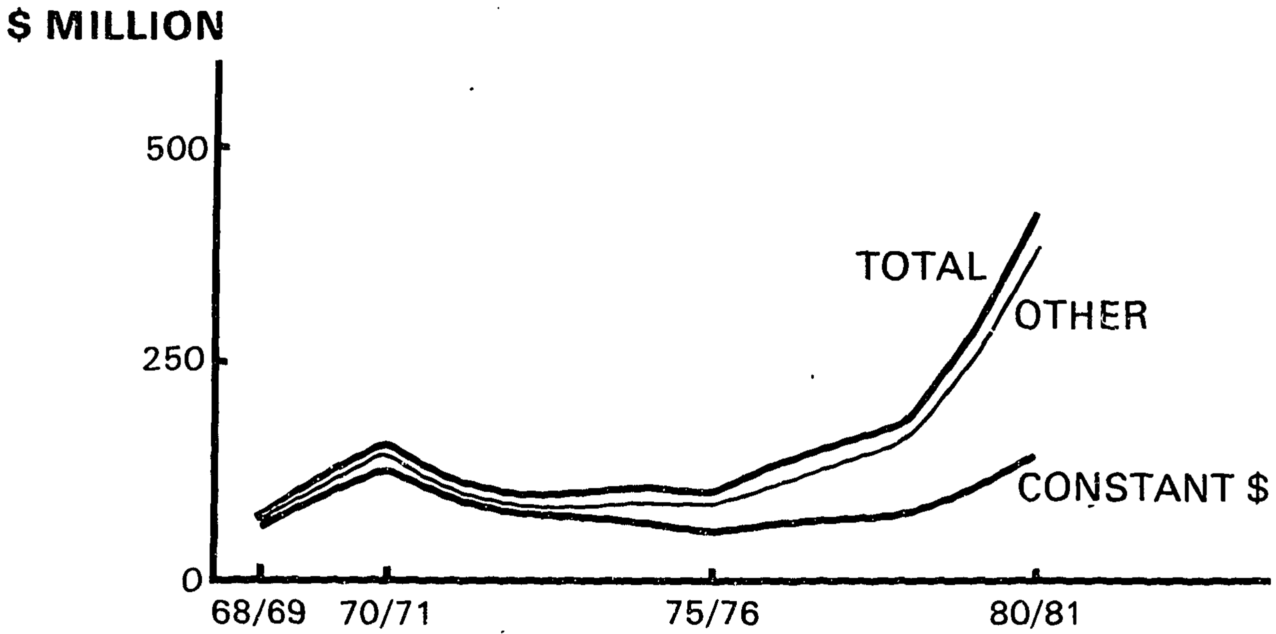
Fig. 2

PRIVATE MINERAL EXPLORATION EXPENDITURE



Record 1982/21 Fig.3 15/99

PETROLEUM EXPLORATION AND DEVELOPMENT IN AUSTRALIA

J.A.W. White

On 29th November 1839, Commander John Lort Stokes of Her Majesty's Ship Beagle inspected some water wells put down by the ship's crew on the east side of Water Valley in the Queens Channel, Victoria River. A sample collected from a depth of 23 feet was described as "a bituminous substance" which, after drying, "ignited quickly when put into the flame of a candle". Such was the first discovery, or was it, of petroleum on the mainland of Australia.

Some sixty years later, shows of oil and gas had been reported from wells drilled for water in the Great Artesian Basin in Queensland and in 1900 Roma's town water bore No. 2 discovered natural gas while being deepened to increase its water flow. The gas flowed freely for some four years, and in 1906 was reticulated to the town for lighting. However, the flow diminished suddenly after 10 days and the lighting scheme had to be abandoned.

Another well was commenced in 1907 and in 1908 struck gas which caught fire. The fire was extinguished with difficulty after it had been burning for 6 weeks, but the well had to be abandoned because of tools lost down the hole.

By 1908 then we had already seen our first discovery, blowout, fire and commercial production, albeit the latter somewhat short-lived.

Sporadic exploration took place in most of the States over the next forty-five years or so, but without any significant discoveries until the newly-formed company, West Australian Petroleum Proprietary Limited, discovered oil with their first well, Rough Range No. 1, in 1953, drilled at a site selected on the results of regional geological and geophysical work done by BMR and a detailed seismic survey by WAPET.

The well flowed at a rate of 550 barrels of oil a day on test but fifteen additional wells drilled in the near vicinity, all proved to be dry.

One consequence to this discovery was a rapid revival of interest in petroleum exploration in Australia. Almost all the areas (Fig. 1) of sedimentary basins, and some basement too, were taken up in exploration titles and in the next four years about 80 wells were drilled.

The new exploration, in spite of the introduction of relatively modern equipment and methods, was not immediately successful but from 1960 onwards a series of small gas discoveries were made in the Roma area. More importantly, Australia's first commercial oilfield was discovered at Moonie in 1961. Encouragement from this discovery and from the Government's Petroleum Search Subsidy scheme introduced in 1957 led to a marked surge in activity and a series of discoveries - Barrow Island oilfield in Western Australia, Gidgealpa and Moomba gas-fields and Tirrawarra oilfield in South Australia, Mereenie oilfield and Palm Valley gasfield in the Northern Territory, North Rankin gasfield offshore Western Australia, and Barracouta and Marlin gasfields and Halibut and Kingfish oilfields in Bass Strait, offshore Victoria.

Exploration activity decreased substantially in the period 1972 to 1977. This was brought about by a combination of factors, including the relative lack of follow-up success of the discoveries of the decade before.

Increased world and hence Australian crude prices, an attractive policy with regard to pricing, the adoption of much improved geophysical techniques, and a better understanding of the geological factors governing petroleum accumulation have led to a dramatic increase in exploration activity since 1977; the last two years in particular demonstrating a sharp rise in exploration effort.

The results of this past exploration now see Australia more than 60% self-sufficient in crude oil supply with three producing areas - Moonie, Barrow Island and the Gippsland Shelf - shortly to be joined by a fourth, the Moomba area fields in South Australia. All State mainland capital cities are now supplied with natural gas from one of the four producing areas - Roma, Gippsland Shelf, Moomba, and Dongara/Woodada. A fifth gas producing area, the Northwest Shelf, is due to come on stream in 1984.

The graph (Fig. 2) showing the number of active exploration drilling units gives an indication of the rise and fall in activity over the years. The boom in 1964 which resulted in so many discoveries (Fig. 3) is well illustrated. After that it looked as if the Australian exploration industry was doomed to terminate with a precipitous fall before bottoming out around 1976. After that date we saw first a gradual and then a steep rise to the high level of exploration activity we can see today with some 29 units drilling onshore and 11 units operating offshore. A similar (Fig. 4) pattern is shown for metres drilled, although there are some variations due to changes in average depths of wells. These changes are generally caused by the larger numbers of relatively shallow wells drilled on Barrow Island and in the Surat Basin. Seismic activity has also varied considerably although there has always been a lag between this activity and the following up drilling activity. (Fig. 5)

The expenditure on exploration and development shows the same story. Dollars are actual, with no allowance for inflation. (Fig. 6)

About two-thirds (4.3 million sq. km) of continental Australia is covered by sedimentary basins. In addition Australia's immense continental margin is mostly of sedimentary origin. (Fig. 7)

Let me take you on a tour of Australia.

Queensland is the logical place to start as it is easily the most thoroughly explored State - although perhaps by world standards it is still in a state of exploration immaturity.

Back in 1958, the BMR ran a seismic survey east from Glenmorgan to examine whether Permian sediments of the Bowen Basin might extend into this area below the Mesozoic sediments of the Surat Basin. A large section of sediments was indicated with a large positive structural anomaly near Cabawin. This lead was followed up by Australian Oil & Gas Corporation and its overseas partners who defined a drilling target by means of detailed seismic surveys. In 1961 Cabawin No. 1 was drilled, discovering a wet-gas reservoir which is now producing substantial quantities of condensate. This discovery was quickly followed by the important oil discovery Moonie No. 1. Several successful assessment and extension wells on the structure resulted in a decision to put the field on production and in 1964 oil started flowing down an 8 inch pipeline to the Brisbane refinery - the first sustained commercial production of oil in Australia. I should add that intermittent production of oil from shafts at Lakes Entrance in Victoria had occurred between 1930 and 1941. A total of 3060 barrels of oil was produced by this means (ie about 20 minutes of Esso/BHP's current production).

In the Roma area, several small gasfields had been delineated and in 1969 the first sustained production of natural gas to a State capital took place, in this case Brisbane.

Other gasfields were discovered in the Rolleston area but due to their relatively small size, and distance from a pipeline, these were not developed. It is of interest that the opening up of markets via the oil pipeline from Moonie, the gas pipeline from Roma and a mini-refinery also at Roma provided a great boost for exploration in the area.

The recent discovery of oil at Jackson and Jackson South in sediments of the Eromanga Basin some 700 km to the west of Roma leads one to speculate that in the event of the construction of a liquids pipeline between Jackson and Brisbane this could well further stimulate exploration for oil in the area between Moonie and Jackson - a vast area.

Further north, several companies are actively exploring the Galilee Basin, following up on a show of oil in the Lake Galilee No. 1 well many years ago.

Interest is also being shown in exploiting the potentially vast but untapped gas resources tied up in the coal measures of the Bowen Basin and in some of the very low permeability sandstones known to contain natural gas.

Offshore Queensland there has been little activity. Some six wells have been drilled with little encouragement. Since 1969 there has been a moratorium on drilling on the Great Barrier Reef and surrounding areas.

Turning to New South Wales, exploration can only be described as sporadic. Currently there are active exploration programs in progress in the State which one hopes will lead to the success which has so far proved so elusive.

In Victoria, a strong gas flow was encountered while drilling Port Campbell No. 1 in 1959. Follow-up drilling proved unsuccessful but 20 years later Beach discovered significant quantities of natural gas at North Paaratte and later gas was also discovered at nearby Wallaby Creek and Grumby. No production plans for these fields have been announced.

Australia's first offshore well, Esso Gippsland Shelf No. 1 - later renamed Barracouta 1 - was spudded-in on 27 December 1964 using the drillship Glomar III. On 18th February 1965, at a depth of 4321 feet the well encountered natural gas in no uncertain manner. This drill vessel, small and ill-equipped by to-day's standards, discovered in subsequent wells in the area, Marlin gasfield and two giant oilfields Halibut and Kingfish. Indeed this vessel found more oil than all other drilling rigs in Australia combined. The discoveries by Esso/BHP were quickly developed, first production of gas being in April 1969 and of oil in October the same year.

These Bass Strait discoveries gave an enormous boost to Australia's crude oil reserves. Production rose rapidly to a figure of around 400 000 barrels a day - a flow rate which has now dropped slightly and which is forecast to drop considerably in about five years time as Kingfish and Halibut become depleted. Production from new fields such as Fortescue, South Mackerel, Tuna and Cobia will help to cushion the reduction but none of these fields is of the same magnitude as the first two. Exploration is continuing in the area, with some success - discoveries in the last year or so included oil at West Seahorse and Yellowtail and gas at Baleen and Sperm Whale. In the Bass Basin, the lack of success in the recently drilled Pipipa well has been yet another disappointment in this Basin. The Pelican gasfield in Tasmanian waters does not appear to warrant development at this stage because of, inter alia, technical problems associated with the abnormally high pressure of the gas.

South Australia was the site of the first well in Australia drilled expressly as a petroleum exploration venture. This was in 1892 at Alfred Flat in The Coorong area. After several early disappointments, Gidgealpa No. 2 discovered a major gasfield in early 1964. This was shortly followed by the discovery of an even larger gasfield at Moomba upon which a decision was made to construct a gas-plant at Moomba and a pipeline to Adelaide. Gas first started flowing to Adelaide in November 1969. Several more gas discoveries were made in this area of the Cooper Basin and a decision was made to market natural gas from Moomba area fields to Sydney - this pipeline was completed in late December 1976.

Exploration offshore South Australia has been somewhat sparse, with little encouragement.

I mentioned earlier the flurry of excitement caused by the discovery of oil at Rough Range. Exploration activity in Western Australia continued but at a somewhat low level until one week in July 1964, two discoveries were made. On Barrow Island, the No. 1 well produced a strong flow of oil from the Jurassic while on the mainland, Yardarino No. 1 produced on test some gas and a very waxy oil from a Triassic reservoir. These wells were the 93rd and 94th exploratory wells drilled by Wapet. Barrow Island was declared commercial in May 1966 based upon intensive development of the Windalia reservoir. There are now more than 600 wells on the island and an active exploration and development program is in progress with the aim of maintaining production rates at current levels for many years to come. The initial success at Yardarino proved frustrating until the discovery of gas at nearby Dongara. This field, and later Mondarra and Gin Gin were developed and a pipeline constructed to supply gas to the Perth area commencing in October 1971.

In more recent times the discovery of oil at Blina in the Canning Basin some 100 km east of Derby, has certainly upgraded the petroleum prospects of this large basin. An evaluation program in progress will, one hopes, enable firm plans to be made for transportation of this oil to a market.

Offshore, very large gasfields have been identified on the Northwest Shelf and one of these, North Rankin, is currently being developed, initially to supply gas to the Perth market and later to process gas onshore at Withnell Bay for conversion to LNG for the Japanese market.

Other major gas discoveries have also been made at Spar, West Tryal Rocks, Gorgon, Scott Reef, North Scott Reef and Tern. On the Exmouth Plateau substantial volumes of gas have been discovered at Scarborough and Vinck, but in water depths of around 1000 m, precluding any possibility of commercial production for many years to come. Oil has been discovered offshore Western Australia at Eaglehawk and at Goodwyn No. 6 well.

Lastly, let us turn to the Northern Territory. In 1964, that magic year, oil and gas were discovered at Mereenie in the Amadeus Basin. Mereenie No. 1 blew out in spectacular fashion and was killed and plugged successfully. Assessment of the Mereenie oilfield is currently in progress.

Palm Valley gasfield was discovered one year after Mereenie; plans have been announced to develop Palm Valley in order to supply the local Alice Springs market with natural gas for power generation.

Currently there is a marked upsurge in exploration activity in several of the sedimentary basins within the Territory. Recently significant quantities of gas were encountered at Dingo No. 1 and the current high level of geophysical exploration activity should be reflected by an increased drilling activity in the next year or so. Offshore, a major gas discovery was made at the Petrel No. 1 location . This well blew out in May 1969 and took some 18 months to bring under control. Other offshore gas discoveries have been made at Sunrise and Troubadour. An oil discovery at Puffin is still being evaluated.

At this point I would like to discuss offshore exploration and production. The technique of drilling and producing in water depths down to about 300 metres has now become fairly standardised throughout the world. For deeper waters, anchoring a mobile drilling unit becomes more and more difficult and dynamic positioning is the means by which drilling vessels, whether ship-shape or semi-submersible, are maintained on location within very close tolerances in spite of adverse weather and oceanographic conditions. Input from these sensors is fed into an on-board computer which, in turn, controls thrusters mounted on the vessel's hull. Several wells have been drilled using this type of positioning around Australia, including all those drilled on the Exmouth Plateau.

When it comes to production, there are theoretically several means of accomplishing this in deep water although it should be pointed out that the deepest production currently anywhere in the world is only some 300 metres.

One possible solution to the problem for deep-water production of oil is the use of a sub-sea manifold connected to a floating production station - there appears to be no reason why such a theoretical concept should not eventuate provided that large enough reserves of oil are discovered. Hardware to back up this study is being developed by several companies; indeed a prototype production manifold such as this is about to be installed in relatively shallow water at Cormorant in the North Sea. One hopes to see at least some deep-water production established somewhere in the world in the not too distant future.

Deep-water gas production is another matter, mainly because of the very large technical problems and the high cost of processing gas to transform it into an easily transported fluid once it has been brought to the surface. None of these difficulties is insuperable and Australia could be one of the first countries in the world to see such development, although I would like to make it clear that such development cannot be envisaged for some considerable time.

There are three factors influencing the level of petroleum exploration that I would now like to expand upon.

Firstly the science and technology of exploration. Secondly the question of incentives, and thirdly the influence of production facilities on exploration.

In the early days of exploration in Australia, a ratio of around one well in a hundred discovered significant petroleum : in fact, two hundred wells were drilled before any discovery was made at all. Nowadays a success ratio of around one in four is being achieved. There is obviously more than one reason for this dramatic change but I believe that possibly the most important is the application of new science, new technology and new thinking. Early wells were located on hunches as much as on known structures and frequently little or no preliminary geological or geophysical work was done to delineate a drilling prospect. The BMR played its role in carrying out basic geological and geophysical surveys which assisted enormously in providing a basis upon which explorers could operate. I have already mentioned the BMR's work leading to the Cabawin and Moonie discoveries in Queensland : I should also like to mention the BMR aeromagnetic survey in Bass Strait which indicated that a thick sequence of relatively young sediments was overlying basement in this area. Nowadays we see the use of satellite imagery, three-dimensional seismic reflection surveys and other sophisticated tools providing a far better indication of geological structure. Petroleum chemistry is providing information regarding the generation of hydrocarbons - this is enabling explorers to focus in on the oil-generating horizons if it is oil rather than gas that is being sought. Analysis of canned cutting head space gas is proving to be a powerful and cheap tool in providing vertical and horizontal maturation profiles within any particular basin.

These new tools are proving of immense value but let us not forget the importance of the basic geological data - one hopes that it is not just the wellsite geologist who examines the cores and cuttings.

On the subject of incentives, it is stating the obvious that price is the most important incentive of all. One now has in Australia, an attractive policy with regard to pricing.

This policy is well established and as recently as 4 May this year , our Minister reiterated that "the stimulation of petroleum exploration and development activity in Australia continues to be one of the Commonwealth Government's major energy policy objectives". I will not attempt to cover other incentives to exploration except to mention one which one hears little about these days. One of the welcome legacies of the Government's Petroleum Search Subsidy Scheme was the provision of data - made available to the public six months after completion of field operations. These data covering 976 geophysical and 654 drilling operations are still eagerly perused by explorers and are proving invaluable.

Finally I would like to briefly examine the influence of production facilities on exploration. This may seem to be a contradiction - the cart before the horse so to speak, but experience has shown that the provision of production facilities can provide an enormous stimulus to exploration, enabling the fruits of success - whether oil or gas - to be marketed and hence providing a cash flow to pay-off exploration costs with little delay. One example of this I have already mentioned : the Roma gas pipeline to Brisbane and the Maranoa mini-refinery at Roma. Up until a couple of years ago, some 75% of mainland onshore exploration drilling was within a 200 km radius of Roma, in spite of the fact that this area contains only some ¼ of 1% of Australia's crude oil reserves and ½ of 1% of our natural gas reserves.

Construction of a liquids pipeline from Moomba to Stoney Point and a gas pipeline from Withnell Bay to Perth is now in progress. Planning for production facilities are also in an advanced stage for

Palm Valley gas (for the Alice Springs market), Mereenie oil (for a mini-refinery at Alice Springs) and Blina oil. It is to be hoped that these new market outlets for petroleum will provide a strong incentive for explorers in these areas.

I believe that we have now reached a new, and more mature phase, in the history of petroleum exploration and production in Australia. A number of companies now have a strong and stable cash flow from production which is being reinvested into exploration - this contrasts strongly with just a few years ago when only a few companies were producing petroleum. In addition, we are seeing now the installation of more production facilities in various parts of Australia, providing a ready outlet for any new oil or gas discoveries. The combination of these two should ensure that although we may have temporary fluctuations in activity, these will not be so extreme as in the past and there will always remain a steady base level of exploration. The new exploration techniques introduced over the past several years should assist in ensuring a continuing high success ratio for wildcat drilling.

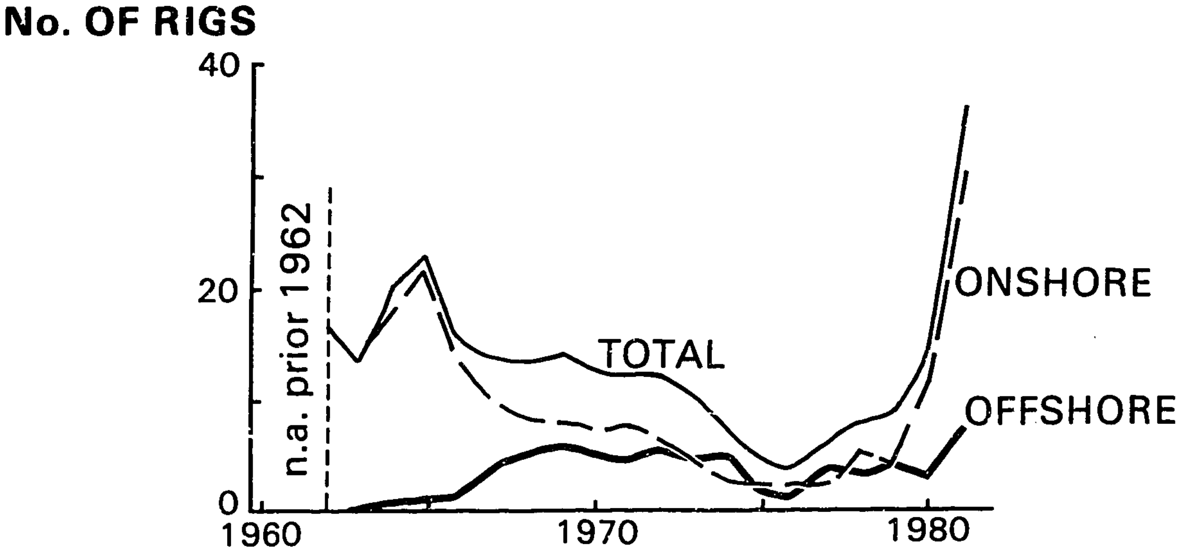
Already this year, 102 exploration and 64 development wells have been drilled.

In conclusion, I consider that although there are some short-term problems due to the current economic downturn and consequent shortage of exploration funds, there is good reason to believe that the increased level of exploration activity we have seen recently <u>can be</u> sustained so long as the discovery rate is maintained. Of course, the discovery of a major new petroleum province would constitute a further impetus to activity and such a discovery is probably essential if the level of activity is to be increased even further.

Fig. 1 Sedimentary Basins

ACTIVE EXPLORATION UNITS

DRILLING UNITS



Record 1982/21 15/118

Fig. 2

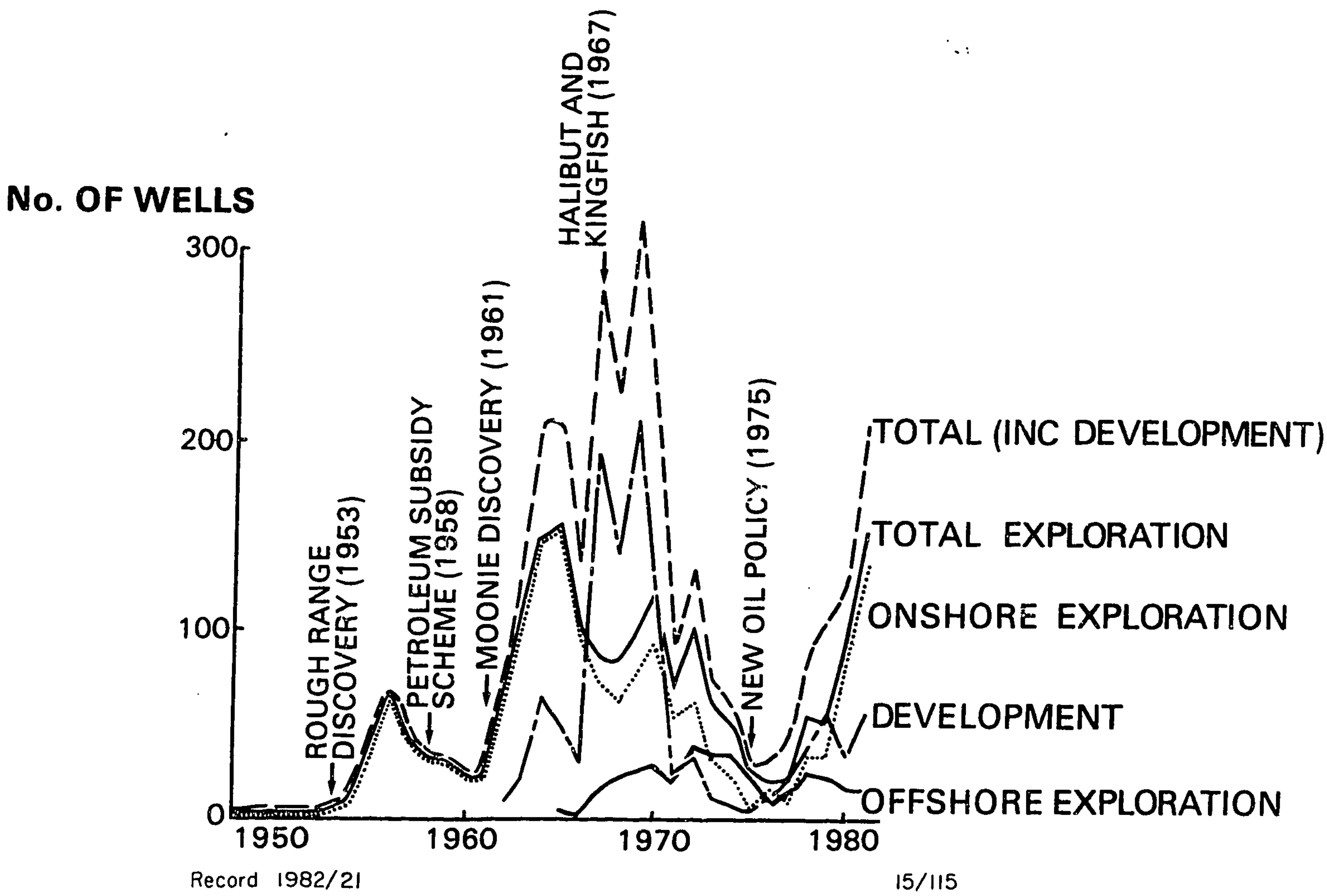


Fig. 3 Graph showing number of wells drilled 1950-1982

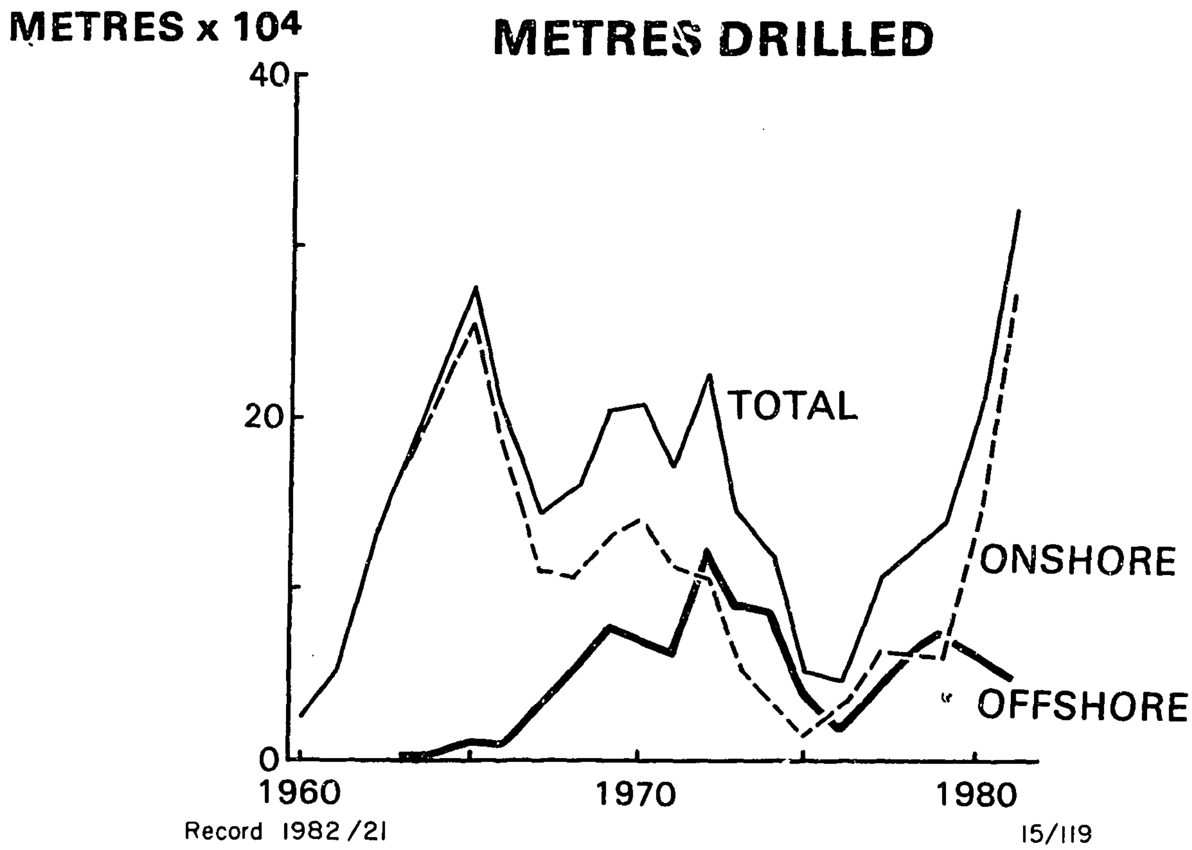
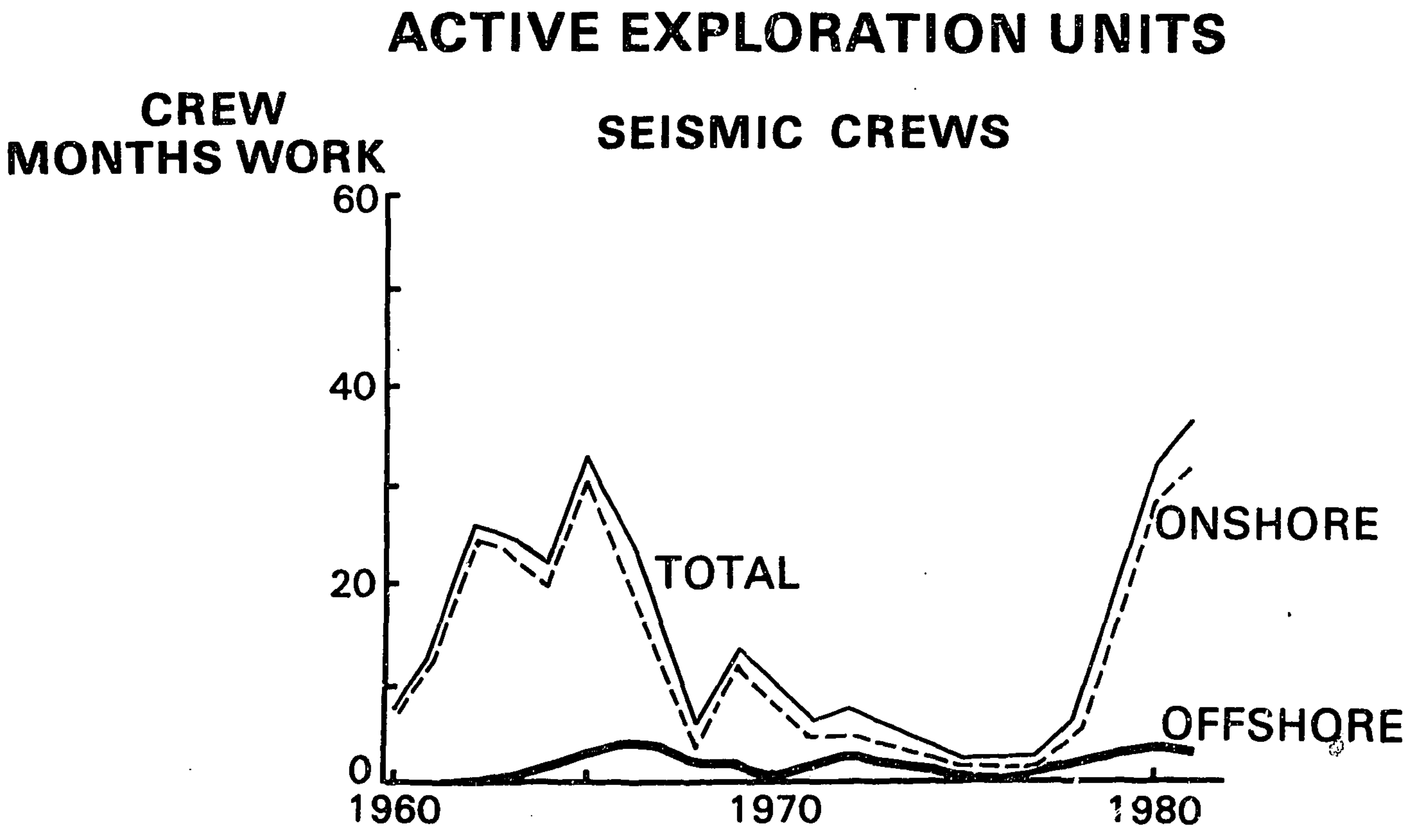

METRES x 10^4
METRES DRILLED
40
20
0
TOTAL
ONSHORE
OFFSHORE
1960
1970
1980
Record 1982/21
15/119

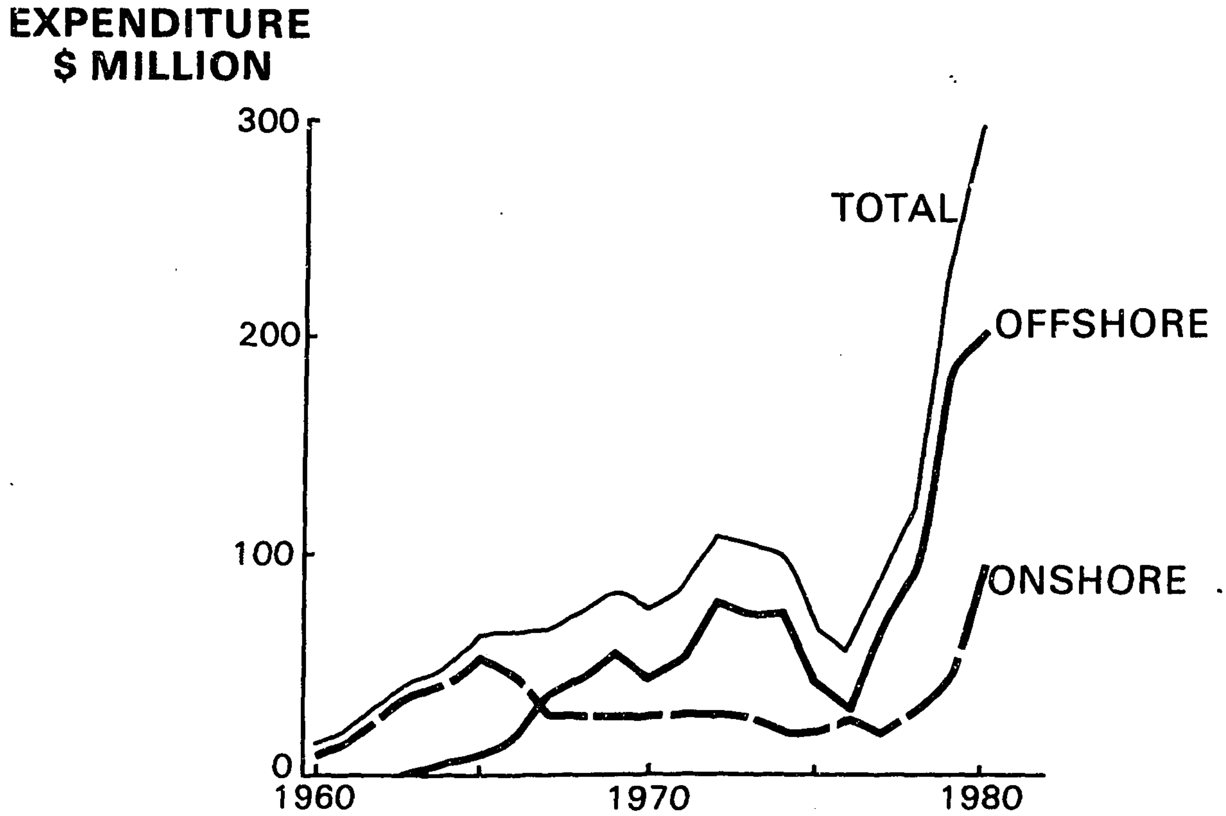
Fig. 4



Record 1982/21 15/120

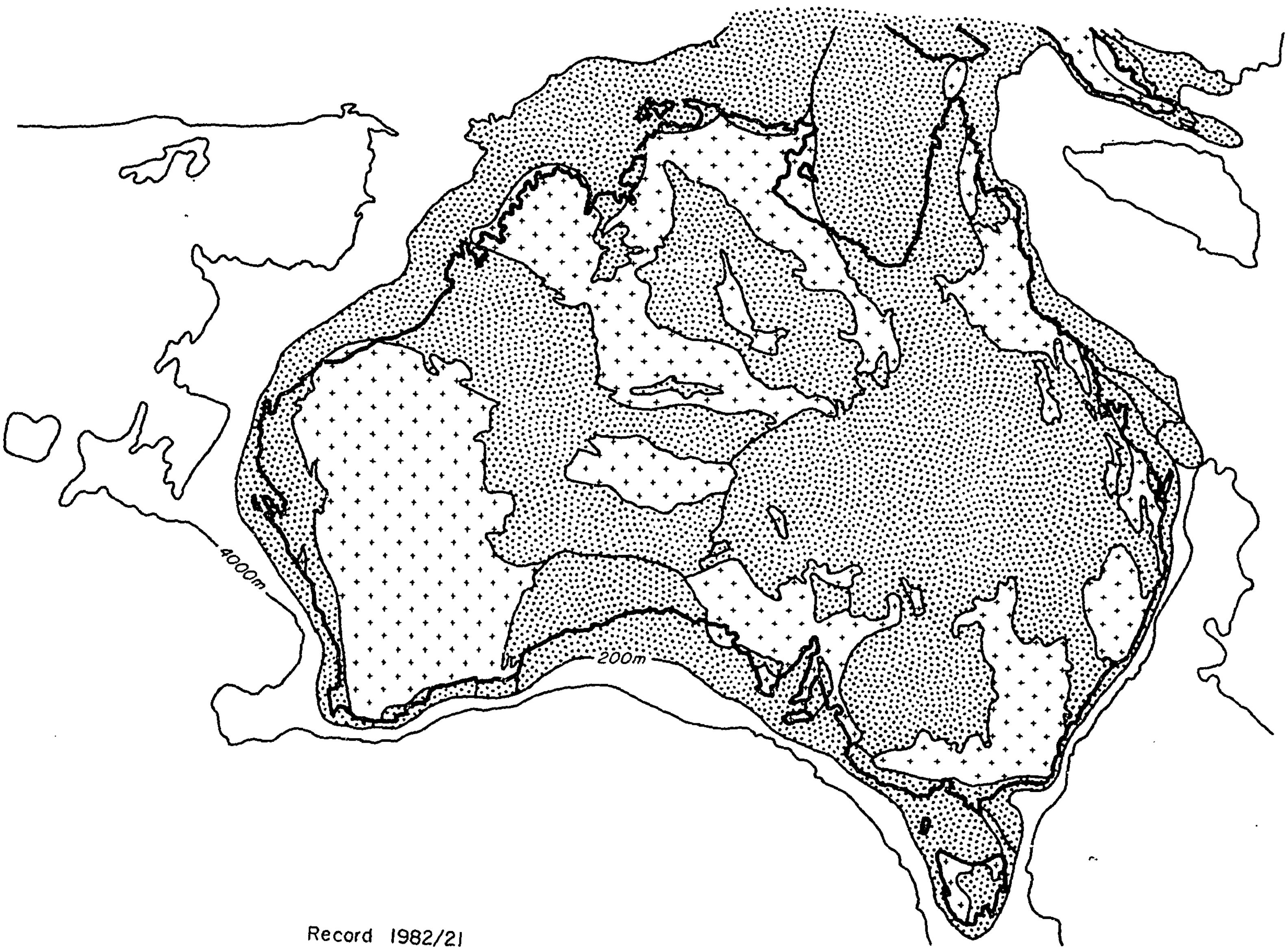
Fig. 5

EXPLORATION EXPENDITURE



Record 1982/21 15/117

Fig. 6



Record 1982/21

15/121

Fig. 7 Sedimentary Basins

AUSTRALIA'S PROSPECTS FOR FUTURE DISCOVERY AND SUPPLY OF PETROLEUM

D.J. FORMAN

Mr Chairman, Ladies, and Gentlemen.

The prospects for future discovery and supply of petroleum were last reviewed in 1980 and the conclusions were published by the National Energy Advisory Committee in their report 'Australia's Energy Resources 1980' and the Department of National Development in their report 'Forecasts of energy demand and supply', sometimes called 'The Pink Panther'.

In today's talk, I will show that despite a number of new discoveries and a considerable amount of new data since 1980, the magnitude of our crude oil resources still seems much the same. I will have a look at how these resources are distributed and then look again at the conclusions that can be drawn. I will suggest that the forecast of production from undiscovered oil fields, as shown in the 'Pink Panther', now appears to be rather high and that there could even be difficulty in maintaining present levels of production through to 1995.

To maintain present levels of production to 1995, we will have to add about 1000 million barrels of crude oil to reserves and to achieve this it appears to be essential that we maintain a high level of exploration activity.

The drilling activity graph on the left hand slide shows the number of wells drilled each year since 1960. It shows that Australia has undergone one cycle of high drilling activity, which peaked in 1965, followed by a period of low activity, with a trough in 1976, and that we have now entered a second cycle of relatively high drilling activity with a record 250 wells now forecast for 1982. (Slide 1)

The histogram on the left hand slide shows the present day estimate of the recoverable reserves discovered on a year by year basis. The reserves are shown on the slide, with oil shown in green and gas shown separately in red for each year, and the units used are traditional oil field units of millions of barrels of oil (abbreviated to MMB) and trillions of cubic feet of gas (abbreviated to TCF) where a trillion equals 10^{12}.

The first cycle of drilling began with the discovery of the Moonie field in 1961. This was followed by the discovery of the Barrow Island and Mereenie oil fields in 1964. Also in that year the first of many gas discoveries was made in the Cooper Basin at Gidgealpa. The first major discovery in the Gippsland Basin was made in 1965 with the discovery of the Barracouta gas field and most of the major oil and gas fields in this area were discovered between 1965 and 1969. However, in the thirteen years since 1969, there have been only two years, 1972 and 1978, when more than 50 million barrels of oil have been discovered, and in each year the discovery was made in the Gippsland Basin. Drilling activity in part of this period was, however, at generally low levels. (Slide 2)

Discovery of gas since 1969 has been more encouraging. Quite large discoveries in the Cooper Basin continued to the early 70's. The gas fields, Petrel and Tern, were discovered in the Bonaparte Gulf Basin in 1969 and 1970. Scott Reef gas field was discovered in the Browse Basin in 1971. Then the major gas fields of the Rankin Trend in the offshore Carnarvon Basin were discovered in 1971 and 1972. Sunrise and Troubadour were discovered in the Bonaparte Gulf Basin in 1974 and 1975.

However, since 1975 there has been only one year when more than 300 BCF of potentially economic gas has been discovered and that was last year (1981), when gas was discovered at Gorgon on the Rankin Trend on the Northwest shelf. I have excluded the gas in three gas fields, Scarborough, Brecknock, and Brewster, that were discovered in deep water of the Exmouth Plateau and the Browse Basin in 1979 and 1980 and are considered unlikely to be economic in the foreseeable future. Another major gas discovery that was made very recently at North Scott Reef is not shown on either diagram. It also lies in deep water (445 m) and would be technologically difficult and very expensive to develop.

Since the start of the second cycle of drilling in 1976, (Slide 1) attention has focussed on some of the older areas and some new ones. Understandably, the Gippsland Basin remains a favourite. The Eromanga Basin sequence overlying the Cooper Basin has been found to contain a number of small oil fields and is receiving considerable exploration. Exploration is also accelerating onshore in the Canning Basin following (Slide 3) discovery of oil in a Devonian reef at Blina No. 1 and indications of oil in the older Ordovician sediments in Acacia No. 1.

Offshore, the Exmouth Plateau has been partly explored and the results to date suggest that it is gas prone, which is unfortunate because gas in these water depths is uneconomic and likely to be so for many years. Three large gas fields have also been discovered in deep water of the Browse Basin, but as mentioned before these too are unlikely to be developed for many years.

Another area of interest is the Carnarvon Basin where exploration has centred around the Barrow Island oilfield and new gas discoveries have been made offshore at Gorgon on the Rankin Trend and onshore at Tubridgi No. 1. In the onshore Perth Basin, Woodada No. 1 discovered a new gas field, the significance of which is still being evaluated.

This latest round of exploration, over the last six and a half years, has discovered something like 18 new oil fields and about 40 gas fields, but these fields have nearly all been small. Only one large oil field (Fortescue) and one large potentially economic gas field (Gorgon) have been found. During this period we have been producing about 150 million barrels of crude oil a year and consuming about 210 million barrels a year.

The net result of exploration and production to date is that (Slide 4) our demonstrated economic resources, remaining at 31 December 1981, are estimated at 1690 million barrels, a drop of 190 million barrels from the amount reported by NEAC 18 months earlier. However additional resources of about 100 million barrels may be inferred in extensions of known fields and there is about 210 million barrels of identified subeconomic resources.

Our assessment of total undiscovered resources is still as was reported by NEAC in 1980. We estimate that there is an 80 percent chance of finding at least another 950 million barrels of oil and only a 20 percent chance of finding at least 3800 million barrels of oil. The average of this estimate is 2600 million barrels of recoverable crude oil but we believe there is only a 34 percent chance that we will find this much. Later on I intend to look further at how this undiscovered oil may be distributed throughout Australia's sedimentary basins, but first let's look at our gas resources.

Demonstrated economic resources of sales gas remain essentially (Slide 5) the same at 22 TCF. However, certain of the new discoveries have increased out sub-economic resources somewhat, and if we were to do another full assessment I believe it would indicate the amounts shown to be conservative. Our current assessment of undiscovered gas resources is only slightly changed with an 80 percent chance of finding more than 23 TCF and a 20 percent chance of finding more than 34 TCF. The average of the assessment is 29 TCF, an increase of 2 TCF over the figure in the NEAC report.

Now I want to show you how our oil and gas resources are distributed in Australia's sedimentary basins. However, the sedimentary (Slide 6) basin map on the left is rather complicated, with basins overlapping and on top of each other, so I propose that instead we look at a number of maps, each one showing just a part of the sedimentary sequence. It is fairly easy to do this because in Australia the sedimentary pile is divided by major breaks or unconformities that can be traced right thro :out the sedimentary basins.

These unconformities enable us to divide the sediments (Slide 7) deposited over the last 600 million years or so into four major sequences : the oldest of these includes all Cambrian and Ordovician sediments; the next youngest includes all the Devonian to Upper Carboniferous sediments; the next includes Upper Carboniferous to Upper Triassic sediments, and the youngest includes sediments from the Upper Triassic to the present time. The corresponding age of these sequences, in millions of years, is shown on the left. There are, of course, sedimentary sequences older than 600 million years, but their petroleum potential is relatively low and I will not be saying much about them today.

So now let's look at the youngest of these sequences of (Slide 8) sedimentary rocks - the one that ranges in age from Upper Triassic to the present. Now this map, and the other three maps that follow, show the present day distribution of sedimentary rocks in the sequence (they occur in the white areas) and the dots show the locations of petroleum exploration wells where vitrinite reflectance values have been determined. The colour of the dots is an indication of both the vitrinite reflectance values and the thermal maturity of the sediments.

Vitrinite is a form of coaly organic matter and the reflectance values can be determined using reflected light on polished sections of rock. Vitrinite reflectance values between 0.7 and 2 are believed to indicate that the sediments are mature and any suitable organic matter in them would have been largely or partly converted to oil or gas. Values over 2 indicate that the sediments are overmature - that is they have been cooked to such a degree that any oil or gas in them would have been destroyed. Values below 0.5 indicate that the sediments are immature and that no oil or gas is likely to have been generated in them. Values between 0.5 and 0.7 indicate that the sediments are marginally mature and that oil or gas generation is possible, but perhaps unlikely.

As you can see, the available data indicates a number of locations where the sediments are mature, shown by green dots, and a number of locations where the sediments are close to mature, shown by brown dots. Where sufficient data are available, these may be used to outline the areas where petroleum could be expected to occur. The mature and nearly mature sediments occur offshore, mainly in fault bounded graben, or onshore where there is a thick sequence of sediments or an abnormally high geothermal gradient.

The slide on the right is interpretative. The areas of (Slide 9) mature and nearly mature sediments are accentuated by solid colour and the areas of thick sediments where data are lacking are shown by cross hatching. The slide also shows how much oil and gas is reservoired in each of these areas. The most prolific area is the Gippsland Basin with about 3 billion barrels of oil and 9 TCF of gas. This is followed by the Barrow and Dampier Sub-basins of the Carnarvon Basin with 260 MMB of oil and 2.6 TCF of gas. Onshore the important areas are the Eromanga Basin and the Surat Basin. The Surat Basin hydrocarbons are believed to have been generated in the underlying Permian and Triassic rocks and to have migrated upwards into this sequence of sediments.

Already, in this sequence, a total of 3230 million barrels of oil and 16 TCF of gas have been discovered, whereas according to our assessment, on average, a further 1730 million barrels of oil and 13.6 TCF of gas remain to be discovered. Some of this undiscovered oil and gas is likely to come from the producing areas; the Gippsland, Eromanga, Surat, and Carnarvon Basins, but our assessment is based on the expectation of further large oil and gas discoveries in areas, such as the Bonaparte Gulf Basin, that are not producing at the present time.

The distribution and maturity of the Upper Carboniferous to (Slide 10) Upper Triassic sediments are quite different. At nearly all locations sampled, these sediments are mature and in some locations they are overmature. For instance, the Cooper Basin contains mature to overmature sediments, the Galilee Basin contains immature to mature sediments, and the Surat Basin contains immature to overmature sediments. Mature sediments of this age are widespread on the Northwest Shelf and the Exmouth Plateau.

Looking at the interpretative slide, we can see that 17 TCF (Slide 11) of gas resources, much of which is subeconomic, have already been found in reservoirs of this age. Permian and Triassic rocks appear to be the source of, and form the reservoirs for, the Cooper Basin gas and for much of the gas on the Northwest Shelf and the Exmouth Plateau. Note that the 17 TCF is closely comparable to the 16 TCF in the younger sequence of sediments.

However, only 50 million barrels of oil have been found in reservoirs of this age, and this amount is very much less than the 3230 million barrels found in the younger sediments. I do not believe this is just a matter of chance and I suggest that it reflects a fundamental difference in the source material in - and possibly the burial history of - the two sequences. This view has also been expressed in two papers delivered at the APEA conference in Sydney in May. It appears that there are different varieties of land plant material in the two sequences. The variety in the Permian to Triassic sequence is gas prone, whereas the variety in the Jurassic to Tertiary sequence can be oil prone.

Consequently, our assessment of undiscovered petroleum resources in these sediments is that there is considerable potential (probably understated) for further gas discoveries (an average of 13.8 TCF), but comparatively low potential for further oil discoveries (an average of 540 MMB).

In the centre of Australia, Australia's Devonian and (Slides 12, 13) Carboniferous sediments are very largely terrestrial red sandstones and siltstones that contain no appreciable land plant organic matter. However marine sediments occur in the west in the Carnarvon, Canning, and Bonaparte Gulf Basins and in the east in the Adavale and Darling Basins, and these could contain oil prone source rocks. The sediments are typically mature to overmature and the best areas for exploration lie on the margins of sedimentary basins and on elevated areas within them.

To date a small gas field has been found at Gilmore in the Adavale Basin and an oilfield has been found in a Devonian reef close to the northern margin of the Canning Basin. On average. we believe the undiscovered oil and gas potential of these rocks is only modest, of the order of 1 TCF of gas and 170 million barrels of oil.

Our Cambrian and Ordovician sediments are very widespread and (Slide 14) they are typically marine - which means that the source rocks are oil prone. Over large areas they are deeply buried and are overmature. In other areas they are very thinly spread and are believed to be immature. However, in parts of the Amadeus, Canning, and Georgina Basins the sediments are mature for oil and gas generation and they may also be mature in the Officer Basin.

The only oil and gas discoveries to date are in the Amadeus (Slide 15) Basin where 1 TCF of gas and 60 million barrels of oil have been identified. Recently oil shows have also been found in the Canning Basin. Once again, on average, our estimate of undiscovered potential is fairly modest, about 1.1 TCF of gas and 160 million barrels of crude oil.

A review of the distribution of Australia's identified and (Slide 6) undiscovered petroleum resources would not be complete unless I mentioned certain omissions. It is important to realise that we have not included gas in deep water (over 200 m) as a resource (whether discovered or undiscovered), nor have we made any assessment of the potential of Australia's external territories or of our widespread Precambrian sedimentary sequences.

Up until fairly recently, the Precambrian sediments, that is sediments that were deposited over 600 million years ago, were thought to have little or no potential for oil or gas. We now know that cyanobacteria in particular, flourished in appropriate environments throughout the Precambrian and that these can form an excellent source for oil and gas. In fact oil and gas have been discovered and are now in production from Precambrian rocks in Oman and in Siberia. Even though these very old sediments have been proved to contain oil and gas, the amount involved worldwide is insignificant when compared to that found in the younger sediments.

In Australia, Precambrian sedimentary sequences are being explored in the Amadeus, McArthur, and Officer Basins. In the Amadeus Basin, gas has been discovered in Precambrian sediments in the Ooraminna Anticline and BMR research indicates that shales in the Precambrian Pertatataka Formation were most probably the source for the gas in the Dingo field. In the McArthur Basin, traces of an oil liquid and bitumen were identified in a BMR stratigraphic hole drilled into Precambrian sediments. We believe that further petroleum discoveries are likely in the Precambrian sediments and we now include a number of the Precambrian sedimentary basins on our map of Australia showing areas prospective for petroleum.

Now, in a general wind-up to this talk, I am going to discuss the rate at which these petroleum resources may become available and some special problems that can be predicted. As I said at the beginning of this talk, despite the discoveries of the last few years, the magnitude of our crude oil resources still seems much the same as presented by the National Energy Advisory Committee in the publication 'Australia's Energy Resources 1980'.

The forecast of demand and the forecast of supply from discovered fields shown here have been taken from figures prepared in the Energy Office of our Department and up to 1990 are the same as the forecast published in the Pink Panther of June 1981. (Slide 16)

The task of forecasting supply from undiscovered crude oil fields is hazardous. Basically, there are two ways to approach the problem. The first approach is to look at the historical data, as (Slide 1) I did at the beginning of this talk, to see what has turned out to be feasible in the past. Simple arithmetic shows that in six and a half years since the end of 1975 we have discovered on average about 60 million barrels of crude oil a year, or as little as 12 million barrels if we ignore the one large field.

As a forecasting method, it is better to calculate the amount of oil discovered per well drilled over the period since 1975. This works out at .83 million barrels per well, if we include the large field, and .16 million barrels per well if we exclude the large field. Hence in a record year like 1982, when 250 wells are forecast, we could forecast discoveries at between 40 and 207 million barrels, depending on which figure we use.

The second approach is to look at our undiscovered resource potential and to try to predict where discoveries might be made. For instance, if we are looking at the 80 percent chance of discovering a further 950 million barrels of oil, we have to subdivide the 950 million barrels into undiscovered fields in the various most likely locations such as the Gippsland, Eromanga, Surat, and Carnarvon Basins, where we can be fairly confident that more discoveries will be made. Any additional discoveries will have to come from a new area or areas where there are presently no production facilities. Having distributed the potential oil in this conceptual fashion, we then have to predict the size of the fields in each area, the likely production profiles for each of the fields, future levels of exploration and the time of discovery, and the lead time for each field to be brought into production.

We went through this exercise in 1980, but I now think that we assumed that too many large fields would be discovered in the first few years. If we were to go through the exercise again today I believe we would probably do it a little differently and I would expect a lower rate of discovery and production.

On the left hand diagram the straight line indicates the level of production from undiscovered fields that is necessary to maintain the present level of domestic production until 1995 - we will have to add about 1000 million barrels of crude oil to economically recoverable reserves - because of the delays in bringing fields into production we will need to achieve this over about the next five to eight years.

Some of this 1000 million barrels will come from additions to known fields, but most of it must come from undiscovered fields.

I would not want to understate the difficulty in finding a further 1000 million barrels or so of crude oil in the next five to eight years. However, the preceeding analysis of the amount of oil discovered per well drilled over the last six years suggests that it is a possibility if the present high level of exploration continues. This, of course, assumes that we will discover several large fields. It would seem unlikely that another field the size of Kingfish will be found in an existing producing area and perhaps Barrow Island or Fortescue-sized fields are the largest that we could hope for.

About half of the necessary additions to reserves is expected to come from the producing areas, and hence the other half will have to come from discoveries and developments in new areas - and in this time frame it would probably not be possible to develop any production from fields in deep water. It will, therefore, be necessary to maintain a high level of exploration outside of the producing areas if we are to maintain existing levels of crude oil production through to 1995.

As regards gas, the Cooper Basin still does not have the reserves to guarantee supplies to both Sydney and Adelaide to the year 2000. The demand for Cooper Basin gas is shown on this slide. For a start the producers need to supply the 0.5 TCF of gas that remains from the original 1.8 TCF contract to Adelaide. Then they need to supply the 1.8 TCF remaining from the original 2 TCF contract to Sydney. A petrochemical plant in South Australia, if developed, will use about 0.2 TCF of sales gas and of course requires the removal of ethane from the sales gas. At this stage we have used up nearly all of the remaining proved and probable reserves of 2.8 TCF and would have only 0.3 TCF left over to supply part of the 0.8 TCF committed to AGL for Sydney. In the absence of further substantial discoveries, this means that supply to Sydney will plateau from 1985 and that there will be insufficient reserves to supply South Australia after 1987. A further 3.5 TCF of sales gas is required to satisfy demand in both SA and NSW through to about 2005, but we think there is only a low probability of finding and developing this amount in the Cooper and Eromanga Basins.

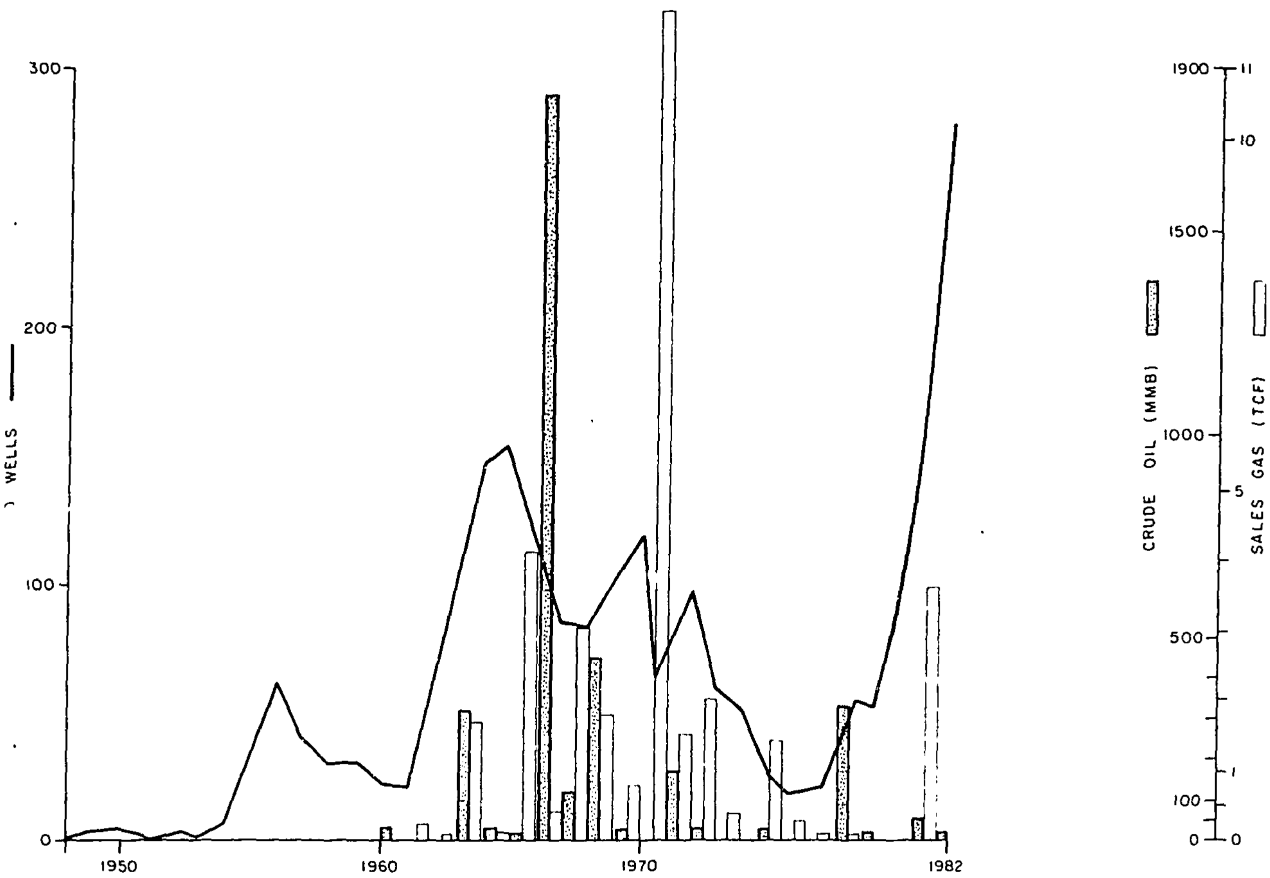
Of course, higher prices for gas would increase reserves by:-

- making it economic to drill more closely spaced production wells.
- encouraging abandonment at lower pressure.
- making it economic to enhance recovery by fracturing tight reservoirs.
- making it economic for explorers to search for and develop smaller fields.

But, even so, there may be insufficient resources in the Cooper/ Eromanga Basins to meet future demand.

In conclusion, I consider there has been no major change to the magnitude of our crude oil resources as a result of discoveries made over the last few years. The additions to potential implied by these discoveries has been cancelled out by the exploration disappointments, particularly in deep water areas. The forecast of production from undiscovered oil fields, as shown in the Pink Panther now appears rather high. It is emphasised that even to maintain present production levels to 1995 requires the discovery of roughly twice as much oil over the next six years as we have in the last six.

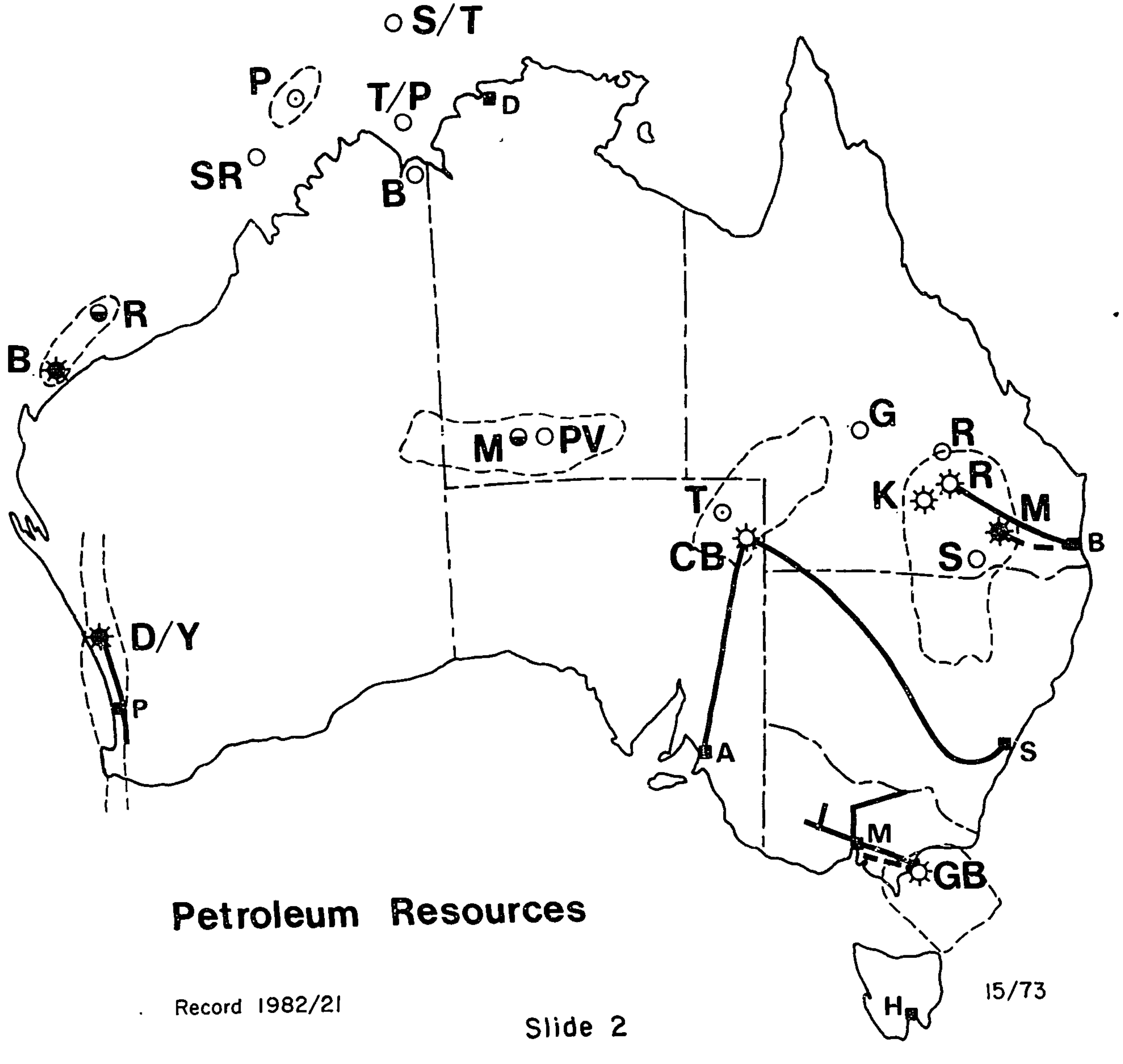
Gas supplies from the Cooper Basin still present a problem although it would appear that part of this could be resolved by higher gas pricing. Even so there may be insufficient resources in the Cooper Basin and alternative sources may be necessary to meet South Australian and New South Wales demand for the next 20 years.



Record 1982/21

Slide 1

15/75

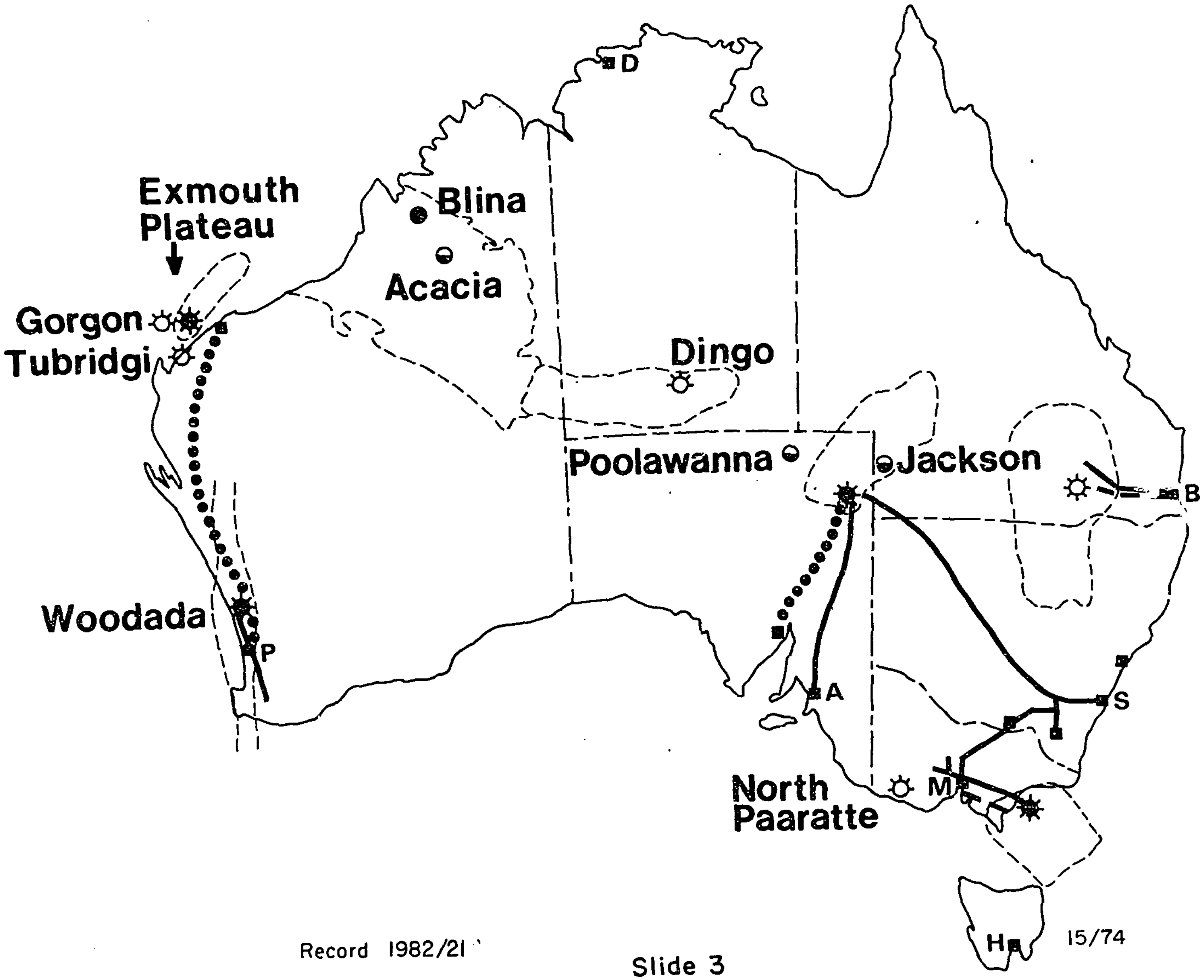


Petroleum Resources

Record 1982/21

Slide 2

15/73



Record 1982/21

Slide 3

OIL RESOURCES 31-12-81

<table>
<tr><th></th><th>DEMONSTR.</th><th>INFERRED</th><th>UNDISCOVERED</th></tr>
<tr><td>ECONOMIC</td><td>270
(1690)</td><td>17
(100)</td><td rowspan="2">150 (950)
80% PROB

420 (2600)
MEAN EST

600 (3800)
20% PROB</td></tr>
<tr><td>SUBECONOMIC</td><td>34
(210)</td><td>?</td></tr>
</table>

Record 1982/21 15/76

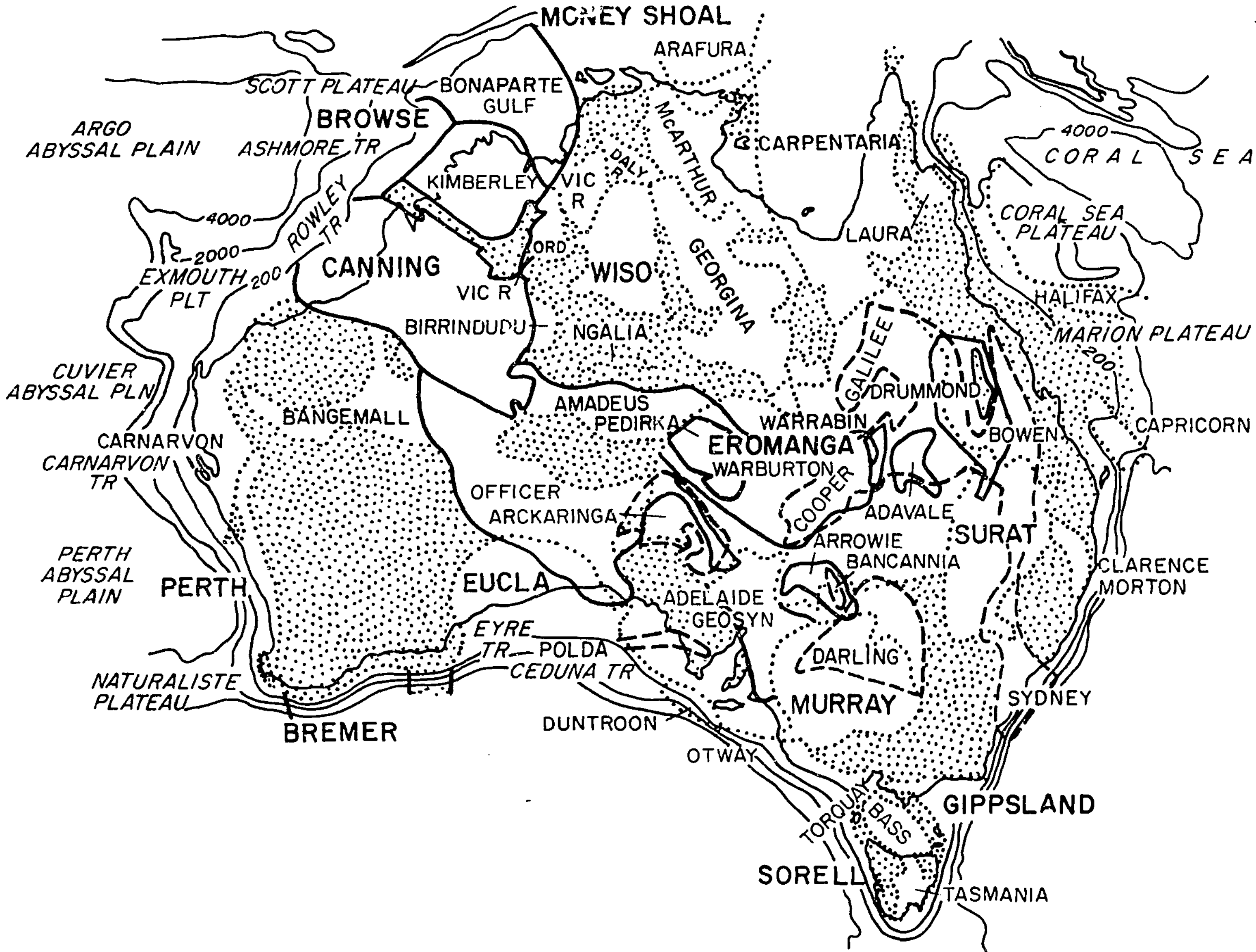
Slide 4

GAS RESOURCES 31-12-81

	DEMONSTR.	INFERRED	UNDISCOVERED
ECONOMIC	630 (22)	68 (2·4)	80% PROB 650 (23) MEAN 800 (29)
SUBECONOMIC	285 (10)	170 (6) ONLY PARTLY ASSESSED	20% PROB 960 (34)

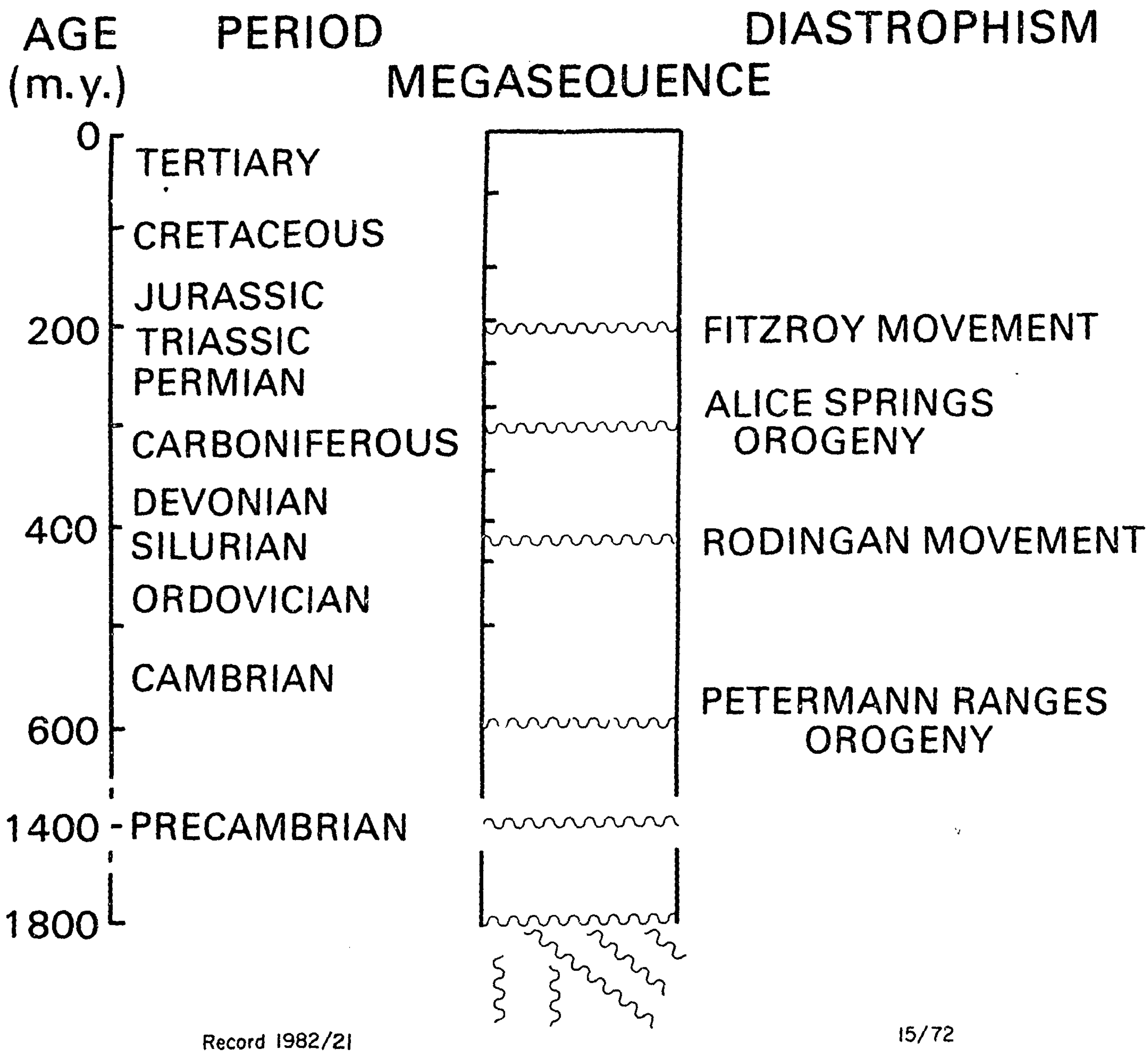
Record 1982/21 15/77

Slide 5

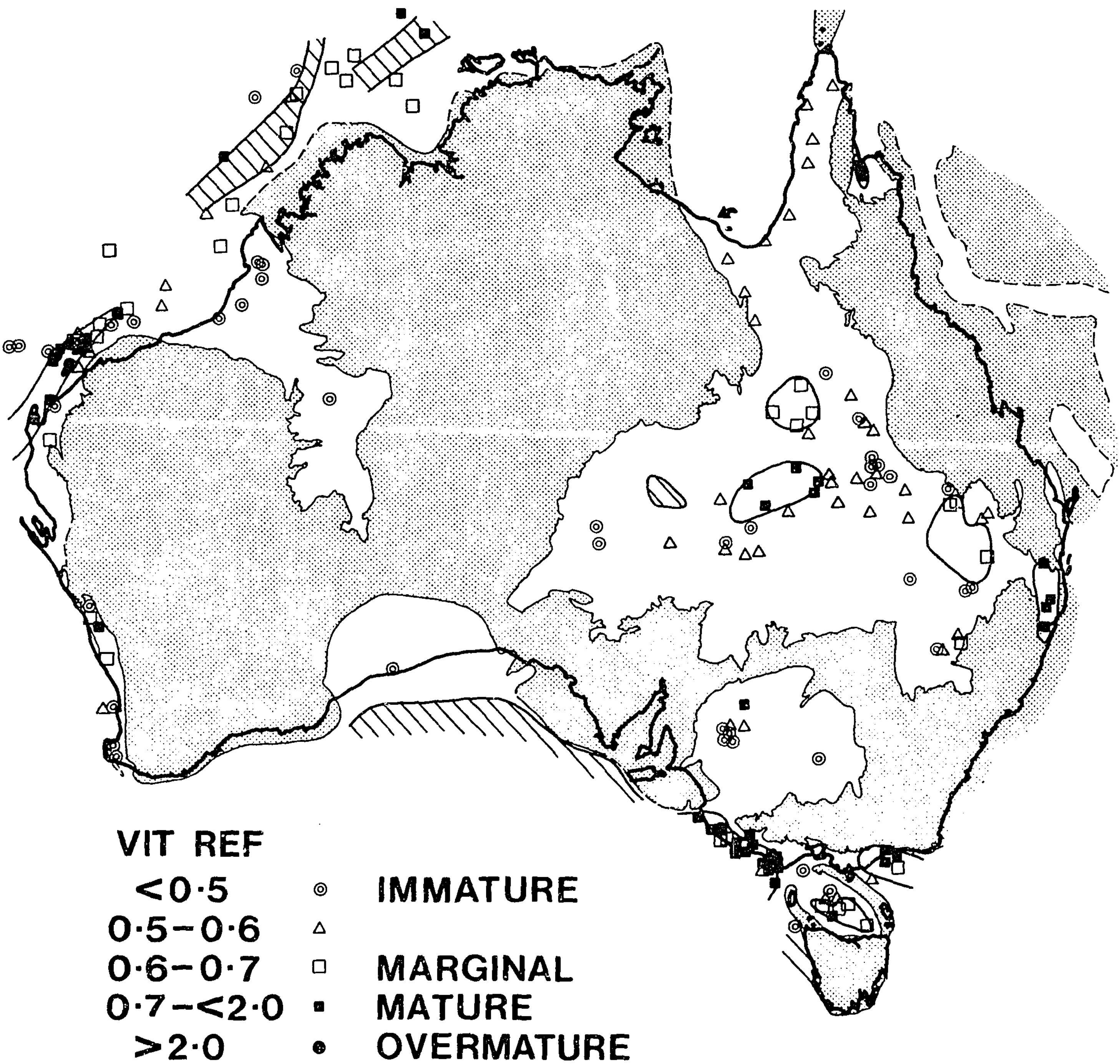


Record 1982/21 15/86

Slide 6


AGE
(m.y.)
PERIOD
MEGASEQUENCE
DIASTROPHISM
0
TERTIARY
CRETACEOUS
JURASSIC
200
TRIASSIC
PERMIAN
CARBONIFEROUS
DEVONIAN
400
SILURIAN
ORDOVICIAN
CAMBRIAN
600
1400
PRECAMBRIAN
1800
FITZROY MOVEMENT
ALICE SPRINGS OROGENY
RODINGAN MOVEMENT
PETERMANN RANGES OROGENY
Record 1982/21
15/72

Slide 7

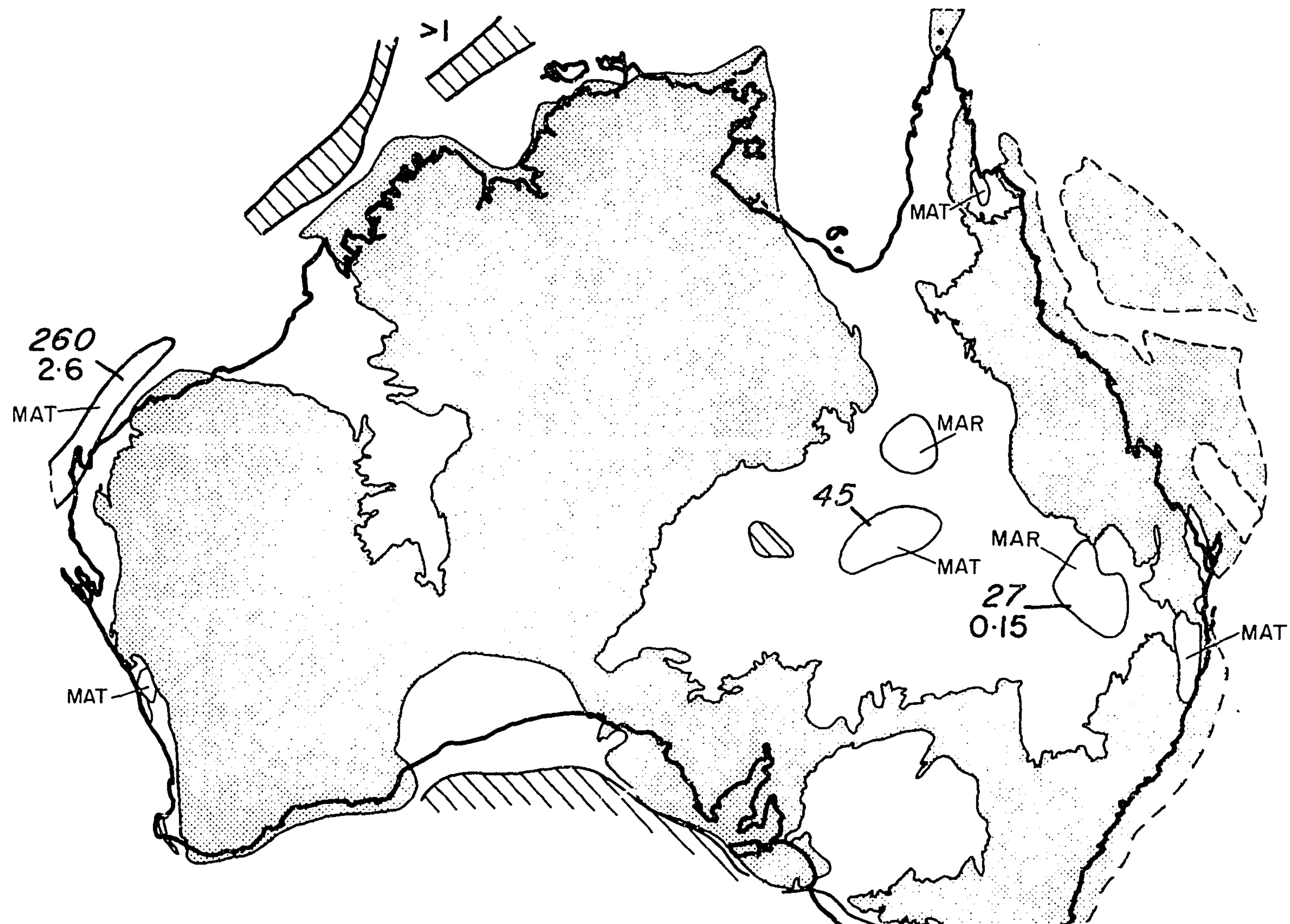


Record 1982/21

Slide 8

15/83

UPPER TRIASSIC TO CAINOZOIC

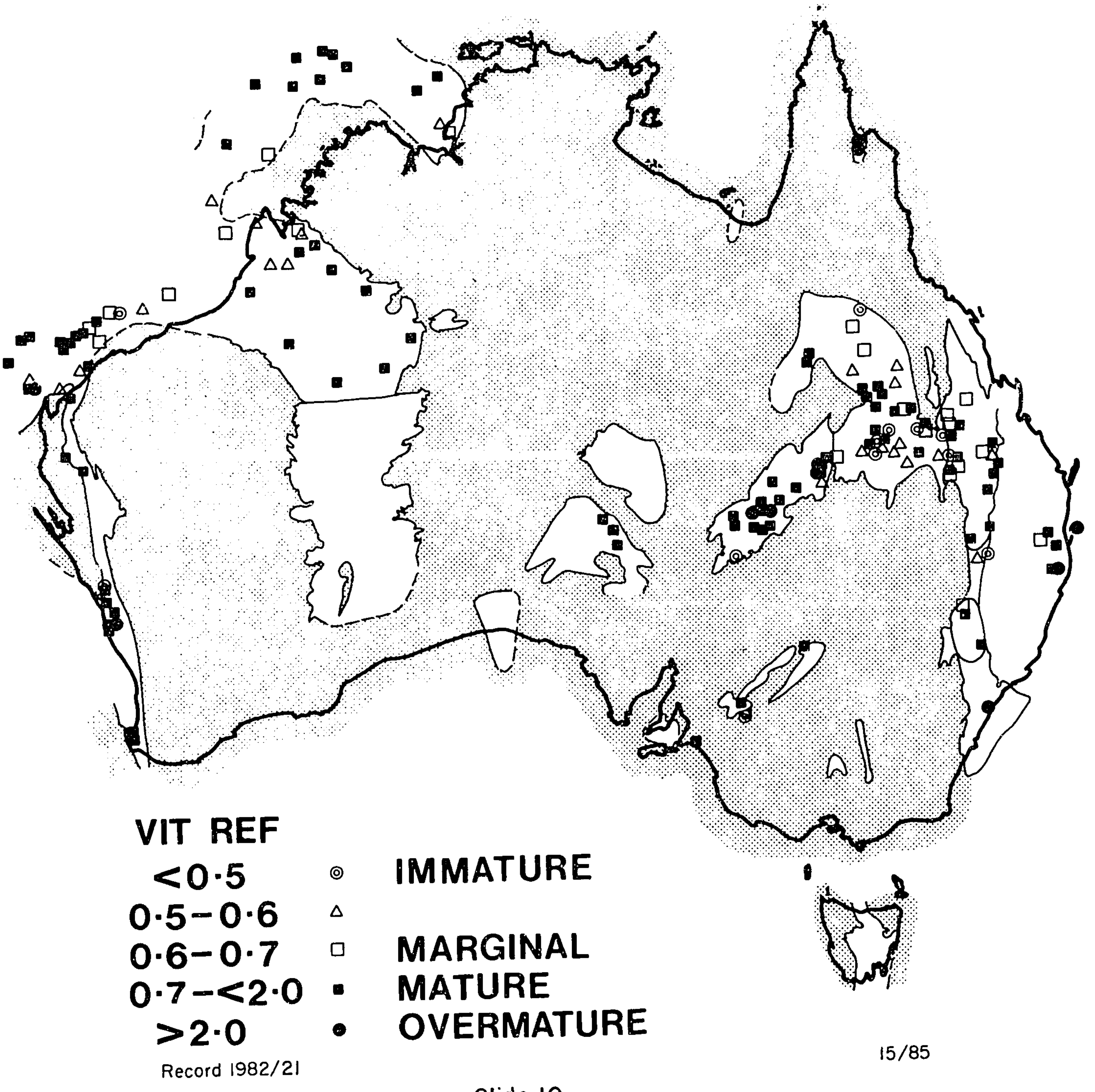


	OIL(MMB)	GAS (TCF)
IDENTIFIED	*3230*	16
UNDISCOVERED	*1730*	13·6

MAR **MARGINAL** MAT **MATURE** **THICK SEDIMENTS**

Record 1982/21 15/82

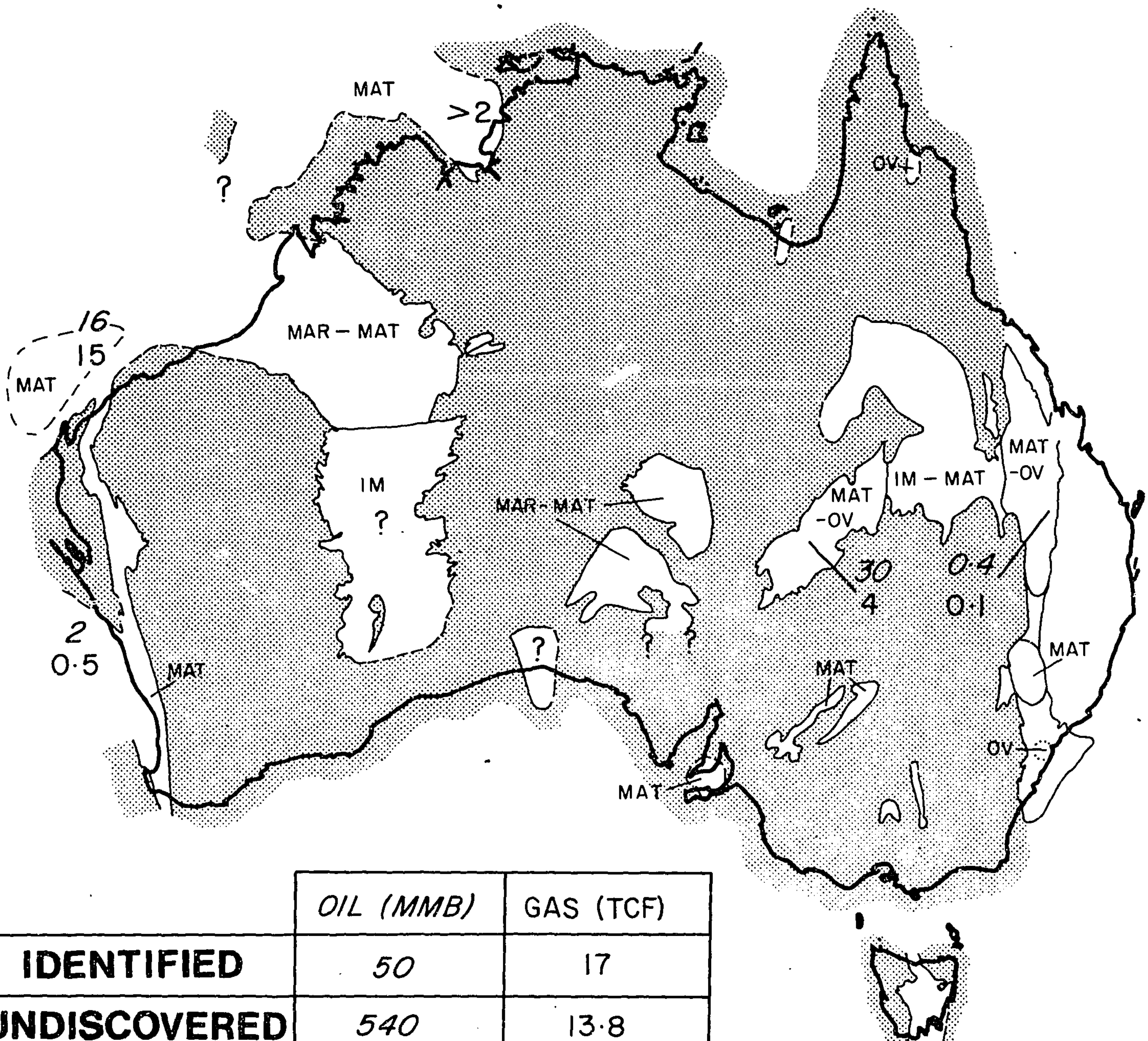
Slide 9



VIT REF
<0·5 IMMATURE
0·5–0·6
0·6–0·7 MARGINAL
0·7–<2·0 MATURE
>2·0 OVERMATURE
Record 1982/21
15/85

Slide 10

UPPER CARBONIFEROUS TO TRIASSIC

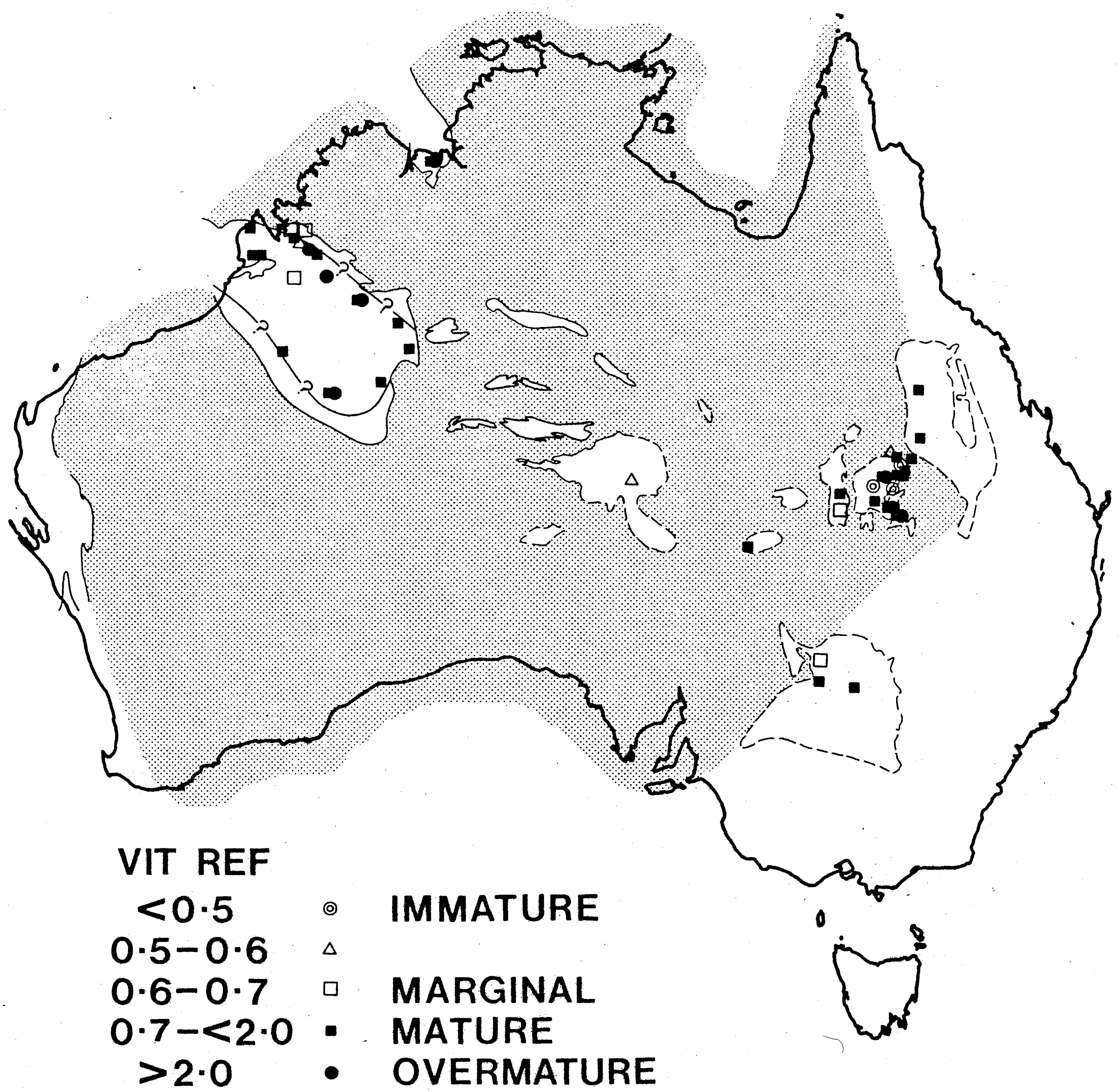


	OIL (MMB)	GAS (TCF)
IDENTIFIED	*50*	17
UNDISCOVERED	*540*	13·8

IM **IMMATURE** MAR **MARGINAL** MAT **MATURE** OV **OVERMATURE**

Record 1982/21 15/84

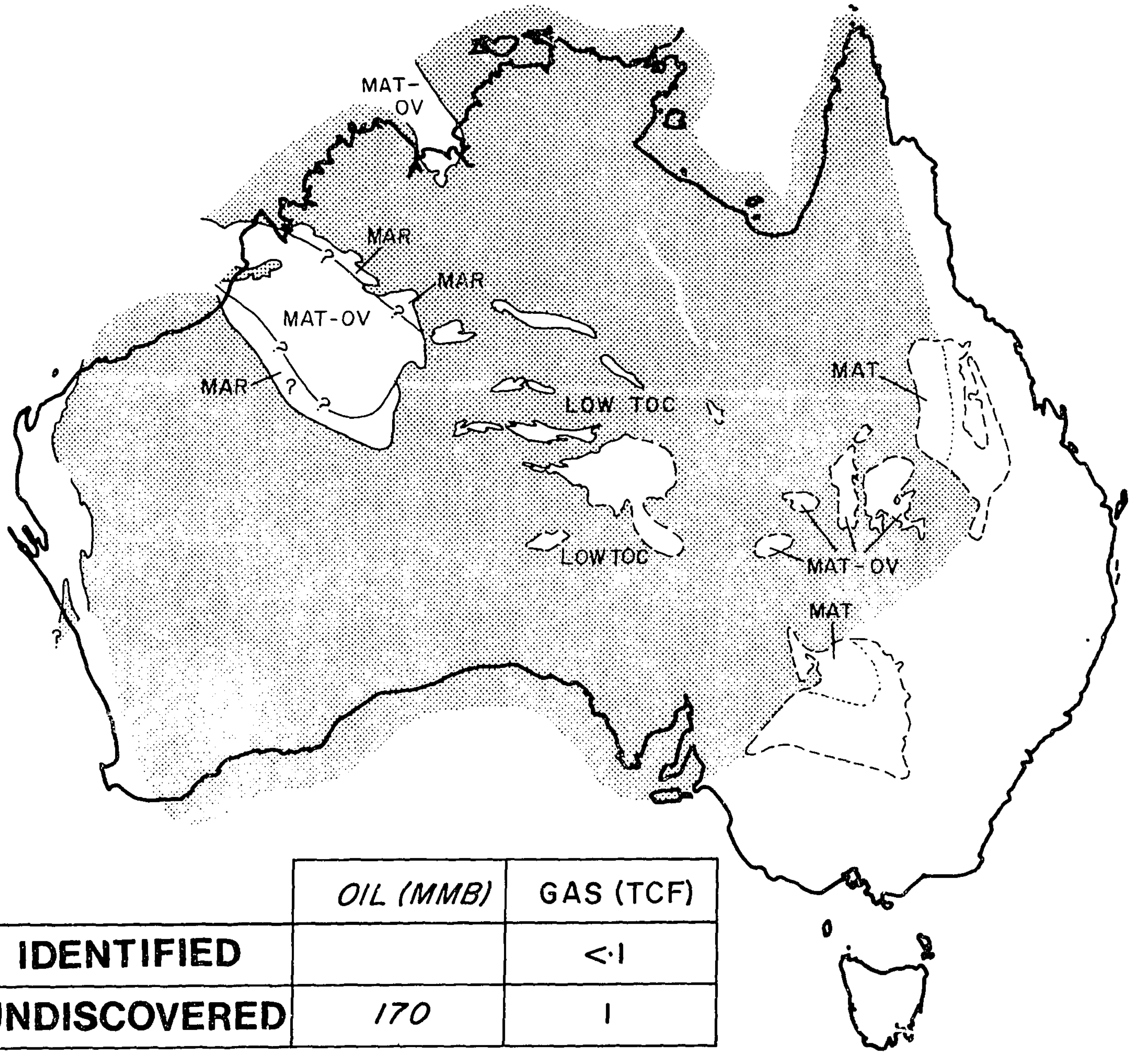
Slide 11



Record 1982/21 15/81

Slide 12

DEVONIAN TO CARBONIFEROUS



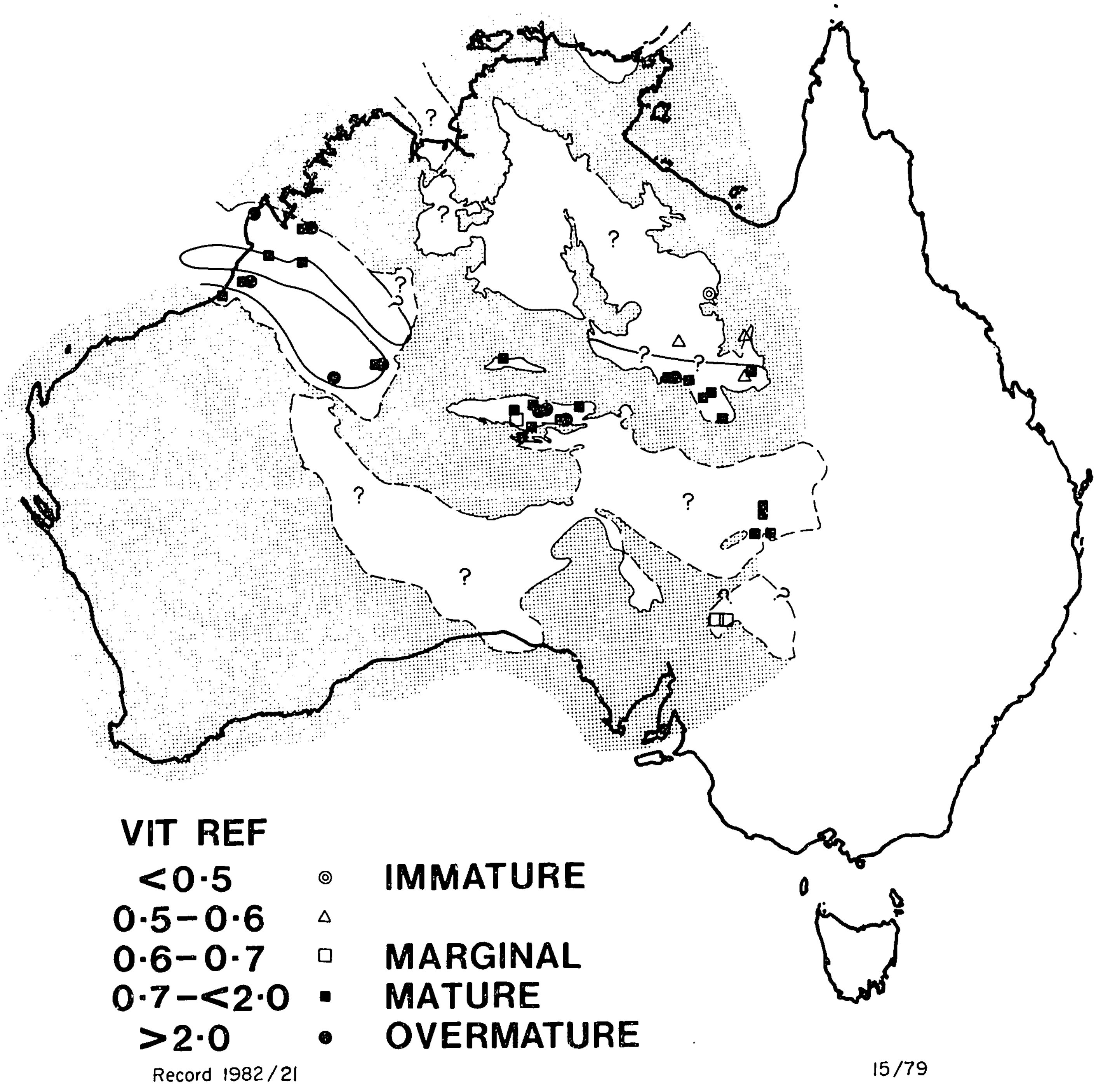
	OIL (MMB)	GAS (TCF)
IDENTIFIED		<·1
UNDISCOVERED	170	1

MAR **MARGINAL** MAT **MATURE** OV **OVERMATURE**

Record 1982/21

15/80

Slide 13


?
?
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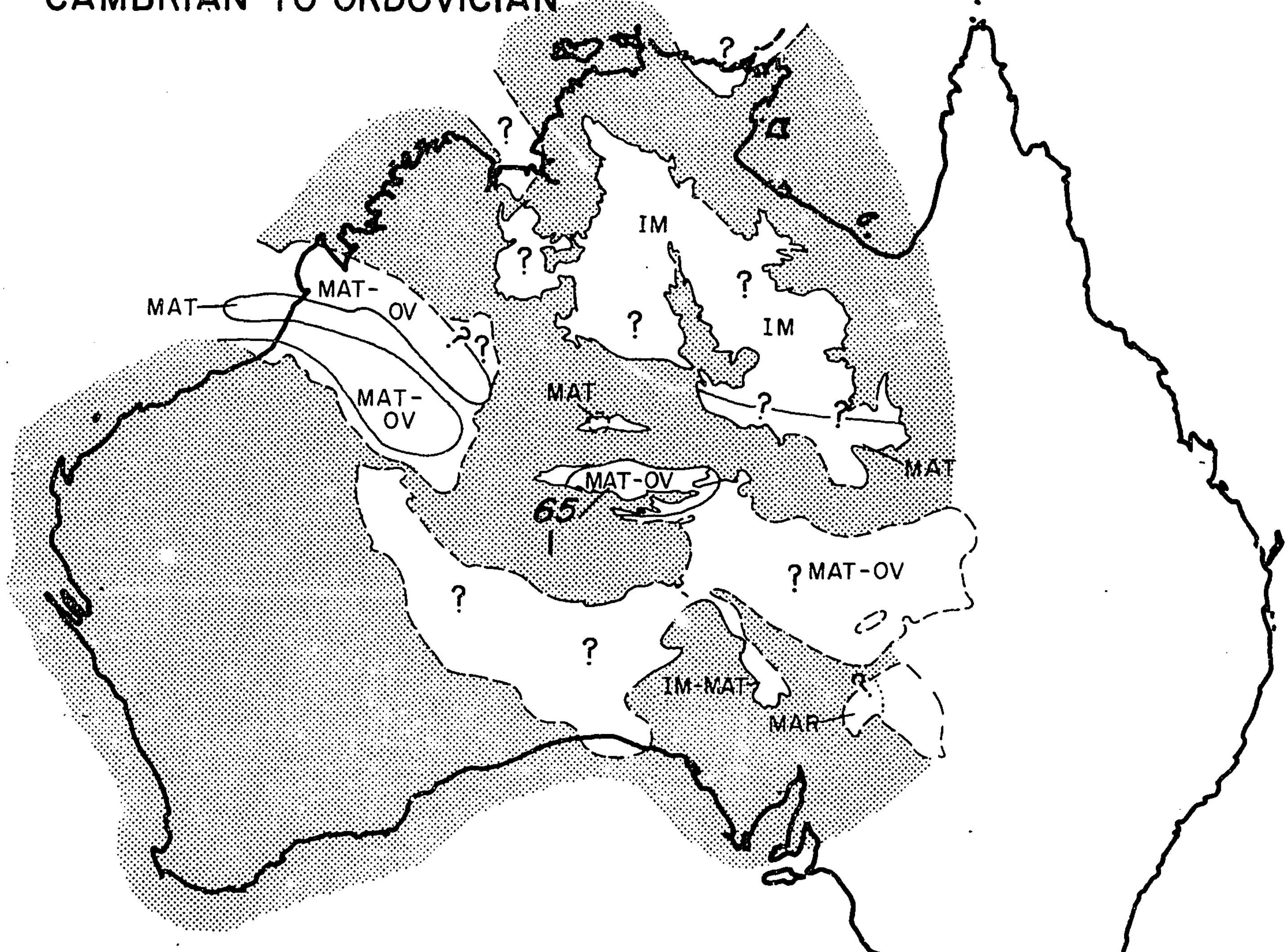
?
?
VIT REF
<0·5 IMMATURE
0·5–0·6
0·6–0·7 MARGINAL
0·7–<2·0 MATURE
>2·0 OVERMATURE
Record 1982/21
15/79

Slide 14

CAMBRIAN TO ORDOVICIAN



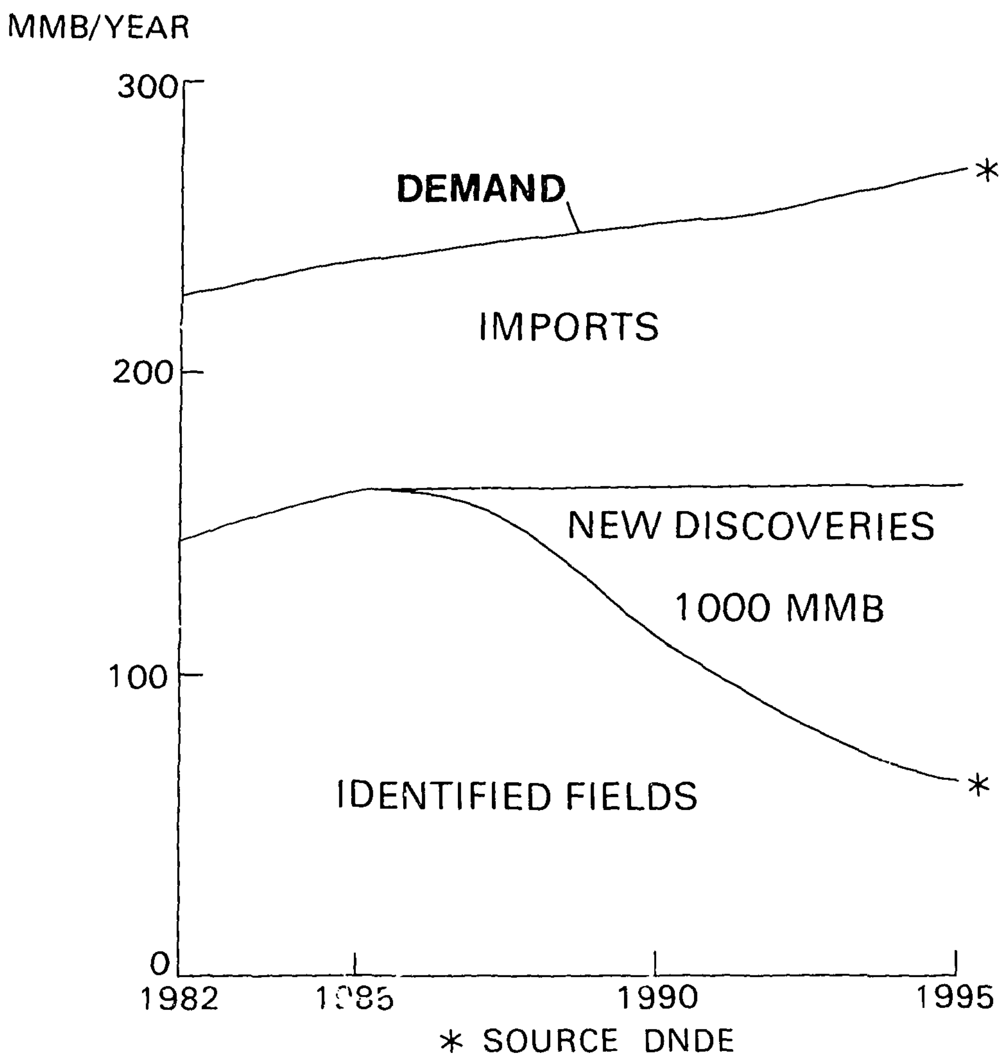
	OIL (MMB)	GAS (TCF)
IDENTIFIED	*65*	1
UNDISCOVERED	*160*	1·1

IM **IMMATURE** MAR **MARGINAL** MAT **MATURE** OV **OVERMATURE**

Record 1982/21 15/78

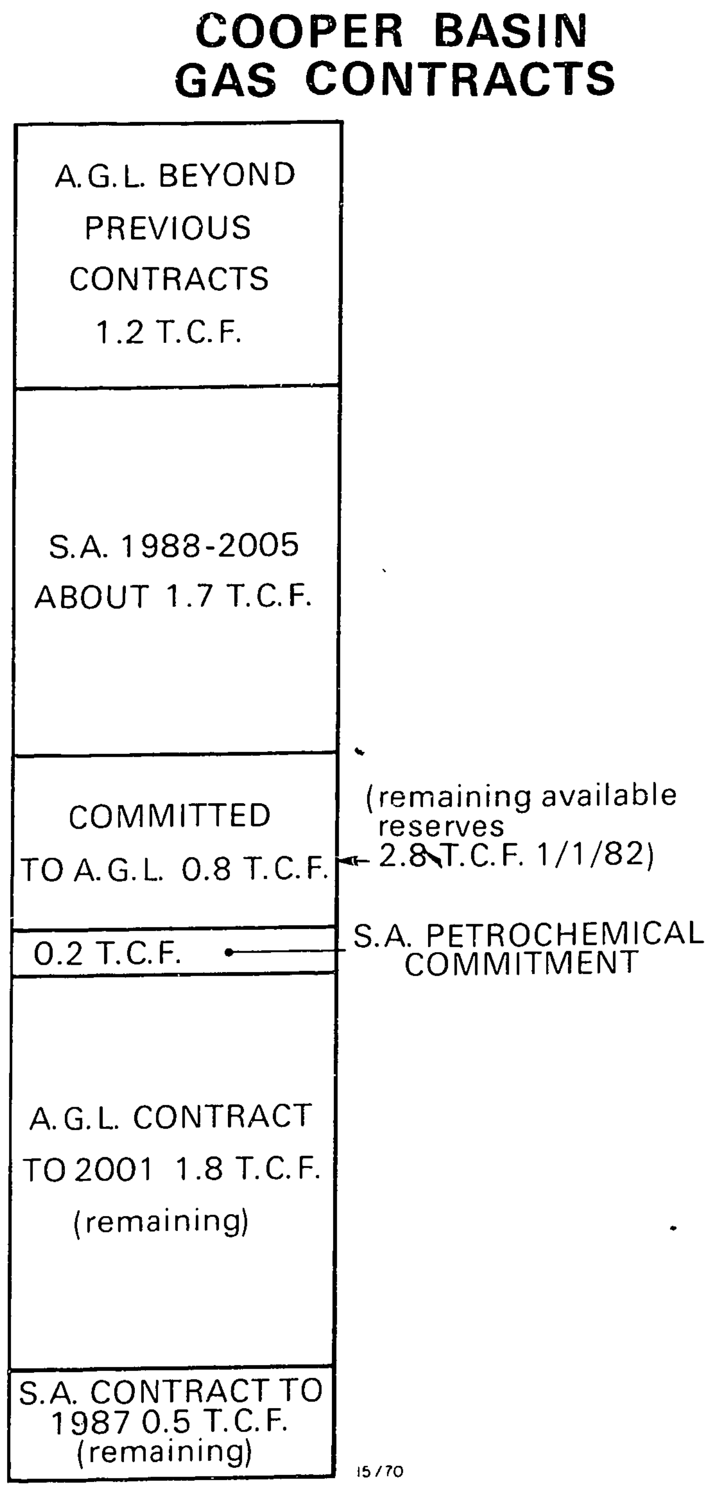
Slide 15

CRUDE OIL/CONDENSATE DEMAND AND SUPPLY SCENARIO



Record 1982/21 15/71

Slide 16



Record 1982/21

Slide 17

AUSTRALIA'S COAL RESOURCES AND THEIR DEVELOPMENT

M.B. Huleatt

Coal is a non-renewable source of energy! Once we use it, it's gone!

This alone should be sufficient incentive for use to maximise the recovery from every mine and to maximise our use of the coal recovered.

As you will all be aware, the Australian coal industry is large. It employs over one-third of all people employed in mining in Australia and about 140 mines are in production. Australia's proven economically recoverable resources of black coal are about 6% of the world total and brown coal about 8%.

In the short time I have I will review the recent history of the industry, in particular the black coal industry, and highlight some of the important technological developments that are taking place. The fact that I will devote most of my time to black coal should not be interpreted as meaning the brown coal industry is not important. It obviously is, particularly in Victoria.

Black coal was discovered in Australia in 1791 near the present site of Newcastle. Mining began from outcrops at Newcastle in 1799 and the first exports were in 1801 when about 150 tonnes were shipped to India.

From this beginning the Australian black coal industry has become one of the most advanced in the world and we are now among the top ten producers and are the second largest exporter after the USA.

Figure 1

Production of raw coal has grown from about 18Mt in 1951 to 111Mt in 1981 and has almost doubled in each 10 year period since 1960. Saleable coal output has also grown rapidly but at a slower rate than raw coal, and has risen from about 18Mt in 1951 to 92Mt in 1981. This slower growth rate is the result of greater demand for higher quality product on the export market. The requirement for higher and consistent quality coals has resulted in increased tonnages of raw coal being washed and consequently increased tonnages of material being discarded and proprotionally smaller tonnages of saleable coal produced. In 1981 about 18Mt of material was rejected at preparation plants.

Consumption by local industry has shown a slow but generally steady increase and has slightly more than doubled in the 30 years to 1981 when 37Mt was consumed.

The importance of the export trade to the industry and to the country as a whole cannot be understated. Exports have grown from a mere 100 000 tonnes valued at about $0.5 million in 1951 to 51Mt tonnes valued at about $2300 million in 1981. The value of coal exports was about 1/3 of the total value of primary minerals exported in 1981 and about 1/8 of the value of all Australian exports last year. Of the 51Mt shipped 10.6Mt was thermal coal and the remainder coking coal. Japan was the major customer taking over 34Mt including 5.7Mt of thermal coal. Increased exports have been the reason for most of the growth in the industry since the Second World War. This growth occurred as the result of increasing demand for coking coal on the international market until the late 70's and for thermal coal from the late 70's to the present.

Figure 2

A popular pastime recently has been forecasting the future of the Australian and world coal industries. Various forecasts have been made in relation to Australia, however, it is not so much the precise forecast that is important but rather the order of magnitude of the growth expected. The consensus at the time these forecastes were made was that exports would about double by 1990 and domestic consumption would increase substanitally, however the recent developments in the oil industry and the continued steel recession will make those forecasts more difficult to achieve. Whether we do in fact reach those levels remains to be seen but there is no doubt that we will continue to see a growth in the industry.

Coal production has come from what I loosely term the traditional areas, and the new areas. By traditional I mean the long established mining areas such as Blair Athol, Ipswich, Newcastle, Wollongong Leigh Creek and Collie. The new areas are those where mines have been developed mainly to meet the growing export demand and are predominantly located in the Bowen Basin in Queensland and the Hunter Valley in New South Wales. These two areas will almost certainly see much of the future development foreshadowed in the industry. Outside of the established producing areas there is considerable potential for future development in regions such as the Galilee, Arkaringa and Perth Basins, as demand warrants.

These developments and those that will take place in the future must be based on an adequate knowledge of the coal resources of the country. In order to define these resources, exploration has accelerated in recent years. Private sector spending has increased dramatically from $23 million in 1978/79 to $47 million in 1979/80 and $76 million in 1980/81. A feature peculiar to the coal industry is that some state Governments are heavily involved in exploration. NSW and Queensland governments carry out extensive drilling projects in coal bearing areas prior to possible release of those areas to industry for detailed exploration and development studies. To give you an idea of the extent of Government involvement in exploration, in 1980/81 the Geological Survey of Queensland drilled 47 874 m and the New South Wales Department of Mineral Resources drilled 11 478 m. In addition, the Electricity Commission of New South Wales drilled 56 610 m during the year. Drilling by the Department and the Electricity Commission in NSW in 1980/81 was over ¼ of exploration drilling in the state.

Figure 3

As a result of exploration carried out to date, Australia's demonstrated resources of black coal were assessed as 51 500 Mt in the ground at the end of 1981. Of this total only about 29 500 Mt are regarded as being economically recoverable with current mining technology and economic conditions.

Figure 4

The distribution of demonstrated resources is heavily concentrated in New South Wales and Queensland which together have over 98% of total in-situ resources. Resources in other states are small by comparison but are very important locally.

As mentioned earlier, most of the coal recovered in Australia is now washed which results in a considerable tonnage of mined material being discarded as waste. In recent years washery rejects have been about 18% of raw coal production. In 1981 the situation improved slightly when 18 Mt out of total raw coal production of 111 Mt was discarded. The combined effect of this discard rate and our inability to recover all in situ demonstrated resources is that less than half of those demonstrated resources will be marketed.

The implication then is that it would be beneficial if we were able to optimise our resource usage by increasing the tonnage of coal recovered and by utilising, as an energy source, some of the material now discarded at the washeries. These two areas appear to offer us the greatest opportunity to significantly improve the utilization of our coal resources and so add to our energy stock. I now want to look briefly at the prospects of increasing the recovery of in situ coal and making use of our coal washery rejects.

Certain developments taking place indicate that we are already on the way towards increasing the recovery rate of the in in-situ resources. These developments include the introduction of pre-stripping of overburden in open cut mines, the increasing use of longwall mining techniques in underground mines and the development of thick seam mining methods for use in underground mines.

Recovery rates in open-cut mines are high, usually up to or in excess of 90%, consequently any development that will extend the depth limits of open-cut mining will add to our recoverable resources and this is particularly important when it is remembered that recovery in underground mines is often less than 50%. Some figures presented to the 1981 technical meeting of the Australian Mineral Industries Research Association by Utah give an indication of the importance of maximising the operating depths of open cuts. In the Central Queensland Coal Associates leases there are about 500 Mt of saleable coal in every 30 m vertical interval, of which about 450 Mt could be recovered by open-cut mining but only 250 Mt by underground mining methods. In other words, at the depth where open cut mining ceased and underground mining commenced, the tonnage of coal that could be mined would fall by just under half for every 30 m of depth. In open cuts using trucks and shovels for overburden removal the main limitation on depth of mining will be the economics of the operation. In mines using drag-lines however, height of the highwall becomes very important and in the Utah case it was concluded that to strip overburden beyond a 60 m highwall in the Central Queensland Coal Associate mines would require additional movement of overburden by equipment other than draglines.

In the CQCA situation, and it is a situation that may have to be faced by other producers, a decision was taken to use other machinery to increase the depth of their open cut operations. That company has opted for a bucketwheet excavator to strip soft overburden at the Goonyella mine prior to further stripping by draglines. CQCA envisage a final highwall height averaging 90 m but up to 105 m in places compared to a height normally expected of about 60 m.

Obviously because of variable ground conditions bucketwheel excavators will not be appropriate in all mines but there are alternative systems for removing overburden prior to dragline stripping that may be used. Underground mines may still be developed concurrently with the operation of the deeper open cuts but, of course, the timing of such development will be a commercial decision for the company.

The second important development towards increasing recovery of coal is the utilisation of longwall mining techniques in underground mines. Longwall, where it can be used, results in greater recovery of in situ coal then the traditional bord and pillar methods. There are also benefits from the mine operators point of view because the increase in recoverable coal resources attributable to longwall mining can extend the life of the operation substantially, thus delaying the expenditure of capital on the development of new mines. The productivity of longwall units are also considerably higher than for continuous miners as will be seen shortly. However, the cost of longwall equipment is greater then for the continuous miners used in bord and pillar mining and ground conditions may prevent the use of longwall techniques. The increasing interest being shown in longwall operations in New South Wales has been referred to by theJoint Coal Board. They point out that in 1980/81 new longwall units were brought into production at 3 mines bringing the total number of units operating to 6 in 4 mines. There are also plans by companies to complete the introduction of longwall units in another 8 mines in New South Wales over the next few years. The Board notes that in May 1981 longwall units accounted for 7.5% of raw coal production in New South Wales underground mines. While this percentage is small it is most significant because if was achieved by only 6 units, while the remaining 92.5% of production was gained by 241 continuous miners in use in that month. The impact that longwall units can have is further shown in the Board's estimate of output per unit shift. In May 1981 continuous miners achieved an average output of 341 t/unit shift while longwall units had an average of 917 t. This high productivity coupled with higher recoveries illustrate the advantages that may be derived from longwall use.

Mining companies will be guided ultimately by economic factors in their decision to use longwall techniques where ground conditions allow however, any decision to use longwall is a step toward the more efficient use of our coal resources.

The third area where there is potential to improve coal recovery is perhaps of more long term interest than the previous two. It is the development of effective methods for underground mining of thick seams. Generally underground mining methods in operation in Australia take only some 3-4 m of a seam leaving any additional coal in the ground and in some thick seams recovery may be as low as 30%. Various thick seam mining procedures are in use in Australia but unless a really effective system can be developed for use in Australian mines much of the coal in these seams may not be economically recoverable. The Joint Coal Board records that in the Singleton North West district in May 1981, 36% of production came from seams 5-21 m thick but that the maximum seam height worked was only 5.5 m. This means, of course, that in any seam worked that was greater than 5.5 m thick coal would have been left in the ground. Had a suitable thick seam mining system been available much more of that coal may have been mined.

ACIRL, the Australian Coal Industry Research Laboratories, with the support of the industry, have been carrying out experimental thick seam mining at the Bowen No. 2 colliery at Collinsville in north Queensland. This trial has shown that in the Bowen seam up to 75% of the seam can be recovered and over the duration of the trial the average recovery was 65%. While this method has not resulted in full recovery the results show a considerable improvement over the recovery of about 50% or less that would normally be achieved in many Australian thick seams. Continued research into the problem will, I am confident, result in the development of more effective systems for mining such seams.

I would now like to consider briefly one technique for coal combustion which may make a major contribution towards the greater utilisation of our coal resources. I am referring to the fluidised bed combustion process in which the coal or coaly material is burnt while suspended in a rising air stream. Earlier I noted that some 18% of the Black coal mined in each year is discarded after washing. The energy content of the annual washery rejects is equal to that of all the brown coal used in Victoria for electricity generation in a year. One of the prime attributes of fluidised bed combustion is that it would be able to use much of this reject material.

The importance of the process is further emphasised when it is realised that it will also permit the use of low quality coals that may not normally be considered for use in any way. In fact it has been reported that the process can use fuels with up to 75% ash and energy values as low as 4.3 MJ/kg. These properties contrast markedly with those of thermal coals now exported which have ash contents less than about 15% and energy values of around 26 MJ/kg.

In addition to the utilisation of energy that would otherwise be lost the process is of environmental benefit because it reduces the amount of reject material that would otherwise have to be disposed of.

At this point, I would like to make a few brief comments about brown coal in Australia.

Australia's demonstrated resources of brown coal total 39 300 Mt in situ, of which 36 200 Mt are regarded as being economically recoverable. All the currently known economic resources are in Victoria. Exploration is continuing on deposits at Mannum and Kingston in South Australia and north of Esperance in Western Australia that may become economic to develop in the future. Bulk samples have been taken from the Wakefield deposit in South Australia to determine the suitability of that coal for use in power stations.

Total Australian production of brown coal has been around 33 Mt in past couple of years and while most is consumed by the SECV for the generation of electricity about 10% is used for the production of briquettes. Difficulties associated with the storage and transportation of brown coal and its relatively low energy and high moisture content preclude its sale to overseas customers.

The future development of Australia's brown coal resources will probably depend primarily on the growth in demand for electricity and increased production will be required to meet the demand for the new Loy Yang power station in Victoria.

Apart from electricity generation, the largest potential use of brown coal is for the production of synthetic fuels. However, the possibility of commercial synfuels production from any raw material appears unlikely during the next decade.

The current world position in relation to oil supply appears to provide us with a breathing space in which advances made in the coal industry may be consolidated. It is suggested that Australia should continue research into the production of synthetic fuels from both coal and oil shale in order to accumulate the data which will be necessary to help choose the most appropriate path to follow should a decision be made to embark on the production of synthetic fuels.

In conclusion, I would like to say that although the current oil situation and the difficulties being encountered by the world's steel industries have reduced the expectations of the Australian coal industry, it does still seem to have a bright future. These set backs largely reflect the current world economic situation. It is not expected that technological problems associated with mining or utilisation will hinder the development of our coal resources. In fact with the consolidation of the developments I have discussed, we should be in a much better position to effectively develop and use these resources in the future.

PRODUCTION, CONSUMPTION, EXPORTS, AND STOCKS OF BLACK COAL IN AUSTRALIA, 1951-81

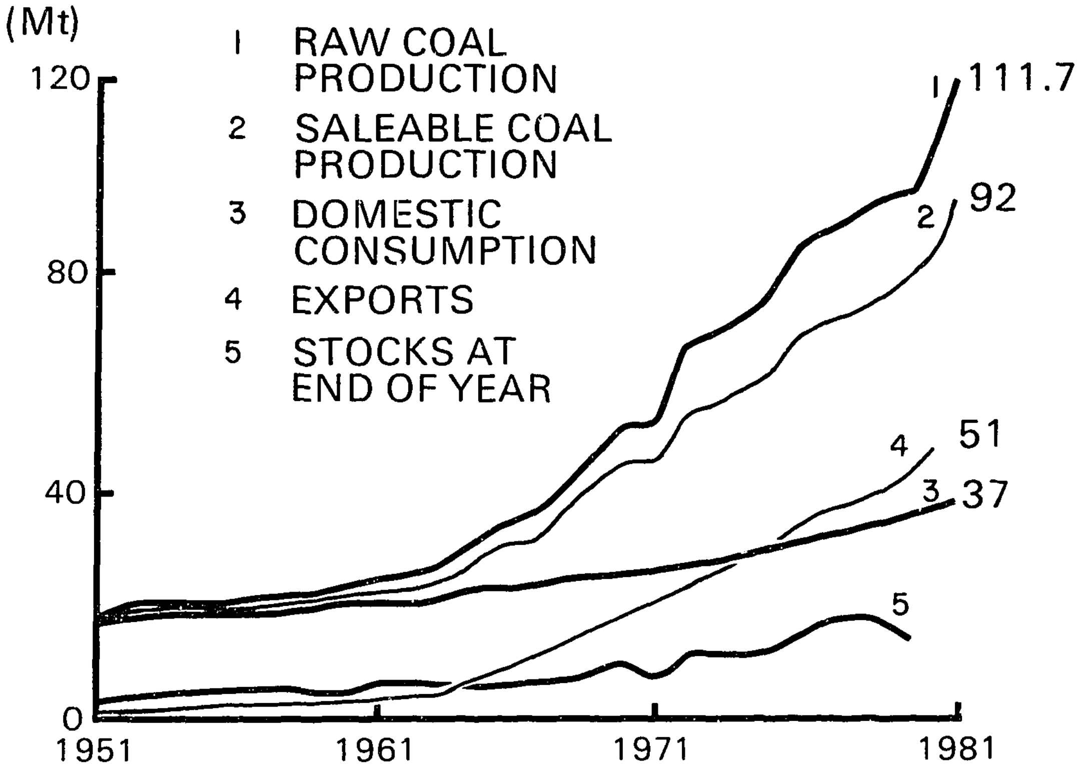


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Fig. 1

FORECAST 1990 EXPORTS AND DOMESTIC CONSUMPTION OF AUSTRALIAN BLACK COAL (Mt)

	EXPORTS	CONSUMPTION TOTAL
DEPARTMENT OF NATIONAL DEVELOPMENT AND ENERGY (1981)	130	
DEPARTMENT OF TRADE AND RESOURCES (1981)	100-130	
WORLD COAL STUDY (1980)	110	76
JOINT COAL BOARD (1980) (1)	115-180	74-98
ACTUAL 1981	51	37

(1) JCB FIGURES ARE ESTIMATES OF DEMAND RATHER THAN OF ACTUAL EXPORTS OR CONSUMPTION

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Fig. 2

AUSTRALIAN DEMONSTRATED RESOURCES OF BLACK COAL

MILLION TONNES (Mt)

	IN SITU	RECOVE-RABLE
NEW SOUTH WALES		
SYDNEY BASIN	21 234	11 001
GUNNEDAH BASIN	972	637
GLOUCESTER BASIN	36	33
OAKLANDS BASIN	500	450
ASHFORD	1	1
	22 743	12 122
QUEENSLAND		
BOWEN BASIN	22 836	13 017
GALILEE BASIN	1 600	896
IPSWICH BASIN	490	245
TARONG BASIN	280	241
CALLIDE BASIN	225	155
MULGILDIE BASIN	15	7
SURAT-MORETON BASIN	2 548	2 217
STYX BASIN	4	2
	27 998	16 780
WESTERN AUSTRALIA		
COLLIE	496	362
TASMANIA	139	69
SOUTH AUSTRALIA	120	120
GRAND TOTAL	51 496	29 453

SOURCES: JOINT COAL BOARD, QUEENSLAND DEPARTMENT OF MINES, NEAC

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Fig. 3

AUSTRALIAS COAL RESOURCES

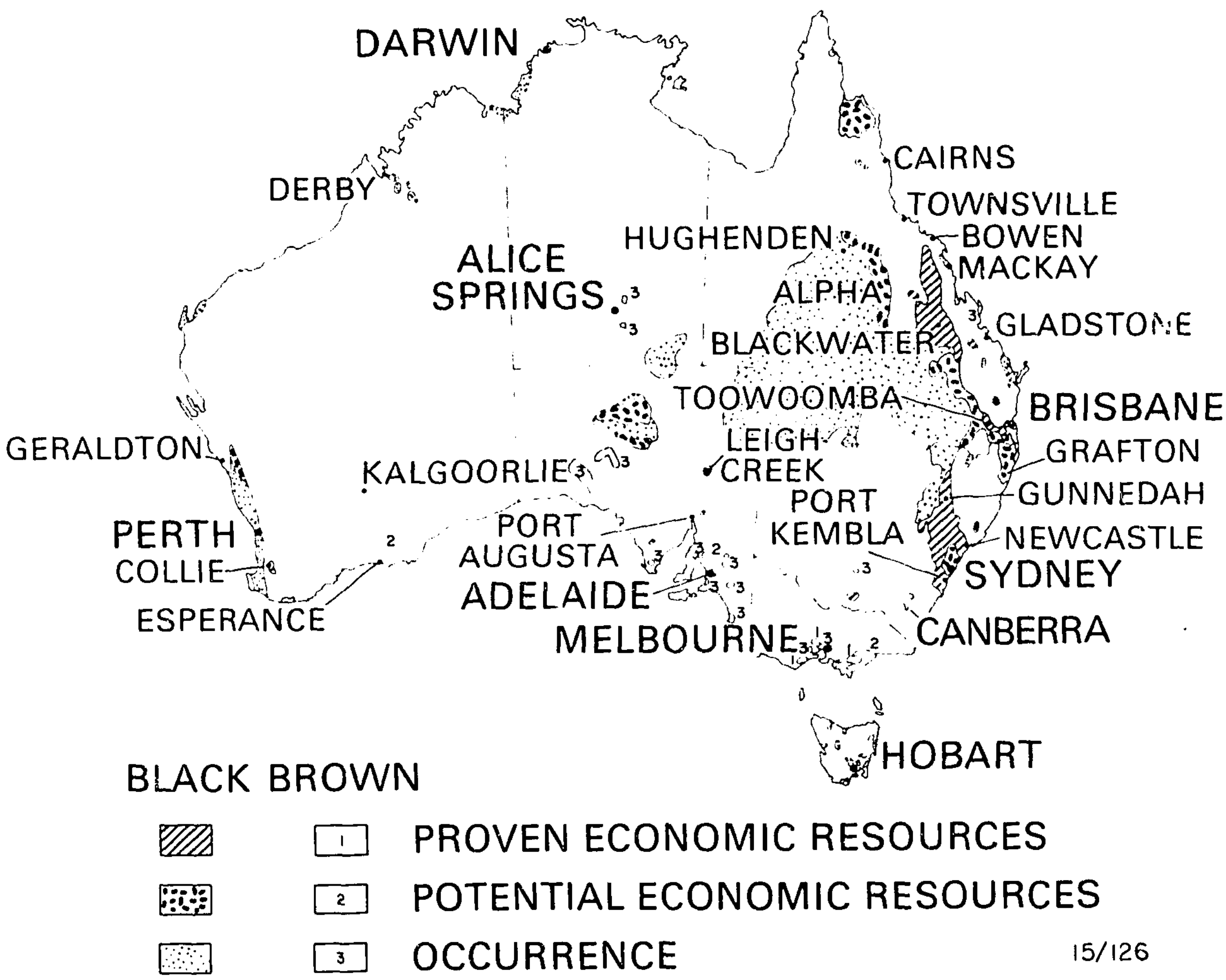

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Fig. 4

OIL SHALE RESOURCES AND DEVELOPMENT

B.G. Elliott & D.L. Gibson

Today I should like to review oil shale resources and their development in Australia against a background of Australian experiences, past and present, and recent events overseas.

Introduction

Oil shales are sedimentary deposits rich in organic matter called kerogen. When kerogen is heated to about 500^{o}C it decomposes to shale oil, gas and a carbon residue which remains with the retorted shale. The proportions and qualities of shale oil, gas and residue produced varies with the retort process, temperature, and the composition of the raw organic matter in the shale.

Crude shale oil can be obtained by either aboveground retorting or in situ processing. In aboveground retorting the shale is mined and then heated in retorting vessels. In a true in situ process a deposit is first fractured by explosives and then retorted underground. In modified in situ processing a portion of the deposit is mined and the rest is shattered by explosives and retorted underground.

Crude shale oil differs from petroleum derived oils in that it generally contains more unsaturated hydrocarbons, nitrogen, sulphur and heavy metals. Some upgrading is therefore necessary to produce a synthetic crude oil, syncrude, which can be used as a crude oil feedstock in conventional refineries.

History of Development

Most Australian production in the period 1865 to 1952 was from high-grade Permian oil shales associated with coal measures in the Sydney Basin of NSW (figure 1). Shale oil was also produced in Tasmania between 1910 and 1934.

The average yield in NSW was probably 300-400 l/tonne but some extremely rich deposits in the Blue Mountains yielded 600-1100l/tonne. However, despite these high grades, by the 1920s increased supplies of crude from newly developed conventional oil fields caused market prices for petroleum products to fall, making it difficult to produce oil from shale economically. Part of the difficulty in Australia stemmed from the fact that oil shale seams were thin, deposits were small and located in rugged country. Expensive underground mining techniques had to be used to recover the shale and it became increasingly difficult to produce shale oil competitively.

Resources

Today, most of Australia's known resources in shale oil are in Queensland but small deposits are also known in NSW, Tasmania and WA. At present, Australia's in situ demonstrated resources amount to about 23 000 million barrels mainly in seven major deposits (Table 1). Assuming that 70% of the shale oil resource can ultimately be recovered, then Australia's recoverable shale oil resources are about 8 times Australia's recoverable resources of conventional crude.

Looking now at inferred shale oil resources, BMR has estimated that the Toolebuc Formation may contain at least one million million barrels (10^{12}). However much of the Toolebuc oil shale is thought to occur as a low-grade seam (about 5 metres thick) deeply buried in the Great Artesian Basin.

Recent Exploration and Developments

Recent exploration for oil shale in Australia stemmed largely from increases in oil prices announced by OPEC in 1973 and 1974. CSR Ltd has been exploring vanadium shales of the Toolebuc Formation in the Julia

Creek area since 1968 and had completed initial studies for a small underground mine to produce 9 000 tonnes/ year vanadium pentoxide and 5-10 000 bbl/day shale oil, but there was little commercial interest in shale elsewhere. Higher oil prices encouraged CSR to consider shale oil development on a larger scale and exploration was undertaken to identify oil shale which could be recovered by open-cut methods.

In 1973, the Rundle twins, Southern Pacific Petroleum and Central Pacific Minerals, began to systematically develop an exploration strategy which has since identified substantial resources at five locations in eastern Queensland. The companies noted that shale oil had been produced prior to the development of conventional oil fields and that shale oil industries were still in operation in Russia and China. Several attempts had been made to develop rich shale deposits in the Rocky Mountains of Colorado but each had failed because of competition from low-cost conventional oil, and high shale development costs associated with remote location, difficult access, and complex development permitting procedures.

As a result of their analysis, the companies selected areas in Australia which were close to ports, power, water and labour. The areas were then examined closely to see if they might contain large deposits of oil shales. This approach led the companies to apply for an Authority to Prospect near the Rundle Range, 30 km NW of Gladstone, where the presence of oil shale had been known since the turn of the century.

Drilling began in 1974, and by 1976 the company's preliminary estimates of the resource at Rundle had reached 800 million barrels. (Fig. 2) Studies of shale mining and processing methods were carried out during 1977, and by mid-1978 preliminary engineering and environmental impact studies of the Rundle project were well advanced. Late that year Southern Pacific announced that they had identified a resource of about 2 000 million barrels.

Exploration activity now increased and broadened to include other prospects. The first drill hole was sunk at the Condor prospect in March 1978 and in the same year exploration began at Duaringa. In 1979 Peabody entered into a joint venture agreement with Central Oil Shale Pty Ltd to explore the Yaamba and other buried Tertiary basins north of Rockhampton. And at Julia Creek, CSR identified an 800 million barrel shale oil resource which could be mined by open-cut methods. During 1980 major deposits were discovered at Stuart, Condor, Duaringa and Yaamba; and at the end of the year identified resources of shale oil in Australia stood at 16 000 million barrels at six major deposits. (Fig. 3)

At this point, growth in exploration activity and expenditure eased. A sound resource base had been established and industry began to re-direct its attention away from geological field work and resource definition. Mine design and process engineering studies were begun and more detailed work undertaken to establish the physical and chemical characteristics of oil shales at several deposits.

After completing its preliminary feasibility study of the Julia Creek project CSR announced in March 1981 that a commercial scale project producing more than 100 000 bbl/day could be established at Julia Creek if the real price of oil rose by 3% per annum.

Studies of mining and processing methods begun at Rundle in 1977 formed the basis for discussions with several potential joint venturers and in February 1980 the Rundle 'twins' selected Esso Exploration and Production Australia to coventure development of the Rundle project. Early plans for the project envisaged a 200 000 bbl/day commercial plant to be developed in two phases. The first phase, estimated to cost around $A 700 million, was to produce about 15 000 bbl/day syncrude by 1985 and prove the technical and economic viability of producing oil from Rundle shale. Once this viability was established the companies planned to increase project capacity in stages to full scale in the early 1990's.

Esso began work at Rundle early in 1980 and key results were announced in April 1981. There were geotechnical difficulties in mining part of the oil shale resource and oil yields in pilot plant tests were lower than expected. Studies indicated that previous estimates for consumption of water and electricity were understated and that there was a need for upgrading the shale oil product.

In addition Esso's cost estimates for the Phase 1 demonstration plant had risen more than 300% to $A 2 000 million and it was recommended that the project not proceed to the demonstration phase as planned.

As a result the Rundle joint venture agreement was revised and in December 1981 the parties signed a formal agreement under which Esso would spend at least $A 30 million over 3 years on a program of research and evaluation studies. The program, to be carried out in the 3 years to December 1984, will include geological and geotechnical studies and other engineering and economic evaluations and is directed towards a decision regarding how to proceed further with the project.

The Condor project was the subject of joint venture discussions between the Rundle 'twins' and Japanese interests. After some months the twins signed an agreement with the Japan Australia Oil Shale Corporation (JAOSCO) in December 1981 to undertake a two-year joint feasibility study of the Condor project. JAOSCO shareholders are the Japan National Oil Corporation and forty leading Japanese companies from the private sector.

The $US 24 million study is to be funded by the Japanese Group and commenced in March 1982. Much of the process investigation work will be carried out by the Japan Oil Shale Engineering Consortium, comprising the Ministry of International Trade and Industry, and 13 Japanese companies, which plan to develop oil shale distillation technology over the next 5 years with its budget of $US 60 million.

During this time steady progress was being made on other projects. After completing their exploration and an initial resource definition program at Yaamba, Peabody commissioned a three-year feasibility study in February 1982. The first phase of the study, which is expected to take 12 months, will include a geological audit of the resource and studies of mining, infrastructure and environmental aspects of the project.

Exploration drilling of the Stuart prospect led to the discovery of another major shale oil resource. Research and engineering investigations began in 1981. Subject to further favourable results from these studies a pilot plant will be installed near the Stuart deposit for testing local and other Australian oil shales. Mining and infrastructure studies are to be carried out with a view to commercial development commencing in the southern portion of the deposit.

Finally the Nagoorin joint venture comprising the Rundle twins, Greenvale Mining and Esperance Minerals announced in December 1981 that they had identified a shale oil resource of 2 650 million barrels at the prospect.

This brought (in March 1982) Australia's in-ground demonstrated resources of shale oil to about 24 000 million barrels in 7 major deposits.

DEMONSTRATED RESOURCES OF SHALE OIL

DEPOSIT	IN-SITU RESOURCES (MILLION BARRELS)	AVERAGE YIELD (LITRES/TONNE DRY)
CONDOR	8 450	66
DUARINGA	3 720	82
JULIA CREEK	1 500	63
NAGOORIN	2 650	91
RUNDLE	2 650	99
STUART	2 510	94
YAAMBA	1 630	96
OTHERS	70	120-420
TOTAL	23 180	

NOTE: OVERALL RECOVERIES FOR EACH DEPOSIT ARE EXPECTED TO BE 50-90%, VARYING ACCORDING TO THE NATURE OF THE SHALE, AND MINING AND TREATMENT METHODS USED.

TABLE 1.

This potentially valuable national resource has been largely established over the last 5 years. The exploration and resource definition phase of development in Australia is now substantially complete in actively prospected areas, but additional resources could be found at Lowmead and Nagoorin, and in new discoveries north of Rockhampton and in NW Queensland.

Current Situation - Project Development Difficulties

It now seems likely that industry will focus its attention on more detailed studies to establish the nature of Australia's resources and test their feasibility of development. As part of these studies there will be greater emphasis on adapting established process technologies to Australian shales. For example, developers are likely to rely heavily on overseas experience in designing or procuring retort technology suitable for their Australian projects. Much of the risk and expense associated with developing, demonstrating and upscaling the technologies can thus be avoided, although there are, of course, some costs involved in acquiring them.

A broad examination of the nature of Australian shales suggests that differences in hardness, moisture content, impurity levels, carbon residue component, etc. between Australian and overseas shales could have a marked effect on the performance of some retorts (Table 2). Re-design requirements for technologies may vary considerably. For example, in situ technology, which treats shale in place, may have to be largely re-designed for each Australian project. Tests indicate that the Union Oil Company's aboveground rock-pump retort is not likely to handle some soft Australian shales efficiently, and could require substantial design changes if adopted for Australian projects. The tendency for the more friable Australian shales to yield a high proportion of fines on crushing may also limit the application in Australia of aboveground retort technologies developed for harder US shales.

CHARACTERISTICS OF OIL SHALE

DEPOSIT	MOISTURE (WT %)	% FINES UPON PRIMARY CRUSHING	% OF INITIAL CARBON LEFT IN SPENT SHALE
RUNDLE	23	40	42-53
JULIA CREEK	6	-	40
CONDOR	8	-	38
OTHER AUST. SHALES	18-32	-	-
USA COLORADO SHALES	2	6-10	23

TABLE 2

Industry studies are also likely to address difficulties of handling, processing and disposing of high volumes of material through the treatment process. Successful beneficiation processes would concentrate the kerogen by removing as much of the waste (host) rock as is possible before shale oil recovery is attempted. We could expect that a reduction in the volume of material to be treated in the retorts would lead to lower plant treatment capacities, and plant capital and operating costs, and to fewer problems in disposing of spent shale and in restoration.

The impacts of project development on the environment will also be looked at closely. Collection of base-line data is already underway at most sites. A typical program of environmental studies is likely to include work to address problems arising from dust generation, toxic emissions from waste process water and flue gases, mobilisation of toxic substances by ground water and spontaneous combustion of stockpiles and waste dumps.

Current Situation - Retort Technology Development

There are about a dozen retorting technologies which have reached an advanced stage of development and/or are being seriously considered in project development feasibility studies (Table 3). Of these the Union Oil, Tosco, and Petrosix technologies have all operated at around 800 bbl/day, and Occidental's commercial-scale in situ retort, currently under test, is expected to produce at about half this rate. Paraho and Superior retorts have operated at about 200 bbl/day. However, none of these technologies has yet been demonstrated at commercial scale.

Commercial-scale plants would comprise several retorts each producing around 10 000 bbl/day. There is therefore a considerable way yet to go in upscaling these technologies. The scaling-up of technology

RETORT TECHNOLOGY DEVELOPMENT OVERSEAS

RETORT TECHNOLOGY	DEMONSTRATED CAPACITIES TREATMENT CAPACITY (t/day oil shale)	DEMONSTRATED CAPACITIES PRODUCTION CAPACITY (bbl/day shale oil)
Union Oil (USA)[1]	1 200	800
Tosco (USA)	1 000	800
Petrosix (Brazil)	1 600	700
Galoter (USSR)[2]	500	400
Occidental (in situ)(USA)[3]	-	400
Kiviter (USSR)	300	-
Paraho (USA)	280	180
Superior (USA)	250	180
Chinese	150	-
Lurgi (FGR)	25	-

1. 10 000 bbl/day retort to be commissioned in mid 1983.
2. A 3300 t/d (2700 bbl/day) plant constructed in the early 1980's
3. Currently being tested.

TYPICAL COMMERCIAL-SCALE SHALE OIL PLANT

- Will require 5 or 6 retort modules each producing about 10 000 bbl/day shale oil.

TABLE 3

from pilot or demonstration scale to commercial scale is certainly one of the major technical barriers to the development of a viable shale oil industry.

Success in overcoming this hurdle, particularly in the short term, will depend largely on the performance of a 10 000 bbl/day commercial-scale retort which the Union Oil Company plans to commission at Long Ridge, Colorado, in the middle of next year. There will be many interested in how well the Union plant performs in relation to its design capacity.

The successful demonstration of Union Oil's technology at commercial scale could (by establishing full-scale operating experience, and firm capital and operating cost parameters) reduce technological risk and assist investor confidence especially among the banking fraternity. Reports indicate that Union believes that its project (estimated to cost $550 million) remains economic at "current oil prices" but it is worth noting that Union has a purchase agreement which calls for the delivery of 10 000 bbl/day of shale-derived military fuels to the US Department of Defence at a minimum price indexed to inflation.

Recent Overseas Developments

Recent developments overseas have been dominated by reconsideration of development plans for a number of projects in the United States. This has been prompted by higher than expected project cost estimates and the recent levelling off in world oil prices.

Exxon announced in May 1982 that it would cease funding the Colony shale oil project in Colorado. The company's estimate of cost for the project has roughly doubled since 1980 from about $US 3 billion to between $US 5 and 6 billion. Exxon acquired a 60% interest in Colony in August 1980 for $US 300 million and with its co-venturer, Tosco, has since spent $US 400 million on the project. Under its joint venture agreement with Tosco, Exxon is to purchase Tosco's 40% interest in the project.

Occidental and Tenneco closed down their Cathedral Bluffs project in December 1981 and a review of the planned scale of operation is underway. The companies had expected to recover 94 000 bbl/day utilising both Occidental's in-situ technology and aboveground retorting. The companies are now considering, among options for further development, an initial project to produce 10 000 bbl/day based on aboveground retorting technology. The future development of a full-scale project may hinge on the success of two commercial-sized retorts at Occidental's Logan Wash experimental site which are expected to produce 200 000 barrels of oil before September 1982.

Outlook

The exploration and related activities of the last 5 years have brought the development of a substantial and potentially valuable new energy resource in Australia a step closer to realisation. The outlook is for feasibility studies and preliminary bulk testing of Australian shale (using various retort technologies) to continue. Technical investigations are likely to concentrate on shale beneficiation techniques and shale characterisation. With improvements in technologies and a resumption of upward movements in the real price of oil demonstration plants could be in operation by the end of the decade with commercial-scale production commencing late in the 1990's.

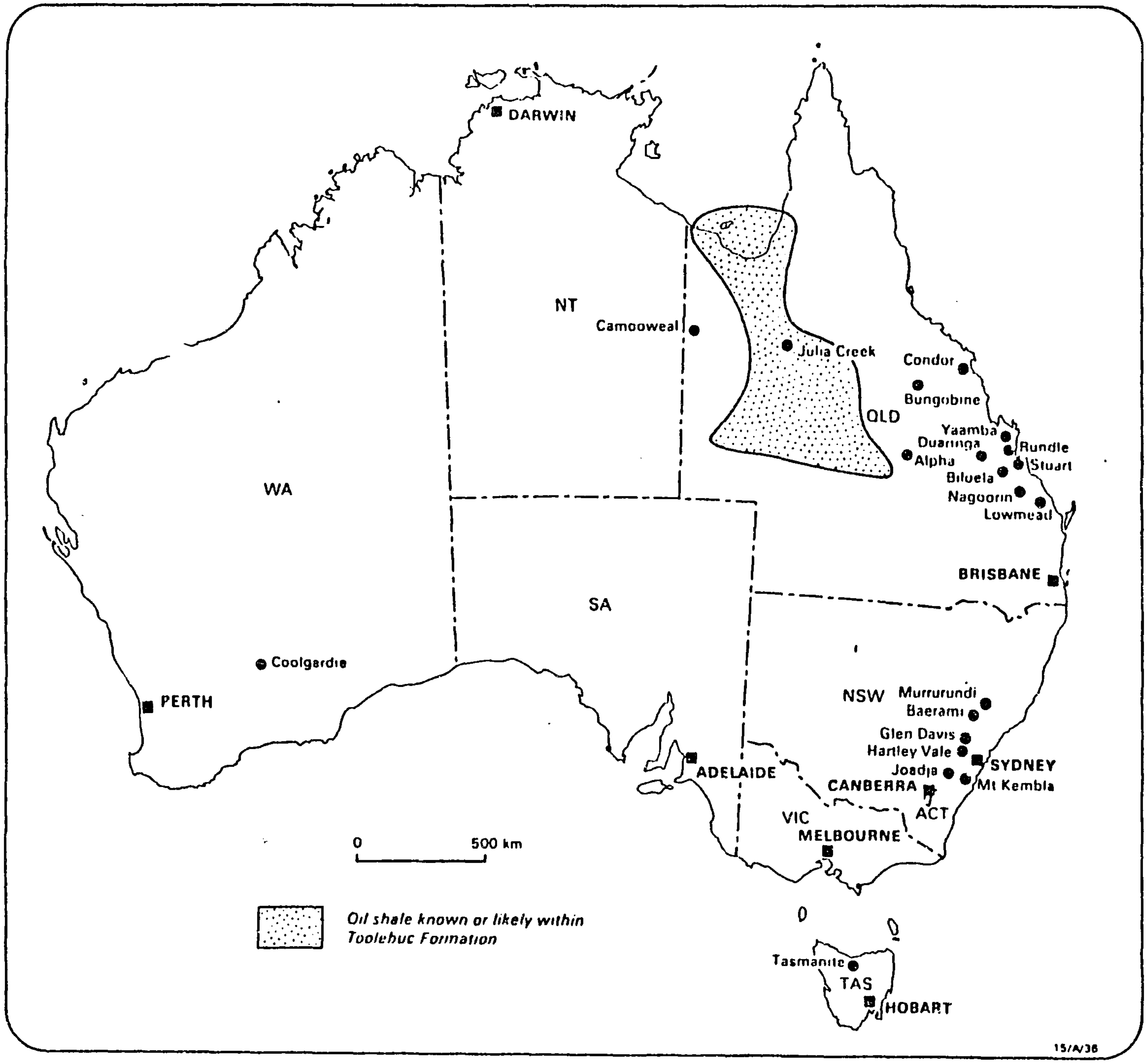


Figure 1. Location of oil shale deposits

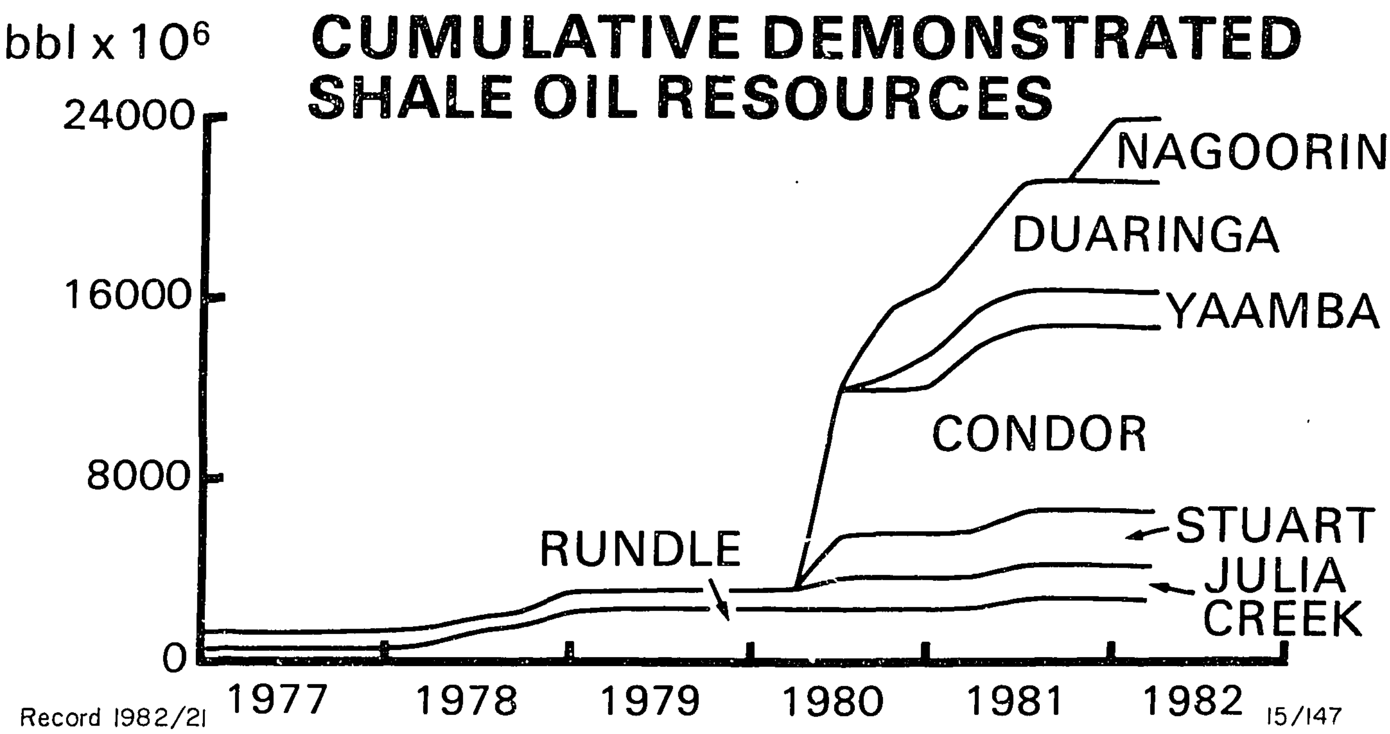
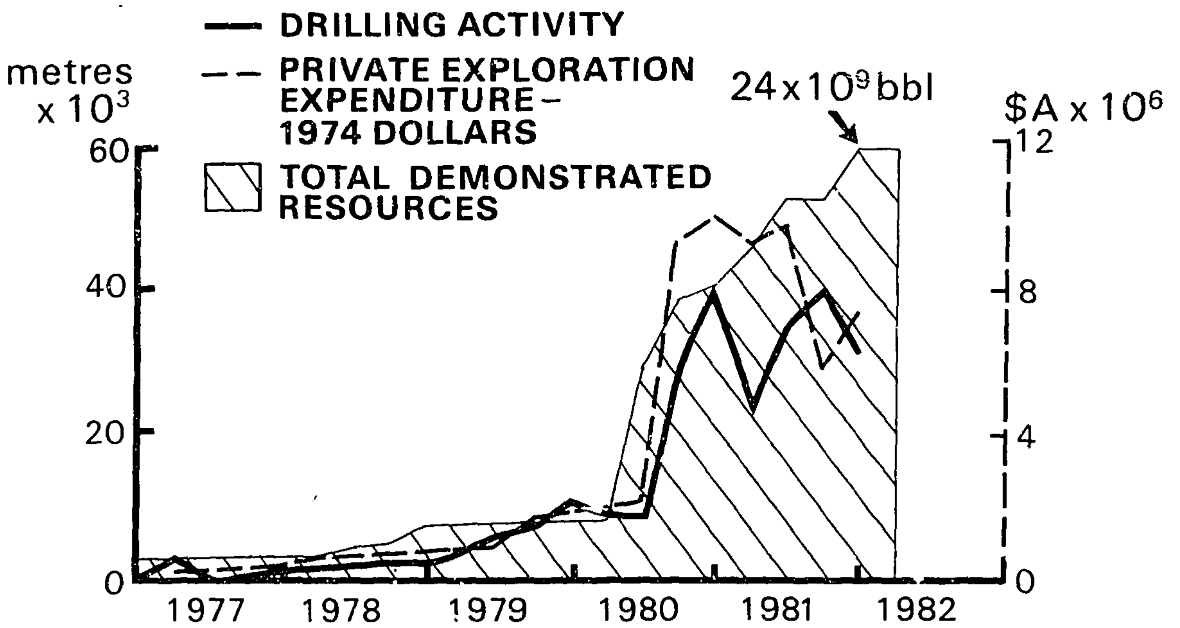

bbl x 10⁶
CUMULATIVE DEMONSTRATED SHALE OIL RESOURCES
24000
16000
8000
0
NAGOORIN
DUARINGA
YAAMBA
CONDOR
STUART
JULIA CREEK
RUNDLE
1977
1978
1979
1980
1981
1982
Record 1982/21
15/147

Fig. 2



Record 1982/21

Fig. 3

15/146

URANIUM RESOURCES AND SUPPLY

THIS MORNING I SHALL REVIEW RECENT DEVELOPMENTS IN THE AUSTRALIAN URANIUM MINING INDUSTRY AGAINST THE BACKGROUND OF THE WORLD'S URANIUM RESOURCES AND THE ADEQUACY OF THESE RESOURCES TO SUPPLY PROJECTED DEMAND.

HISTORY:

THE HISTORY OF THE DEMAND AND CONSEQUENT SEARCH FOR AND PRODUCTION OF URANIUM IS RELATIVELY RECENT. THIS IS IN CONTRAST TO METALS SUCH AS GOLD AND COPPER WHICH HAVE BEEN IN DEMAND FOR THOUSANDS OF YEARS.

URANIUM WAS DISCOVERED IN 1787 BY THE GERMAN CHEMIST, KLAPROTH. THE NATURAL RADIOACTIVITY OF URANIUM WAS DISCOVERED BY THE FRENCH PHYSICIST, BECQUEREL, IN 1896. IN 1898 PIERRE AND MARIE CURIE SEPARATED RADIUM FROM URANIUM AND THIS LED TO WHAT WE MAY CONSIDER AS THE FIRST URANIUM PRODUCTION BOOM EARLY IN THE 20TH CENTURY. OF COURSE, AT THIS TIME THE INTEREST WAS ON RECOVERING RADIUM WITH THE ASSOCIATED URANIUM CONSIDERED AS A WASTE PRODUCT.

A DEMAND FOR URANIUM FOR MILITARY PURPOSES AROSE DURING THE SECOND WORLD WAR AND PEAKED IN 1959 DURING THE HEIGHT OF THE COLD WAR WITH A PRODUCTION IN THAT YEAR OF SOME 34,000 TONNES U IN THE WESTERN WORLD AS SHOWN ON THIS SLIDE.......(Slide 1) FROM THIS POINT THE MARKET BECAME DEPRESSED AND IT WAS SOME TWENTY YEARS BEFORE PRODUCTION AGAIN ATTAINED THIS LEVEL. THE SECOND INCREASE IN DEMAND AND PRODUCTION AROSE FROM THE ESTABLISHMENT OF SUBSTANTIAL NUCLEAR POWER PROGRAMS, A DEVELOPMENT ACCENTUATED BY THE OIL CRISIS OF 1973/74. FROM LATE 1973 TO EARLY 1976 THE SPOT PRICE FOR URANIUM INCREASED SEVENFOLD FROM US\$6.00/LB U_3O_8 TO US\$41.50/LB U_3O_8.

AS ONE MIGHT ANTICIPATE EXPLORATION FOR URANIUM HAS FOLLOWED THIS PATTERN OF DEMAND AND PRODUCTION WITH VIGOROUS EXPLORATION PROGRAMS IN THE 1950'S FOLLOWED BY A LULL DURING THE 1960'S AND A DRAMATIC REVIVAL IN THE 1970'S.

THE MORE SIGNIFICANT AUSTRALIAN DISCOVERIES ARE SHOWN ON THIS SLIDE.......(Slide B) THE FIRST EXPLORATION SURGE OF THE 1950'S RESULTED IN THE DISCOVERY OF RUM JUNGLE AND MARY KATHLEEN AND NUMEROUS SMALLER DEPOSITS. THE SECOND EXPLORATION PHASE RESULTED IN THE DISCOVERY OF RANGER, NABARLEK, KOONGARRA, JABILUKA, BEVERLEY, YEELIRRIE, OLYMPIC DAM AND OTHERS.

THE SIGNIFICANCE OF THESE LATER DISCOVERIES IS DEMONSTRATED IN THE INCREASE IN AUSTRALIAN RESERVES FROM 6,200 TONNES U IN 1967 TO 294,000 TONNES IN 1981. INDEED, A DRAMATIC INCREASE!

WORLD SCENE:

THERE WAS A GREAT DEAL OF SECRECY SURROUNDING URANIUM EXPLORATION, PRODUCTION AND DEMAND IN THE YEARS WHEN URANIUM WAS REQUIRED PRIMARILY FOR MILITARY PURPOSES.

IN MORE RECENT TIMES THERE HAS BEEN A GREAT DEAL OF INTERNATIONAL COOPERATION IN THE PREPARATION OF URANIUM RESOURCE ESTIMATES AND SINCE 1965 THE OECD NUCLEAR ENERGY AGENCY HAS PERIODICALLY PUBLISHED REPORTS ON URANIUM RESOURCES PRODUCTION AND DEMAND. SINCE 1967 THESE REPORTS HAVE BEEN PREPARED IN COOPERATION WITH THE INTERNATIONAL ATOMIC ENERGY AGENCY. THE LATEST ISSUE OF THEIR PUBLICATION, URANIUM RESOURCES PRODUCTION AND DEMAND, PUBLISHED IN FEBRUARY 1982, IS THE NINTH OF THIS SERIES WHICH ARE COMMONLY REFERRED TO AS THE "RED BOOK". THE STATISTICS PUBLISHED IN THE RED BOOK REPRESENT THE MOST AUTHORITATIVE FIGURES AVAILABLE ON URANIUM RESOURCES. QUESTIONNAIRES ARE SENT TO NATIONAL AUTHORITIES AND THE REPORTS ARE PREPARED UNDER THE DIRECTION OF THE NEA/IAEA WORKING PARTY ON URANIUM RESOURCES WHICH INCLUDES REPRESENTATIVES OF THE MAJOR PRODUCER AND CONSUMER NATIONS.

........(slide 2) AS SHOWN ON THIS SLIDE, URANIUM RESOURCES ARE CURRENTLY CLASSIFIED INTERNATIONALLY INTO REASONABLY ASSURED RESOURCES, ESTIMATED ADDITIONAL RESOURCES AND SPECULATIVE RESOURCES, REFLECTING DECREASING LEVELS OF CONFIDENCE IN THE QUANTITIES REPORTED. THE CATEGORIES ARE FURTHER SUBDIVIDED ACCORDING TO THEIR COST OF EXPLOITATION INTO LESS THAN US$80/KG U; $80-130/KG U AND $130-260/KG U. THE REASONABLY ASSURED RESOURCES AT LESS THAN US$80/KG U ARE REGARDED AS RESERVES. YOU WILL NOTE THAT ON THIS SLIDE THE RESERVES ARE SHOWN ON THE LOWER LEFT HAND SIDE WHICH IS THE CONVENTION ADOPTED INTERNATIONALLY FOR URANIUM RESOURCES AND DIFFERS FROM THE CONVENTIONAL POSITION ADOPTED BY SPEAKERS ON OTHER MINERALS AT THIS CONFERENCE.

IT SHOULD BE EMPHASISED AT THIS POINT THAT THESE COST CATEGORIES REFER TO FUTURE COSTS AND DO NOT TAKE INTO ACCOUNT PAST EXPLORATION COSTS INCURRED IN DISCOVERING AND DELINEATING DEPOSITS OR PAST DEVELOPMENT COSTS OF A CAPITAL NATURE. WHERE URANIUM OCCURS AS A BY-PRODUCT, SUCH AS THAT OCCURRING IN MANY OF THE SOUTH AFRICAN GOLD MINES, ONLY THE COST OF RECOVERING URANIUM FROM THE MILL CIRCUIT IS CONSIDERED AS THE REMAINDER OF THE COSTS ARE ATTRIBUTED TO GOLD PRODUCTION.

Australian delegates to the NEA/IAEA Steering Group on Uranium Resources responsible for these definitions have been concerned that the Estimated Additional Resource Category contains both extensions of known deposits and undiscovered deposits believed to exist along a well defined geological trend with known deposits. It is anticipated that in the next edition of the red book Estimated Additional Resources will be subdivided to distinguish between resources in "known" deposits and those in "undiscovered" deposits. These resource definitions all refer to "uranium that could be recovered from deposits" and yet many nations have made a practice of not taking account of milling losses. It is anticipated that this too will be rectified in the next edition of the red book.

The estimate of the Western World's resources in the Reasonably Assured Category at less than $US130/kg U has decreased by 11% between 1979 and 1981. The world's reserves (i.e. Reasonably Assured Resources below US$80/kg U) have been decreased by 6% during this period. These decreases can be attributed to increased capital and production costs resulting in certain resources being moved into higher cost categories, particularly in the U.S.A., and also to increased production exceeding new discoveries. As shown on this slide .... (Slide 3) the current resource estimates of the Western World in the Reasonably Assured Category as published in the latest edition of the Red Book are 1,747,000 tonnes below US$80/kg U and a further 546,000 tonnes between US$80-130/kg U. In the Estimated Additional Category the estimates are 1,605,000 tonnes below US$80/kg U and 1,115,000 tonnes U between US$80-130/kg U. The speculative Resources below US$130/kg U, which are not shown on this slide, are estimated to be between 6,600,000 tonnes U and 14,800,000 tonnes U.

Since this slide was prepared in early June the estimates of uranium resources in the USA as at 1st January, 1982, have been released and there are further significant decreases which are attributed to increases in operating costs and a low rate of exploration and development. The estimate of reserves (i.e. Reasonably Assured Resources below US$80/kg U) has been reduced by a further 56% during 1981 and now stands as 158,000 tonnes U, a reduction of 204,000 tonnes in the past year and 373,000 tonnes in the past three years.

One might expect that because uranium is now produced almost exclusively for industrial nuclear power, very reliable estimates of future uranium demand could be prepared. We have found, however, that the estimates made in the 1970's were optimistic and the growth of nuclear power is less than that anticipated at that time.

Future uranium requirements are considered in the NEA/IAEA Publication, Nuclear Energy and Its Fuel Cycle, termed the "YELLOW BOOK". Estimates are prepared of future electricity demand and then assumptions are made of the proportion of this demand which is likely to be met by nuclear power. Various nuclear reactor strategies have to be considered which vary with the introduction at varying times of more fuel efficient reactor systems. The rate at which such systems are introduced will have a very significant effect on future uranium requirements.

Provided uranium prices are sufficient to justify exploitation of resources up to US$130/kg U, the current resources in the RAR and EAR categories would be adequate to increase production capability to meet any of the current annual requirement projections until the year 2000. A lower growth of nuclear power or earlier introduction of more fuel efficient reactor systems will extend this date beyond 2000 from current resources.

World production capacity currently exceeds demand and production capabilities are planned to increase from 49,000 tonnes U in 1981 to 78,000 in 1986. If these planned facilities are built many of them would not operate at full capacity in the absence of increased demand.

Because of the sluggish growth of nuclear power in recent years relative to predictions made in the 1970's and the increased supply capability and production developed to satisfy the anticipated demand, an over-supply situation has developed and uranium prices in real terms have fallen. Numerous producers, particularly in the USA, have heavily curtailed or ceased mining. Announcements have been made of the iminent closure of Mary Kathleen in Australia and Beaverlodge in Canada. This situation of over-supply is not expected to continue in the mid and long term and the large lower cost projects in Canada and Australia are in a good position to exploit the expanding demand that will arise in the late 1980's and 1990's. Demand is currently increasing.

The spot price for uranium, as previously mentioned, rose from US$6.00/lb U_3O_8 in late 1973 to US$41.50/lb U_3O_8 in early 1976. It is currently about US$21/lb U_3O_8. It must be remembered that most of the uranium from producing mines is sold at long term contract prices, not spot prices. The demand figures published in the red and yellow books by the NEA/IAEA do not indicate the proportion of future demand which is uncommitted, that is to say, for which contracts have not yet been made. Hence it is difficult to predict the effect of future demand on future prices.

EXPLORATION FOR URANIUM ON A WORLD-WIDE BASIS IS DECREASING FROM THE RECORD LEVELS OF 1979. THIS DECREASE IN EXPLORATION IS MOST NOTICEABLE IN THE USA, AS SHOWN ON THIS SLIDE ....(Slide 4) WHERE WE NOTE THE EXPENDITURE ON EXPLORATION PEAKING IN 1979 AND DECREASING DURING THE PAST TWO YEARS. THE DECREASE IN THE EXPLORATION ACHIEVED IN SHOWN MORE DRAMATICALLY IN THE DECREASE IN THE METRES DRILLED DURING THE PAST TWO YEARS.

URANIUM EXPLORATION DATA
U.S.A.

YEAR:	SURFACE DRILLING No. OF HOLES.	SURFACE DRILLING M DRILLED (x 1,000)	TOTAL EXPLORATION EXPENDITURE
1977	105,100	13,900	US$258,000.000
1978	104,400	14,700	US$314,000,000
1979	90,600	12,500	US$316,000,000
1980	59,800	8,600	US$267,0-0,000
1981	24,300	4,000	

WE HAVE ALREADY NOTED THAT CURRENT RESOURCES ARE ADEQUATE FOR THE NEXT TWO DECADES BUT, IN VIEW OF THE LONG LEAD TIMES INVOLVED FROM THE COMMENCEMENT OF EXPLORATION TO THE COMMENCEMENT OF PRODUCTION, THERE IS CONCERN THAT CURRENT INVESTMENT IN EXPLORATION AND DEVELOPMENT MAY FALL SHORT OF THE LEVELS REQUIRED TO ENSURE TIMELY AVAILABILITY TO MEET FUTURE REQUIREMENTS. FROM THE EXPLORATION RESULTS OF THE PAST THIRTY YEARS AND THE INTERNATIONAL EVALUATION OF THE WORLD URANIUM POTENTIAL, PUBLISHED BY NEA/IAEA IN DECEMBER 1978, I FEEL VERY CONFIDENT THAT, PROVIDED THE NECESSARY FUNDS ARE AVAILABLE, FUTURE EXPLORATION WILL RESULT IN THE DELINEATION OF ADEQUATE RESOURCES TO MEET ANY FORSEEABLE DEMAND.

AUSTRALIA:

TURNING FROM THE WORLD SCENE TO LOOK AT THE SCENE IN AUSTRALIA WE SEE NO EVIDENCE TO THE END OF 1980 (WHICH ARE THE LATEST FIGURES WE HAVE) OF ANY SIGNIFICANT DECREASE IN URANIUM EXPLORATION ACTIVITY AS SHOWN ON THIS SLIDE........ (Slide 5)

URANIUM EXPLORATION DATA -
AUSTRALIA

	TOTAL EXPLORATION EXPENDITURE
1975	A$ 8,000,000
1976	13,000,000
1977	17;000,000
1978	25,000,000
1979	29,000,000
1980	35,000,000

One might well wonder why there has not been a decrease in uranium exploration expenditure in this country similar to that experienced in the U.S.A. I believe that the answer might well be the remarkable success rate here in Australia where the cost of discovery per kg U is remarkably low.

A comparison of exploration costs with increases in reserves for Australia and the U.S.A. is shown on this slide........
(Slide 6)

	Reserves 1966 tonnes U	Reserves 1980 tonnes U	Increase 1966-1980 tonnes U	Costs 1966-1980 $M	Cost $US/kg increase
AUSTRALIA	6,200	294,000	287,800	217	0.75
U.S.A.	123,000	362,000	239,000	842	3.52

Now both Australia and the U.S.A. have large uranium reserves and are of comparable area and yet the cost of discovery per kg U for the period 1966 to 1980 was five times higher in the U.S.A. than in Australia. The reduction by 56% of the United States reserves i.e. Reasonably Assured Resources below US$80/kg U during the past twelve months would make this comparison of discovery costs much more to Australia's advantage. These figures also illustrate the fact that expenditure on uranium exploration in recent years was much greater in the U.S.A. than in Australia.

For several years most of the Alligator Rivers Uranium Province has not been available for exploration. This Province, which contains a significant percentage of the world's reserves, has been inadequately explored to date and there is a potential for finding more high grade deposits. A resumption of exploration in this area would be expected to result in a significant increase in uranium exploration in Australia.

In Australia uranium resource estimates are prepared in categories as defined by the NEA/IAEA by the Uranium Resource Evaluation Unit, which has recently been transferred from the Australian Atomic Energy Commission to the Bureau of Mineral Resources, Geology and Geophysics. These estimates are prepared from the basic data provided by companies in accordance with the Atomic Energy Act 1953. The practice is for the Uranium Resource Evaluation Unit to prepare a draft report detailing their estimate of the in situ resource, the parameters on which this estimate is based and a reconciliation defining any discrepancies with company

ESTIMATES. THIS DRAFT IS THEN DISCUSSED WITH TECHNICAL OFFICERS OF THE COMPANY PRIOR TO THE PREPARATION OF A FINAL REPORT. FROM THESE ESTIMATES OF IN SITU RESOURCES, ESTIMATES OF RECOVERABLE URANIUM ARE PREPARED MAKING ALLOWANCE FOR MINING AND MILLING LOSSES. THESE ESTIMATES ARE REGARDED AS COMMERCIAL IN CONFIDENCE AND ARE NEVER PUBLISHED. THEY ARE AGGREGATED TO PREPARE NATIONAL TOTALS IN THE VARIOUS RESOURCE CATEGORIES.

THE LATEST AVAILABLE RESOURCE ESTIMATES ARE THOSE OF JUNE 30, 1981, AS SHOWN ON THIS SLIDE........(Slide 7)

	(TONNES U)
REASONABLY ASSURED RESOURCES AT LESS THAN US$80/KG U	:294,000
REASONABLY ASSURED RESOURCES BETWEEN US$80-130/KG U	23,000
ESTIMATED ADDITIONAL RESOURCES AT LESS THAN US$80/KG U	:264,000
ESTIMATED ADDITIONAL RESOURCES BETWEEN US$80-130/KG U	21,000

THE AUSTRALIAN ESTIMATES ARE ALL EXPRESSED AS RECOVERABLE URANIUM WITH DUE ALLOWANCE FOR MINING AND MILLING LOSSES. THE AUSTRALIAN ESTIMATES FOR ESTIMATED ADDITIONAL RESOURCES DO NOT INCLUDE ANY ESTIMATES OF RESOURCES FROM UNDISCOVERED DEPOSITS AND DIFFER IN THIS WAY FROM THE ESTIMATES PREPARED BY MOST OTHER NATIONS. WE CONSIDER THAT THE CURRENT PRACTICE ADOPTED BY THE NEA/IAEA OF ADDING ESTIMATES OF KNOWN DEPOSITS TO THOSE OF UNDISCOVERED DEPOSITS IS TECHNICALLY UNACCEPTABLE AND ANTICIPATE THAT THIS MATTER WILL BE RECTIFIED IN THE NEXT EDITION OF THE RED BOOK.

AUSTRALIA, WITH 294,000 TONNES U, HAS 17% OF THE WESTERN WORLD'S REASONABLY ASSURED RESOURCES BELOW US$80/KG U BASED ON THE ESTIMATES PUBLISHED IN THE LATEST RED BOOK. WHEN ACCOUNT IS TAKEN OF THE REDUCTION OF THE UNITED STATES ESTIMATES, PUBLISHED A FEW WEEKS AGO, AUSTRALIA NOW HAS THE LARGEST URANIUM RESERVES (I.E. REASONABLY ASSURED RESOURCES BELOW US$80/KG U) IN THE WORLD AMOUNTING TO SOME 19% OF THE WORLD'S RESOURCES IN THIS CATEGORY. I CONSIDER THE POTENTIAL OF SIGNIFICANT INCREASES IN AUSTRALIA'S URANIUM RESOURCES IS VERY HIGH PROVIDED THE EXPLORATION EFFORT IS MAINTAINED.

THE QUESTION IS SOMETIMES RAISED AS TO WHY THESE AUSTRALIAN ESTIMATES FOR RESOURCES BELOW $80 ARE SO MUCH GREATER THAN THOSE IN THE $80-$130 CATEGORIES. THE MAJOR REASON IS THAT COMPANIES MAKE LITTLE ATTEMPT TO DELINEATE RESOURCES IN THIS CATEGORY BECAUSE THEY WOULD BE SUB ECONOMIC. THE ESTIMATES THAT ARE THERE REPRESENT THE RESULTS OF SOME OF OUR MORE UNSUCCESSFUL EXPLORATION WHERE FEASIBILITY STUDIES HAVE ESTABLISHED THAT COSTS ARE OF THIS ORDER AND THE PROJECTS DO NOT MEET THE TARGETS ANTICIPATED IN EARLIER STAGES OF EXPLORATION PROGRAMS.

Uranium production in Australia has increased in recent years as a result of the development of two of the deposits in the Alligator Rivers Uranium Province. Production commenced at Nabarlek in June 1980 and at Ranger in August 1981. Total Australian production to the end of 1981 totals 14,143 tonnes U compared with Western World production which exceeds 650,000 tonnes. Thus, while Australia has 19% of the world's uranium reserves i.e. reasonably assured resources below US$80/kg U, total production to date from this country is relatively low.

I shall now review very briefly the current status of the existing mines and the more important deposits in Australia.

Mary Kathleen was discovered in 1954 and commenced production in 1958. Production was suspended in 1963 and resumed in 1976. The company has announced that it is proposed to cease production in December 1982 because the remaining resources would be uneconomic at current prices. I well remember the discovery of this deposit by a prospecting syndicate, the competition by many companies to assess the prospect and attempt to purchase it, the development of a mine and mill, the establishment of a delightful little town to service it and now for the second, and I expect the last, time production will cease.

Nabarlek was discovered in 1970 and commenced production ten years later. The development at Nabarlek is somewhat unique in that the entire ore body was mined and stockpiled for eventual treatment in the mill. Nabarlek is one of the highest grade deposits in the world.

Ranger was discovered in 1970 and commenced production in 1981. It is interesting to note that during a period when it was considered difficult to secure sales contracts, the management of Energy Resources of Australia have announced that sales contracts have been concluded for the total initial designed capacity of the project. A township is being constructed nearby at Jabiru and this town will service Ranger and the development of other projects in this region.

While Mary Kathleen, Nabarlek and Ranger are the only existing uranium mines in Australia at the present time there are several other projects which are proceeding towards development.

Government approvals have recently been granted for the development of the Lake Way deposit in Western Australia and the Honeymoon Deposit in South Australia. The Honeymoon deposit is to be mined by solution mining and represents the first uranium development of this nature in this country. There are several existing mines using this technology in the U.S.A.

A metallurgical plant has been constructed at Kalgoorlie to establish the treatment process for ore from the Yeelirrie deposit in Western Australia. Although it was recently announced that one of the parties had withdrawn from this project the operator still considers that production will commence in 1986.

Conditional approval was recently announced for the joint venturers at Jabiluka to proceed to secure sales contracts. Jabiluka in the Northern Territory is one of the largest uranium deposits in the world and to date the deposit is not completely delineated. It was originally proposed to mine the deposit as an open cut but the current proposal is to develop an underground mine.

Negotiations are in progress with the appropriate Aboriginal representatives for the proposed development of the Koongarra deposit. Since this deposit is held by a Canadian company, appropriate equity arrangements would be required to satisfy the Government's requirements on the percentage of Australian equity in proposed uranium developments.

An environmental impact statement is being prepared for the proposed development of the Ben Lomond Deposit in Queensland. Since this deposit is held by a French company it does not currently satisfy Government requirements for Australian equity for developmental approval.

Work is proceeding to secure Government approval for the development of the Beverley deposit in South Australia using a solution mining technique. The Beverley deposit was discovered in 1969.

Drilling is continuing to further define the copper and uranium resources at Olympic Dam on Roxby Downs Station in South Australia, which was discovered in 1975. To date the company has not announced any reserve estimates but the detailed drilling results they have announced indicate that it is certainly a major deposit. A shaft is currently being sunk to obtain geological and engineering data and samples for metallurgical testing.

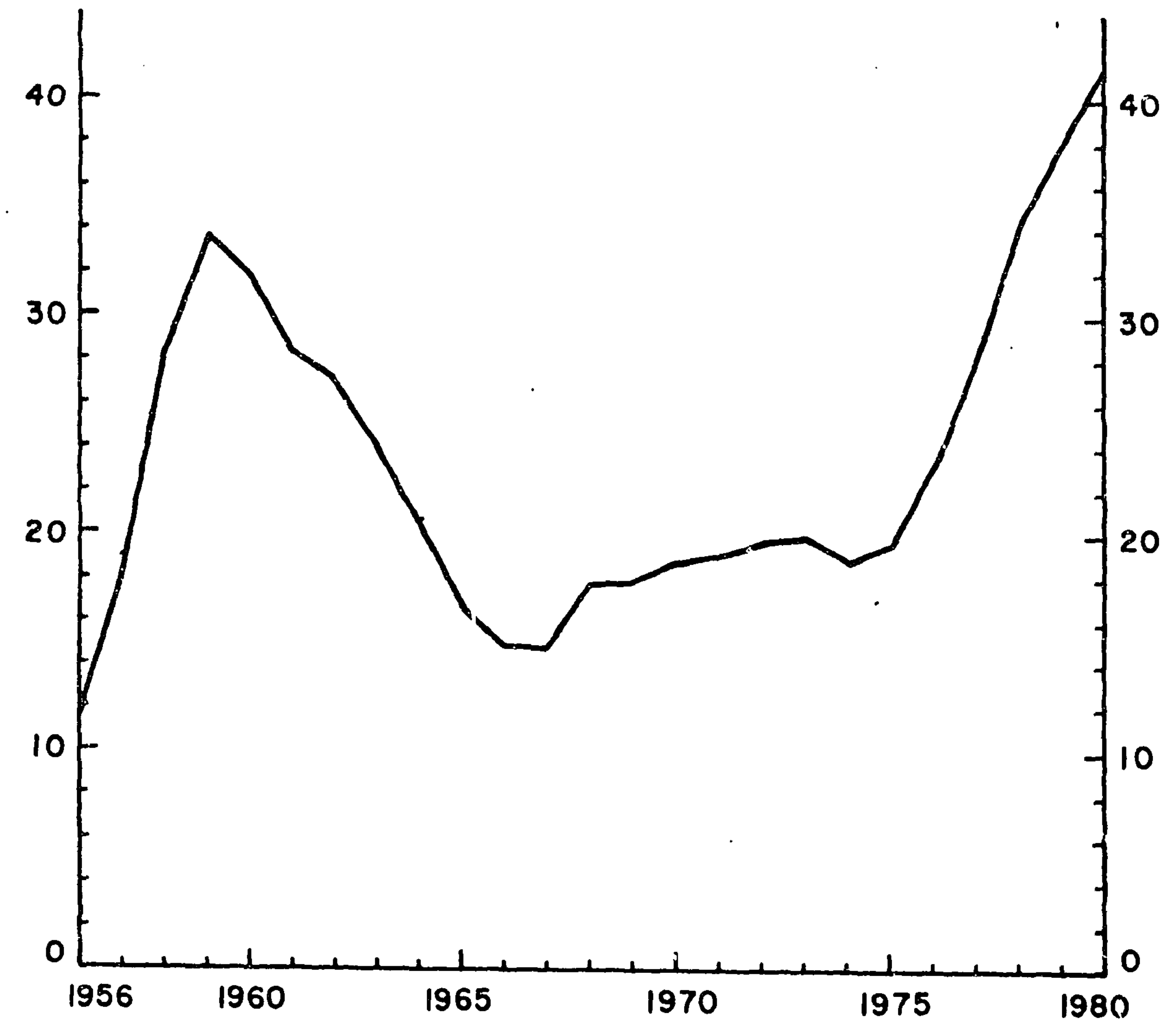
OTHER DEPOSITS WHERE SIGNIFICANT RESOURCES HAVE BEEN ANNOUNCED AND WHERE DRILLING IS CONTINUING OR WHERE FEASIBILITY STUDIES ARE BEING UNDERTAKEN INCLUDE WESTMORELAND IN NORTH WEST QUEENSLAND, WHICH WAS DISCOVERED IN 1956, AND THE BIGRLYI DEPOSIT IN THE NGALIA BASIN IN THE NORTHERN TERRITORY AND THE ANGELA DEPOSIT IN THE AMADEUS BASIN IN THE NORTHERN TERRITORY.

SUMMARISING WE SEE ON AN INTERNATIONAL SCALE A REDUCTION IN URANIUM EXPLORATION ACTIVITIES WHICH TO THE END OF 1980 AT LEAST IS NOT REFLECTED HERE IN AUSTRALIA. WE SEE ON AN INTERNATIONAL SCALE A SIGNIFICANT REDUCTION IN REASONABLY ASSURED RESOURCES IN THE LOW COST CATEGORY WHEREAS IN AUSTRALIA OUR RESOURCES IN THIS CATEGORY WERE REDUCED BY LESS THAN 2% IN 1981. WITH REGARD TO PRODUCTION WE SEE INCREASING AUSTRALIAN PRODUCTION TO THE END OF 1981 WITH AUSTRALIAN PROJECTS SECURING SALES CONTRACTS DURING A PERIOD OF INTERNATIONAL OVER SUPPLY.

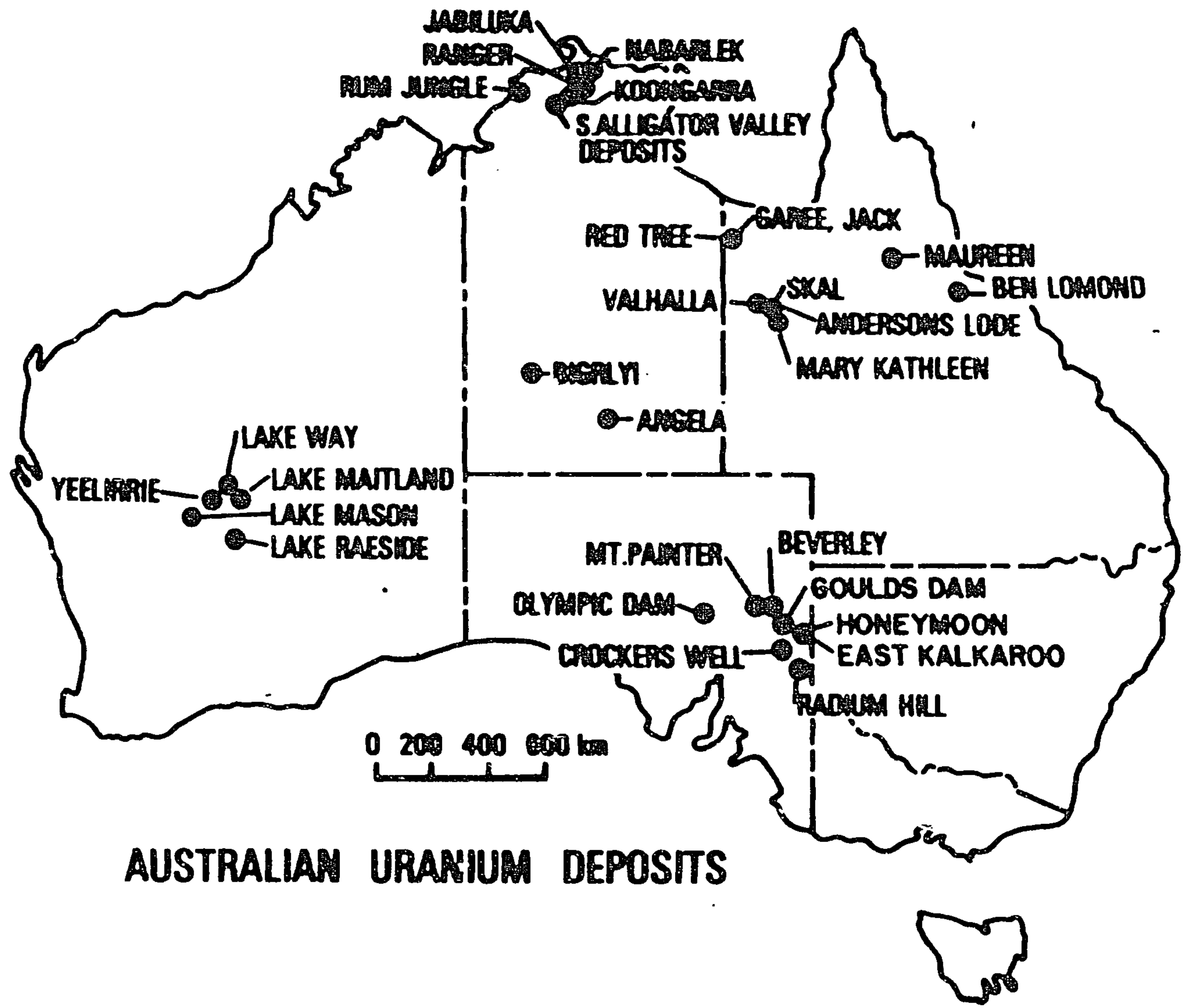
URANIUM PRODUCTION

WORLD OUTSIDE THE CENTRALLY PLANNED ECONOMIES AREA

In 1,000 tonnes U



SLIDE (1)



AUSTRALIAN URANIUM DEPOSITS

SLIDE (B)

NEA/IAEA CLASSIFICATION SCHEME FOR URANIUM RESOURCES

EXPLOITABLE AT COSTS	US $130–$260 kg/U	REASONABLY ASSURED RESOURCES	ESTIMATED ADDITIONAL RESOURCES	SPECULATIVE RESOURCES
	US $80–$130 kg/U	REASONABLY ASSURED RESOURCES	ESTIMATED ADDITIONAL RESOURCES	SPECULATIVE RESOURCES
	Up to US $80 kg/U	REASONABLY ASSURED RESOURCES	ESTIMATED ADDITIONAL RESOURCES	

DECREASING CONFIDENCE IN ESTIMATES →

SLIDE (2)

URANIUM RESOURCE ESTIMATES

WORLD OUTSIDE THE CENTRALLY PLANNED ECONOMIES AREA

FEBRUARY 1982

	REASONABLY ASSURED RESOURCES (tonnes U)	ESTIMATED ADDITIONAL RESOURCES (tonnes U)
US \$80 – \$130 kg/U	546,000	1,115,000
Up to US \$80 kg/U	1,747,000	1,605,000

SLIDE (3)

URANIUM EXPLORATION DATA - USA

SURFACE DRILLING

YEAR	NUMBER of HOLES	METRES DRILLED (x 1,000)	TOTAL EXPLORATION EXPENDITURE ($ x 1,000)
1977	105,100	13,900	258,000
1978	104,400	14,700	314,000
1979	90,600	12,500	316,000
1980	59,800	8,600	267,000
1981	24,300	4,000	

SLIDE (4)

URANIUM EXPLORATION DATA – AUSTRALIA

TOTAL EXPLORATION EXPENDITURE

1975	A$ 8,000,000
1976	13,000,000
1977	17,000,000
1978	25,000,000
1979	29,000,000
1980	35,000,000

SLIDE (5)

COMPARISON OF URANIUM RESERVES AND URANIUM EXPLORATION EXPENDITURE

AUSTRALIA – USA

	RESERVES 1966 tonnes U	RESERVES 1980 tonnes U	INCREASE 1966–1980 tonnes U	EXPENDITURE 1966 – 1980 $m.	EXPENDITURE US $/kg Increase
AUSTRALIA	6,200	294,000	287,800	217	0·75
USA	123,000	362,000	239,000	842	3·52

SLIDE (6)

URANIUM RESOURCE ESTIMATES–
AUSTRALIA
JUNE 30, 1981

	REASONABLY ASSURED RESOURCES (tonnes U)	ESTIMATED ADDITIONAL RESOURCES (tonnes U)
US $80–$130 kg/U	23,000	21,000
Up to US $80 kg/U	294,000	264,000

SLIDE (7)

TIN - A CHANGING COMMODITY

I.R. McLEOD

Tin has been with us for a long time. It was one of the earliest metals used by man and it is part of our everyday lives in food packaging, soldering for electronics and plumbing, and so on.

However, its traditional uses have been under threat for some time by substitutes and after a period of record prices a couple of years ago the price has fallen sharply and is now heavily supported by the International Tin Council through buffer stock buying and export quotas. Most tin producers are operating at a loss.

On the other hand, some forecasters see production and consumption coming into balance (some quite soon) and even the possibility of a production deficit in the longer term.

So what does the future hold for tin?

Let's begin by looking at the past.

Australia was the world's largest tin producer in the late 19th century. Reliable figures are not available but it is likely that annual production in the early 1880s was surpassed only a couple of years ago. However, mine production had fallen to about 1 500 tonnes the mid-1950s.

Production picked up in the late 1950s (Fig.1 - t.i.c. = tin-in-concentrates) and levelled off in the early 1970s at above 11 000 tonnes, making Australia the fifth largest world mine producer after Malaysia, Indonesia, Thailand and Bolivia.

A feature of tin mining in Australia, and perhaps in the world generally, is the importance of small miners. In Australia there are several hundred of these, each producing a tonne or two, or even less than a tonne. In aggregate, this makes up between 5 and 10 per cent of total Australian mine production.

I might add here, that the statistics I've used are for the western world only. They do not include USSR and China. Mine production by both these countries is believed to exceed Australian mine production. USSR production is thought to be over 30 000 tonnes, and China's 15 to 17 000 tonnes.

Australian production increased in the 1960s largely because of expansion at Renison and opening of the Cleveland and Ardlethan deposits. These three together now account for about three-quarters of the total mine production.

Since the early 1960s smelter production has fallen behind mine production. I'll come back to this in a moment. With this divergence and increased smelting capacity in other tin-producting countries, Australia is now the largest exporter of tin concentrates.

Mine production in the early 1960s was mainly from alluvial or quartz lode deposits. These ores allowed good recovery of cassiterite as a clean, high-grade concentrate.

Production in Australia is now mainly from hard rock deposits, many of which contain a high proportion of other metallic sulphide minerals such as iron, copper and arsenic. High recovery of cassiterite (the tin mineral) from these ores is difficult.

Concentrate grades are low and the concentrates still contain some of these other sulphides, which affect the smelting process.

The main Australian smelter at Sydney was designed to handle alluvial concentrates. Although it has put in plant to facilitate treating impure concentrates the change in the type of feed and other problems have meant that smelter production has not increased in line with mine production.

The second smelter recently built at Greenbushes produces about 400 tonnes a year of antimonial tin. Other producers have looked at the feasibility of putting up a smelter. However, there is currently a world wide surplus of smelting capacity. In fact, capacity is about twice current production, and it seems likely that Australia will remain a major exporter of concentrates for some time yet.

Production of secondary tin in Australia is only a few hundred tonnes a year. One feed source is canmakers' scrap. Decreased tinplate coating weights increase the costs of tin recovery from this scrap and I do not see any great increase in secondary production.

Fig. 2 shows how total Australian tin metal consumption depends on consumption in tinplate manufacturing. Currently this accounts for a little less than two-thirds of total Australian consumption. The other main use, solder, takes about one-third.

The tonnage of tinplate produced has increased but the average tin coating thickness has decreased, and tin used, as a percentage of tinplate produced, has fallen from about 0.75% in 1973 to 0.46% in 1981.

However, these statistics do not tell the whole tinplate consumption story. Average tinplate sheet thicknesses have decreased also, so there is a much greater surface area per tonne. So actual coating weights have fallen more than proportionately, from over 5.6 grams per square metre to, commonly, 2.8 grams per square metre, and to as little as one gram per square metre. These figures are for each side of the sheet.

Let's turn to resources of tin in Australia.

TABLE 1

LIFE OF TIN RESOURCES

DER 1981	215 600 t
Estimated Recoverable	151 000 t
T-I-C Production 1981	12 100 t
R/P Ratio	12
Apparent Life Expectancy	10

TABLE 2

LIFE OF TIN RESOURCES EXCLUDING RENISON

DER 1981	32 300 t
Estimated Recoverable	23 000 t
T.I.C. Production 1981	7 100 t
R/P Ratio	3

TABLE 3

AUSTRALIAN TIN RESOURCES (TONNES)

Demonstrated Economic	215 600
Inferred	123 900
Total	339 500
Sub Economic	485 100

Demonstrated economic resources are those where the tonnage, grade and outlines of the orebody are known well enough to allow mining to be carried out, or planned, and which can be economically worked. They are broadly the same as measured plus indicated reserves.

Demonstrated economic resources of contained tin in 1960 were 28 000 tonnes of which about half was hard rock and half alluvial. In 1973, they had increased to 151 000 tonnes and 92% of these were hard rock. In 1981 they had increased further to 216 000 tonnes and the proportion of hard rock resources had increased to 96%.

Each set of figures is on a somewhat different basis but nevertheless, it is clear that demonstrated economic resources have increased about seven fold while production has increased about five fold.

Are our tin resources adequate?

There are various ways of looking at the adequacy of resources. Perhaps the simplest is to divide total demonstrated resources by annual production, to give a resource/production ratio.

If we do this for tin, and allow for losses during production of concentrates, which can be quite high for tin, we get a resource/production ratio of 12.

We can improve on this a little by forecasting future production over a selected period, and calculating how much of demonstrated economic resources this forecast production accounts for.

Here we are also allowing for treatment losses in the production of concentrates, and we get an apparent life expectancy of 10 years for current demonstrated economic resources (Table 1).

However, this does not mean that all our tin mines will be exhausted in 10 years time. The calculation was done using totals, and of course each mine has its own production rate and amount of resources.

A large part of the demonstrated economic resources are in fact in the Renison deposit. I can illustrate the qualifications that need to be kept in mind with this sort of exercise by doing the same calculation with Renison's resources and production excluded from the totals (Table 2).

This gives a resource/production ratio of 3, compared with the ratio of 12 obtained from the totals. And the apparent life expentancy is 3 also.

One of the reasons for the small apparent life expectancy is that two mines have a large annual production but small demonstrated economic resources. And many other deposits have maintained their resources at low, but relatively constant, levels for many years.

So I do emphasize that results of calculations such as this are only indicative, and not absolute. It is important to look behind the figures.

When we do this, the picture is not nearly as gloomy as it might seem.

Renison's annual production is greater than Australian consumption and Renison's current proved and probable reserves (equivalent to demonstrated economic resources) are sufficient for more than 20 years at current production rates. Furthermore, the figure for resources does not include large accumulations of tailings. Resources in these are large because of past low recoveries; and technical advances now allow retreatment of these tailings, although perhaps not economically at current low prices. And, very importantly, we are forecasting future production but assuming there will be no addition to current demonstrated economic resources. This assumption is undoubtedly unduly pessimistic in the medium term at least.

Also, the calculation was done using demonstrated economic resources. There are, in additon, large inferred resources, which are resources known well enough for them to be classed as demonstrated economic resources. Much of these could eventually be proved up to the demonstrated economic category by further testing (Table 3).

Several deposits in the borderline area of being economic have large resources, and there are others which are further away from being economic.

Some other deposits are not economic because their ores are metallurgically difficult, and technical developments could make these deposits economic if the price is right. One such development is matte fuming.

This is a process in which a sulphide-bearing concentrate, which can be very low grade, is melted. The tin boils off as a sulphide, which turns to tin oxide, and the tin oxide can go on to the normal smelting process.

Matte fuming can give much better recoveries than current methods from some of these metallurgically difficult ores.

In the medium to long term it is likely that current levels of demonstrated economic resources will be at least maintained, even allowing for depletion of resources by mining, and possibly the resources may actually increase. However, this depends on the tin price increasing relative to costs.

Which brings us to prices.

The price of tin, in real or constant dollar terms, has increased considerably in the last 20 years. The Australian price, for example, has almost doubled (Fig. 3).

Incidentally, this real price increase distinguishes tin from some other metals. As a trend, over the last 20 years at least, the real prices of lead and zinc have been almost constant and the real price of copper has gone down slightly.

Most of the tin increase was in the late 1970s. We can see one reason for this if we look at world production and consumption (Fig. 4).

Tin production over the last 20 years generally has been less than consumption. However, prices did not go through the roof because the deficit was largely made up of surplus metal from the United States strategic stockpile.

The total of production and US stockpile sales is in much closer balance with consumption.

I am not taking account here of tin sales by China. These are about 3000 to 4000 tonnes a year, and are unlikely to increase much, if at all. Nor does the graph take account of tin imports into the USSR and German Democratic Republic, which have been around at least 15 000 tonnes a year for several years.

The slide was prepared before I had 1981 world data, so it doesn't show US stockpile sales of nearly 6 000 tonnes in 1981. In fact, the gap between consumption and supply (supply being production plus US stockpile sales) - which was 22 000 tonnes in 1980 - increased to nearly 40 000 tonnes in 1981 - not taking account of a net flow to Communist countries of about 12 000 tonnes.

The price increase occurred when consumption exceeded production, when very little tin was available for sale from the US stockpile.

The price increases of the 1970s led to increased world production, although, as might be expected, this lagged by a couple of years.

Production now greatly exceeds supply. In 1981, production of metal was about 196 000 t while consumption was only 162 000 t. A few months ago, before export quotas were imposed, a similar production surplus in 1982 seemed likely.

However, unlike production, consumption has not increased and it does not seem likely that it will for some time, so unless production falls, a surplus will remain.

The price fall earlier this year probably will bring about some decrease in world production and the export quotas imposed by the International Tin Council will probably accentuate this trend, because some mines will not be able to keep going at lower production rates or hold large stocks.

However even when production and consumption come into balance, and that may be some time off, there will be three potential non-mine sources of tin metal which will overhang the market.

The first of these is in the US stockpile. This has almost 20 000 t available for sale, plus another 130 000 tonnes not required for strategic purposes, but not available for disposal at present. Although the US Government has stated that disposals will be done in a way that does not unduly disrupt the market, and it has not sold much in the last few months, it has not given any indication that it will actually cease selling.

The second is the holdings of the ITC buffer stock. No information on these holdings has been made public since the announcement that it held 2 490 t at the end of December last. It is well known that the buffer stock manager has been a heavy buyer over the last four months, and market opinion is that the buffer stock holds around 40 to 50 000 tonnes.

However, the purpose of the buffer stock is to even out price fluctuations. The buffer stock manager cannot be a net seller of tin when prices are low and he would not appear as a net seller until the price rose into his upper sector, that is at an Australian equivalent of about $15 000 at current exchange rates. The current Australian price is about $13 400.

The third source is tin bought by the so called unidentified quarters that supported the price in the second half of 1981. They are thought to hold over 20 000 t, which is a fairly large and unpredictable potential source of tin.

So something like 80 000 t of tin is waiting in the wings as it were. This represents about half a year's consumption.

With these sources and current and likely production and consumption, any great price increase seems unlikely for several years, even disregarding the impact of export quotas. This means that, bearing in mind the lead times for development of new mines, and also the small reserves at some existing Australian mines, there is not likely to be much increase in Australian production before the mid 1980's.

And export quotas are likely to have more than the immediate impact on Australian producers. If they are prolonged and especially if the percentage by which production is cut is increased, we could see mine closures.

When I looked at the title of this talk - Tin a changing commodity - I wondered whether I should put a question mark after it.

In the short term there have been some dramatic changes, particularly in prices.

However, worldwide the main uses are still tinplate and solder. Leaving aside the last 12 months, the price has broadly trended upwards, as it has for many years. Production has increased over the last three or four years after being at about 180 000 tonnes a year for 10 years. Consumption has trended down from a post war peak of 214 000 tonnes (and it was a marked peak) in 1973, and world production is considerably more than consumption. But this has happened before, although the last occasion was in the 1950s.

So if we are taking the medium to longer term view, are we just seeing a replay of something that has happened before?

Only time will tell.

But perhaps there have been some fundamental changes.

40 percent of world tin consumption is in tinplate, and most of this goes into packaging. This is a fiercely competitive market, with aluminium, tin-free steel, plastics, and paperboards all competing with tinplate. Deep frozen and other convenience foods have had their impact also. Where tinplate is used, the amount of tin per can is much less than it was.

Packaging changes have had an effect also on solder, which accounts for about 25 percent of world consumption. The advent of the two piece can has meant a greatly decreased use of solder in can making. And concern about lead in foods is likely to see the soldered three piece can largely replaced by welded cans.

In electronics, printed circuits and integrated circuits have led to much less solder being required per unit of equipment.

Paradoxically, tin has largely kept its markets by reducing the amount of tin used in each article - whether it is a tin can or a radio set - but many more articles are being made, so the total amount used has not decreased - until recently.

It remains to be seen to what extent tin can remain competitive by continuing to reduce unit consumption in its main uses. It also remains to be seen what effect increasing demands for tinned food in some countries, especially in Southeast Asia and South America, will have on consumption. Many people see this as the best potential for increasing tin consumption.

Some changes are less obvious, and some we have yet to see the full effects of, especially on the production side.

Most of the world's mine production is still from alluvial deposits. Perhaps for this reason, the reverbatory furnance is still the mainstay of the smelters, but more technically efficient methods are being developed, such as CSIRO's submerged smelting process, and perhaps we will see wider use of fuming to increase recovery. Matte fuming in particular could change the scene markedly, especially in Australia where many deposits are metallurgically difficult hard rock deposits.

Froth flotation, which has long been used for concentration of base metal ores, is being used increasingly to improve recovery of tin from hard rock ores. Traditional gravity concentration methods, such as jigs and tables, are being extended by using techniques such as heavy media separation, spirals and cones.

Turning to the economic side, it is hard to be precise, but the data suggest that average mining costs world wide have more than tripled over the last 10 years but the tin price has less than tripled in the same period, that is costs have gone up faster than prices.

World wide there is of course a wide range of production costs (and tin is not unique in this). It has been stated that 40 percent of world mine production in 1980 was uneconomic.

1980 production minus 40 percent is about 120 000 tonnes. 1980 consumption was over 170 000 tonnes, so there would be a substantial deficit if that 40 percent actually disappeared.

It also seems likely that much of the resources that are in sight to replace currently economic resources as they are worked out are at the higher end of the cost range.

These two things mean that, in the medium to long term, the average cost of world mine production is going to increase if current consumption levels are to be met.

Whether tin can retain its markets if such a cost (and price) increase comes about is a subject all of its own, which I am not going to pursue here.

Let's come back to the Australian scene.

In Australia production is now predominantly from lode deposits and 3 mines produce three-quarters of the total. Economic resources at 2 of those mines are quite small.

Even disregarding the effect of export quotas, an increase in Australian mine production seems unlikely at current prices. In fact production could well fall, and indeed some small to medium-sized mines have closed recently. An effect of export quotas will of course be decreased production.

If export quotas continue for a prolonged period, as seems possible, it may be difficult for some Australian tin mines to stay in operation. That is, Australian mine production could remain below recent levels even after quotas are removed.

However, let's look beyond the export quotas.

Detailed feasibility studies are being done for several deposits. Each of these deposits has the potential to produce over 1000 tonnes a year of contained tin.

There is a lot of tin available in tailings, and technology is available to recover this.

Processes like matte fuming could enable metallurgically difficult deposits to be mined and greatly increase recovery from the ores of many hard rock deposits and, perhaps, from tailings.

So the potential is there for Australian production to increase substantially.

The price will have to increase in real terms for this to happen, but this increase does not necessarily have to be to the record levels seen in the past.

Provided Australian costs stay in line with those in other countries. I believe that a price increase, when it enentually arrives, will see increased Australian production and this will lead to Australia increasing its share of total world production.

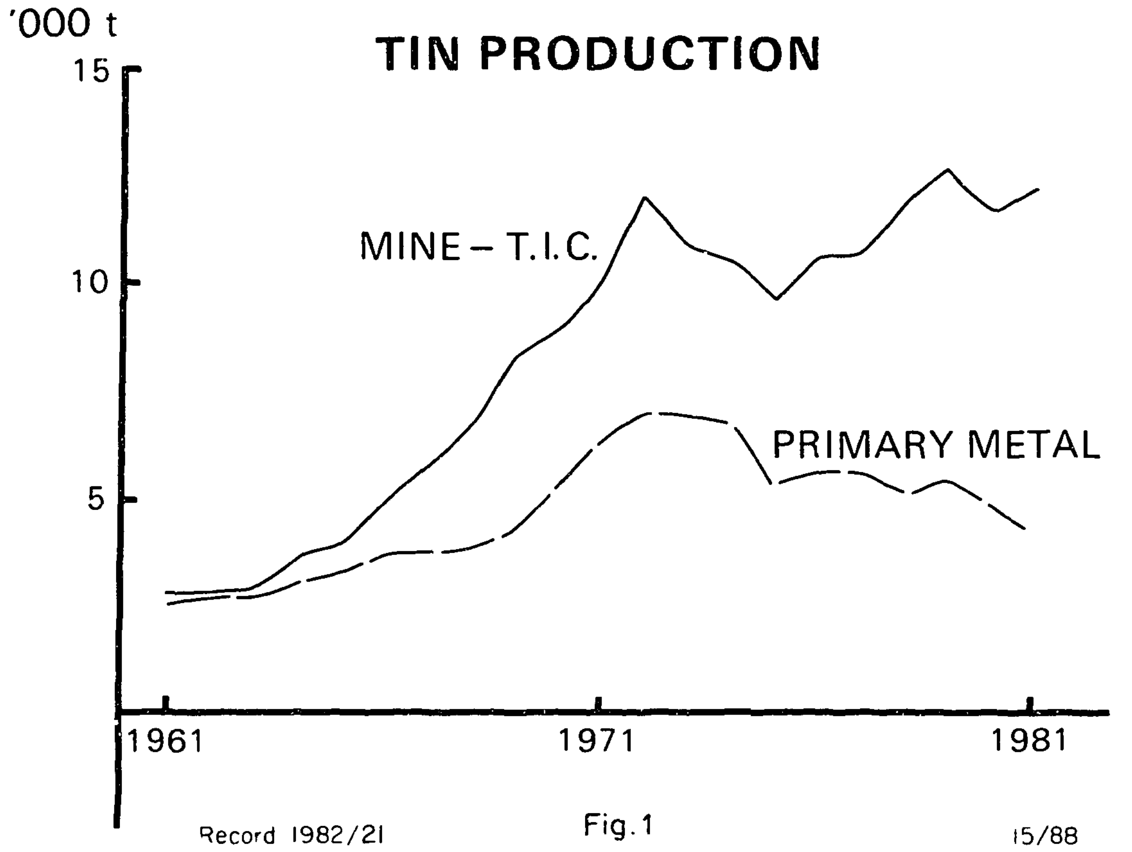
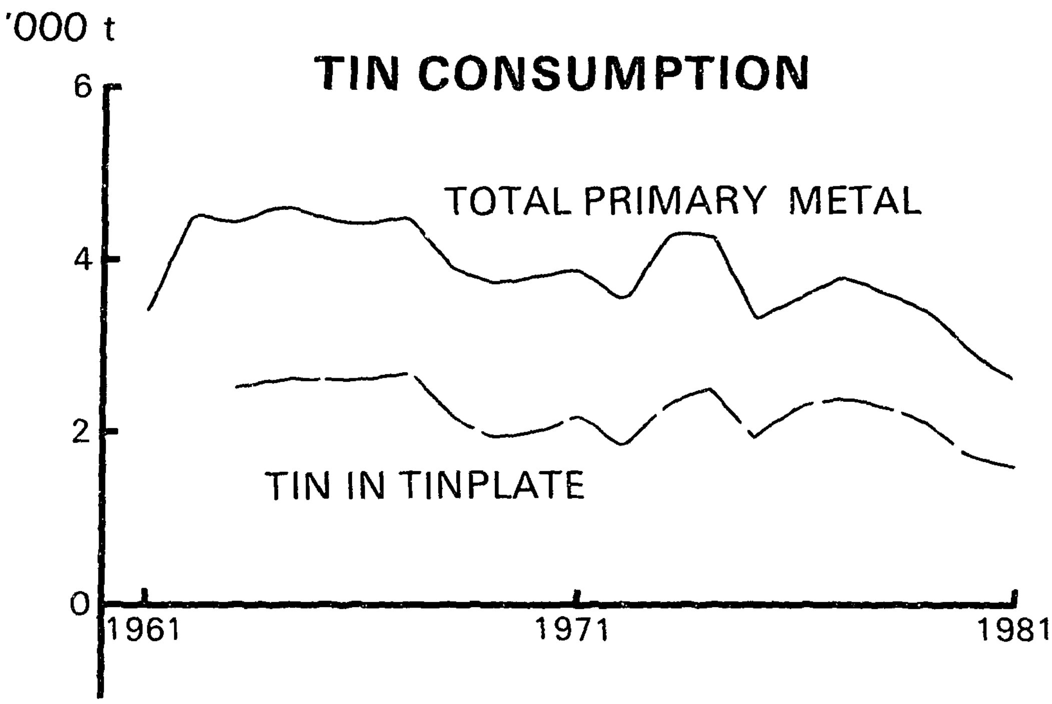
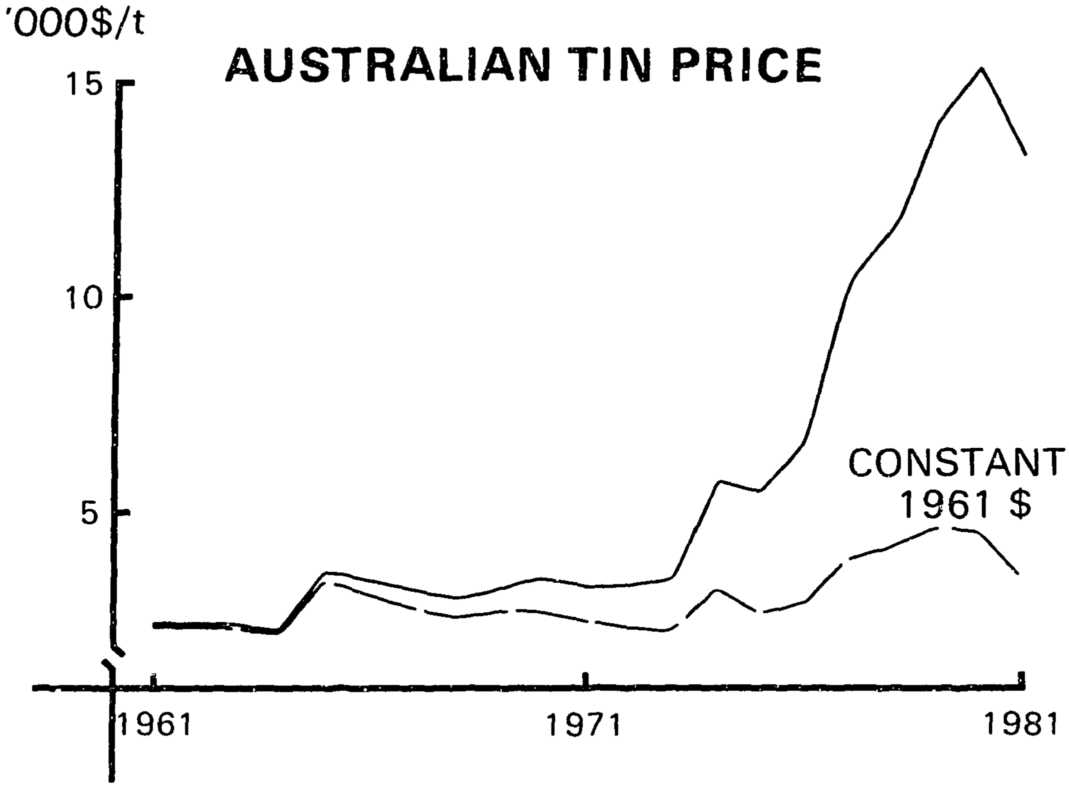

'000 t
TIN PRODUCTION
15
10
5
MINE – T.I.C.
PRIMARY METAL
1961
1971
1981
Record 1982/21
15/88

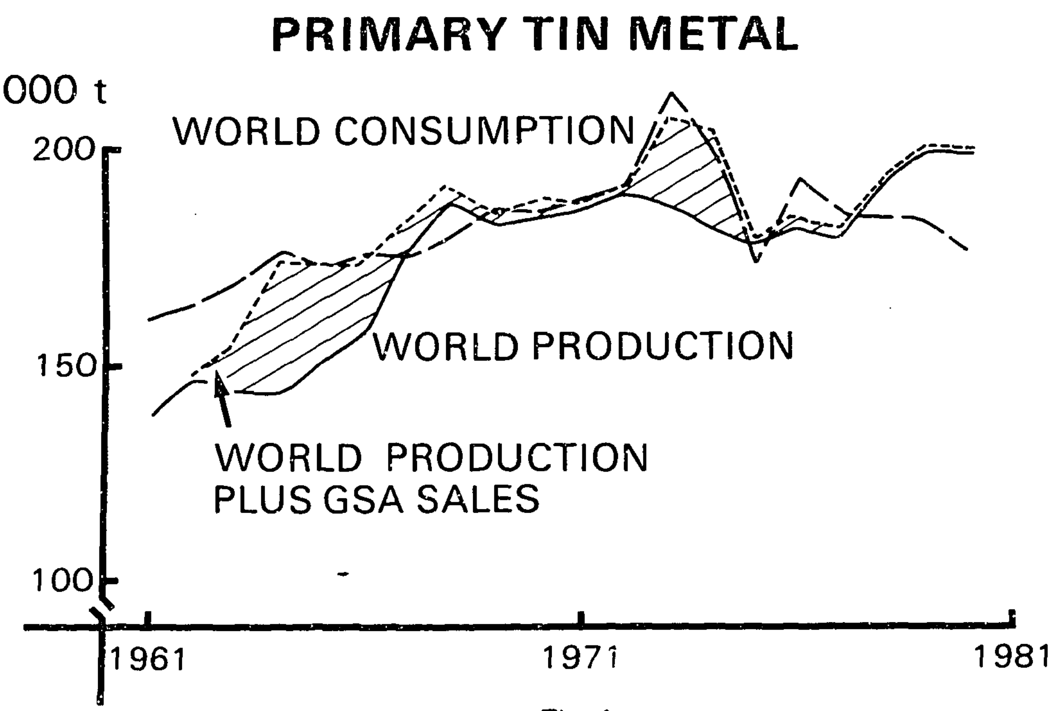
Fig.1



Record 1982/21 Fig. 2 15/89



Record 1982/21 Fig. 3 15/91



Record 1982/21 Fig. 4 15/92

MINERAL SANDS - THE INDUSTRY IN A WORLD CONTEXT

J. Ward

Mr Chairman, Ladies and Gentlemen,

What I want to do this afternoon is:

- quickly trace out the history and development of our domestic industry
- summarise its current standing and its competitive position on a global scale
- and finally, I hope to leave you with some thoughts as to what the future thrust of our industry should be.

First, a little background history.

SLIDE 1

Commercial production and export of mineral sands as mixed concentrates commenced on the east coast at Byron Bay in the mid-1930s. Operations were on a small scale until World War II gave mineral sands a boost as it did to many other commodities. In this case it was for rutile as a coating of electrical welding rods. Demand weakened after the War and it was not until the early 1950s that the market recovered mainly because of strategic interest in titanium the 'wonder metal' and the stockpiling of rutile by the US General Services Administration. However, in the late 1950s a reassessment of the potential use of titanium in military aircraft caused a sharp decrease in projected demand and rutile prices were drastically reduced, to £17/ton at one stage. It was not until the early 1960s that the development by Du Pont of the chloride process for pigment production using rutile, opened up a new market. Under the stimulus of long-term contracts for rutile for pigment production, Australian rutile production expanded progressively to a peak of 390,000 t in 1976, before weakened demand, reduced prices and other factors caused production to be cut, particularly on the east coast, to an output of only 229,000 t in 1981.

The Australian ilmenite industry is much younger. While ilmenite-rich mineral sand deposits were delineated in the southwest area of WA in the 1940s and early 1950s, commercial production did not commence until the latter half of the 1950s. More recently (the early 1970s) rich heavy mineral deposits were discovered in the Midland area of the Swan coastal plain south of Geraldton at Eneabba and Jurien Bay. Deposits at Eneabba have now been developed and are regarded as a major world source of titaniferous and zirconium minerals as well as rare earths.

Let me graphically sum up this development. Slide 2
Slide 3

So what has been achieved?

To the end of 1981, production of concentrates totalled

6.4Mt of rutile
7.4Mt of zircon
14.9Mt of ilmenite (low chrome)
102,000t of monazite (saleable grade of + 90% monazite)

Only a small proportion of output has been consumed in Australia and over the years mineral sand concentrates to the accumulative (unadjusted) value of \$1573M have been exported. In addition, domestic production of TiO_2 pigments at Burnie and Bunbury has saved imports valued at approximately \$515M. i.e. improvement in balance of pigments of some \$2 billion. Meanwhile the industry has become a world leader in the development of alluvial minerals and ore dressing equipment, and has contributed significantly to other facets of the domestic economy particularly in the socio-economics of coastal communities many of which have been largely dependent on the industry for employment.

And how do we stand now?

Well, 1981 was a bad year for mineral sands; if zircon prices had not held it would have been disastrous. As it was rutile prices dropped from about \$400/t in mid-1980 to \$280/tonne in 1981 and now are down to \$250/tonne for bulk material. Notwithstanding this downturn, Australia remains the world's leading producer and exporter of rutile, zircon, ilmenite and monazite concentrates and is expected to be called upon to meet a substantial proportion of world demand until the turn of the century at least. However, in recent years we have lost our almost complete dominance as the world's rutile and zircon supplier. At this stage let me quickly summarise our position as a world supplier.

SLIDE 4

On the world scene ilmenite production dropped sharply after the OPEC oil crisis (1973). It is now about 4.5 Mt/year with an increasingly high TiO_2 content. The world production of natural rutile has been maintained at about 400,000 tonnes a year. Zircon production has increased from 500,000 tonnes a year to 6-700,000 tonnes a year mainly because of continuing demand for refractory use. Monazite has almost doubled as its miscellaneous uses for rare earths have been expanded.

While Australia has increased its share of world production of ilmenite from 20% to 30% and of monazite from 35% to over 60% in the last ten years, mainly the result of development at Eneabba, our share of zircon production has fallen from 80% to 70% and of rutile from 95% to 60%. In fact, looked at in the light of high titania feed suitable for chlorination and welding rod coatings Australia's share is now down to about 37%.

So where do we go from here? I suppose it all comes back to a question of supply and demand. We can do little about the demand position. We are very small consumers of mineral sands and use only about 10% of the 2 Mt of concentrates produced annually and our aim must be to ensure that we get our share of the action in expanding world markets. In the case of supply we have a much greater say. I suppose any discussion on supply must start with the resource position.

SLIDES 5, 5A, 5B

From a resource point of view the east coast continues as the world's main source of natural rutile. It is also the main source of inherently high grade premium zircon concentrates very low in iron and TiO_2 - ilmenite relatively high in chromic oxide - some monazite - approx. 45% unavailable to mining because of environmental considerations.

The ilmenite of the southwest corner of WA (Capel - Yoganup area) is very low in Cr and V, less than one half of 0.1%, some zircon and monazite, very little rutile. Eneabba ilmenite has low chrome (0.1 - 0.2 Cr_2O_3). Although not as low as Capel, ideal for chlorination and upgrading, large tonnages of zircon somewhat weathered and iron-stained and associated with kyanite - substantial tonnages of rutile. Projected levels of production indicate that in the next 20 years we will need to produce as much zircon and rutile again as produced since 1940 and 1½ times the ilmenite produced since the mid 1950s. At this rate about 60% of our DER of mineral sands will be depleted, and in the case of rutile virtually all of our known economic resources will be worked out, statistically speaking.

But, back to the market place. For the short-term there is little doubt that world market will pick up again in line with renewed world industrial activity, and, with a continuing firmness in ilmenite and zircon prices, domestic producers should recover quickly from the ill-effects of reduced revenues from rutile over the last couple of years. The position is not so clear in the longer term, but it is doubtful if Australia's pre-eminence in rutile and zircon of the pre-1980s will return. For one thing domestic producers on the east coast are operating on ore grades about 1/10 of those mined 20 years ago. We can't do much about falling grades - like the ageing process it is progressive and terminal. However, over the years domestic producers have coped with falling grades by technological advances in the mining and treatment of mineral sands and have not only maintained output but have actually expanded it substantially.

The main difference now is that whereas our main concern was the level of world demand and internal competition between domestic producers for this market, we are now faced with new world producers who have emerged and are aggressively competing for their share of world trade in mineral sands. In particular, major heavy mineral alluvial operations have been commissioned in Sierra Leone and in South Africa, and in Brazil extensive carbonatite-hosted anatase deposits are being tested with a view to their development.

SLIDE 6

Let us look at how these developments will affect our position as the major world supplier of zircon and rutile concentrates.

The operation of Sierra Rutile Ltd and Sherbro in Sierra Leone (about 270 km south of Freetown) is basically a rutile-producing one and because the deposit is a lacustrine one rather than a beach deposit concentrated on high-energy surf dominated strandlines the mineral grains are comparatively angular and poorly sorted. However, the grade of rutile mined - 1.6% is about five times the grade of east coast material, and the final concentrates are of a high grade (96% TiO_2) and are being used for pigment production - 50,000 tonnes in 1981; 75,000 tonnes in 1982; and a projected capacity of 100,000 tonnes a year.

The Richards Bay project involves the annual production of

- 120 000 tonnes of zircon
- 50 000 tonnes of rutile
- 400 000 tonnes of high titaniferous slag (85% TiO_2)
- 220 000 tonnes of low manganese pig iron

RB zircon has run-of-the-mill grades of up to 0.2% each of Fe_2O_3 and TiO_2, is quite suitable for foundry applications. Capacity is available for acid leaching and upgrading of about 60,000 tonnes per year of this material to so-called ceramic grade, the increased cost of treatment being passed on to the consumer. The rutile, although comparatively low in TiO_2 and high in ZrO_2, is finding increasing uses for welding rod electrodes. The titania slag is being used for pigment production both by the sulphate and chloride routes.

Quality and efficiency-wise Australian producers can more than hold their own vis a vis other world producers of zircon and rutile. Australian producers have become world leaders in mineral sand technology and have learned to live with the ups and downs of the international economic rollercoaster. However, in the market place there are factors outside the control of producers - viz. relative currency exchange rates, ocean freight rates and national aspirations and Government assistance and subsidies which could well offset the advantages of natural resources and production efficiencies.

The world ilmenite market has always been a highly competitive one with Australia's competition coming mainly from hard-rock producers in Canada (Allard Lake - Quebec QIT); USA (Tahawus in NY State); Norway (Tellnes); and Finland (Otanmaki). To this must be added the re-emergence of the Indian/Sri Lankan alluvial deposits as a supply of ilmenite, and more especially the development of high-titania slag from the alluvial deposits of Richards Bay. The latter development has particular relevance to Australia's future export markets for ilmenite and rutile, in as much as the high-titania slag can be used to produce TiO_2 pigments both by the orthodox sulphate route and the more recently developed chloride route. Over 90% of ilmenite is used in pigment production and about 70% of rutile is also consumed for this end use. Because of its importance in this exercise let me refresh your memories on the salient features of the two competing processes -

SLIDE 7

<u>Sulphate</u> Flexible, simple, relatively low capital cost, high operating cost and effluent troubles

<u>Chloride</u> Sophisticated, high capital cost, relatively low operating cost, minor effluent trouble.

In 1981 world capacity for TiO_2 pigment was about 2.3Mt of which about 30% was based on a chloride process (2/3 in the United States), the balance on the traditional sulphate process.

In general, sulphate users are tending to move towards higher TiO_2 feed, particularly slag. Chloride producers are moving to escape their dependency on natural rutile and to use a feed stock blend of natural rutile, upgraded ilmenite and high titania slag.

Up until now titania slag from QIT (70-72% TiO_2) has been directed exclusively to the sulphate process where, because of effluent considerations it has advantages over ilmenite. RB slag (85% TiO_2), while developed primarily as a sulphate feed, has been successfully tested for use in the chloride process. Possibly 100,000 tonnes per annum of RB slag is now being used for chloride pigment and in welding rods. This significantly broadens RB's output spectrum, promotes slag and low-manganese pig-iron as the main revenue earners, and allows zircon and rutile to be shipped virtually at cost or less. It also highlights Australia's vulnerability where processing of mineral sands concentrates is concerned. Our processing of zircon, rutile, and monazite concentrates is negligible. About 20% of our ilmenite production is processed locally to pigment by the sulphate route at Burnie and Bunbury, and to UGI at Capel, WA i.e. of about 2Mt/year of concentrates produced, only about 10% is processed in Australia.

The difficulties of domestic processing lie in markets and cost of production - e.g. chlorine cost, rather than mineral resources and technological know-how. Although processing of rutile (both natural and synthetic) to pigment and metal or to titanium tetrachloride (the intermediate stage common to both end products) is most attractive when viewed from the aspect of value added, the cost-competitiveness of such processing will depend to a large extent on the availability of low cost chlorine provided by a chemical complex which itself would require low-cost salt and power and a market for other products, chiefly caustic soda.

Prospects for the processing of ilmenite are more promising. Increase in the production of pigment by the sulphate process should be slow and steady and will depend on increased domestic consumption (currently about 33,000 tonnes/year) and greater penetration by Australian pigment producers into the world markets. Growth in beneficiation of ilmenite could be more spectacular. Australia is well to the forefront in this development. Current domestic production capacity of 60,000 t/year could well be doubled by 1985.

In this connection I would refer you to a report published last year. "Australia's Mineral Sands Processing Industry - Potential for Expansion" prepared by the Commonwealth/State Joint Study Group on Raw Materials Processing.

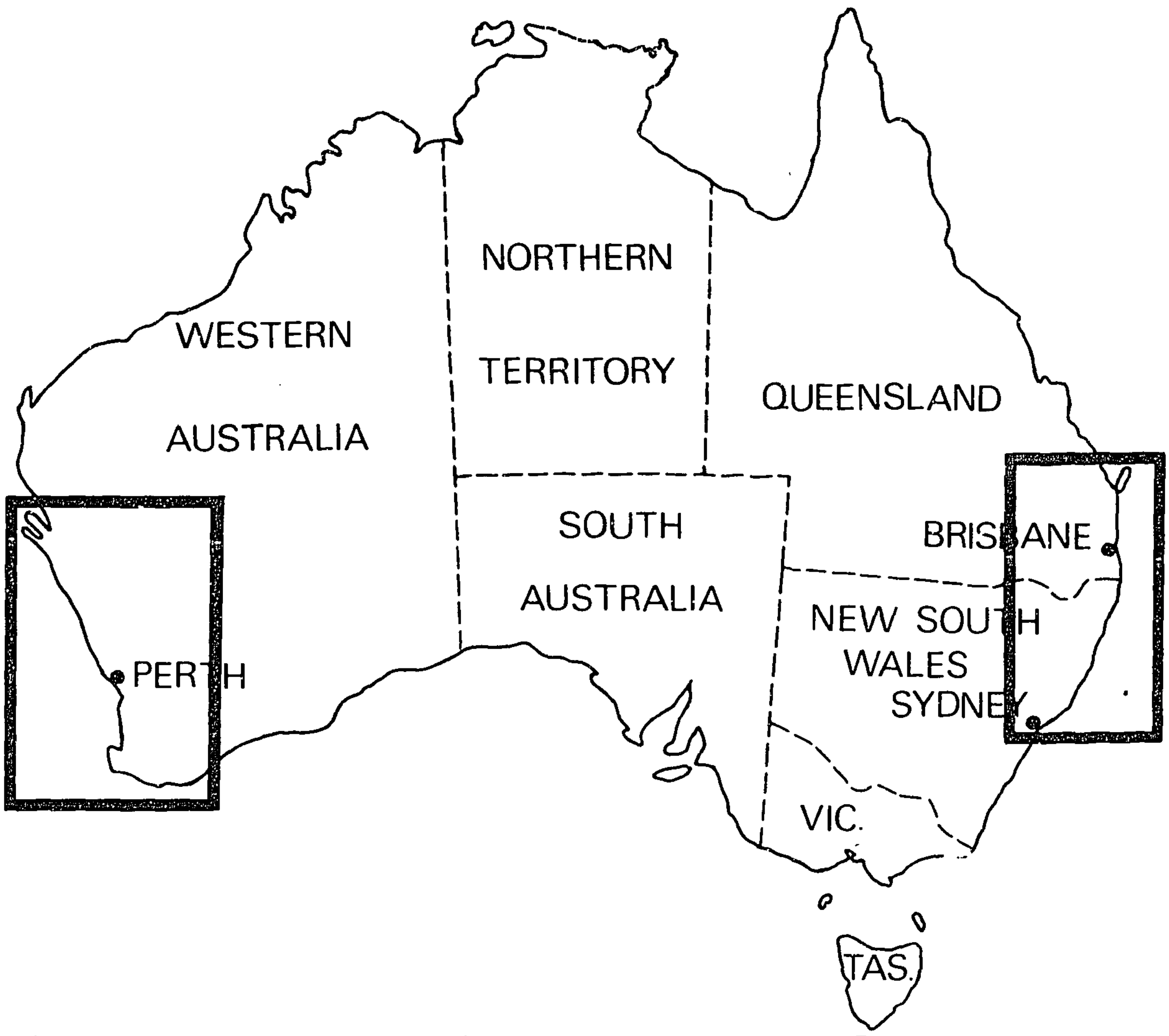
Gentlemen, time has overtaken me so let me sum up.

In the short-term, revival of the world economy should see renewed demand for rutile particularly now that consumer stocks have been largely liquidated. While natural rutile (at the right price!) should continue to be the preferred feed for the chloride route albeit recent trends indicate that consumers are becoming more sophisticated in their preference for natural rutile supplemented by synthetic rutile and other forms of high titania - e.g. slag. In the longer term, if Australian producers are to maintain their competitive position as world suppliers I suggest we will need to -

- delineate new alluvial resources of heavy minerals onshore and offshore, and give some thought to the eventual development of hard-rock titaniferous deposits e.g. the titaniferous magnetites of Western and South Australia.

- continue R & D particularly in the fields of mining and mineral ore dressing aimed at exploiting low grade disseminated aeolian deposits and those currently regarded as uneconomic because of mining and ore dressing difficulties - e.g. highly indurated orebodies and those badly weathered and high in iron and slimes.

- extend the spectrum of the domestic industry to include a substantial content of mineral processing thereby increasing value added, reducing the disadvantages of geographic isolation and transport charges particularly to Europe, and increasing the range of saleable products to current and potential consumers.



LOCATION OF PRINCIPAL MINERAL SAND RESERVES AND MINING OPERATIONS

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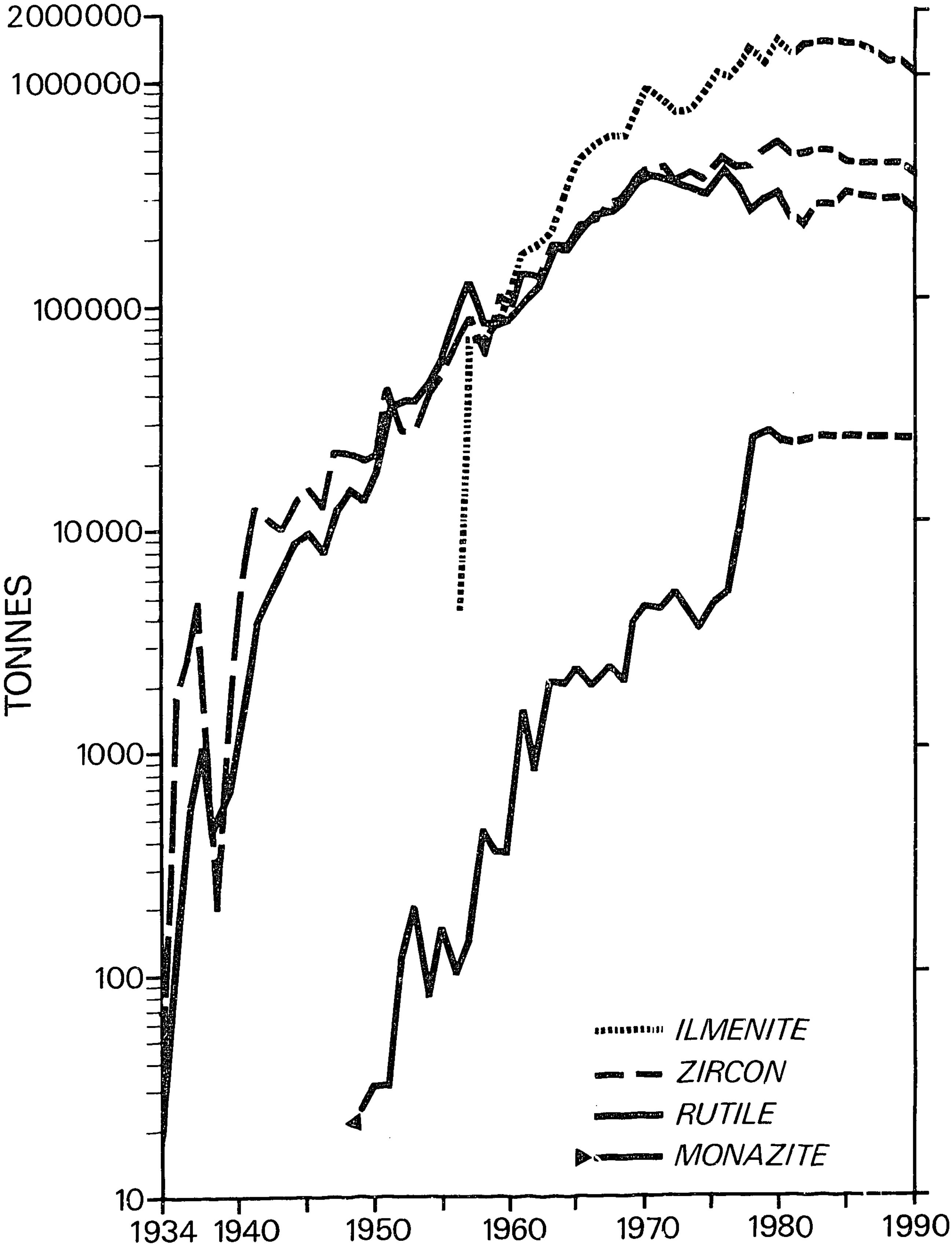
Slide 1



AUSTRALIAN PRODUCTION OF MINERAL SANDS 1934-1990

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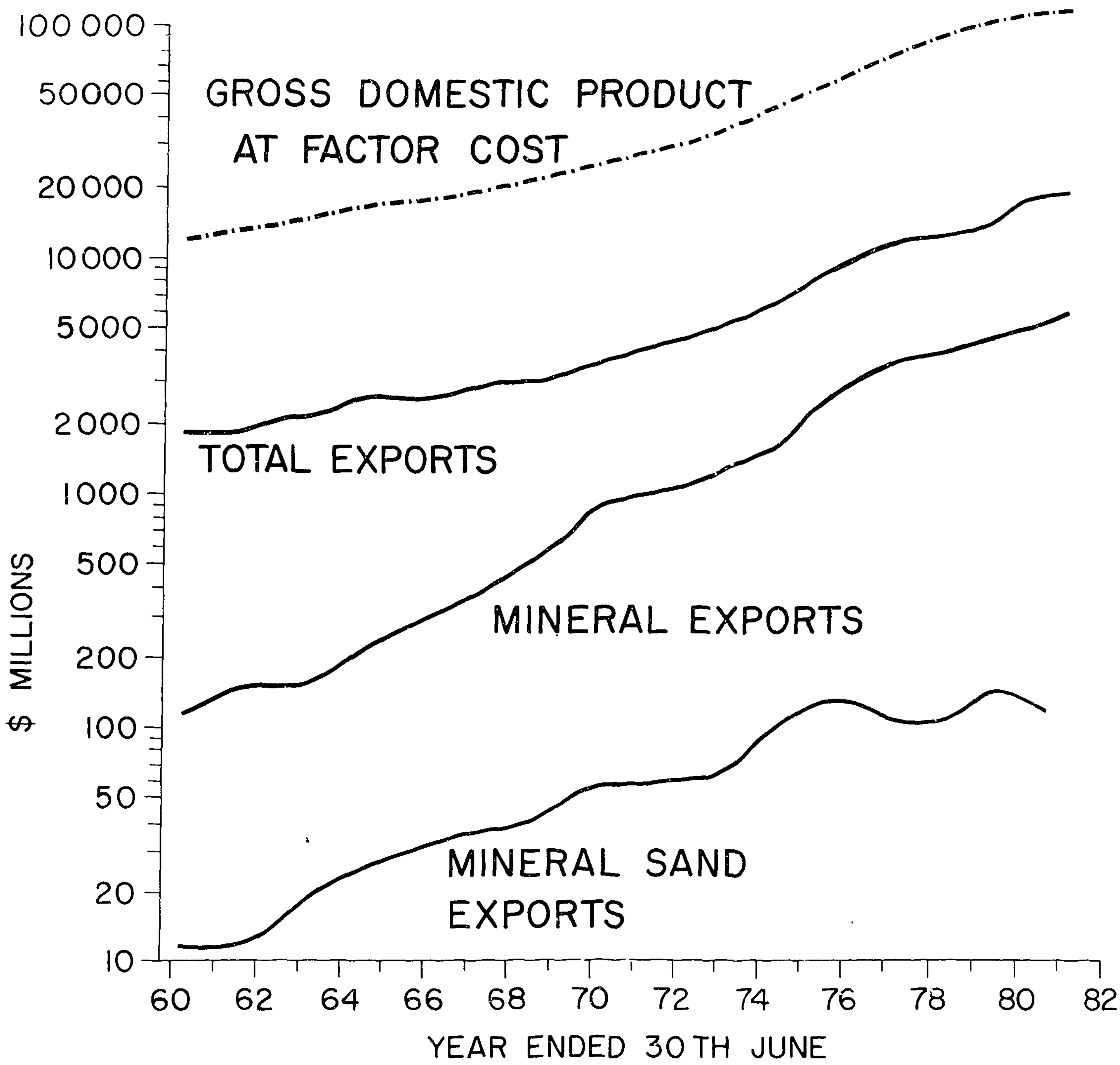
15/152

Slide 2



CONTRIBUTION OF MINERAL EXPORTS
TO THE NATIONAL ECONOMY

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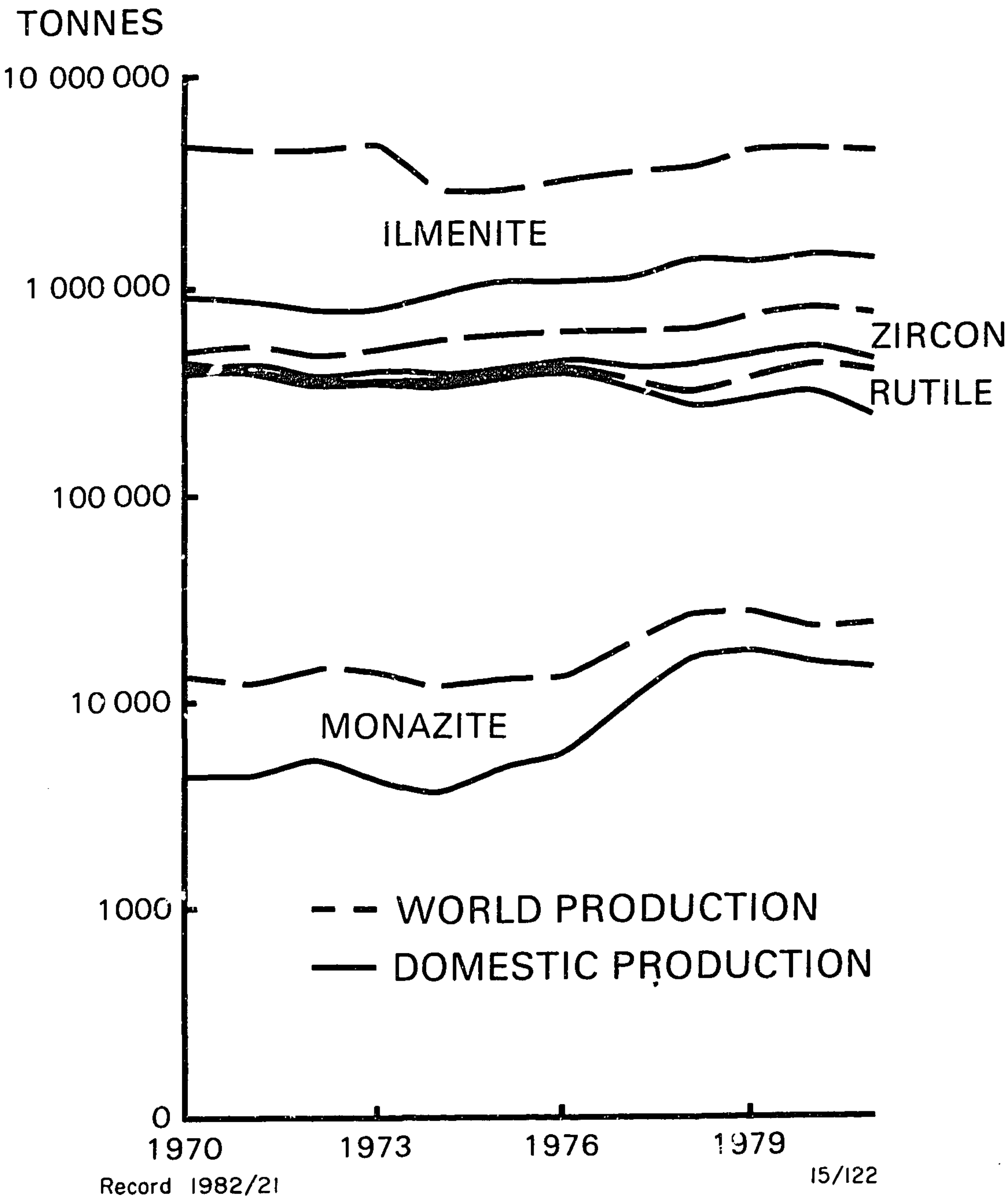
Slide 3


TONNES
10 000 000
1 000 000
100 000
10 000
1000
0
ILMENITE
ZIRCON
RUTILE
MONAZITE
WORLD PRODUCTION
DOMESTIC PRODUCTION
1970
1973
1976
1979
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15/122

Slide 4

DOMESTIC MINERAL SAND RESERVES ('000s TONNES) 1981

	DEMONSTRATED				INFERRED				TOTAL			
	R	Z	I	M	R	Z	I	M	R	Z	I	M
EAST COAST	6156	5746	13738	56.4	269	248	546	2.7	6425	5994	14284	59.1
WESTERN AUSTRALIA												
(SOUTH WEST)	95	1304	12853	67.4	4	14	126	0.1	99	1318	12979	67.5
(MIDLANDS)	3008	6403	16295	207.0	NOT AVAILABLE				3008	6403	16295	207.0
TOTAL	9259	13453	42886	330.8	273	262	672	2.8	9532	13715	43558	333.6

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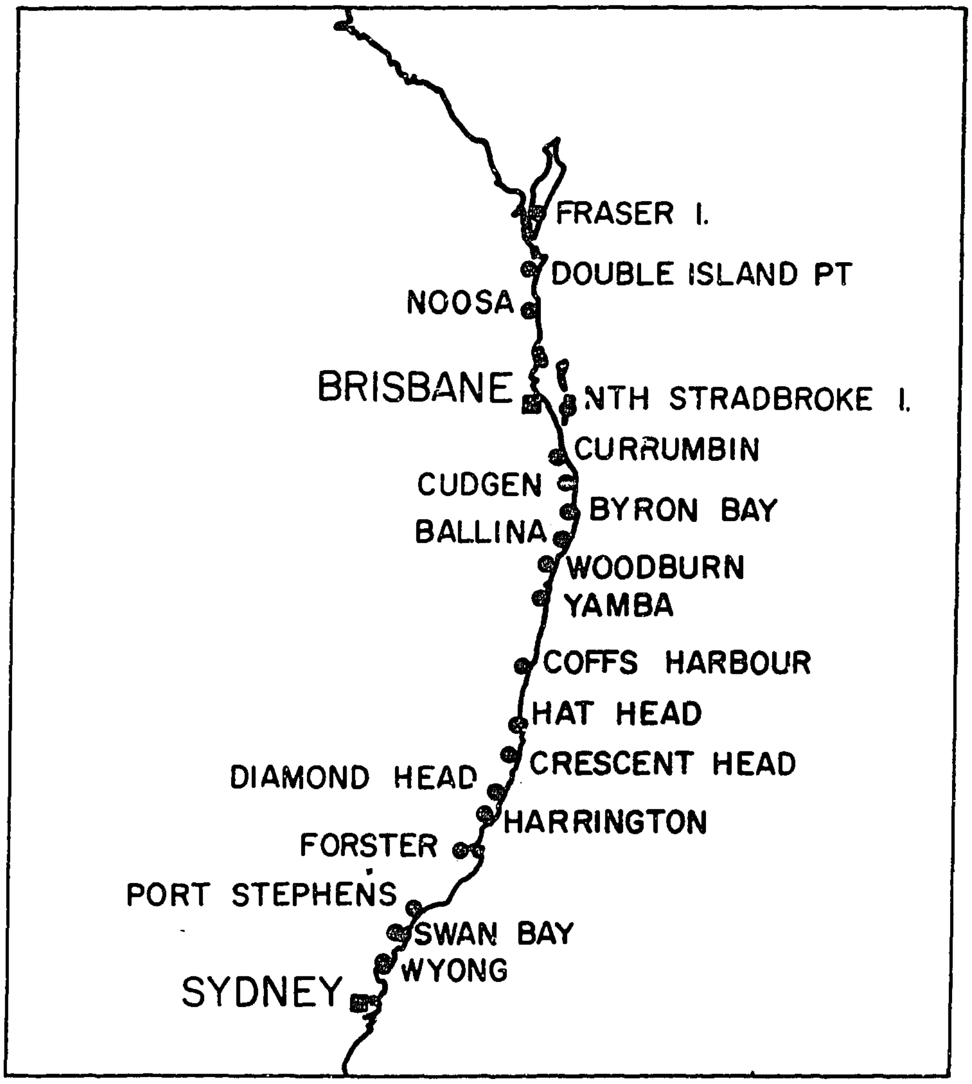
Slide 5



Slide 5a Principal mineral sand reserves & mining operations, east coast

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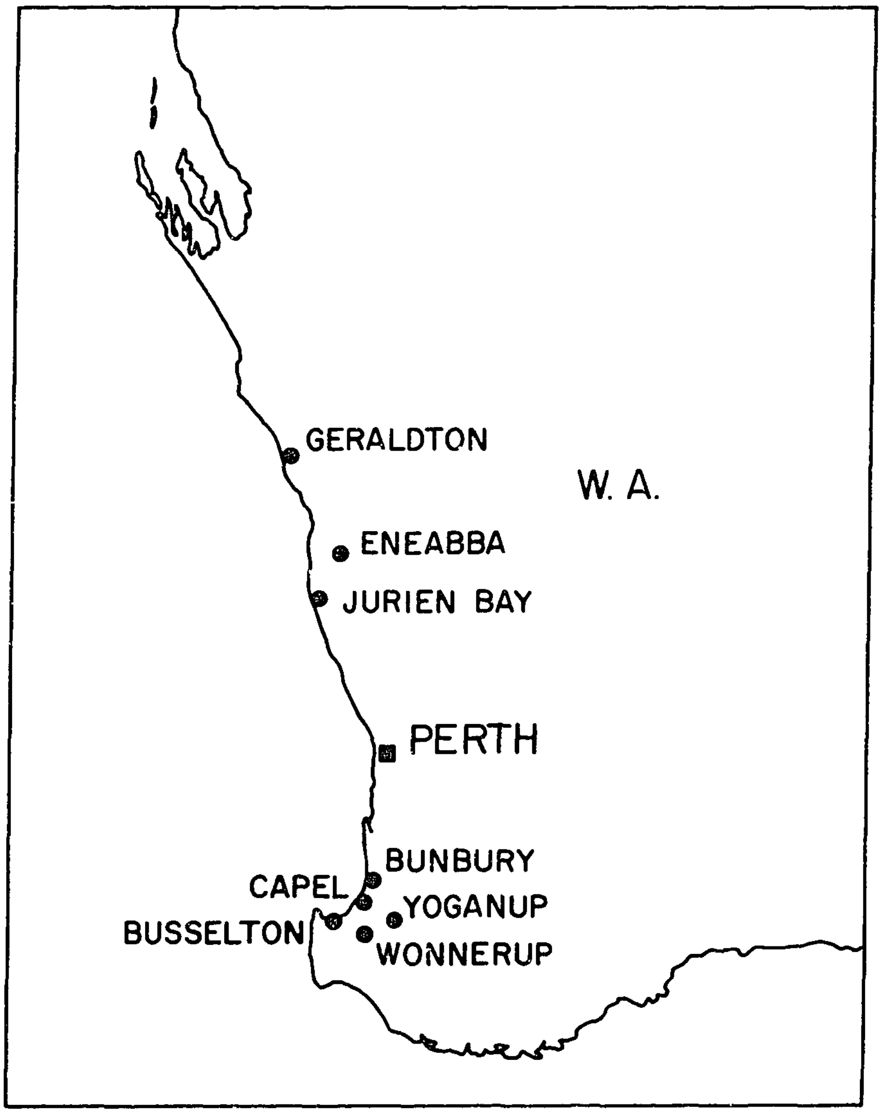

Slide 5b Principal mineral sand reserves & mining operations

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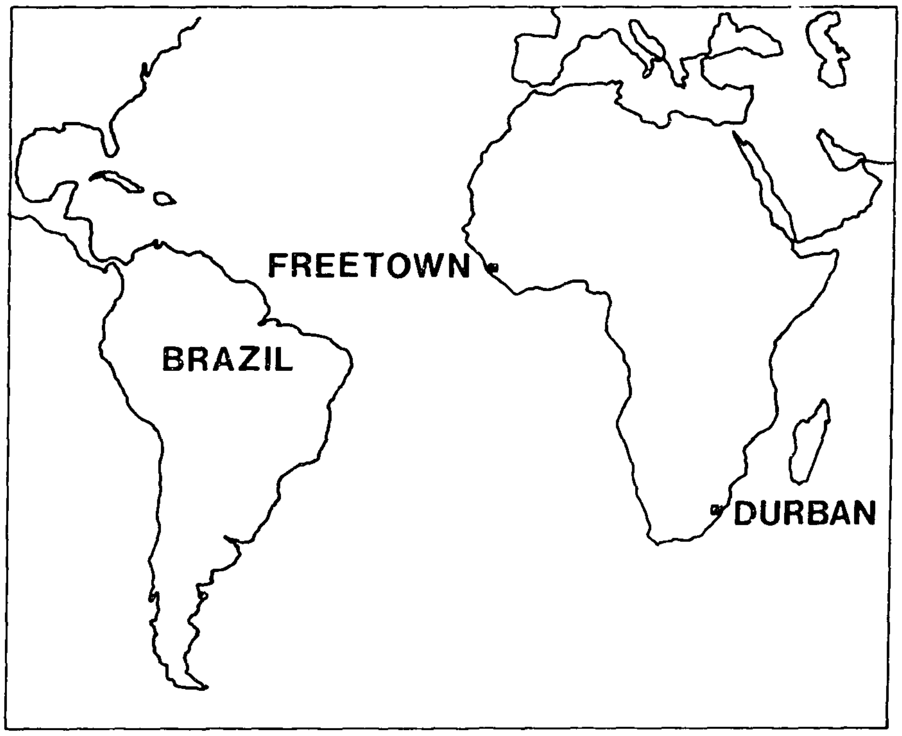

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Slide 6

TiO_2 PIGMENT

SULPHATE ROUTE V CHLORIDE ROUTE

RAW MATERIALS	
Cheap, wide-spread readily available – ilmenite, titania slag (70-72% TiO_2)	Expensive and restricted – natural rutile, synthetic rutile, high-titania slag (85% TiO_2)
PRODUCTION FLEXIBILITY	
Able to produce either rutile or anatase grade pigment	Normally produces rutile-type pigment
TECHNOLOGY	
Relatively simple	Sophisticated-high pressure, high temperature gaseous reaction
QUALITY OF PIGMENT	
Improved quality since chloride route introduced	Claimed to produce premium quality pigment
CAPITAL COST	
≑ US\$950/t of pigment	≑ US \$1300/t of pigment

OPERATING COSTS

Operating costs for Cl plant when operated continuously ar[illegible]ally automated up to 30% < those of SO_4 plant

EFFLUENT	
3.5 t/t of product	0.3 t/t of product

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Slide 7

NON-METALLIC MINERALS - A PROFILE OF THE INDUSTRY

A. Driessen & R. Towner

Although the non-metallics sector of the mineral industry is not as conspicuous as its counterpart metal and energy mineral sectors, it is nevertheless an important area of economic activity and it sustains our everyday living standards in ways which many of us are not fully aware Non-metallic minerals are indeed used in a very wide variety of products and processes and while the markets of many metals tend to be sensitive to more remote international economic, and sometimes political, influences non-metallic markets tend to respond more to levels of personal expenditure on things like bricks, mortar, glass and ceramics as make up a large part of our homes, as well as many other everyday products including paint, paper, plastics and aerosol sprays.

In this talk I have confined myself to the non-metallic minerals thus excluding minerals like ilmenite, rutile, zircon and chromite, even though these are regarded as industrial minerals, a term sometimes taken to be generally synonomous with non-metallics. I have also, for the purpose of this talk, aggregated the various non-metallics into five groups (Fig. 1). Overlaps and inconsistencies are difficult to eliminate and indeed reflect the overlapping markets for many of these commodities. For example, diatomite is included with "other industrials" because it is used mainly as a filter medium as well as a filler and as a mild abrasive. However, diatomite is also used as a refractory and as a thermal and acoustic insulator in wallboards.

Before focusing on individual groups, study some comparative statistics on the non-metallics sector as a whole. In terms of ex-mine value of production (average of 1979 and 1980) the three sectors of the mineral industry compare as follows (Fig. 2):

Energy	$3100 M
Metals	$3000 M
Non-metallics	$ 670 M

The degree to which the non-metallics sector is overshadowed to some extent highlights one of the basic features characterising metals and non-metals, namely, the level of technology required to sustain supply. The continuing supply of metals in general relies more on advances in technology which enable mining at deeper levels and metallurgical recovery from lower-grade ores; this is ultimately reflected in rising production costs and thus higher ex-mine values. Non-metallic minerals are generally mined, quarried or dredged in surface operations and used in toto, after minimum processing. I don't mean to imply that technology is a stranger to the non-metallics sector, but it does tend to be restricted to the processing end of operations and consequently beyond the measure of these statistics.

Fig. 2 also compares apparent consumptions for each of the sectors, that is, in terms of ex-mine value. In such terms imports and exports of non-metallic minerals are about equal; that is, net trade is zero so that value of production equates with value of consumption. The metals and energy mineral sectors are net exporters. For the metals sector imports are negligible so that net exports approximate total exports -

about three-quarters of production. The comparatively lean margin in favour of energy mineral exports masks the actual values of oil imports and coal exports.

Staying for the moment with measurements in ex-mine values, the non-metallics sector is neither a net exporter nor net importer. Net exports of $6M + $2M are offset by net imports of $5M + $2M + $1M (Fig. 3). Although standardising measurements of mineral production and trade in terms of ex-mine value helps in making comparisons across the production to consumption spectrum, the obvious disadvantage of such an approach is that such comparisons do not take account of values added along the way by any processing and transportation. The cost of these activities appear in free-on-board or f.o.b. values. On the basis of trade statistics measured in f.o.b. values, the non-metallics sector is a net importer to the extent of $160M (Fig.4). That trade deficit reflects mainly imports of phosphate rock, and sulphur.

Many people would not think of construction materials and other construction industry minerals when thinking of non-metallics, yet they account for 75% of the non-metallics sector by ex-mine value; statistics are incomplete but this value represents some 150Mt of material representing mainly broken and crushed stone, sand and gravel, limestone, brick shale, glass sand, and gypsum. Although the New South Wales Geological Survey appropriately refer to these materials as community minerals, these, more than any other, highlight the conflicts associated with competing land use. At the lowest end of the unit value scale (on average less than $5/t - apart from asbestos which I included in this group), these materials are the most sensitive to transport costs and tend to be extracted so close to their markets as to be ultimately overrun by them (i.e. by urban development). Notwithstanding that many such resulting land-use conflicts could be resolved by imporved long-term planning, this is not made easy by the fact that various State Governments do not regard many construction materials as minerals under their Mining Acts so that legislation covering exploration and exploitation is fragmented, in one case in up to 6 Government Departments (including Local Council) and partly depending on whether deposits are located on private or crown land or in intertidal or sub-tidal areas.

Generally speaking, the commodities in this group occur in abundance. Yet the Geological Survey of New South Wales, in a very comprehensive publication called <u>A review of industrial minerals and rocks in New South Wales</u> list only 3 non-metallic commodities as rating very high priority for additional work and studies and these are all in this group: construction materials, clays, and silica sand. Thus the major challenges facing this industry (and government), in at least the most populous State, relate to resolving competing land use conflicts and to ways of containing transportation costs. Most industrial mineral and rock commodities are transported by road - generally regarded as the costliest mode of transport - but also by rail. Sea transport accounts for only a minor fraction and rivers go virtually unused.

In 1980 Renison Goldfields, whose parent company is the largest miner of marine aggregate in the UK, applied for leases for dredging sand offshore from Palm Beach. The company's application was ultimately refused but the area of potential interest was declared a reserve under the Mining Act. Estuaring and marine deposits, in some cases already being exploited, constitute a fairly obvious potential resource of aggregate for the future.

Gem and semi-precious stones make up the second largest industry in the non-metallics sector but it is rather specialised. I am, therefore, going to restrict myself to some very broad observations. Ex-mine value of production of $90M is made up of an estimated $55 M for opals - three-quarters of which come from South Australia - and about $25 M for sapphires which come from Queensland and New South Wales. The remaining $10 M represents nephrite and other material. Total exports are valued at about $45 M and imports, almost all diamonds, are valued at about $50 M. Most table headings relating to Australian statistics are prefaced by the word 'reported', implying that unknown quantities of production and exports probably go unreported; the industry is made up of a large number of small operators. Needless to say, statistics for diamonds are in the process of being re-written. Reports indicate that the Ashton Joint Venture could be producing at a rate of 2 million carats/year, valued at about $15M, by the end of this year. Full scale production at a rate of 20 million carats/year valued at $150 M, the export component of which could add some $100 M to Australia's trade balance, is anticipated from 1985.

Sapphire production from the New England region in New South Wales is expected to decline over the next 10 years as resources are depleted. The New South Wales Geological Survey believes that it will be able to outline new prospective areas in other parts of the State which should sustain this industry.

Being the most import-dependent for its raw materials, the fertiliser and chemical minerals industry offers, prima facie, the best opportunities for increased raw material production in Australia to replace imports. But new opportunities have also been created by other circumstances. Last year, the Australian government, by disbanding the BPC and CIPC (The British Phosphate Commissioners and Christmas Island Phosphate Commission), substantially de-regulated the phosphate rock market, mainstay of Australia's fertiliser industry. Although the Christmas Island deposit is now being mined by a newly-formed Australian Government-owned mining company, and Australia's fertiliser manufacturers have re-grouped into an Australian Phosphate Corporation, the agreement covering the operation of the APC as approved by the Trades Practices Commission leaves the Australian phosphate rock market virtually de-regulated; membership of the APC requires minimum purchases of only 20,000 tonnes/year of phosphate rock and 5,000 tonnes/year of sulphur and members are free to purchase additional supplies from other sources if they so wish.

Notwithstanding that Western Mining resumed production from the Duchess deposit late last year, there would still appear to be scope for continuing phosphate exploration, particularly in regions closer to markets. For example, each 1c/km/tonne rail freight is equivalent to $10/tonne on the landed cost of Duchess rock in Townsville. Shipping freights would add substantially to the cost of landing rock at the main fertiliser manufacturing centres at Newcastle, Port Kembla, Geelong and the various plants in other States especially Western Australia, which is Australia's largest consumer of phosphatic fertiliser. Western Australia has known occurrences of sedimentary and igneous apatite and indeed two companies are actively exploring for phosphate in that State.

Following the problems of earlier years, company statements now indicate that full-scale production of phosphate concentrates from run-of-mine Duchess rock, rather than the selectively-mined direct-shipping-grade rock being produced now, in from 5-10 years away. The scale of such an operation would depend very much on the company's ability to develop overseas markets.

Australia has virtually always imported its potash requirements; domestic consumption is small - only some 200,000 product tonnes with an f.o.b. value of about $20 M.

Australia's dependence on imported sulphur has increased from less than 50 percent some 6-7 years ago to about 75 percent now. That is, only about 25 percent of Australia's sulphur requirements of some [illegible]00,000 tonnes/year are presently recovered from indigenous raw materials such as metallic sulphides. This trend mainly reflects the comparative economics of transporting elemental sulphur to acid plants situated very close to final consumption markets, as opposed to transporting recovered acid from metal smelters to these same markets. One possibility for reversing this trend in the long-term lies with an Australian-conceived hydrometallurgical process for recovering some metals from concentrates. In this process sulphur is separated not as sulphur dioxide, but as elemental sulphur.

Australia's fluorspar requirements continue to be met solely from imports but these are only small - only some 35,000 tonnes/year. One possibility for increased demand in the future lies with uranium processing; one tonne of uranium contained in yellowcake would require 1.1 tonnes of fluorspar for conversion to uranium hexafluoride.

One other mineral commodity not shown on the table and which is attracting increasing interest overseas and in Australia, is trona-naturally occurring sodium carbonate. This interest stems from 2 factors.

Firstly, natural sodium carbonate is obviously a potential substitute for synthetic sodium carbonate, which is manufactured from salt and limestone. In Australia, sodium carbonate, used mainly in glass, is manufactured only by ICI, at one plant near Adelaide; salt statistics indicate a production rate of about 350,000 to 400,000 tonnes/year of sodium carbonate. The trend towards trona, particularly evident in the US, is being sustained by rising manufacturing costs and costs associated with disposal of waste calcium chloride which is produced in equivalent amounts.

Secondly, trona offers a more appropriate route, at least for Australia, to sodium hydroxide, presently manufactured from salt by electrolysis. This latter process also produces chlorine and indeed the economics of production depend largely on markets for both products. Without a large petrochemical industry, the main market for chlorine, Australian production of sodium hydroxide has been restricted to about 150,000 tonnes/year even though Australian requirements are about 1 M tonnes/year (mainly for producing alumina from bauxite). Thus the bulk of Australia's requirements of sodium hydroxide are met by imports at a cost of about $50 M/year f.o.b. or, say, $80 M landed in Australia.

About 60-65 percent of all refractories, which would include alumina, bauxite, chromite and zircon not shown here, are used in iron and steel production. Australian mine production of refractory raw materials is valued at about $10 M and manufacturers' sales and transfers of refractory products are valued at about $55 M. Imports are needed to meet a sizeable proportion of Australia's overall requirements of raw material - about 90,000 to 100,000 tonnes/year comprising about 30,000 tonnes/year of clay calcines, 25 000 tonnes magnesite and lesser amounts of calcined bauxite, chromite and alumina cement clays.

Production in Australia is dominated by Australian Industrial Refractories, Kaiser Refractories, and Harbison-ACI: these companies' main operations are centred on Australia's largest industrial region encompassing Newcastle, Sydney and Wollongong. The effect of transport costs remain evident. Local manufacturers vying for markets on more distant coasts, such as smelters at Gladstone or Portland, invariably find their level of natural protection eroded to the extent that Australia's coastal shipping coats are relatively higher than costs of shipping from overseas.

Last year, a Standing Joint Group on Raw Materials Processing, set up by the Australian Minerals & Energy Council and the Commonwealth/State Industry Ministers' Conference, published a report called Australian refractories industry - Potential for expansion. Although the report was prepared when the outlook for increased smelter capacity, particularly for aluminium, looked brighter than it does right now, its assessment of opportunities for expansion remain valid, albeit in a lengthened time frame. I recommend the report as a comprehensive source of information on this industry.

The minerals in my so-called "other industrials" group, by no means a complete list, are used in a very wide range of applications. Measured by quantity, calcite (limestone) which is used mainly as a filler in many products but especially, in plastics, is the most important commodity.

This particular industry, like every other in the non-metallic sector, has experienced its share of rationalisation. After about a decade of intermittent company mergers and takeovers, Steetley Industries, Cudgen RZ and ACI have emerged as the main operators, at least in the main eastern States' market.

Without big and concentrated domestic markets, operators in this industry, unlike their counterparts in the US and Europe, have had little opportunity to specialise in particular products. Thus with minor exceptions the Australian industry has tended towards selective mining of some crude ores, supplemented by imports, for processing in multi-purpose milling centres located almost exclusively in Australia's larger capital cities. But perhaps the first signs of product specialisation are starting to emerge. Last year Omya Minerals, a subsidiary of Cudgen, commissioned a 100,000 tonnes/year calcite plant at Bathurst. Subsequently a joint venture comprising Steetley and Blue Circle Cement commenced construction of a similar facility at Moss Vale; this plant is expected to come on-stream in 1983. In other changes ACI-Tennant last year purchased Cudgen's multi-purpose milling plant at Beverly (Adelaide) and redirected operations there towards limestone processing for ACI's glass requirements.

To conclude, non-metallics, generally speaking, are less scarce than metals. On the other hand the much tighter relationship between mine and market (i.e. specifications) impose other restrictions. As well, the economics of transport have a much greater influence on the production of non-metals than on metals. Overseas, trends towards more intensive exploitation of some non-metallic mineral deposits i.e. the mining of particular rocks for all its constituents, are becoming evident. Thus particular coarse grained granites are being exploited for felspar, mica, and quartz, each for its own market. Continuing developments in this direction are obviously sensitive to economies of scale. Given Australia's small market base success for such a venture in Australia could have to depend on one such project cornering the market and/or producing for export.

Survival in any market demands current awareness and this is none-the-less true of non-metallics. Many South Australians have inherited an awareness of non-metallics from the fact that their State has practically no forests so that form earliest days of settlement stone was substituted for timber. Consequently that State probably has the best developed non-metallics industry in Australia. Sustaining a current awareness of non-metallics does not come easily. Prices, the ultimate market signal, are generally, but particularly in Australia, not freely quoted; in contrast, metal prices are not only more quoted, but quoted more often, sometimes even twice per day.

Never mind; to coin a phrase, 'life wasn't mean to be easy!' Still, I have noted from recent company reports that, while many metal producers are reporting marked falls in profit, due to lower metal prices, those companies with interests in non-metals as well as metals are reporting closer to normal profits. In the last 10 years the ex-mine value of production of non-metallics, in constant dollars, has mirrored the rise of GDP at constant prices - 2.6 percent/year. That is the minimum average rate of real growth I predict for this industry in the next 10 years.

FOR PURPOSE OF THIS TALK

CONSTRUCTION MATERIALS	GEM AND SEMI-PRECIOUS STONES	INDUSTRIALS	FERTILISER AND CHEMICAL	REFRACTORIES
COARSE AGGREGATE	DIAMONDS	BARITE	FLUORSPAR	DOLOMITE
FINE AGGREGATE	OPAL	BENTONITE	PHOSPHATE ROCK	FIRE CLAYS
UNPROCESSED MATERIALS	SAPPHIRE	DIATOMITE	POTASH	MAGNESITE
ASBESTOS	OTHER	FELSPAR	SALT	PYROPHYLLITE
BRICK CLAYS		KAOLIN	SULPHUR	SILLIMANITE
GYPSUM		MICA	NB EXCLUDES NATURAL GAS	NB EXCLUDES BAUXITE, CHROMITE AND ZIRCON
LIMESTONE		PERLITE		
SILICA SAND		TALC		
		NB EXCLUDES ILMENITE AND RUTILE		

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Fig.1

EX-MINE VALUE OF AUSTRALIAN MINERAL PRODUCTION COMPARATIVE STATISTICS – CONSTANT (1980) DOLLARS (MILLIONS)

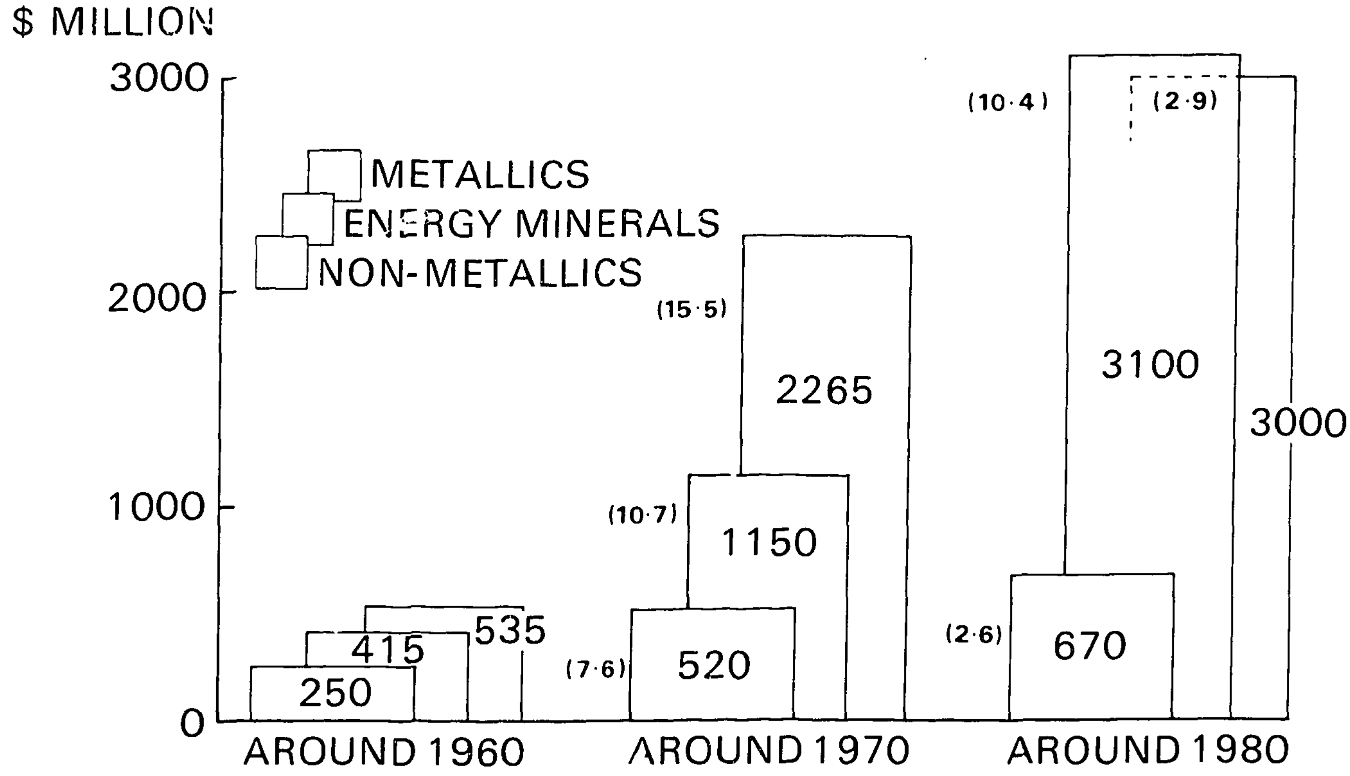

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Fig. 2

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AUSTRALIA'S SUPPLY BALANCE IN NON-METALLIC MINERALS

(EX-MINE VALUE OR EQUIVALENT)
AVERAGE (ROUNDED) OF 2 YEARS — 1979 AND 1980

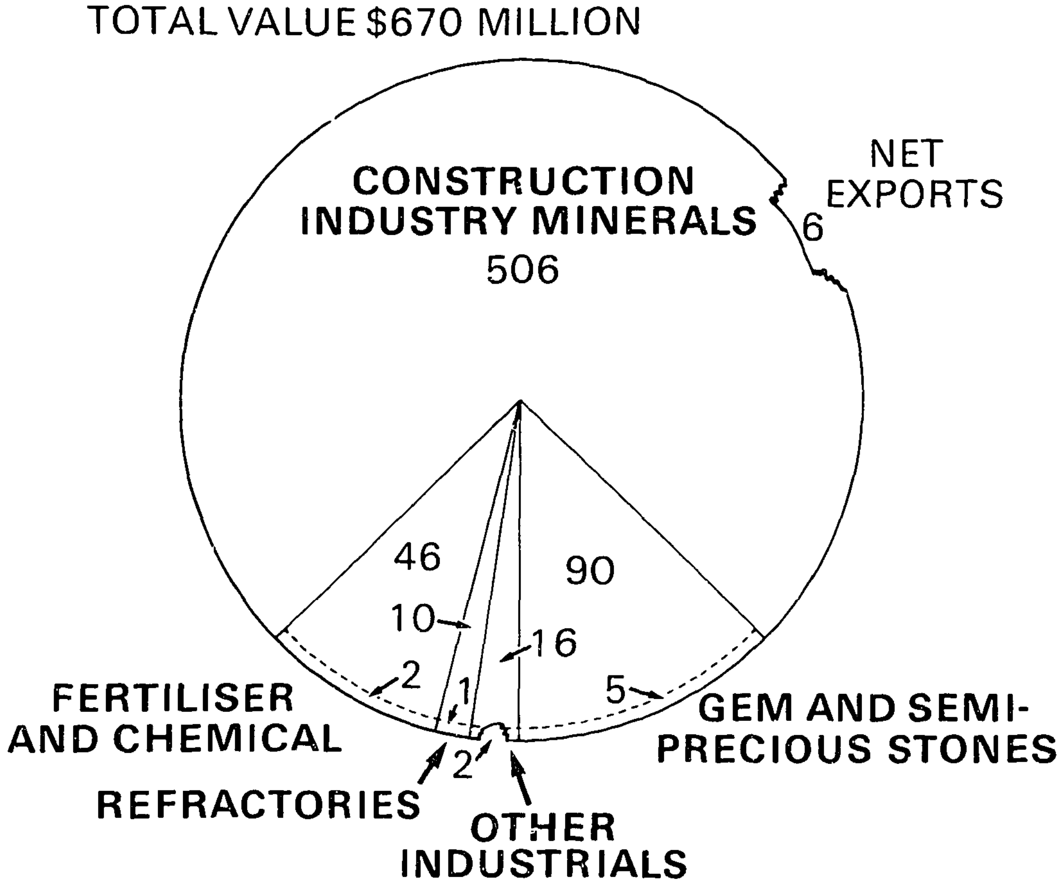

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Fig. 3

AUSTRALIA'S SUPPLY BALANCE IN NON-METALLIC MINERALS EX-MINE AND FOB VALUES, 1980

$ MILLION

	PRODUCTION EX-MINE	IMPORTS FOB	EXPORTS FOB
METALLICS	3290	120	4480
ENERGY MINERALS	3400	1700	2200
NON-METALLICS			
CONSTRUCTION MINERALS	560	20	25
GEM AND SEMI-PRECIOUS STONES	75	50	36
FERTILISER AND CHEMICAL	55	180	44
REFRACTORIES	10	6	1
OTHER INDUSTRIALS	10	24	14
SUB-TOTAL	710	280	120
TOTAL	7400	2100	6800

Record 1982/21 Fig. 4 15/106

Chromium in Australia

R. Pratt

INTRODUCTION

- Chromium is one of industry's most versatile elements.

- It has a wide and diversified range of uses and is of major strategic importance.

- The concentration of resources and production in only a relatively few countries has historically led to supply disruptions to major industrial consuming nations.

- Chromium's principal use is in stainless steel where it is an important alloying element.

- Chromite, which consists of varying percentages of chromium, iron, aluminium and magnesium oxides, is the only mineral from which chromium can be extracted commercially and 97 percent of world chromite resources occur in the Republic of South Africa, and Zimbabwe.

- Australia, like most industrialised countries is almost totally dependent on imports of chromite for supplies.

- Australia's import dependence extends to most chromium manufactured products, including ferrochromium and chromium chemicals.

- Though ferrochromium and chromium chemicals were once produced locally, production plants have closed because they were not competitive with overseas plants.

- As part of its mineral resource assessment role BMR recently assessed Australian chromite resources.

- The assessment included results of recent exploration work and indicated Australia's chromite resources to be considerably larger than previously believed.

USES (Figure 1)

- The industrial uses of chromium are conveniently classified as metallurgical, chemical and refractory.

- About 70 percent of world chromite production is consumed as ferrochromium and ferrochromium silicon in the metallurgical industry.

- Both are chromium iron alloys; the chromium content of ferrochromium ranges between 50 and 75 percent.

- New techniques for producing stainless and other alloy steels which account for the bulk of ferrochromium use (some stainless steels contain up to 30% of their weight as chromium) have enabled greater use of lower grades of ferrochromium at lower cost in recent years.

- This has in turn enabled the use of lower-grade high-iron chromite (down to 40% Cr_2O_3 content) in ferrochromium production. Most chromite for metallurgical use was once required to have a low iron content and a chromium oxide content greater than 48 percent.

The advances in refining techniques have made available to the metallurgical industry resources of chromite which are vast in relation to the quantities consumed.

- In the chemical industry lower-grade high-iron chromite is suitable for the production of sodium and potassium dichromates from which most chromium chemicals are derived.

- The pigment-making and leather-tanning industries are major users of chromium chemicals.

- Chromite for refractories must have a high aluminium content (usually greater than 20% Al_2O_3) and is converted with minimal processing, sometimes with a proportion of magnesite, into bricks and mouldings for furnace linings.

- Chromite consumed in refractories production has declined in recent years, as open-hearth steelmaking, the main user of chromite refactories, has been replaced by the basic-oxygen steelmaking process which requires dolomite or magnesite refractories.

- Chromite's use in the foundry sand industry as a corrosion-resistant moulding medium has become important.

- Chromite composition requirements for the foundry sand industry are similar to those for the chemical industry.

<u>OCCURRENCE</u> (Figure 2)

- Chromite occurs in most Australian States.

- Many small pod-like deposits occur in north-south trending belts in Eastern Australia

- Most of these deposits contain chromite with potential for use in refractories because of their high aluminium content.

- The largest single high-aluminium deposit is in the Rockhampton district in northern Queensland at Princhester but the chromite would need to be upgraded for use in industry.

- Almost all of the smaller deposits of economic interest would require upgrading.

- Recorded output from the Rockhampton district between 1910 and the mid-1960 s totals about 15 000t.

- Similar small, often impure, deposits occur in belts at Gray Creek, Queensland, and in New South Wales at Baryulgil, the Warialda-Nundle-Port Macquarie region and the Thuddungra-Tumut area.

- The deposits between Thuddungra and Tumut produced about 32 000t of both metallurgical and refractory-grade chromite between 1894 and 1958; most of this being in the 10 years to 1904.

- This compares with total recorded Australian output of 80 000t.

- Output from the Warialda-Nundle and Baryulgil districts totals about 13 000t.

- A small amount of chromite occurs in beach sands along the east coast, and at Strahan and Ann Bay in Tasmania. Ilmenite concentrates produced during mineral sand mining on the east coast contain chromite which is not economically recoverable and is considered an impurity.

- In the Beaconsfield district, northern Tasmania, chromite occurs in alluvium and was produced recently for the foundry sand industry; total output between 1978 and 1980 when production ceased was 4 000t.

- Similar deposits occur elsewhere in northern and western Tasmania.

- The largest Australian chromite deposits occur in Western Australia.

- The chromite is not high-grade, containing a high iron content; but it has potential for use in low-grade ferrochromium or in chemical manufacture.

- At Lamboo in the Kimberley district extensive deposits of chromite are contained in thin steeply-dipping bands which extend over a distance of 13 km.

- Of more economic significance are deposits at Coobina in the Pilbara. Over 200 separate deposits are exposed at the surface and produced about 15 000t in the 1950's for local ferrochromium production. Drilling in the 1970's confirmed their potential to meet Australian metallurgical requirements in an emergency.

RESOURCES (Figure 3)

- Under parameters of geological certainty of occurrence and economic feasibility of extracting, BMR classified all Australian chromite resources as subeconomic.

- Simple economic analysis of the various deposits groups using approximate mining and freight costs and minimum prices of grades likely to be produced indicated that some deposits may have potential to be economic.

- Minimum prices used for chromite landed in Australia were \$110/t for Philippines refractory chromite and \$85/t for Transvaal high-iron chromite.

- However, in all instances insufficient detailed information was available to demonstrate the economics of mining or to confirm that resources currently inferred to exist do in fact occur in concentrations of economic size and grade.

- Australian demonstrated resources exceed 2 Mt and inferred resources approximate 20 Mt.

PRODUCTION AND TRADE (Figure 4)

- Australian production of chromite began on a regular basis in the 1890's and a relatively small output was maintained up to 1968.

- Production resumed after a 10 year lapse in 1978 at Beaconsfield, Tasmania, but stopped in 1980 after resources were exhausted.

- Ferrochromium production began in Australia in the early 1940's, following construction of a ferroalloy plant at Newcastle by The Broken Hill Proprietary Co Ltd.

- The company had decided to produce its own ferroalloys for steelmaking because of the uncertainty of receiving supplies during war time.

- Difficulties experienced in obtaining certain chromium chemicals at this time led to the establishment of a chromium chemicals manufacturing plant in 1943.

- Australia's chromite requirements for ferrochromium and chromium chemicals as well as for refractories could not be met from local sources and imports expanded considerably, reaching a peak in the 1960's.

- The chromium chemicals plant was closed in the late 1960's because of competition from imports, and the ferroalloy plant at Newcastle was closed in the 1970's because it became obsolete and relatively inefficient.

- All requirements of ferrochromium and chromium chemicals are now imported, and we now annually require about 14 000t of ferrochromium and about 6 000t of chromium chemicals.

- Since chromite is no longer imported for use in ferrochromium and chromium chemicals production, imports are now used only for refractories and foundry sand.

- Chromite imports currently average about 12 000t/year.

- Imports of chromite since the 1960's have fallen mainly because of a decrease in the use of chromite refractories in steelmaking.

- A slight upward movement in imports in the late 1970's reflects growth in imports of chromite from South Africa used in Australia mainly in the foundry sand industry.

<u>IMPORTS</u> (Figure 5)

- The combined value of Australia's ferrochromium, chromium chemicals and chromite imports has increased steeply in recent years partly because of increased prices and partly because of growing ferrochromium and chromium chemicals requirements.

- However, this upward trend was checked in 1981 when reduced steel and chemical industry requirements caused imports of all three products to fall so that the total was valued at about $12 million compared with $19 million in 1980.

- Major sources of imports are South Africa for ferrochromium, the Philippines and South Africa for chromite, and Japan, USSR, Italy and West Germany for chromium chemicals.

<u>CONSUMPTION</u> (Figure 6)

- Over the last 10 years Australian consumption of ferrochromium is trending upwards by about 4 percent/year.

There is an upward trend of 1 percent/year for chromium chemicals consumption, and a slight downward trend (less than 1 percent) in consumption of chromite.

- The metallurgical industry uses about 60 percent of the chromium consumed in Australia and the bulk of this is in the form of ferrochromium for stainless and alloy-steel production.

- Over 85 percent of ferrochromium used in Australia are lower-cost high-carbon grades including ferrochromium with high silicon content, known as charge chromes.

- Stainless steel production plant at Port Kembla (which consumes most of this material) has used an argon oxygen decarburisation refining vessel since 1975.

- Ferrochromium use in Australia will be dependent on stainless and alloy-steel output which, in line with world trends, has historically increased at a greater rate than total crude steel output.

- Chromite consumption for use in refractories is expected to fall substantially when additional basic-oxygen steelmaking plant is installed at Port Kembla at the end of this year and open-hearth steelmaking plant, currently the major consumer of chromite refractories, is subsequently closed.

- Chromium chemicals consumed in Australia are mainly for use in the production of pigments and allied products, for use in the tanning and textile industries, and for use in corrosion control,including plating.

- The major chemicals imported are tanning preparations containing chromium sulphate, sodium dichromate, and other chromates, chromium oxide, chromium trioxide and chromium pigments.

- The chromium chemicals industry in Australia has lost some markets to other materials, particularly in the tanning industry, and future growth will largely depend on growth in demand from the pigment and leather-tanning industries.

CURRENT POSITION

Prices (Figure 7)

- Prices of chromite imported into Australia mainly for refractories from the Philippines have followed an upward trend from the early 1970's.

- Prices of Turkish lump-chromite and friable high-iron chromite from Tansvaal, South Africa, have tended to diverge in relative value since the 1970's, largely reflecting excess production capacity in South Africa, and the preference for higher grades of chromite by consumers.

- Though not applicable to Transvaal chromite, most metallurgical-grade chromite prices increased substantially after 1975 because of supply problems and shortages experienced during that year.

- Decreases of up to 30 percent in chromite prices early this year reflect the current depressed demand position for chromium following reduced steel output over the last two years.

WORLD CHROMITE PRODUCTION (Figure 8)

- World chromite production in 1981 and 1982 is expected to be well below that in 1980.

- South Africa continues to be the major producer.

- It has increased its share of production from about 20% of the total in the 1960's to a current 35% and may eventually produce more than 50% of total output as the USSR is considered likely to be a less important source in the future.

- Albanian production has increased strongly in recent years, as has that of Finland (340 000t in 1980) and Brazil (250 000t).

- India is also a moderately large producer but its output has declined in recent years (to about 250 000t in 1980).

WORLD FERROCHROMIUM PRODUCTION (Figures 9 and 10)

- Reduced Western World consumption in ferrochromium in the last two years has caused major users in USA and Western Europe to reduce ferrochromium output substantially, partly by closing higher-cost production facilities, thus continuing the trend for ferrochromium production capacity to shift from the major industrialised consuming countries to the major chromite producting countries.

- In 1960 countries with indigenous chromite supplies produced very little ferrochromium, but now produce about 50% of the total.

- Chromite producers in South Africa and Zimbabwe now have over 35% of Western World ferrochromium production capacity.

- Additional production capacity is being installed in Zimbabwe, Philippines, Brazil, Greece, Albania, India, and Turkey.

- Reasons for the shift in capacity to chromite producers include a reduction in the gap between alloy and ore prices, a desire by chromite producers to increase the value of their products, savings in freight, the availability of cheap energy sources in some countries, and environmental protection legislation in industrialised countries.

- With the shift in emphasis by chromite producers to production of ferrochromium, it is not surprising that chromite exports have increased only slightly in the last 10 years, but ferrochromium exports have almost tripled to over 1 Mt in 1981.

- South Africa, with the largest production capacity, now accounts for over 60% of ferrochromium trade.

WORLD OUTLOOK

- Undoubtedly a recovery in the world's chromium industry will be mainly dependent upon an upturn in the steel industry.

- Stainless steel output fell by 10% in 1981 to about 6 Mt, the second consecutive year output has declined after increasing continuously from 1975 to 1979.

- Steel output has continued to drift downwards in 1982, reflecting depressed demand and low levels of construction and durable goods output, as well as de-stocking activities in many countries.

- There are no clear indications of a further strong deterioration in steel demand, but there are no indications of an early upturn.

- In view of substantial chromium production capacity in South Africa, and new capacity for ferrochromium being installed in other countries, chromium over-supply can be expected to persist for some time even with a recovery in steel output.

- While the short-term outlook is one of over-supply, for the consumer, world chromium supplies can be seen as adequate for many years provided there are no major changes in South African political stability.

OUTLOOK FOR AUSTRALIA AND CONCLUSION

- Australian chromium requirements are relatively small but rtheless they are essential to the metallurgical, chemical and ractory industries.

- In conjunction with its plans to meet future domestic steel-industry requirements for major ferroalloys, the Australian ferroalloy industry has considered the possibility of installing a universal or multipurpose furnace in Australia which would be capable of producing high-carbon ferrochromium and other miscellaneous alloys.

- It has also considered the possibility of installing plant to produce lower-carbon alloys, including low-carbon ferrochromium by electro-silico-thermal methods.

- The Australian ferroalloy industry has been adversely affected by the steel industry recession and only recently announced it was reducing production and part of its workforce.

- Certainly any expansion in ferroalloy capacity and renewed ferrochromium production seems unlikely in the short-term.

- Any major expansion of Australian steel production capacity and therefore in ferroalloy and ferrochromium requirements also appears unlikely in the next few years.

- The possibility of producing chromium chemicals from chromite in Australia has been investigated in recent times but apparently cannot be justified.

- In conclusion, provided suitable processing plant is available, Australia's chromite resources appear to be sufficient to provide almost total long-term self-sufficiency in chromium for metallurgical and chemical use.

- However, because of the characteristics of known deposits, a decision on large-scale development would require further intensive testing, and problems of mining and beneficiation would need to be solved.

- Currently supplies of most chromium products can be readily obtained from overseas at relatively cheap landed prices and the practice of importing requirements is foressen to continue in the immediate future.

CHROMITE USE

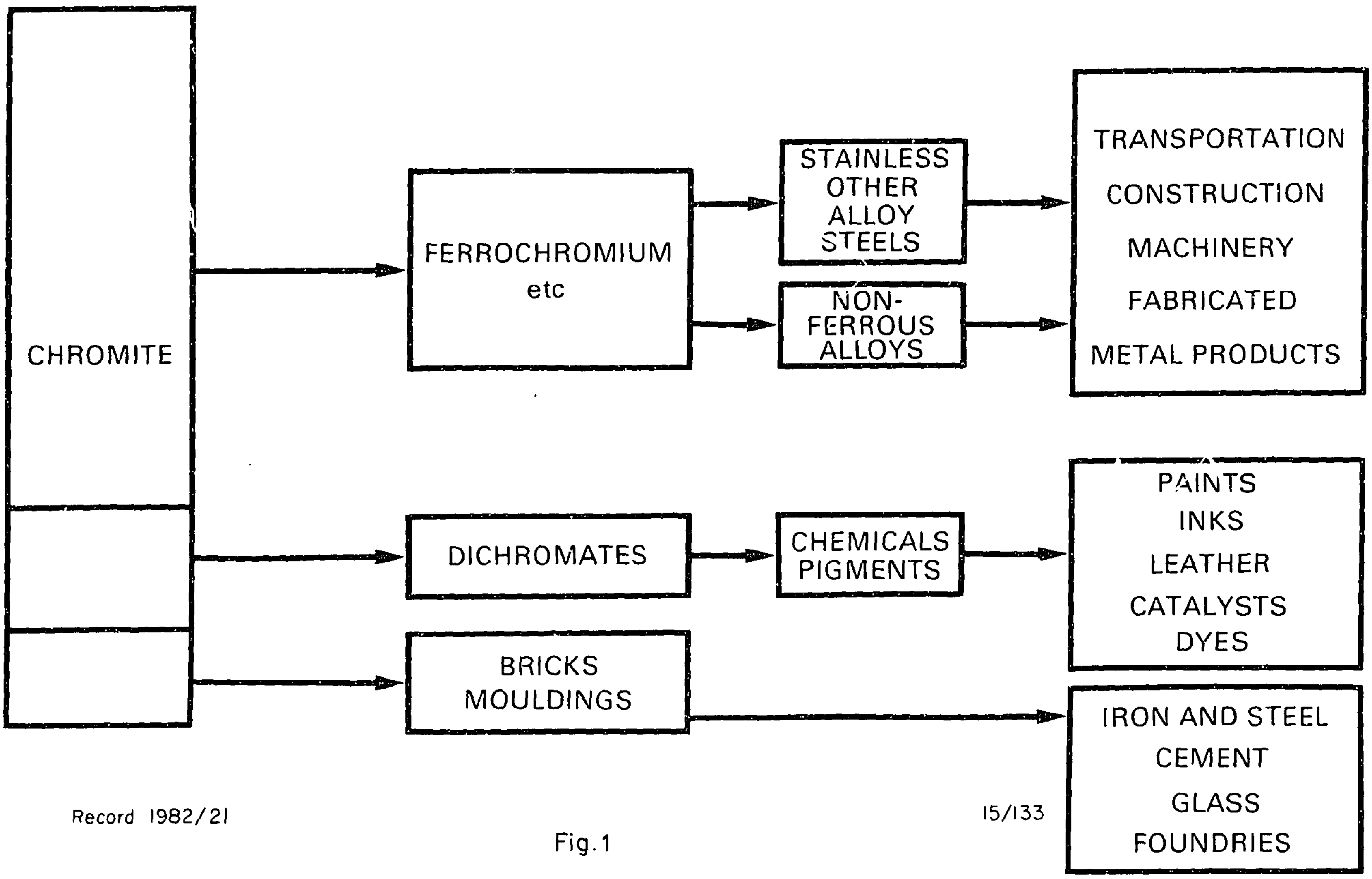

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Fig. 1

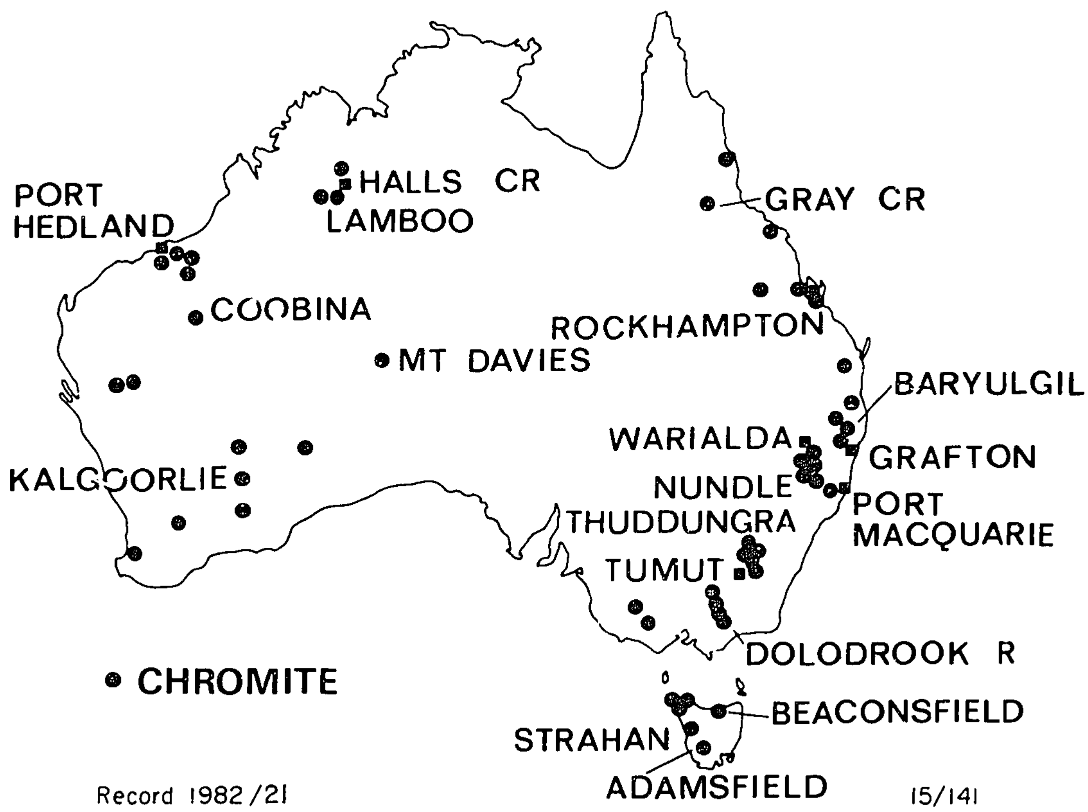

Fig.2 Occurrences of chromite

CHROMITE RESOURCES
(Mt of chromite)

	ECONOMIC	SUB-ECONOMIC
REPUBLIC OF SOUTH AFRICA	1067	2083
ZIMBABWE	559	559
USSR	22	22
AUSTRALIA	–	22
OTHERS	46	43
TOTALS	1694	2729

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Fig.3

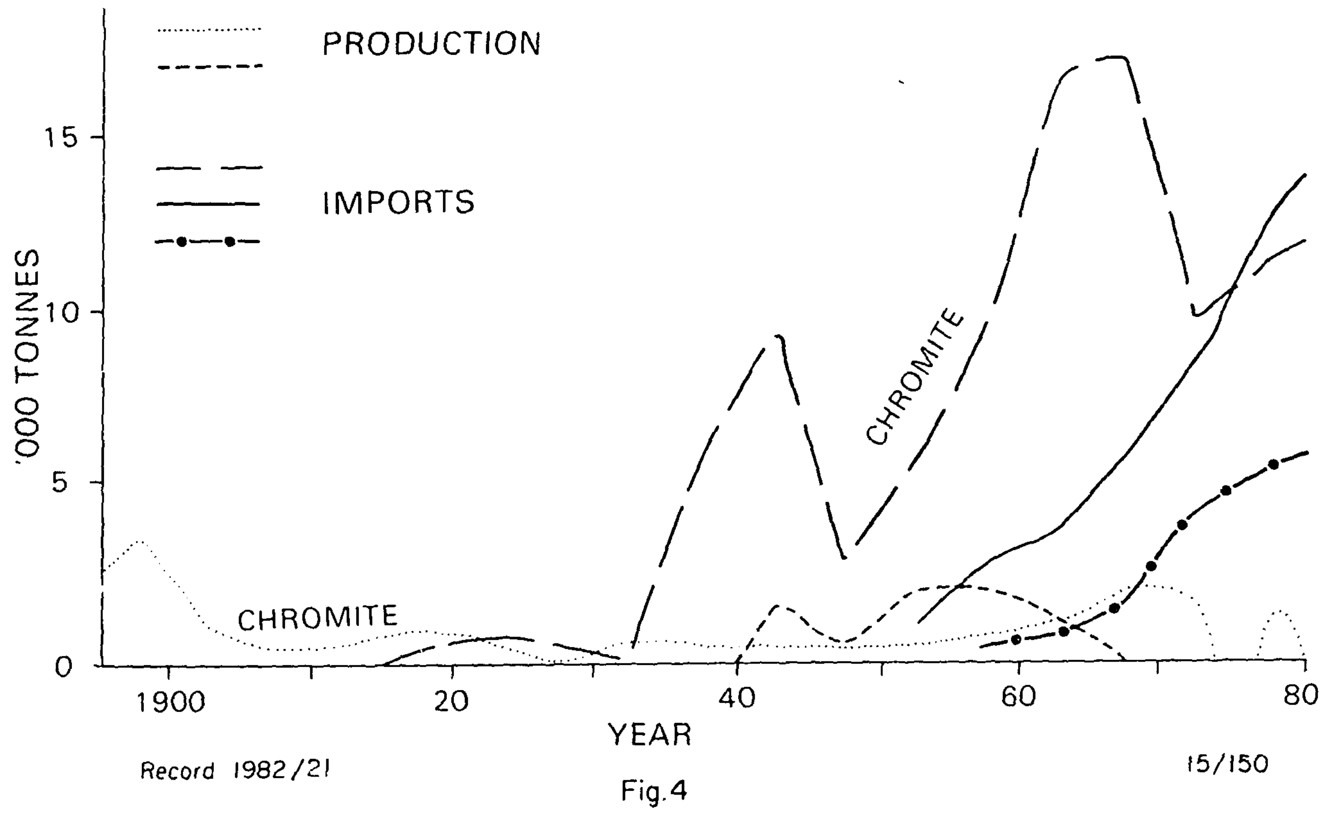
PRODUCTION
IMPORTS
CHROMITE
CHROMITE
'000 TONNES
0
5
10
15
1900
20
40
60
80
YEAR
Record 1982/21
15/150

Fig.4

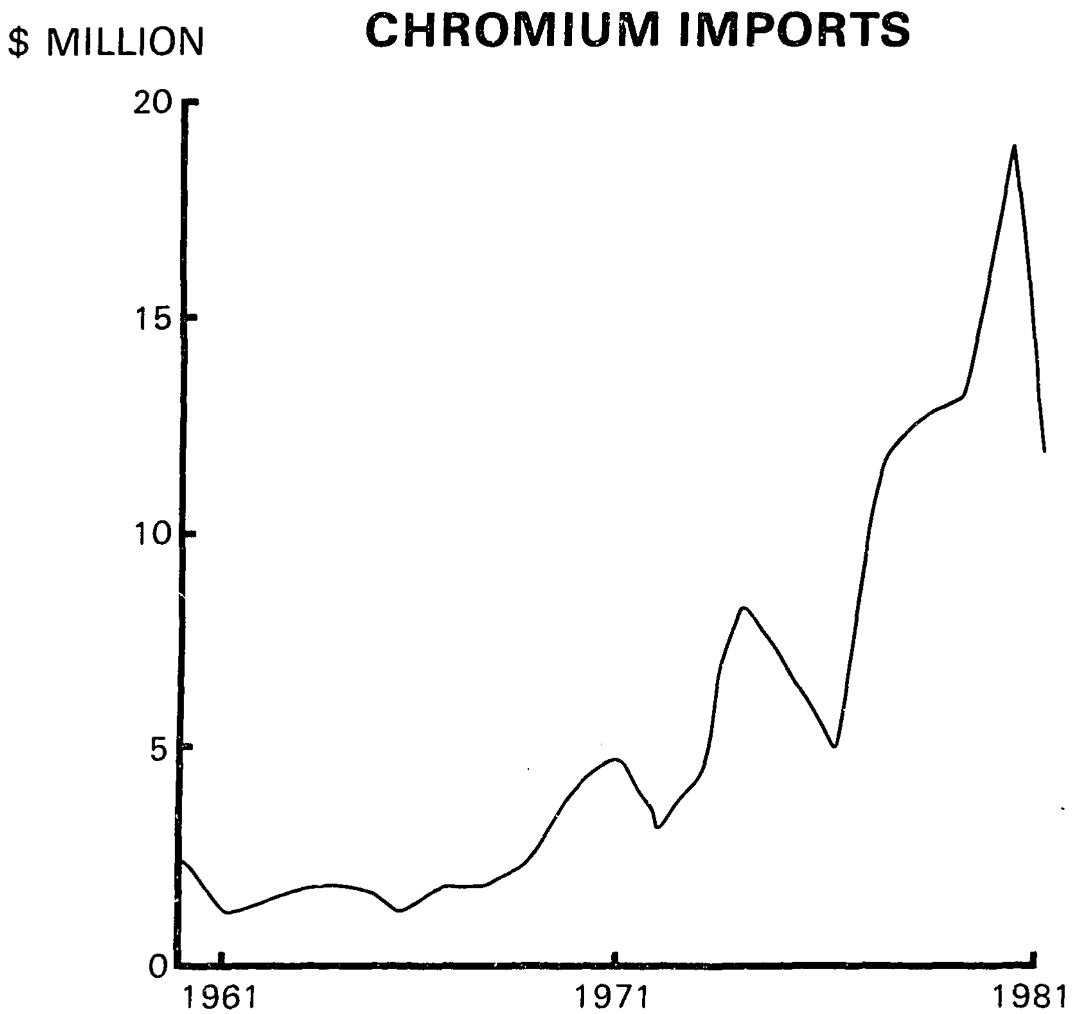

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Fig.5

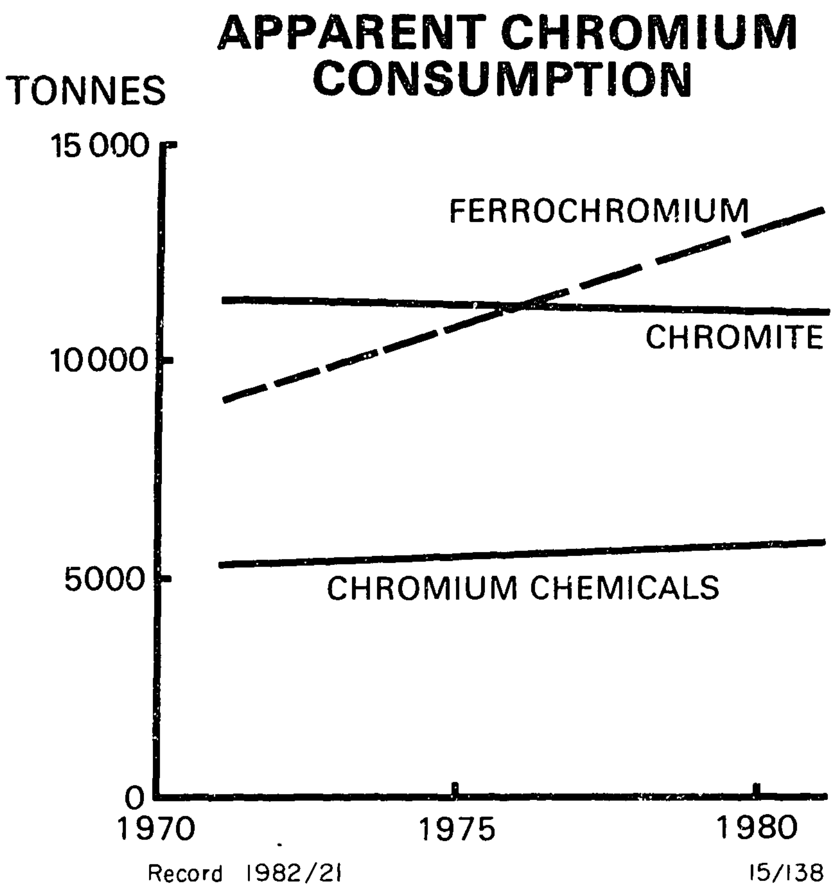
APPARENT CHROMIUM CONSUMPTION
TONNES
15 000
10000
5000
0
FERROCHROMIUM
CHROMITE
CHROMIUM CHEMICALS
1970
1975
1980
Record 1982/21
15/138

Fig.6

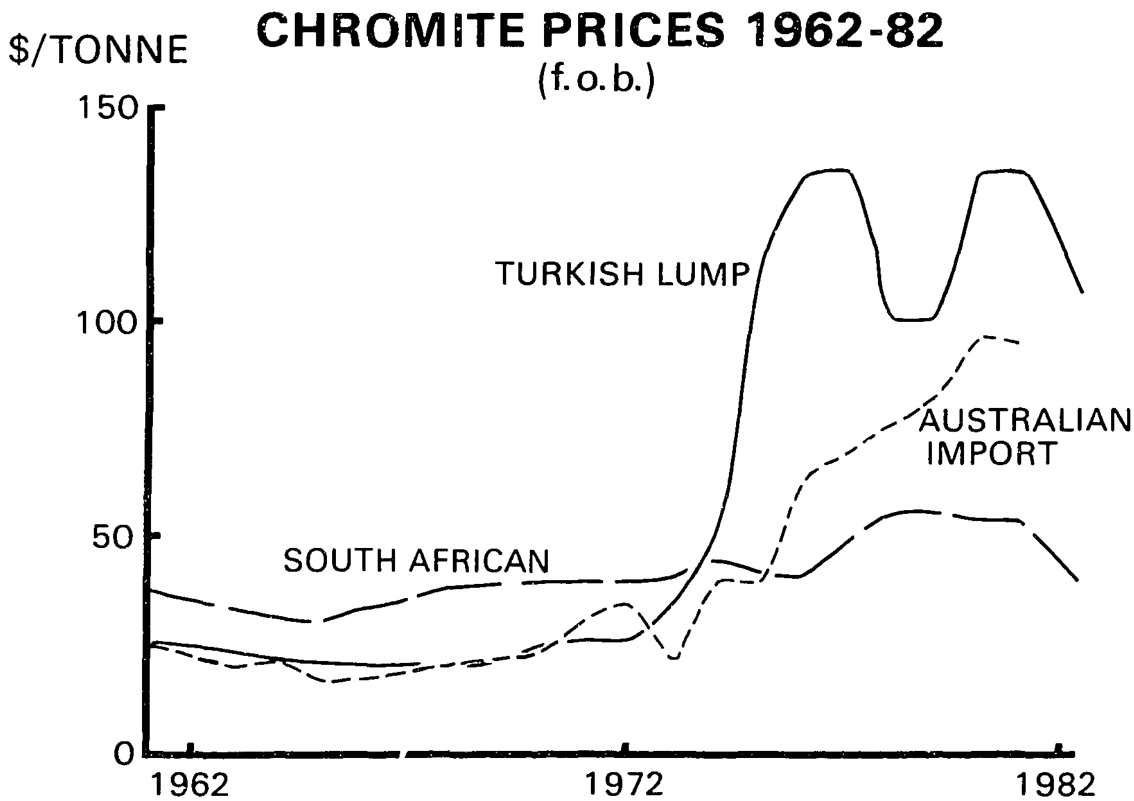

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Fig. 7

CHROMITE PRODUCTION 1980
(000't)

REPUBLIC OF SOUTH AFRICA	3430
USSR	2450
ALBANIA	1200
ZIMBABWE	550
PHILIPPINES	530
TURKEY	450
OTHERS	1220
	9830

Record 1982/21 15/135

Fig.8

FERROCHROMIUM PRODUCTION CAPACITY 1981 (000't)

REPUBLIC OF SOUTH AFRICA	825
WESTERN EUROPE	650
JAPAN	700
ZIMBABWE	300
USA	320
BRAZIL	100
OTHERS	205
	3100

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Fig.9

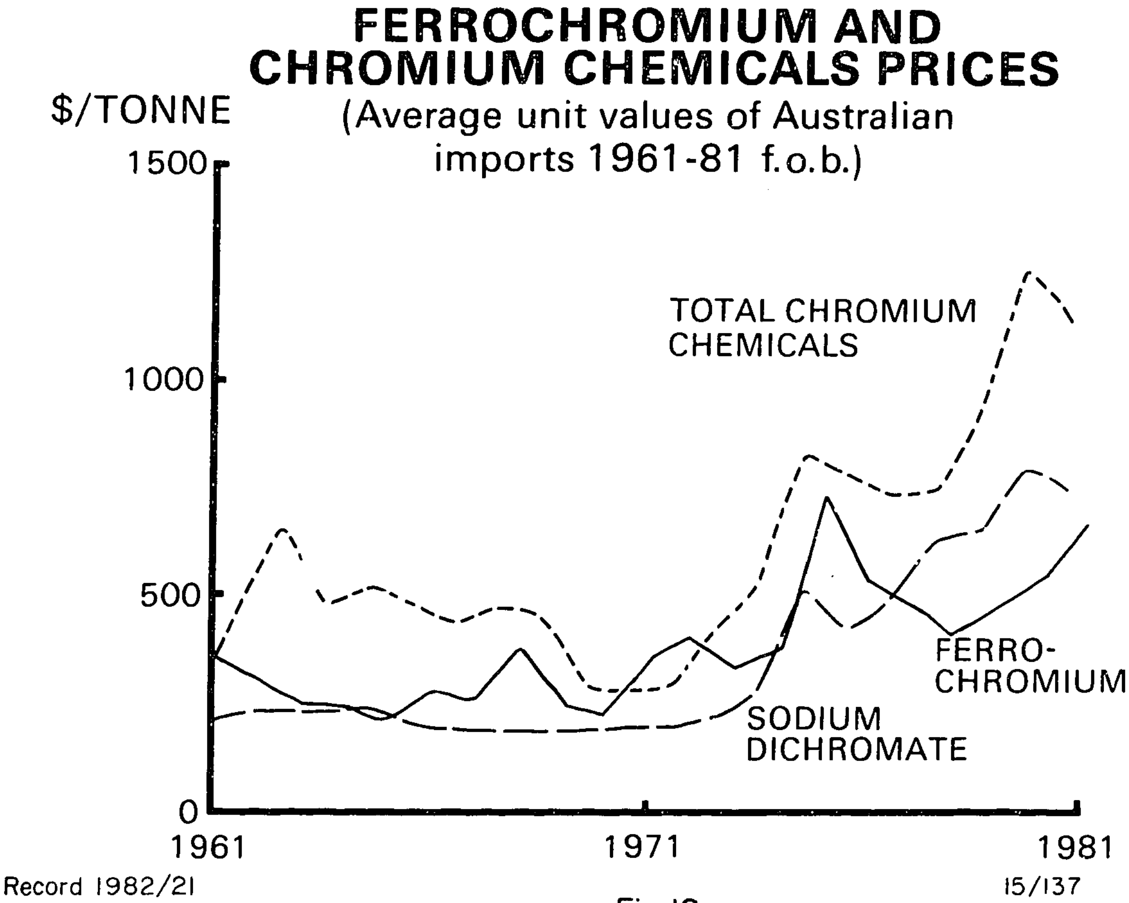
FERROCHROMIUM AND
CHROMIUM CHEMICALS PRICES
$/TONNE
(Average unit values of Australian
imports 1961-81 f.o.b.)
1500
1000
500
0
TOTAL CHROMIUM
CHEMICALS
FERRO-
CHROMIUM
SODIUM
DICHROMATE
1961
1971
1981
Record 1982/21
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Fig. 10