Mining has been the mainstay of the Western Australian economy for longer than most people can remember. Early in the 21st century, the minerals and petroleum industries produce about 60 per cent of all exports and contribute millions of dollars to State revenue. They generate considerable employment and have been directly responsible for the building of towns, ports, airfields and railways. Substantial contributions are also made to community projects and the arts.

The MERIWA Effect tells the story of a unique statutory authority established to benefit the industry and the people of Western Australia. Commencing its life as the Western Australian Mining and Petroleum Research Institute (WAMPRI) in 1981, the Minerals and Energy Research Institute of Western Australia has facilitated an enormous diversity of applied research projects and provided a crucial meeting place for academic research and industry requirements.

Jointly funded by government and industry, MERIWA targets efficiency, safety and sustainability — and authors Brankovich, McIlwraith and Spillman argue that its record provides compelling evidence of the value of partnerships across the sectors.

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Brankovich • McIlwraith • Spillman

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Foreword

Minerals and Energy Research Institute of Western Australia (MERIWA) is to be congratulated for commissioning this commemorative volume reviewing twenty years of history and achievement. The MERIWA story, beginning with the establishment of its predecessor, the Western Australian Minerals and Petroleum Research Institute (WAMPRI), is an important and fascinating one. Through these statutory authorities, successive State governments have supported applied research relevant to the minerals and petroleum industries to provide long-term benefits to the economy and the community.

MERIWA provides an outstanding example of a productive partnership between government and industry. During its twenty years of existence, the research institute has managed over 220 projects with a total cash value of $30 million. In 2002, twenty-six projects were under management worth $6.7 million, with industry contributing 74 per cent of the cost. Most of the research is carried out in Western Australia's universities and the CSIRO.

Furthermore, MERIWA projects have facilitated the growth and progressive development of intellectual and professional capital in this State. Before the advent of WAMPRI, collaboration between industry and academia was almost non-existent, with only pure research meeting Commonwealth guidelines for funding. WAMPRI provided an interface between these two sectors and MERIWA has continued to bind them together. Many academic research careers and reputations have been enhanced nationally and internationally by involvement with MERIWA projects, while the institute's scholarships encourage leading young researchers to stay in Western Australia. The achievements of MERIWA grant recipients enhance the State's international reputation as a centre of excellence for minerals and petroleum research and innovation.

Ultimately, Western Australia seeks to be recognized for both its natural and intellectual resources. As Minister for State Development, therefore, I derive great pleasure in commending this book to all those with an interest in the development of these two precious assets.

Hon. Clive Brown, MLA
Minister for State Development

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Acknowledgements

On 15 December 1998, the MERIWA board approved the preparation of a volume to celebrate the achievements of the institute during its first twenty years, and to record the events leading to its genesis. Building on the original concept of the late John Roberts, the institute's Executive Officer at that time, it was agreed to offer a post-graduate scholarship for a student to research and write MERIWA's history and that of its predecessor, WAMPRI.

This offer was accepted by Jasmina Brankovich, who took a four-month interregnum in her doctoral history studies at the University of Western Australia to interview key people and collate her research. Subsequently, it was decided that Jasmina's manuscript could usefully be augmented by a guide to the technical and intellectual benefits of the institute's projects. At the invitation of the board, Professor Odwyn Jones, Chair of the Minerals Research Advisory Committee, convened an editorial team to review WAMPRI/MERIWA achievements. John McIlwraith accepted the challenge of synthesizing this material and collaborating with Jasmina to amalgamate their contributions. The resulting manuscript was then used by Dr Ken Spillman to compile this publication.

The MERIWA office staff, David Milton, Dr Pam Smith and Gwen Davies, prepared the appendices, illustrations and figures, and generally provided a focus for all involved in this project.

Dr Jenny Gregory, Maureen de la Harpe, Sam Wilson and the production team at University of Western Australia Press are thanked for their professionalism in bringing this publication to fruition.

Dr Colin Branch
Chairman of the Board
Minerals and Energy Research Institute of Western Australia

Introduction

The formation of the Western Australian Mining and Petroleum Research Institute (WAMPRI) in 1981 was an important milestone for the Western Australian mining industry. WAMPRI was a first-of-its-kind research institution in Australia, a statutory authority created to facilitate applied research projects, providing an interface between academic research and mining industry needs. It was the result of the interplay of social, political and economic forces specific to the history of Western Australia. This brief history of the institute, which became the Minerals and Energy Research Institute of Western Australia (MERIWA) in 1987, explains those forces and acknowledges many significant individuals involved in the establishment of the institute and its subsequent operations. The occasion of MERIWA's twenty-first birthday in 2002 is a fitting time to reflect on the institute's achievements over two eventful decades.

MERIWA remains a unique statutory authority in Australia and, through it, the Western Australian Government signals its ambition for this State to be recognized as an international centre of excellence for minerals and petroleum research. The ultimate aim of MERIWA is to provide long-term sustainable benefits for the State's economy and community. It achieves this by supporting research aimed at giving a competitive edge to the minerals and petroleum industries, which generate 60 per cent of the State's export income, and by assisting these industries to achieve safety and environmental standards exceeding community expectations. Continuing and repeated financial backing from minerals and petroleum companies operating in Western Australia indicates industry's strong support for MERIWA and the projects it selects.

The present State Government's 'Innovate WA' policy supports this initiative, and the Premier's Science Council has been appointed to implement this policy. Building on the exceptional record it has established since 1981, MERIWA can immediately further this policy for the minerals and petroleum sectors, under the guidance of the council, by:

- Managing a program to attract internationally recognized researchers, identified by the minerals and petroleum industries, to senior academic positions in Western Australian universities;

- Attracting and retaining superior university graduates in Western Australia by awarding competitive scholarships and fellowships;
- Encouraging the involvement of TAFE colleges in cooperative research projects with universities and industry, with an emphasis on enhanced workforce training, safety awareness and competence;
- Promoting research of long-term benefit to the future needs of the State;
- Supporting the provision of infrastructure and its maintenance in the State's minerals and petroleum centres of excellence to further attract researchers and industry to Western Australia;
- Expanding the initiatives MERIWA already supports.

The present decline of several major minerals and petroleum research institutions overseas has opened a window of opportunity for Western Australia. MERIWA stands ready and able to lead the initiatives that will keep Western Australia at the cutting edge of minerals and petroleum research for the long-term benefit of all.

Dr Colin Branch
February, 2003

ONE

AN INVESTMENT IN KNOWLEDGE

1:1

Mining and the Western Australian economy

In the twenty-first century, it is difficult to imagine a Western Australia without the mineral and petroleum industries. For as long as most people can remember, mining has been the mainstay of the Western Australian economy. It produces about 60 per cent of all exports and contributes hundreds of millions of dollars directly to State revenue through royalties, levies, rentals, taxes and payments to statutory authorities. About a sixth of those in the State's workforce owe their jobs to mining, and the industry has been directly responsible for building towns, ports, airfields and railways. Substantial contributions are also made to community projects and the arts.

Yet mining was slow to find its feet as an industry in Australia's western third, ultimately recognized as one of the world's richest mineral provinces. The first mining company was not formed in Western Australia until 1846, almost two decades after white settlement, and it was spectacularly unsuccessful. The colony's first mineral exports were produced from a lead mine established on the Murchison River in late 1849, and a profitable base metals industry developed during the 1850s. Even during its most profitable period, however – the five years after 1874 – the industry produced only a tiny proportion of Western Australia's total exports.[1]

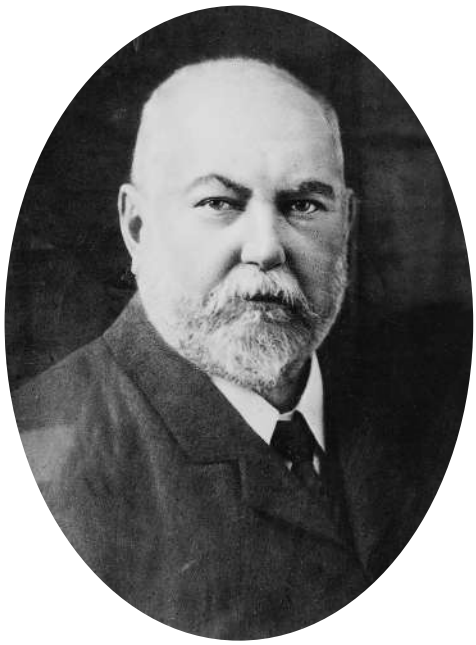
Rewards for the discovery of gold were offered by a private syndicate in 1854 and by the government in 1862, but almost another quarter of a century passed before Charles Hall and John Slattery were successful in striking

payable gold at Hall's Creek. The notification of this discovery sparked Western Australia's first significant gold rush, and the Kimberley Goldfield was officially proclaimed on 19 May 1886. The long-term significance of the Hall's Creek rush was that it established Western Australia as 'a mining colony' attracting overseas and intercolonial investment interest. It also substantially increased the likelihood of new gold discoveries elsewhere in Western Australia through the dispersal of prospectors and, before the end of 1887, new finds had been reported at locations in the Yilgarn and Pilbara districts. The two new goldfields were proclaimed in October 1888, overshadowing news of the discovery of stream tin at Greenbushes near the Blackwood River in the colony's southwest.

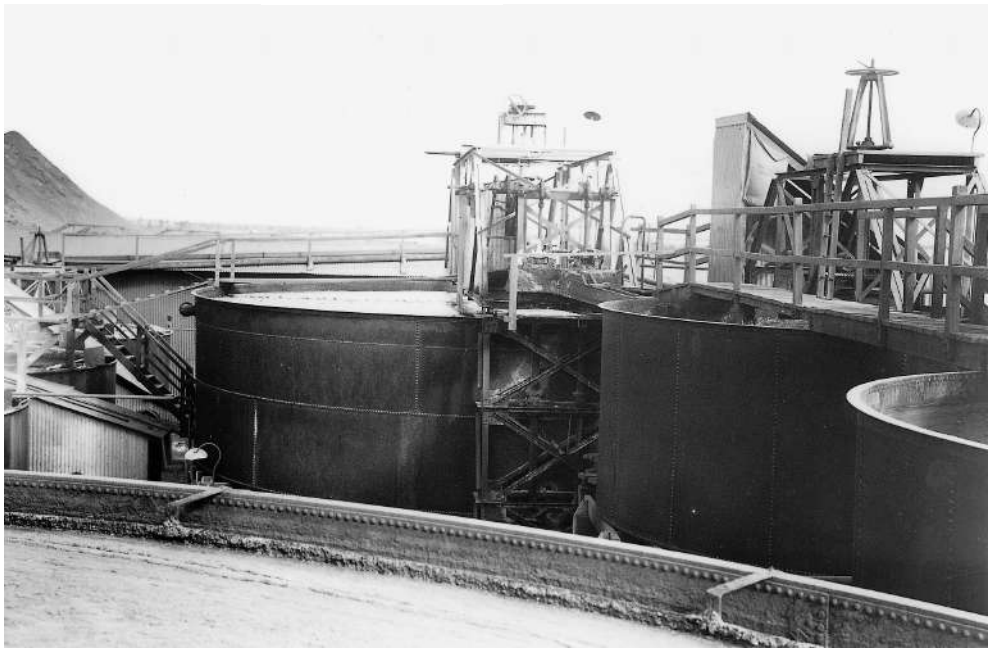
After 1890, discovery accelerated rapidly. The Ashburton Goldfield was proclaimed in December 1890 and, after several promising finds on pastoral runs in the Murchison district, another major goldfield was discovered with focal points at Nannine and Cue. The impact of these discoveries on the newly self-governing colony was dramatic. Enhanced credit-worthiness enabled the government of Sir John Forrest to embrace a comprehensive public works agenda, giving priority to railway construction, telegraph extension and harbour improvements. Supported by British capital, the mining boom continued throughout the 1890s. Bayley and Ford's amazing Coolgardie find, reported at Southern Cross in September 1892, was followed by other discoveries at Dundas in November 1892 and Kalgoorlie in June 1893. The value of gold production surpassed one million pounds for the first time in 1896 and exceeded five million pounds in 1899; in 1900, gold accounted for 81 per cent of the value of all Western Australian exports. Between 1890 and 1895, the colony's population more than doubled, and the following year there were more than 35,000 new arrivals, increasing the total by 36 per cent. By the time of federation in 1901, Western Australia's population was approaching two hundred thousand.

Government recognized the importance of mining and, during the 1890s, Sir John Forrest was responsible for several schemes designed to assist the industry and, if possible, perpetuate the boom. The most famous of these was the goldfields water pipeline, conceived in the middle of the decade as the ultimate solution to the difficulties of living and working in Western Australia's arid interior and finally completed in 1903. Earlier, the government introduced cash bonuses for the sinking of shafts and, in 1898, it approved the erection of state-run batteries, which assisted mining interests by carrying out the custom-milling of ore from small mines. Under Forrest, the first steps were also taken toward the establishment of a system of mining education with the

Right: Sir John Forrest, Premier of Western Australia 1890–1901. The Forrest Government was responsible for a number of schemes designed to assist the mining industry and perpetuate the boom.



Below: Cyanide tanks at Wiluna, 1935. In the 1930s, improvements in metallurgical practice – some the result of research at the School of Mines in Kalgoorlie – contributed to a gold mining revival.



establishment of a School of Mines in November 1902. The government also cleared the way for the exploitation of coal deposits in the colony's southwest. Testing was carried out in the area throughout the early 1890s, and a mine was opened under the supervision of the Public Works Department to procure sufficient quantities of coal for trials in locomotives, furnaces and steamships. By the beginning of 1896, it had been proven that coal seams extended over a considerable area, and the Collie coalmining district was gazetted and thrown open for selection. The government's mine was leased to private interests and, by the turn of the century, coal production was soaring.

By then, however, the mining industry's glory days appeared to have passed. Gold discoveries continued to be made but, in spite of the government's initiatives, production declined after 1903 due to falling yields and metallurgical problems associated with sulphide and telluride ores. This forced the Western Australian mining industry into a period of rationalization, with many smaller mines closing or amalgamating. In 1925, a Royal Commission castigated the gold industry for its neglect of development work and failure to deal with mining, metallurgical and industrial problems, and by 1928 gold production was less than 400,000 fine ounces, one-fifth of the 1903 record. Although coal production increased steadily, quadrupling between 1904 and 1928, coal's value to the State continued to be dwarfed by that of gold – and the importance of mining relative to other industries waned accordingly. Whereas mining accounted for nearly 85 per cent of the value of Western Australia's exports in 1903, it could claim less than 6 per cent of the total in 1928.

There was a temporary revival of gold mining's fortunes in the 1930s following improvements in metallurgical practice, which significantly reduced treatment costs. The 'flotation' method of gold ore treatment resulted from experimental work at the Kalgoorlie School of Mines and effectively increased the reserves of mines by making the extraction of lower grade ores profitable. The industry was further boosted by the 1931 introduction of a Commonwealth Government 'bounty' on the production of gold, and by favourable exchange rates and higher gold prices which combined to improve returns to producers, encouraging investment and accelerating the industry's modernization. Between 1929 and 1934, gold output almost doubled, and many moribund mining centres again became hives of industry. The revival was further stimulated by the provision, by both State and Federal Governments, of sustenance and other forms of assistance to prospectors during the 1930s depression, which contributed to a growth in employment within the mining industry. In a decade of high unemployment, the total number of men engaged in mining increased from 4,284 in 1930 to 16,174 in 1937.

The mini-boom of the 1930s did not, however, return the mining industry to the prominence of the 1890s or establish a foundation for steady growth. The detrimental impact of the 1939–45 war was appreciable. A gold tax introduced by the Federal Government weighed heavily upon the industry, while enlistments and internments brought about shortages of labour and essential materials (such as cyanide). Delays were experienced in obtaining machinery and plant due to changed manufacturing priorities and shipping problems, and the Commonwealth contributed to the difficulties by requisitioning equipment – mainly power units – from operating mines. Many mines were forced to close, and gold output declined from nearly 1.2 million fine ounces in 1939 to less than half a million fine ounces in both 1944 and 1945. In spite of steady coal production at Collie and promising developments in respect of Western Australia's known deposits of 'strategic' minerals – tantalum, for example, was in short supply due to trade restrictions – the number of people engaged in all types of mining decreased, over the duration of the war, from 16,199 to only 6,071.

For the goldmining industry, the immediate postwar period was a time of unforeseen obstacles and frustratingly slow progress. Labour shortages continued, there were delays in the return or replacement of commandeered machinery, new machinery and plant was difficult to obtain, and stores were in short supply owing to shipping problems. Since the beginning of the war, production costs had risen steeply. Wage rates and the price of capital goods had both increased by approximately 30 per cent, while in the same period, 1939–46, the price of gold had remained relatively stable. There was a gradual acceleration in gold output in spite of these hindrances but, by 1947, the Western Australian Government and the Chamber of Mines were sufficiently worried about the future of the gold industry to seek federal aid. The Commonwealth Government agreed to a limited scheme of assistance to large mines able to prove that their survival was in jeopardy. The limitations of this scheme were that it excluded smaller mines, and did not encourage new operations or the expansion of existing enterprises, and overall it did little to revive the industry.

Government’s concerns about goldmining did not, however, extend to other minerals. Reconstruction, industrialization and rearmament had resulted in markets clamouring for a wide range of metals, building materials and fuels, vastly improving prospects for coal, base metals, and a range of other commodities (such as kyanite, antimony and asbestos) which had previously excited little commercial interest. These conditions encouraged diversification to such an extent that, between 1950 and 1970, the transformation of the Western Australian mining industry was almost as striking as its growth.

Although gold production increased after 1950 and remained relatively stable for almost a decade after 1954, there was unprecedented activity in other types of mining and the importance of gold relative to other minerals declined significantly. In the period 1950–60, the value of mineral production almost doubled, increasing form £11.5 million to £22 million, but gold's contribution to the total slipped from 82 per cent to 61 per cent. This trend was even more pronounced in the next ten-year period: by 1966, astonishingly, gold had lost its once unchallenged status as Western Australia's leading mineral by value of production. By 1970, it ranked fifth among the State's minerals and accounted for only 2 per cent of all mining.

Assisted by exploratory work supervised by the Geological Survey of Western Australia and government purchasing contracts, the coal industry had been boosted by wartime demand and responded to the economic environment of the late 1940s with unprecedented growth. The commencement of opencut mining at Collie in 1943 contributed to a run of record annual production figures, stabilizing in the 1950s when greater emphasis was placed on quality and deep mining. There was a resurgence of opencut mining after 1960, however, and between 1963 and 1970 production increased annually: by 1970, production had reached 1,197,734 tons (1,216,898 tonnes), 61 per cent of which came from opencut mines.

An embargo on the export of iron ore, imposed by the Commonwealth Government in 1938 because known reserves were limited, remained operative until 1960, but two important steps had been taken toward the establishment of a significant iron ore industry in the late 1940s. The Western Australian Government's decision to establish a charcoal-fired pig iron plant at Wundowie, implemented during 1947, resulted first in the mining of lateritic ores from hills nearby and, from 1950, the development of higher-grade iron deposits at Koolyanobbing. At the same time, private enterprise investigated long-recognized iron ore deposits on Cockatoo Island, in Yampi Sound off the Kimberley coast. Feasibility studies, carried out in 1944, resulted in the establishment of the necessary mining plant between 1947 and 1950 and a first shipment of ore to Newcastle, New South Wales, in July 1951. During the next decade, production from the Yampi Sound deposits increased a hundredfold and there were several major discoveries of high-grade ore – mainly in the Pilbara region – which ensured substantial Western Australian participation in the international iron ore trade after 1960. To facilitate the large-scale development of the iron ore export industry, the State Government entered into various public and formal agreements with international mining companies that exchanged long-term security of tenure for firm commitments to exploit

Drilling on the crest of an iron ore lode on Cockatoo Island, off the Kimberley coast, in 1953. Over the next fifteen years, the economic impact of the development of Western Australia's iron ore reserves was profound.

known mineral resources. Other terms specified timetables and infrastructure responsibilities, and defined royalties and processing arrangements.

The economic impact of the development of the State's iron ore resources was profound. In 1966, when mines at Koolanooka, Mt Goldsworthy and Mt Tom Price commenced production, the value of iron ore exports from Western Australia reached $18 million. The value of pig iron output in that year being almost $3 million, iron surpassed gold ($19.7 million) as the State's most valuable mineral. Production increased further in subsequent years, and iron ore wealth propelled the State to an important milestone: in 1968–69, Western Australia was able to discontinue its financial dependence on the Commonwealth Grants Commission.

Lasting economic benefits also ensued from the establishment of an oil and gas industry following the discovery of oil at Rough Range, near Exmouth Gulf, in November 1953. There was a long history of oil exploration in Western Australia, and the existence of oil had been suspected before 1920 and confirmed in 1921. The Rough Range discovery, however, sparked more intense exploration activity which declined only after 1956 because of the failure of the initial strike to prove economic, and a lack of further discoveries.

The opening up of a commercial oilfield in Queensland during 1961 revived Western Australian hopes and the resulting upsurge in exploration led to the discovery of payable oil at Barrow Island, off the northwest coast, in 1964. Production commenced in early 1967 and exceeded 4.5 million barrels of crude oil, valued at nearly $15 million, in the first year. Closer to Perth, a gas field was discovered at Dongara, and this was brought into production before the end of 1971. By then, offshore drilling, which had commenced during 1961, had identified vast gas fields on the northwest shelf, ensuring significant production beyond the end of the century.

Mineral sands also became a major contributor to Western Australian export earnings and royalty revenue during the 1960s. This sector of the mining industry had its beginnings in 1949, when beach sand from the shores of Cheyne Bay on the south coast were exported for testing. The Cheyne Bay project was short-lived, however, and the first production of ilmenite on a commercial scale was at Koombana Bay, near Bunbury, in 1956. Operations commenced at Capel in 1957 and at Wonnerup and Yoganup during 1958–59. By 1960, overseas shipments of ilmenite were valued at almost half a million pounds, and other heavy minerals were growing in significance. The value of ilmenite, rutile, leucoxene, monazite and zircon exports escalated steadily during the next decade and, by 1970, when large deposits of heavy mineral sands were identified at Eneabba, exceeded $9 million.

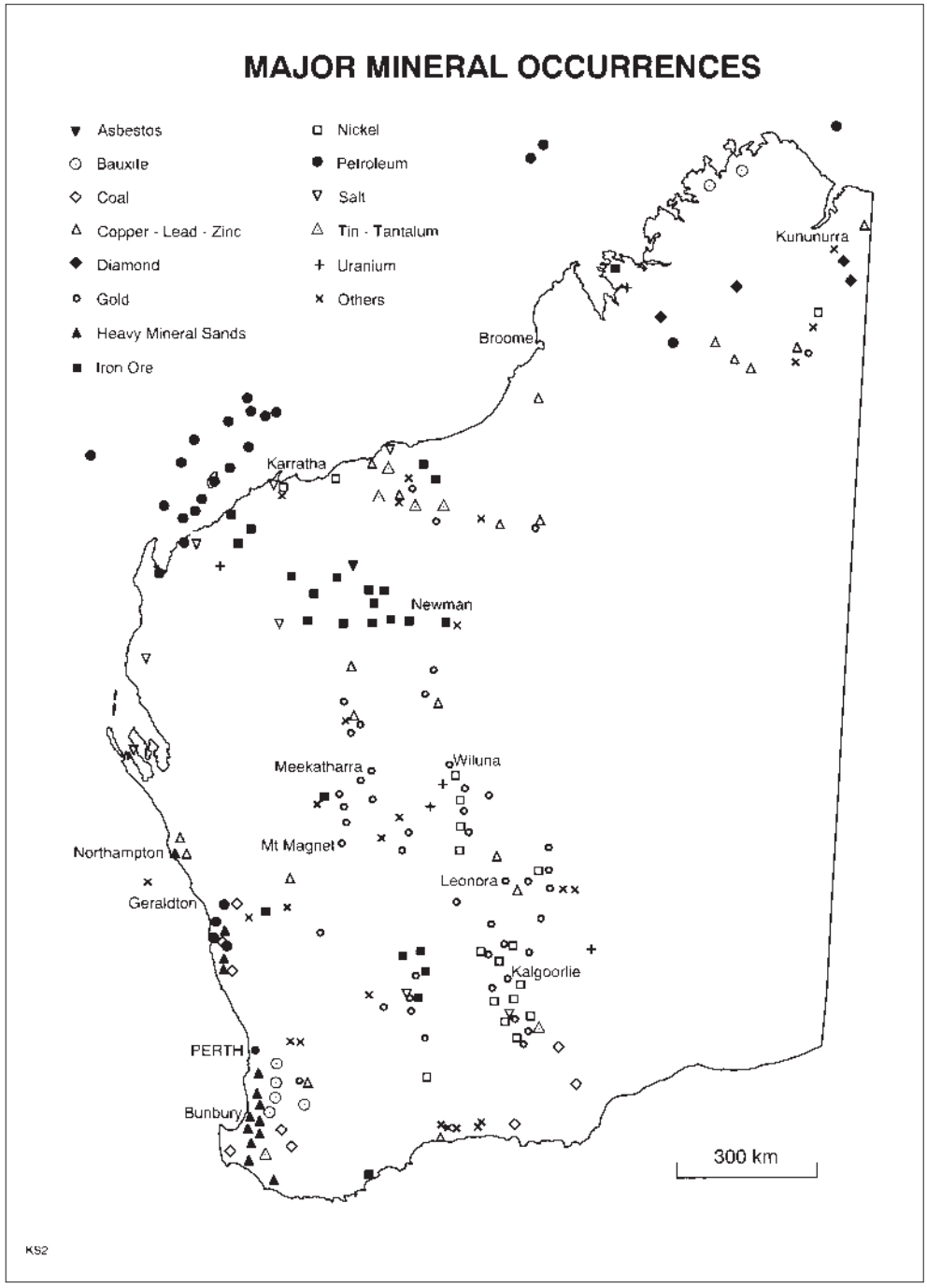
The existence of bauxite in Western Australia had been recognized just after the turn of the century and, when mining began near Jarrahdale in 1960, it achieved rapid success. Under the terms of a 1961 agreement between the State Government and Western Aluminium NL, an alumina refinery was established at Kwinana, south of Perth. The first Jarrahdale ore was railed to the refinery in July 1963, and in 1964, the first full year of production, 370,784 tons (376,716 tonnes) of alumina were recovered. By 1969, production had more than doubled and plans had been completed for a second refinery at Pinjarra; in that year, the value of alumina production was almost $50 million, second only to iron ore.

Of all the developments in Western Australian mining during the 1960s, none generated more public excitement and exploratory activity than the discovery of high-grade nickel sulphide ore at Kambalda, south of Kalgoorlie, in January 1966. The search for nickel had begun on a small scale in the middle of the 1950s but, until Western Mining Corporation initiated an examination of the Lake Lefroy area on the eastern goldfields in late 1964, exploration had yielded little of commercial promise. The Kambalda discovery sparked a prospecting and stock market boom of gigantic proportions, reviving memories

of the 1890s gold rushes. Estimated expenditure on nickel exploration climbed from $2.6 million in 1966 to a peak of $46.5 million in 1970, and resulted in a string of discoveries stretching from Norseman to Wiluna. Production from Kambalda commenced in 1967 and, within three years, the total value of the State's nickel output was $87.4 million, with a refinery having been commissioned at Kwinana.

These and other mining developments carried the value of mineral production to previously inconceivable heights. Between 1961 and 1965, the total value increased by 20 per cent to £26.9 million; by 1970, production was worth $579.4 million, an increase of 662 per cent since the introduction of decimal currency in 1966. Although this extraordinary rate of growth was not sustained in the next five-year period, mineral production in 1975 was valued at more than $1,240 million. Not surprisingly, the structure of the State's economy changed markedly. Whereas in 1963–64 mining and quarrying accounted for only 6.2 per cent of all recorded production in Western Australia, and for 11.6 per cent of primary production, the figures for 1974–75 were 30.9 per cent and 48.8 per cent respectively. There were numerous multiplier effects associated with the mining industry's expansion and diversification, and the most obvious of these were employment growth and population influx. Industrial development accelerated and the face of the Perth metropolitan area was irrevocably changed. Between 1961 and 1966, Western Australia's population increased by 15.1 per cent to 848,100, which compared with a national increase of 9.9 per cent. The rate of national population growth was unchanged in the next five years, but the Western Australian population increased by 21.5 per cent to exceed one million. Mining's contribution to the Western Australian economy also included large royalty payments to the State by producers. By 1975, royalty receipts exceeded $42.8 million, with the largest receipts from iron ore (90.6 per cent), nickel (3.5 per cent), oil and gas (3.5 per cent) and alumina (1.4 per cent). Promisingly, too, there were signs of a resurgence for goldmining, with higher gold prices after 1974 reversing the long slide and stimulating a new gold boom after 1980. Another signal development in the mining industry during the late 1970s was the discovery of rich diamond deposits in the Kimberley region, which led to a government-private enterprise development agreement in 1981.

The magnitude of the 1960s mineral boom had given Western Australian governments an acute awareness of mining's historical role and continuing importance. The industry had always been a major catalyst for growth in Western Australia while, conversely, periods of economic stagnation have been associated with the industry's troughs. Just as John Forrest had done in



Major mineral occurrences in Western Australia

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the 1890s, the coalition government led by Sir Charles Court in the 1970s established a record of supporting exploration and mining to ensure 'the full and responsible development of our mineral and energy resources, and to add value to whatever extent was possible'.[2] Technological advances had made more affordable the extraction of the immense riches available in Western Australia, providing new impetus to the industry and, in turn, leading to unprecedented interest in development of a Western Australian minerals and petroleum research culture.

In this environment, 'value-adding' became a catch-cry, and processing opportunities received new focus. Peter Jones, a minister in the Court Government, later remembered 'ongoing discussions with, and within, industry bodies regarding a coordinated approach to research associated with adding value to WA's mineral wealth'.[3] The beneficiation of iron ore and the separation of mineral sands were the two main types of value-added processing being undertaken, but other possibilities were handicapped by the cost, availability and quality of energy sources. An example, recalled by Sir Charles Court, was that 'we had no potential, with our existing energy resources, to proceed from alumina to aluminium on a competitive basis.'[4]

As the 1970s progressed, several sectors of the local resources industry were adversely affected by sharp falls in world prices, and the downturn prompted both government and industry to examine ways of securing a profitable future. The difficulties faced by mining companies were exemplified by the experience of Hamersley Iron in launching a pellet plant, producing marble-sized fragments to make the operation of blast furnaces more efficient. Technical and economic difficulties beset this initiative, and the problems were compounded further by energy costs – specifically, the high cost of oil which powered the plant.[5] Such experiences served to make the prospect of cheaper energy sourced from the Western Australia's remote northwest region, as well as the possibility of value-adding through improved extraction and metallurgical activity, more attractive. In 1979, the establishment of the North West Shelf Natural Gas Project signalled that the State Government was prepared to legislate to provide the required volumes of clean, affordable energy for subsequent value-added processing. Cooperation between the government and industry 'opened up an era of government-private enterprise partnership agreements which gave a new character to the mining development and, indeed, made it possible'.[6] Clearly, the time was ripe for a joint approach to research and development to ensure that future opportunities for mining and economic development were not wasted.

1:2

Recognizing a need: first proposals for a minerals and petroleum research institute

The 'opening up' of the relationship between the government and industry during the 1970s was given a new dimension early in the following decade with the establishment of a new statutory authority, the Western Australian Mining and Petroleum Research Institute (WAMPRI). Founded to coordinate research projects in minerals and petroleum fields, and to facilitate productive contacts between industry sponsors and researchers, WAMPRI was a symbol of government's ongoing commitment to exploration, mining and processing. It was an investment in the future.

The growth of the mining industry had exposed its relative dependence on research pursued outside the State, much of which was inappropriate (or, of limited relevance) to Western Australia. The Charles Court Government was encouraged by the industry to take a leading role in promoting local research and development, and particularly recognized the need for a 'coordinated initiative'.[7] At the time, a relatively small amount of research was being carried out at the State's tertiary institutions; geological mapping and the production of mining bulletins were tasks performed most ably by the Geological Survey, a branch of the Department of Mines which had undergone remarkable growth in the 1960s despite a shortage of qualified geologists.[8] This dearth of geologists was itself an example of the substantial challenges for the State Government consequent to rapid economic and industrial development. Emeritus Professor John de Laeter, who was then Dean of Applied Science at the Western

Australian Institute of Technology (WAIT, later Curtin University), recalled:

> I was always very conscious of the demands [made by the industry], because the Geological Survey couldn't really cope. They were a government organization, they weren't really set up for research [but] … for mapping…[9]

In 1978, some WAIT staff began contemplating closer contact between academia and the mining industry by persuading companies to fund research and development in geology and other relevant areas – particularly when the industry itself would be the major beneficiary of the research. The mineral boom of the 1960s had created a situation in which those in the mining industry frequently encountered problems requiring urgent, almost pre-emptive, treatment. As de Laeter explained:

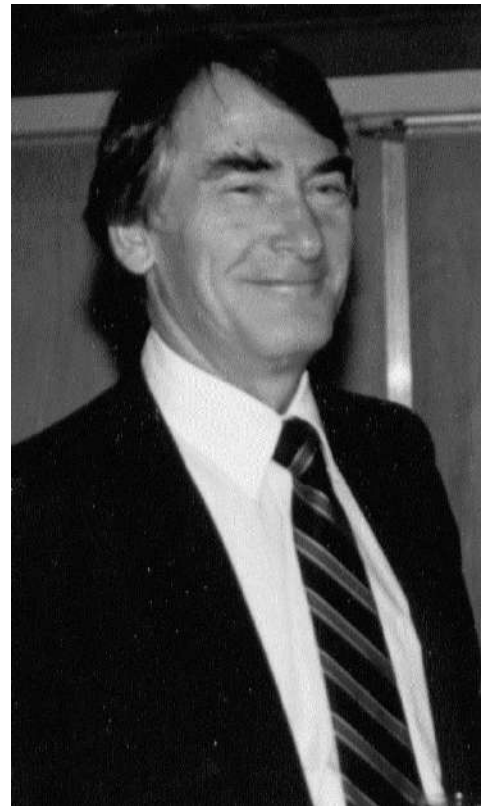
> Almost every time you did anything, there was a research problem that arose from it, because you were breaking new ground. If you started mining different minerals, for example, or different mine sites, there were invariably problems that you encountered… In the old days, when we used to work as prospectors, if you came across chunks of gold, you had a mine. By this stage… you had to do much more sophisticated things. The climate was ripe for applied research.[10]

One apparent barrier to an increase in minerals research and development projects was the State's lack of appropriate research facilities, reflecting an underdeveloped research culture despite the existence of the tertiary institutions. Research in geology carried out at The University of Western Australia, which had a respected Department of Geology, was considered by de Laeter to be 'pure research'; in general, it fitted criteria set by such organizations as the Australian Research Council (ARC) rather than promoting research of practical and immediate benefit to the State's mining industry. Murdoch University had teaching programs in mineral science and mineral processing, but the only mining school in the State was the Western Australian School of Mines (WASM) at Kalgoorlie, administered by WAIT. As a second-tier tertiary institution in the 1970s, however, WAIT was not sufficiently funded to be able to address the need for a practical research base, and was later described by de Laeter as 'a poor institution [in which you]… really had to scramble for what you could get and when you could get it'.[11] At that time, the only major Australian research organizations facilitating an interface between researchers and industry were the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Australian Minerals Industry Research Association (AMIRA), based in Melbourne, and the Julius Kruschnitt Centre at the University of Queensland.

As Dean of Applied Sciences at the Western Australian Institute of Technology, John de Laeter played a key role in cultivating a productive relationship between tertiary institutions, industry and government.

In 1978, driven partly by a desire to improve research facilities at WAIT, de Laeter travelled overseas to investigate ways of establishing closer ties with industry, particularly in the research and development area.[12] It was obvious to the staff at WAIT that the booming mining industry was the 'logical place' to seek funding for applied research which it could not undertake itself. As de Laeter recalled, 'The industry did not have the time to do it [research], they probably didn't have the manpower to do it… and they certainly didn't have the facilities to do it.'[13] There were constraints on research for WAIT, too, which had a ceiling on academic awards, a Masters degree being the highest qualification it could confer. Quite clearly, bringing the major players in the mining industry together – the State Government and the private sector – would benefit tertiary institutions while also having a long-term impact on the development of research, particularly applied research, at state, national, and even international levels.

The Department of Geology at WAIT's School of Mining and Mineral Technology, was capably led, in the mid-to-late 1970s, by Dr Peter Power. Emeritus Professor Odwyn Jones, who was Dean of the School during that



Peter Power, whose proposal to form a new research institute led to the birth of MERIWA'S predecessor, WAMPRI.

period, later remembered that Power 'was concerned about the fact that there was no mechanism in Western Australia whereby the government could provide some seed funding for fundamental and basic research relating to the mining and petroleum areas'.[14] Power was interested in obtaining the funds necessary to support 'research concepts that needed to be developed to the point where perhaps other sponsors could be brought in'. For example, a particular concern to the iron ore industry related to slope stability in open cut mines where the banded iron formation had been severely folded – a problem which seemed to cry out for a broad-based industry solution. Proposing the formation of a new research institute, Power aimed to bring the State's major research institutions closer together and form a 'consolidated research base', combining the intellectual and funding power of researchers in all the State's tertiary institutions. Insularity of academic institutions was often a barrier to the cross-fertilization of knowledge required by the growing and increasingly sophisticated industry.[15] The pressure of teaching and research on academic staff was also perceived as an impediment to WAIT's objective of bringing industry and academia closer together. If this problem could be overcome,

applied research projects could be housed under the same roof as 'pure' academic research, encouraging cross-fertilization and creating a different research culture with lasting economic benefits.

As Dean of Applied Science at WAIT, de Laeter was strongly supportive of Power's initial proposal detailing the formation of the institute. Power had worked extensively in the petroleum industry, and had developed a profound understanding of the particular difficulties faced in the industry. Odwyn Jones believed that Power's industry experience had also given him the commitment and passion necessary to develop an interactive and collaborative relationship between academia and industry, with an emphasis on research of direct and immediate benefit to industry.[16] According to de Laeter, Power deserved 'ninety-five per cent of the credit' for devising the concept of a research institute.[17] It was, however, Power's ability to harness support from within his own academic environment that proved crucial in the realization of his idea.

Power's proposal carried several specifications regarding the nature of the proposed institute. To qualify for a financial grant, research would be expected to be of immediate benefit to Western Australia's mining industry. The research institute would be a cooperative venture promoting learning and the dissemination of knowledge, a process seen as essential to the broader industrial progress of the State. It would be a statutory authority set up by the State's legislature, with a brief to facilitate contact between the researchers in state-financed and private research institutions, on the one hand, and industry, on the other. The concept involved, de Laeter explained, the establishment of

> a fund of money, which could be used to promulgate research that industry wanted to have done. That meant that industry had to support the idea of the research being done, and they had to be prepared to put in about fifty per cent of the money that it would cost.[18]

As Odwyn Jones reflected later, 'we were not just trying to provide funds for WAIT, because at that time there was a limit to WAIT's capacity to respond to the requirements of the industry in the area of applied research and development.'[19] The goal was to involve all research institutions in Western Australia under the banner of the institute, which would ensure that research results were accessible to all and published in a variety of publication formats. Accessibility was important because this, it was believed, would translate into extensive utilization of research findings by companies other than those sponsoring the research. In other words, competition between the industrial giants would be balanced with cooperation and a sharing of research results, serving the broader interests of the Western Australian community.

Peter Power had suggested as early as December 1977 that the WAIT School of Mining and Mineral Technology should deliberately develop a greater research role as part of an effort to become 'a centre of excellence'.[20] Convinced that this was 'vitally important for the future wellbeing of our mining and petroleum industries',[21] the School's board set up a working party, with Power as convenor, to investigate possible ways in which WAIT could promote applied research in the minerals area. The working party extended an invitation to other sectors of WAIT and other research organizations to participate in the planning stages for the establishment of an institute, and develop strategies to market the idea outside the confines of WAIT. Another working party initiative, approved by WAIT, was to bring Professor Des Pretorius of the University of Witwatersrand, South Africa, to Western Australia to help formulate and explain the idea to representatives of government and industry.[22] Pretorius' reputation for running the Economic Geology Research Unit at his home university since 1959, and his support for Power's concept, convinced WAIT's administration of its potential.

It was important to have the support of people like Pretorius in the late 1970s because of the rapid expansion of Western Australia's mining industry and consequent debate over the whole issue of mining-related education in the State. As Emeritus Professor Odwyn Jones recounted, the government-sponsored Partridge Committee's report, published in January 1976, recommended that WAIT's Kalgoorlie-based mining-related courses be relocated to its main campus in the Perth suburb of Bentley. This proposal generated a fractious debate both within WAIT and the industry, which continued for more than two years. It concluded with the Western Australian School of Mines (WASM) being allowed to remain in Kalgoorlie as part of a 'federation of institutions' that included the local TAFE college. In the late 1970s and early 1980s, the mining industry, through the efforts of the Chamber of Mines, individual mining companies and such people as Sir Laurence Brodie-Hall, provided generous support for WASM in the form of sponsorship of teaching posts, student scholarships, research funds and funds for residential accommodation. Those companies in the vanguard included Western Mining Corporation, Normandy Mining, Homestake, Alcoa and Hamersley Iron. It was apparent, however, that the establishment of a minerals research institute would stimulate the work of the school, as well as that of other research institutions, and lead to its closer ties with the industry.

For all of these reasons, WAIT's administration threw its support behind Power's proposal to establish a minerals and petroleum research institute. Power had already harnessed support from other individuals. On 4 July 1978,

his efforts culminated in a meeting of representatives of WAIT, the Western Australian School of Mines, The University of Western Australia (UWA), Murdoch University, the Geological Survey of Western Australia, the Government Chemical Laboratories and the CSIRO to discuss the institute's possible formation. The participants 'agreed in principle that an approach be made to [State] Government to set up such a coordinating body'. Several days later, a rewritten draft proposal was presented by Power and Pretorius, together with Professors Peter Harris (UWA) and Jim Parker (Murdoch University), to the Minister for Industrial Development, Mines, and Fuel and Energy, Andrew Mensaros, asking the government to support the initiative. In the proposal, Power suggested that 'such an action could be a tribute by the State to an industry historically associated with it and in no small part responsible for its growth, on the occasion of the State sesquicentenary.'[23]

The final draft of the proposal was sent to Minister Mensaros in September 1978, while Power continued to harvest support from the industry and research institutions. Sir Laurence Brodie-Hall appears to have been an influential figure in this lobbying, partly because of his position in the Chamber of Mines and partly because of a personal and professional relationship with the Minister.[24] Although Power resigned from WAIT to take up an overseas post late in 1978, the momentum was maintained. The Government was immediately sympathetic to the proposal for a 'coordinated approach to selective research', but pointed to the need for 'a more detailed assessment and consideration to be given'. It was considered essential to 'reach a clear understanding with industry, and with the various academic and research institutions, [about] how the concept would actually operate'.[25] A useful model was the Solar Energy Research Institute of Western Australia (SERIWA), established a year earlier and, like the envisaged minerals institute, involving project partnerships between industry and government.

In 1979, the State Government circularized all its departments asking for suggestions and proposals 'considered suitable for new initiatives for the Government'.[26] The Geological Survey of Western Australia, led by Joe Lord, promoted, among other proposals, Power's idea to establish a research institute modelled on the successful SERIWA. Meanwhile, Professor John de Laeter had taken over the coordination of advocacy activities, including political lobbying, following Power's departure. He remembered: 'I was involved with it simply because I was part of WAIT. I was responsible for the area [as Dean of Applied Science and]… I had some – not really political connections – but history of pushing government on all sorts of things.'[27] De Laeter's political savvy bore fruit on 2 November 1979, when Premier Charles Court announced in his

keynote address at the annual conference of the Western Australian School of Mines that a minerals research institute should be created. Particular enthusiasm and support for the institute was reportedly expressed by the Minister Mensaros and the Under Secretary for Mines, Bernie Rogers. Mensaros' successor observed: 'The announcement at the School of Mines Annual Conference was the next "stage" of considerations which had been progressing for several years.'[28]

Premier Charles Court was said to have given his support for an institute because 'he could see no logic in WA's continuing to send materials to other states and overseas for metallurgical testing'. It was clear, he said, that, 'The era of chance discovery and convenient surface outcropping of great mineral deposits was ending. New technology must be developed to break through the barriers of existing knowledge.'[29] Court's commitment to the venture was confirmed in a press release of February 1980, when he promised funding of $500,000 if his Government was returned to office at the forthcoming election – on condition that the Western Australian industry matched this support on at least a dollar-for-dollar basis. This pledge was subsequently included in the Liberal Party's pre-election policy document.[30] The principles behind Power's idea – first and foremost, the drive to facilitate a research relationship between the industry and researchers – had now been embraced by government, and the reality of a research institute was merely a matter of time.

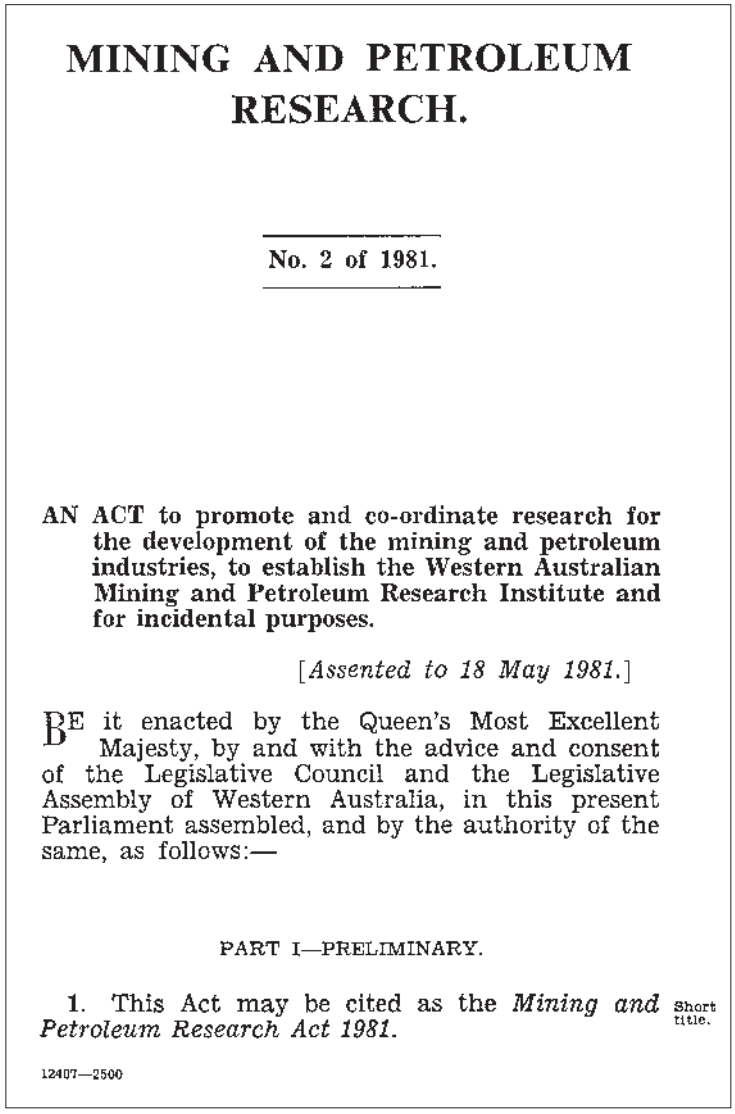
1:3

Wheels turn: the birth of WAMPRI

The Charles Court Liberal Government was returned to office in May 1980, but twelve months elapsed before legislation drafted to establish the new institute came before the Western Australian Parliament. In August 1980, members of the Legislative Assembly were advised by the new Minister for Mines, Peter Jones, that that the initial steps had been taken in the preparation of a suitable bill,[31] and a further update was given by Court during question time several months later. The bill, the Premier reported in November, 'was prepared almost to the stage of introduction', but he added that 'it was one of those which could be called "one of life's unclaimed treasures".' Indicating that the Government had found itself facing an overpowering work schedule, Sir Charles said that 'a line had to be drawn as to what bills would be introduced this session and that bill fell below the line.'[32]

Behind the scenes, however, the wheels of government were turning. Upon its return to office, the government had immediately instructed Joe Lord, Director of the Geological Survey, to prepare the bill for presentation to the State Parliament and carry out an inventory of available or interested research expertise and facilities available in Western Australia.[33] Other states were visited, and discussions were held with such related organizations as the Australian Minerals Research Industry Association (AMIRA) and the various government departments responsible for the mining industry. This consultation process produced the anticipated confirmation that the planned Western

Mining and Petroleum Research Act 1981, which established WAMPRI.
For the first time, a mechanism had been put into place to provide Western Australia's expanding mining and petroleum industries with research and development support funded jointly by government and industry.



MINING AND PETROLEUM RESEARCH.

No. 2 of 1981.

AN ACT to promote and co-ordinate research for the development of the mining and petroleum industries, to establish the Western Australian Mining and Petroleum Research Institute and for incidental purposes.

[*Assented to 18 May 1981.*]

BE it enacted by the Queen's Most Excellent Majesty, by and with the advice and consent of the Legislative Council and the Legislative Assembly of Western Australia, in this present Parliament assembled, and by the authority of the same, as follows:—

PART I—PRELIMINARY.

1. This Act may be cited as the *Mining and Petroleum Research Act 1981*. Short title.

12407—2500

Australian institute would effectively pioneer the concept of a 'research-industry' interface specific to the needs of regional industries.[34] Preparations needed to be thorough. As Peter Jones later reflected:

> It was especially important to have the involvement and confidence of the industry, having regard to the finance required, as well as ensuring the priorities of the work to be undertaken … A key element was to consider the roles and responsibilities of the various academic and research institutions.[35]

The Premier, Sir Charles Court, eventually introduced the bill into the State Parliament on 19 March 1981. In moving the bill's second reading six days later, Minister for Mines Peter Jones said that the reasons for the establishment of the institute were two-fold. First, research was required into methods of locating and testing concealed deposits of minerals and energy resources. Second, the sophisticated research equipment available in the State would be fully utilized as a consequence of an increase of research funds and projects.[36] The increase in project funding would create employment for postgraduate researchers, as well as technicians and administrative personnel, preventing 'the necessity of many of them having to move away from the State for suitable employment'.[37] Importantly, Jones emphasized, 'the most appealing benefit to the research workers will be having an institute which will coordinate research activity without interfering with their own autonomy, or *modus operandi*.'[38]

The bill received bipartisan support in the Western Australian Parliament, and the new Act received the Governor's assent in June 1981. *Mining and Petroleum Research Act 1981* established the Western Australian Mining and Petroleum Research Institute – the original name being used by Power in his early proposals – as a body corporate with the 'powers, functions, authorities and duties conferred or imposed by or under this Act'. The functions of the institute, or WAMPRI as it became known, were:

- to encourage the development of the mining and petroleum industries within Western Australia by fostering and promoting all aspects of mining and petroleum research;
- to undertake research in its own right or in cooperation with other researchers, and to evaluate projects so undertaken;
- to coordinate where appropriate research projects in Western Australia;
- to receive funds from Government, industry, sponsors and any other sources, and allocate such funds to approved research projects undertaken by outside organizations;
- to evaluate all mineral research undertaken in the State; and
- to promote a public awareness of matters relating to minerals research.[39]

The structure of WAMPRI resembled that of other statutory authorities. Policy and management were the responsibilities of a board of three directors, one of whom would be the chair, appointed by the Governor on the nomination of the Minister for Mines. Investigative work and assessments of the merit and appropriateness of research proposals, however, were to be carried out by an advisory committee. During the passage of the Mining and Petroleum Research Bill, members on both sides of the Legislative Assembly agreed that 'the industry

itself is in the best position to know… what is going on and, secondly, to advise on the information we should be gathering from elsewhere, and the way in which it should be related to this State.'[40] The task of the Mining and Petroleum Advisory Committee, therefore, was to provide specific academic and research expertise to the institute and make recommendations on funding. Effectively a conduit for all relevant industry interests to be represented on WAMPRI, the committee's membership would include representatives from the Confederation of Western Australian Industry, the Chamber of Mines, the Australian Petroleum, Production and Exploration Association (APPEA), the two universities and WAIT, CSIRO, and the State Department of Resources Development. The constitution of the advisory committee therefore ensured that the evaluative processes employed by WAMPRI, which was obliged by the Act to 'pay due regard' to the advice of the committee, were as far removed from government influence as possible. It married instead the imperatives of industry with the interests and capabilities of the scientific community.

To ensure the efficiency of WAMPRI, the Department of Mines agreed to provide the bulk of the administrative and other support required, especially in the institute's formative period. This reflected government's intention that 'as high a percentage as possible of the institute's funds should be directed towards research and development and not administrative and overhead expenses.'[41] Support for individual research projects would, in the first instance, be obtained from industry sources, with matching funds provided by the government. This would ensure that finite human and financial resources were put to good use, with WAMPRI functioning at minimal cost to Western Australian taxpayers.

In his 1978 proposal for the establishment of a mining and petroleum research institute, Peter Power had written: 'It can be confidently predicted that the mining and petroleum industries will continue to be the dominant element in Western Australia's growth.' At the same time, Power had pointed out that, of the five major metal-producing countries in the world, Australia had the lowest regional value of average metal production per square kilometre, suggesting that 'a great number of commercial deposits remained undiscovered'. It had been apparent to Power that in order 'to turn the potential to account', many complex problems in exploration and the exploitation and processing of mineral deposits and petroleum reserves needed to be solved.[42] Three years later, with the establishment of WAMPRI, there was reason to believe that the means had been established to tackle those problems as they arose. For the first time, a mechanism was in place to provide Western Australia's expanding and multifaceted mining and petroleum industries with collaborative support from government and industry for research and development projects.

1:4

Up and running: WAMPRI's early days

With the proclamation on 29 June 1981 of *Mining and Petroleum Research Act 1981*, the Western Australian Mining and Petroleum Research Institute completed the conversion of vision into reality. The inaugural WAMPRI board was chaired by the highly respected former Director of Geological Survey of Western Australia, Joe Lord, and its two other members were Wilf Ewers, formerly Senior Principal Research Officer at the CSIRO, and Peter Wall, a retired Secretary/Treasurer of West Australian Petroleum (WAPET). The members of the first Mining and Petroleum Advisory Committee, meanwhile, included a variety of representatives with diverse interests and expertise. There was Ken Short from the Australian Petroleum Exploration Association, and Bill Peart from the Confederation of Western Australian Industry. The Chamber of Mines of Western Australia was represented by Tom Ivankovich and Charles Wyatt; the CSIRO representative was Arthur Gaskin; and the academics included UWA's Professor of Geology, Peter Harris, Murdoch's Professor of Chemistry, Jim Parker, and WAIT's Head of the Department of Metallurgy, Dr Terry Pyle. In addition, there were four ministerial nominees: the committee Chair, Rex Baker, Dr Odwyn Jones, Jim May and John Roberts.

The inaugural joint meeting of the board and the advisory committee was held on 18 September 1981, marking the official start of the institute's operations. The meeting was addressed by the Minister for Mines, Peter Jones, who reiterated his support for WAMPRI and outlined his hopes for its future.

Joe Lord, founding chairman of the Board of Directors of WAMPRI, photographed in September 1989. Lord had served as Director of the Geological Survey of Western Australia from 1961 to 1980.

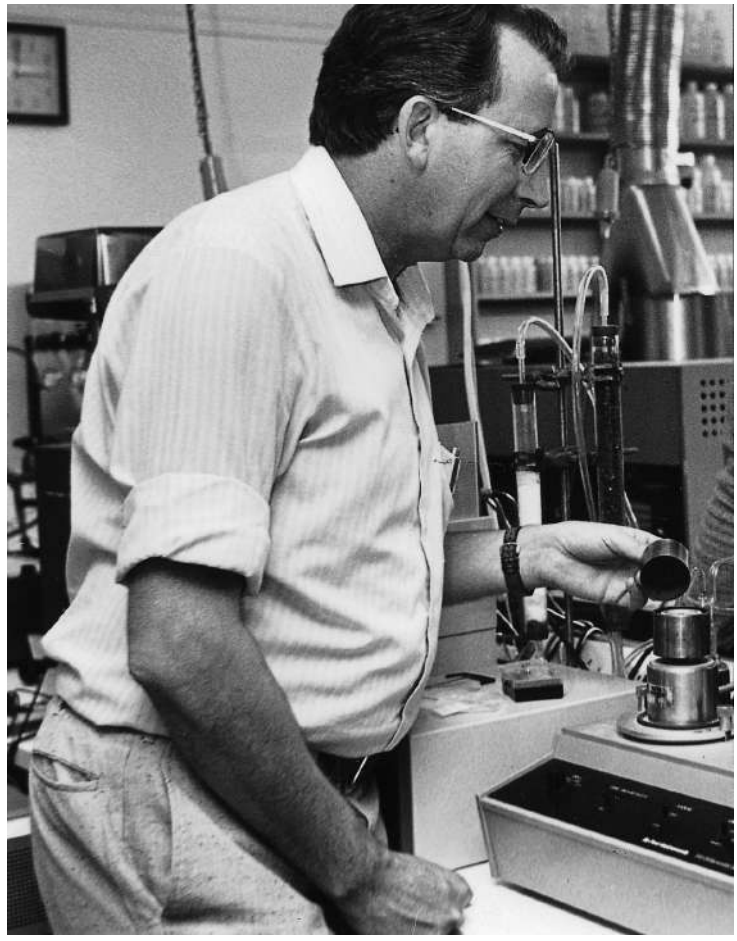
Jones 'impressed on the members the necessity to develop relevant research expertise within Western Australia', which would assist industry in all aspects of mineral and hydrocarbon development, with a particular emphasis on processing.[43] Reflecting on this occasion twenty years later, Jones emphasized that WAMPRI's mandate was not 'research for its own sake', but rather the establishment of a relationship between scientific research and 'economic development and growth'. WAMPRI, Jones added, was 'not an end in itself'. It was instead 'a service institution', intended to complement other services provided by government and industry to support and enhance 'the main development thrust' of the Charles Court Government.[44]

One of the WAMPRI board's first priorities was to call for funding applications closing in late October 1981, and its publications prominently displayed notices. The first issue of the newsletter *Mining and Petroleum Research News* also summarized the institute's funding policy, highlighting again WAMPRI's desire to cement ties between researchers and industry. In order to establish and maintain a close relationship between industry sponsors and research teams, the board stipulated: 'A sponsor is kept informed on a quarterly basis of the status of the project, and at longer intervals will be invited to inspect and to discuss progress with the researchers.'[45] WAMPRI was to be the facilitator of contact between all stakeholders, and the board clearly recognized that the success of a particular project – indeed, the future of the institute – depended

The inaugural board of the Western Australian Mining and Petroleum Research Institute (WAMPRI), September 1981. *From left:* P.L. Wall, J.H. Lord and W.E. Ewers.

on communication and consultation. There was also, from these earliest days, an advocacy role. The fledgling institute counselled against shortsightedness and made this special appeal to potential research sponsors: 'If you should receive a request for financial support for a project in your field, please do not make a hasty decision but consider the benefits which may accrue to your operations.'[46]

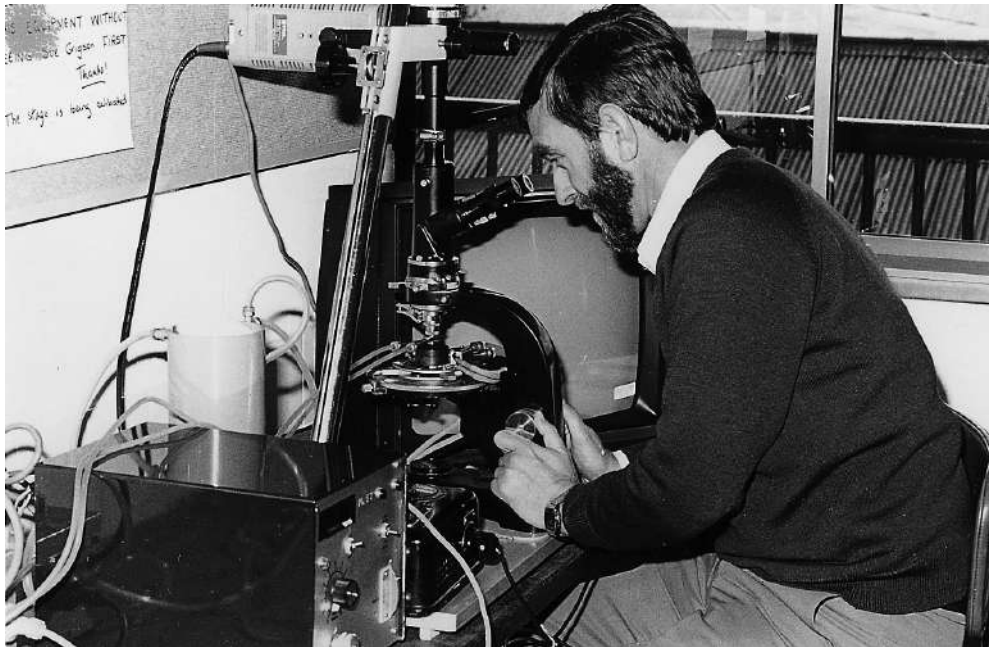
In the nine months before the close of its first fiscal year, ending on 30 June 1982, WAMPRI received an encouraging number of applications for funding. Despite the difficult economic climate of the early 1980s, including a severe downturn in the mining industry marked by big falls in prospective and expected growth rates,[47] twenty-one proposals for research projects were considered. The first six projects – needing over $270,000 – generated a total cash commitment from the industry to the value of $162,500. The notional value of these first six projects, which included a conservative valuation for the use of facilities, equipment and contribution by assistant staff, but excluded the support, advice and supervision by senior research staff, was $430,000. The cost of generating this research – WAMPRI's administrative costs – was minuscule by comparison, amounting to just over $14,000. Joe Lord commented on the funding success of



Dr J.G. Dunn working on the flash smelting of nickel sulphide ores in 1982. (Project 2).

the institute's first year: 'This is better than the dollar-for-dollar objective suggested by the Government.'[48] That the institute would mature into a 'lean' organization became even more apparent after its first full year, during which WAMPRI generated research with a notional value of over one million dollars while once again keeping administrative costs to a minimum.[49]

Much of the credit for WAMPRI's initial success, and for establishing a solid foundation for the future, can be attributed to Lord. Lord had retired from the position of Director of the Geological Survey of Western Australia in 1980, and was viewed as the founder of the modern Geological Survey, where he began his career in 1946. John de Laeter rated Lord's directorship as 'the best' in Australia, and Lord would be remembered for his key role in defining the geology of the coal deposits in the Collie Basin, and for overseeing the geological mapping of the entire State at a scale 1:250,000.[50] Lord was also a



Dr David I. Groves, supervisor of a project on the development of exploration concepts for Sn-Ta Pegmatites, inspects a thin section in 1982. (Project 4)

founding chairman of Geoconferences (WA) Inc., a not-for-profit organization made up of committed volunteers aiming to promote geoscience by arranging conferences, symposia, excursions and social and professional events. He had become involved in the campaign for the establishment of a research institute when Peter Power harnessed his support for lobbying both the industry and the government. Lord had numerous allies and contacts and was, de Laeter recalls, 'a consummate public servant; he understood what… is achievable and what is not'.[51] Foundation advisory committee member John Roberts remembered that Lord promoted the idea of an institute tirelessly:

> That was a good reason to have someone like Joe Lord at the helm because he knew the industry people. I would think that Joe probably just got on the phone and just rang people up… I think it was probably just word of mouth, Joe Lord to the industry.[52]

Subsequently, the Charles Court Government had demonstrated its trust in Joe Lord by asking him to prepare the bill that established WAMPRI. Even more remarkably, the State Cabinet had approved the establishment of the WAMPRI

Dr N. Stockton (left) and Dr A. Gupta developing equipment for use in a project on the on-line control of hydrocyclones during 1984. (Project 16)

board and its advisory committee before the passage of the bill. The board and the committee were then instructed to prepare and formulate policy and guidelines for the development of the institute, and these were included in the legislation. In John de Laeter's view, therefore, Lord 'really has to take most of the credit, along with Peter Power, for really making it [WAMPRI] a success'. Quite simply, Lord 'showed that the idea Peter Power had come up with was a good, working, practical reality'.[53] It had not been surprising, therefore, when Lord was appointed to the WAMPRI chair and given the chief responsibility in the Institute. According to Dr Colin Branch, Lord's successor,

> It was Des Kelly who was then the CEO of the Department of Mines, who recognized, through [Minister] Mensaros… that here, in Joe, was a person who would be available full-time, was well known by industry and academia, had the respect of the Minister himself – and that's very important

As part of research into the development of a load monitoring, display and reporting system for shovels, a calibration mass is connected to a shovel dipper in 1984. (Project 37)

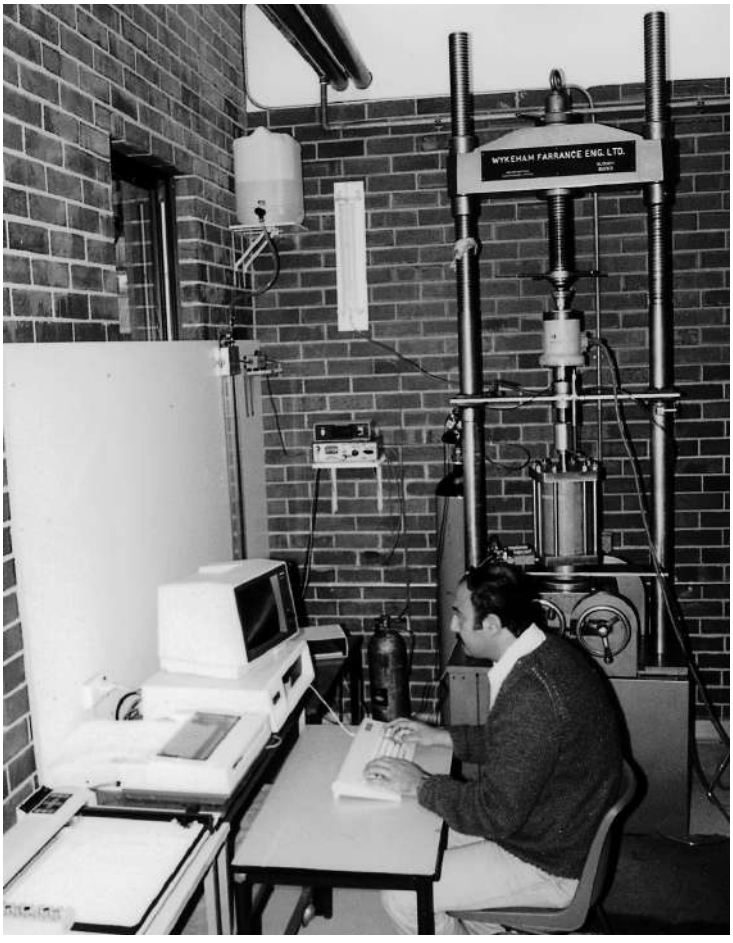
> in this job... Joe was the person on the spot at the right time, and under the right conditions to be asked on a full-time basis essentially to establish this new organization.[54]

One of Joe Lord's greatest achievements as Chairman of WAMPRI was the growth of the institute's reputation as a 'lean' organization. As de Laeter articulated it, Lord ran the institute 'on the smell of an oily rag'. Similarly, the report of a review committee chaired by geologist Dr Don Zimmerman, analysing the first five years of the institute's operations, stated that 'WAMPRI's low administration cost reflects its efficient management.'[55] The institute's total expenditure to the end of June 1986 was just over $3 million, of which only $150,000 – or approximately 5 per cent – were operational costs. Furthermore, WAMPRI's status as a statutory authority enabled it to invest government grants in a number of ways approved by the State Treasury, and

then retain the interest earned. In the highly inflationary years of the mid-to-late 1980s, the interest earned on bank accounts controlled by the board was such that it was able to meet the organization's administration costs. Branch noted, therefore, that the institute's administration was effectively 'free to government, the researchers and industry'.[56] The Zimmerman Report noted, indeed, that during WAMPRI's first five years, more than 99 per cent of all funds were used by, or available to, researchers.[57] Its principal conclusion was that the institute was beneficial to the State by an amount substantially more than the funds employed, which prompted Minister for Mines David Parker to comment: 'It is most gratifying to find that this report confirms my view that WAMPRI is an effective organization making a valuable contribution to Western Australia.'[58]

Zimmerman's five-year review committee also found that WAMPRI promoted applied research and therefore stimulated substantial research activity at the Curtin University of Technology, including the Western Australian School of Mines, which accounted for about 44 per cent of research funds committed to mid-1986. The committee's report also concluded that the WAMPRI board, ably assisted its honorary advisory committee, the sponsors and referees, provided disciplined and quality management from the application stage through to publication of the final report. Without any shadow of doubt, the institute had stimulated an increase in local research and research facilities, especially in mining engineering and mineral processing. The Zimmerman Report cited impressive financial benefits. For example, energy cost savings of more than one million dollars per annum had been effected at the Kalgoorlie Nickel Smelter for a research outlay of $8,000 from industry. Other less quantifiable benefits were apparent because research findings from a number of projects were being applied in ongoing operations.[59]

Industry support for WAMPRI generated the necessary financial support for research projects and had helped realize the goal of promoting a 'research culture' in the State. The long list of sponsoring companies included both well-known names in the mining industry such as Alcoa of Australia, Ampol, BHP, and Western Mining, as well as various state and non-government agencies and associations such as the Chamber of Mines and the State Energy Commission. Companies were further encouraged to support projects when, in 1987, WAMPRI was accepted as an 'approved research institute' for the purposes of Section 73 of the *Income Tax Assessment Act* – which translated into a tax concession of 150 per cent for all companies which provided financial sponsorship of WAMPRI's projects after 1 July 1985. As the importance of innovation and competition became more explicitly recognized in Australia, the Commonwealth Government decided to 'concentrate greater research and

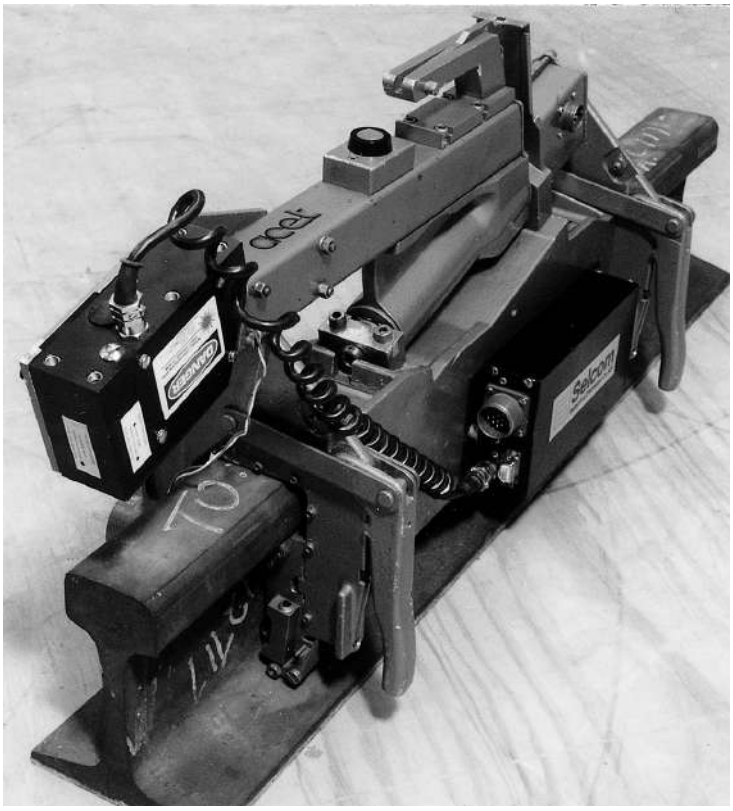


A research assistant using tri-axial test apparatus during a study of pore pressure variation on sandstone behaviour in the Collie Basin, 1986. (Project 74)

development effort in the private sector and to provide a mechanism for improving the links between industry and Australia's R&D expertise in CSIRO and the tertiary institutions'. Investing in research and development was defined as 'systematic investigation of experimentation involving innovation or technical risk the outcome of which is new knowledge'.[60]

Industry and other external support was also crucially important in harnessing the human resources that were required for the effective operation of the institute. The inaugural chair of the Mining and Petroleum Advisory Committee, Rex Baker, noted that committee members were appointed on an honorary basis:

> You're asking very talented and very busy people to do work free – there was no payment – and the evaluations of the applications for research assistance were quite an extensive commitment of time. They gave of their time without hesitation. We also used external assessors to help in



The prototype model of a gauge for measuring the wear of rails, 1984. (Project 45)

both the time and expertise needed to consider the applications. Many of the research project applications were very detailed and complex. We used our contacts in industry, academia and government to obtain the services of the assessors. The knowledge and time availability of the assessors was also very much appreciated.[61]

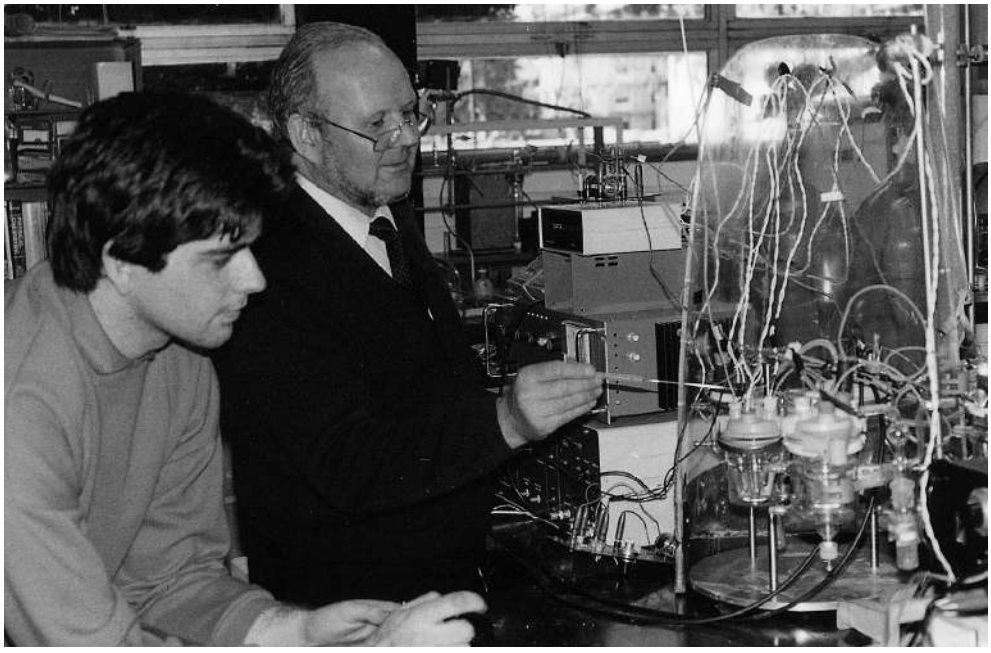
From WAMPRI's earliest days, the highly specialized nature of applied research demanded setting up additional layers of expertise, the Mining and Petroleum Advisory Committee subcommittees. These subcommittees, specializing in geoscience, mining and engineering, mineral processing and hydrocarbons – and with a further subcommittee for general matters – made detailed examinations of projects and recommendations to the advisory committee, which would, in turn, make recommendations to the WAMPRI board. As Baker reflected: 'I think we were able to do very thorough analyses of the applications with the procedures we had in place.'[62]

1:5

An arranged marriage and a change of name

Many academic researchers believe that the establishment of WAMPRI was a pivotal event for the Western Australian mining industry, reflecting John de Laeter's comments about difficulties in obtaining research funds before its establishment.[63] Previously, the research funding bodies, principally the Australian Research Council (ARC), had been primarily interested in supporting fundamental research and the specific needs of Western Australian industry had been poorly addressed, if at all.[64] Moreover, academics and industrialists had been wary of each other, a consequence of poor articulation of research goals and insufficient clarification of the benefits of such research to both parties.[65] Before WAMPRI's establishment, therefore, collaboration between academia and industry had been stunted and severely underdeveloped. By pledging ongoing support for particular projects, WAMPRI had also helped overcome the problem of intermittent funding lapses – a serious problem for many researchers, causing major delays in industrial operations.[66]

The success of WAMPRI underlined the careful thought and thorough preparation preceding its foundation. Whereas, for example, the Australian Minerals Industry Research Association (AMIRA), established in the 1950s, played a role in bringing research and industry closer together, it relied solely on funds provided by industry. The research results of individual projects were not necessarily applicable to the unique geological setting of Western Australia and, perhaps most restrictively, results remained the property of the sponsoring



Dr Terry Quickenden and research officer Todd Green (left) with test cell and automatic monitoring equipment designed to test 'cold fusion' in 1989. (Project E138).

company. Individual companies often pursued applied research projects with the researchers on a one-to-one basis to capitalize on the intellectual property developed in the core project.[67] WAMPRI was unique in having at its disposal matching government funding, and illustrated the deep commitment of successive Western Australian governments to the promotion of applied minerals research for the benefit of all. In short, WAMPRI had filled a void. It had opened the door for a greater emphasis on processing in the State mining industry, and consequently the continued development of the State's natural riches.

Yet successful beginnings rarely obviate the need for an organization to build, adapt and streamline. In late 1987, WAMPRI underwent the most significant change in its history and commenced a new phase of existence under a new name. By then, WAMPRI's worth had been proven many times over. In its seven-year existence, the notional value of all projects supported was $7,300,000. Industry support had been maintained at 55 per cent of project funding while operational expenses were miniscule, with administrative costs of $236, 802 being offset by interest of $288,992. Of the more indirect benefits

W.E. Ewers (left), R.E. Butters (standing) and J.H. Lord at the first board meeting of the Minerals and Energy Research Institute of Western Australia, 19 February 1988.

flowing from the funding available to the institute, an effective example, WAMPRI claimed in 1983, was the creation of employment – mainly for science graduates and industry people new to research.[68] It was widely believed that there was no reason a slightly metamorphosed organization could not operate in similarly efficient manner and continue to fulfil the original goals.

In 1986, the Western Australian Government decided to terminate the Solar Energy Research Institute of Western Australia (SERIWA) – upon which WAMPRI had been modelled – and pass the responsibility for providing research grants for both renewable and non-renewable energy projects to a new organization. The Minerals and Energy Research Institute of Western Australia (MERIWA) was the result of this merger, and *Minerals and Energy Research Act 1987* repealed the 1981 Act, which established WAMPRI. In his introduction of the 1987 bill, Minister for Local Government, Jeff Carr – speaking on behalf of the Minister for Minerals and Energy, David Parker – explained that the reasons for this marriage of the two organizations were 'to promote a more cost-efficient, needs-based use of public funds and to reduce duplication' of both research and administration.[69] The new Act closely resembled the 1981 Act,

The first meeting of the Minerals Research Advisory Committee (MRAC), 5 February 1988.
Standing (L to R): D. Muir, W. Sashegyi, T. Pyle, R. Hudson, A. Daffen, M. Seal.
Seated (L to R): J. May, O. Jones, R. Baker, J. Roberts, C. Powell.

with modifications that reflected the institute's expanded interests. In short, MERIWA would 'promote and coordinate research for the development of the minerals and energy industries'.[70]

Bringing these two areas of research under one umbrella organization did not involve any serious problems for staff or researchers, primarily due to the uncomplicated nature of the changes being enacted. MERIWA's structure was very similar to that of WAMPRI, with minor changes reflecting the incorporation of energy research previously administered by SERIWA. With its new name, the institute continued to perform its primary function, acting as a 'broker' between Western Australian industry and research interests. An extra director was appointed to represent energy interests, and MERIWA's inaugural Board of Directors, responsible to the Minister for Mines, comprised: Joe Lord (Chairman); fellow longstanding board member Wilf Ewers; Rowley Butters; and the previous Chairman of the Solar Energy Advisory Committee, Ron Douglas.

In parallel to the Minerals Research Advisory Committee (MRAC), an Energy Research Advisory Committee (ERAC) was appointed. Like MRAC, the new committee was made up of experts in relevant research areas and project

The first meeting of the Energy Research Advisory Committee (ERAC), 22 July 1988.
Standing (L to R): M.R. Thornber, J.C. Lenzo, J.A. Appleyard, I.H. Carne, R. Kirkpatrick.
Seated (L to R): G.F. Baverstock, T. Edwards, J.G. Dunn, M.F.J. Daly, A. Davies.

development. It included representatives from tertiary institutions (such as John Appleyard from The University of Western Australia), industry (such as John Riley, from James Hardie Energy Products), and statutory authorities (such as Kevin Wulff, from the State Electricity Commission of Western Australia). As with MRAC, there were also members nominated by the Minister for Mines, and one of these was Jeff Dunn (Curtin University), the inaugural Chairman of ERAC. Funds for the 'minerals' section were kept separate from those of the 'energy' section, the intention being 'that industry's contribution to any project will be identifiable'.[71]

The incorporation of renewable energy into the institute's charter resulted in other changes. Some of these reflected a growing interest in energy research, particularly associated with Murdoch University. At the first meeting of ERAC in July 1988, nine applications for research funding were considered and recommendations on funding were sent soon afterwards to the MERIWA board. Funding increased accordingly. In the financial year 1988–89, the State budget provided the funds requested by MERIWA, with minerals research allocated $523,000 and energy research receiving $250,000 – a record total for the institute.

By 1990–91, the allocation for minerals research alone was $560,000, with a further $250,000 for energy research bringing the total to $810,000.[72]

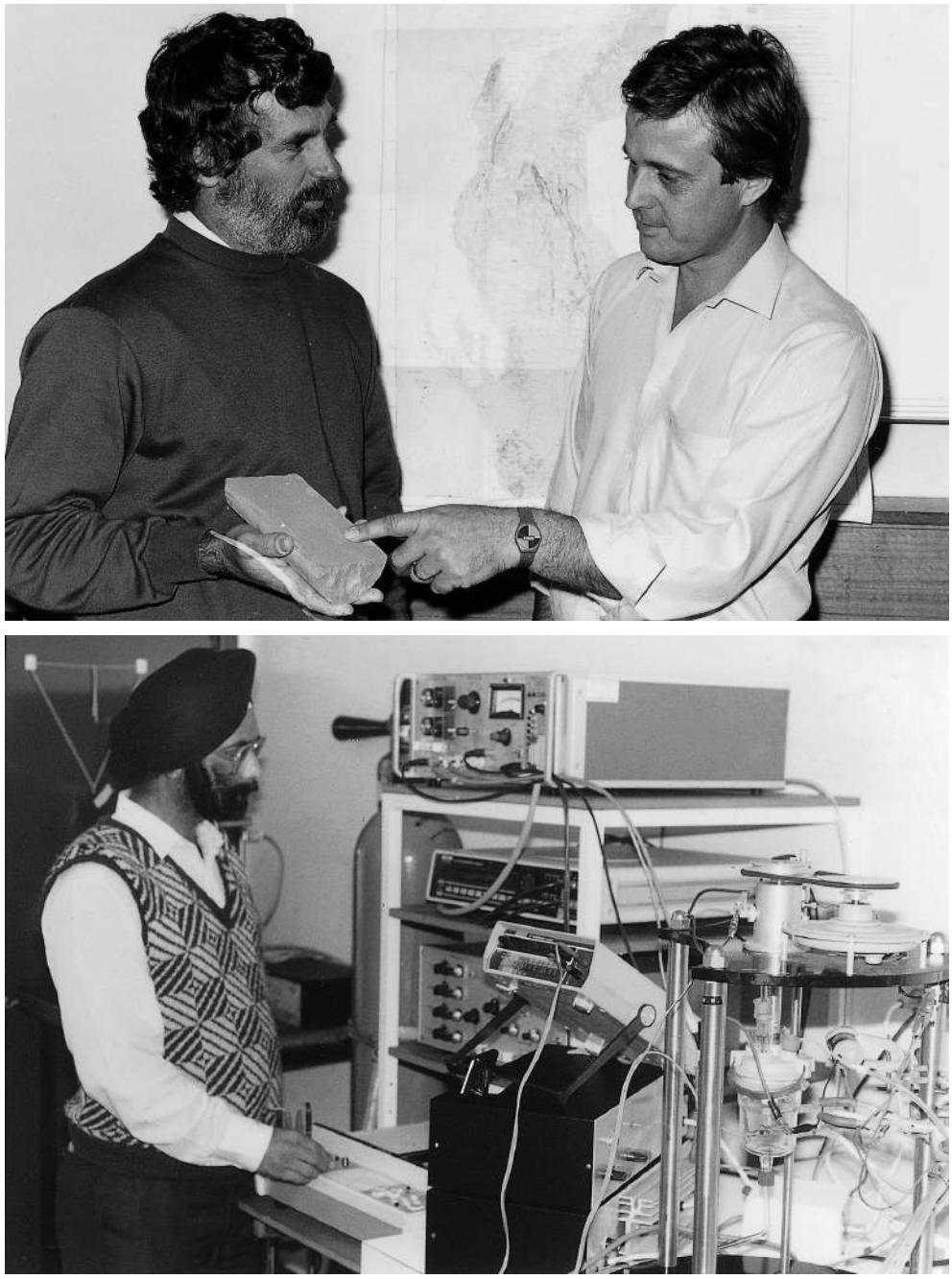
The personnel of the institute also changed in the late 1980s and early 1990s. The respected and longstanding chairman, Joe Lord, retired in 1991, and was succeeded by the Deputy Director General of the Department of Mines, Dr Colin Branch. Executive Officer Michael Seal had departed the previous year, and his replacement was Bob Hannaford, previously Project Manager at Goldsworthy Mining. Upon Hannaford's appointment to MERIWA, new strategies were set in place to help cultivate ties with industry. Whereas previously the energetic Lord had taken the lead in bringing the industry and the research together around a particular project, this work now took more formal shape as an administrative task. Hannaford explained:

> The Executive Officer would send out invitations to various companies we thought would be interested, depending on what the subject was, and they [the researchers] would put on a seminar, an afternoon presentation of what it was all about. Then we would have a general discussion of who would be interested in this… and then follow it up in the next month or so.[73]

To assist with the ever-increasing pressure of office work, Gwen Davies was brought in as administrative assistant.

Inevitably, in spite of the ease with which the transition from WAMPRI took place, MERIWA inherited some of the dilemmas faced by its predecessor. As Colin Branch observed, a perennial question was 'whether MERIWA should be initiating projects, or whether industry itself should be taking the initiative'.[74] Constraints of a financial nature defined MERIWA as a meeting place between industry and research, with the initiative for projects typically coming from researchers. As the global economic climate became more complex, the institute's work reflected fluctuations in the nature of the relationship between the industry and industry-related research. Rex Baker, who became a MERIWA board member in 1993, noted:

> I don't think many people in the eighties realized that the industry was in, or at least entering, a global business environment. I think we were a little parochial in those days. More focus, and a higher priority on technology started to happen in the late eighties to early nineties. The scene today is that the industry has realized it must be globally competitive; technology improvements are fundamental to its existence, along with innovation and creativity. Consequently there is a lot more emphasis on this side of the business.[75]



Top: Dr Lindsay Collins (left) with Roger Hocking discussing a core section in 1987. (Project 84).

Bottom: Dr Pritam Singh checks experimental cell monitoring equipment in 1989. (Project E109).

The institute had brought about a 'good interface' between industry and research but, generally, industry was seen to be lagging in innovation and initiative. In the 1990s, as the number of project applications and their funding requirements increased, MERIWA would look to industry to provide the greater portion of funding for particular projects, and to initiate the research projects from which it could benefit.

1:6

Securing a future: the value of partnerships

During the 1990s, MERIWA worked tirelessly to encourage the development of a sustainable Western Australian minerals and energy research culture. A 1993 review of its performance – following a brief period during which the institute had operated as constituent part of the Department of Minerals and Energy[76] – highlighted the breadth of its achievements, and concluded that the mining industry had been very well served.

Impressively, completed research covered the full gamut of mining industry activities – exploration, mining, processing, marketing and rehabilitation. The 1993 review committee described how a number of reports prepared by the Geology Department at UWA provided mineral exploration companies with new understanding and investigative methods for locating mineral bodies in Western Australia's Archaean rocks, the known host for gold or nickel deposits.[77] One report by the CSIRO facilitated exploration for nickel deposits,[78] while another provided a better understanding of heavy mineral sand concentration in very young sediments near coastlines.[79] The review committee noted that exploration geophysics research had been directed mainly towards improving methods of interpretation of seismic data on which petroleum exploration was so largely dependant. Three reports, compiled at Curtin University, described newly-developed computerized data processing procedures valuable in oil exploration.[80] Petroleum exploration had also been assisted by research into the thermal history of the Canning Basin employing geochemical methods, and by the correlation of

geological and geophysical results to produce a comprehensive account of the Lower Cretaceous deposition in the southern North West Shelf.[81] Another report, prepared at the WA School of Mines, was directed at computerized interpretation programs relating to metalliferous deposits in crystalline rocks.[82] All these geophysical interpretative tools are now used by industry.

The review committee found that a wide range of useful technology had been generated by mining engineering research, including the development of a technique to repair fatigue damage in welded joints on heavy mining machinery.[83] A study of airblast and ground vibration in smaller open cut mining operations resulted in development of blasting and monitoring methods, without which it would have been impossible to proceed with the Kalgoorlie/Boulder super pit due to its proximity to residential and business development.[84] Another project described improvements to laboratory methods for the measurement of rock strength, leading to the more accurate prediction of rock behaviour in underground mines, with obvious safety implications.[85] An ingenious study showed how a good-quality 35mm camera could be adapted photogrammetrically to measure and map geological features on open-pit faces and further used to monitor pit wall stability.[86] A study was launched into the causes of failure of conveyor-belt splices and methods of making more durable linkages that have prolonged belt life.[87] Other projects helped the mining industry to produce ore more economically.[88]

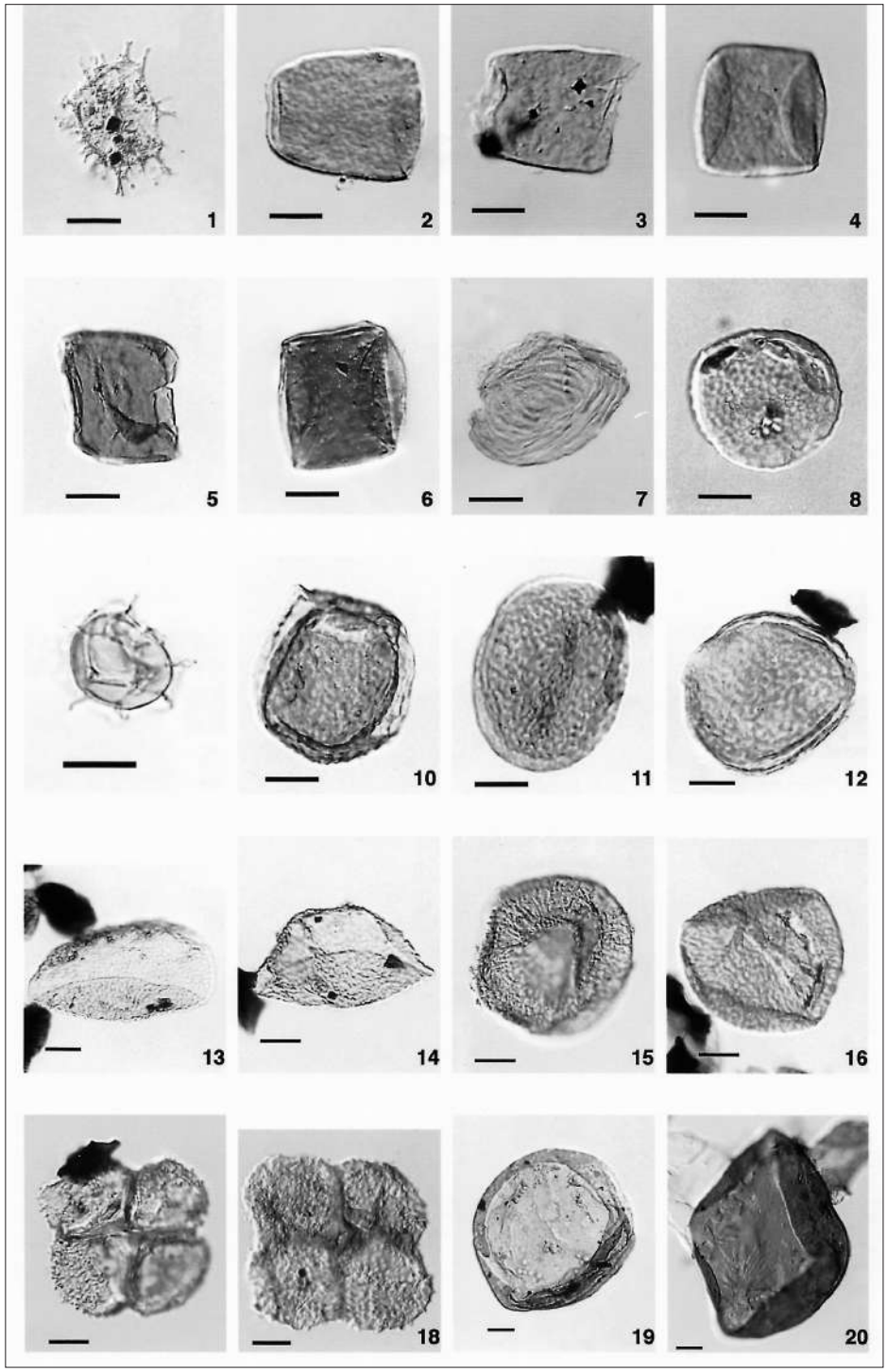
By 1993, mineral processing – with twelve completed projects – had received the greatest share of MERIWA's research attention. There was groundbreaking work on the flash smelting of nickel ore,[89] and other studies that led to improved recovery of cobalt as a payable by-product from nickel refining.[90] Research led to improved methods of gold recovery[91] and more efficient means of beneficiation of bauxite to produce alumina.[92] A potentially useful method of recovery of ultrafine iron ore from currently wasted fines was demonstrated,[93] and other work indicated a feasible flotation method for reducing the iron oxide content of the Mt Weld phosphatic deposit.[94]

With increasing importance being placed on rehabilitation of mine sites, it was not surprising that mining companies had a need for botanical research. Environmental problems have been addressed in research on the revegetation of overburden stockpiles and the rehabilitation of mine sites.[95] Other minerals research demonstrated the wide range of MERIWA's support, from studies of the relationship between international monetary exchange rates and commodity prices,[96] to others on radon gas in underground mines, a health issue.[97]

In the years following the 1993 review, MERIWA's reputation continued to grow as the list of projects it facilitated was extended, and as the results of

research were noted and applied by industry. There was a slight narrowing of the institute's portfolio in July 1995, when the management of alternative energy projects was transferred to the new Alternative Energy Development Board (AEDB), established within the Office of Energy. Seven years later, however, legislative changes enabling the AEDB to operate autonomously had not been enacted, and funding was still being channeled through MERIWA. Except in this area, funding contributions by industry relative to those by government increased during the 1990s, and there were also signs of an increased preparedness by industry to initiate research projects. Long-serving MERIWA board member Rex Baker noted in 2000 that, although 'the best result can come from a joint approach', there was a logic in this trend. It made, sense, to Baker, that 'the first call should come from the customer who has the problem or the need, rather than the researcher who may have a concept.'[98] In part, however, a shift in the point of balance between Government and industry was made necessary by pressures within Government budgets. In real terms, Government funding declined in the nineties, a 1997 MERIWA report stating that 'the funding available to MERIWA in 1990–91 in present day dollar terms was 40 per cent more than in 1996–97'.[99] A science and technology policy outlined in 1997 by the Western Australian State Government aimed to increase the level of expenditure on research and development and to allocate additional funding to MERIWA to achieve this objective. In turn, the institute called on Government to focus on the need for increased spending on research benefits the results of which can only be measured in the longer term.[100] By the early years of the new century, however, the days of a fifty-fifty split had passed: the State Government's contribution was 35 per cent of the total cost of a project, with industry committing the balance.

The goals and functions of the institute remained unchanged – and were, indeed, essentially the same as those expressed in the original 1981 charter of its predecessor, WAMPRI.[101] Two decades after WAMPRI's establishment, indeed, MERIWA could reflect with satisfaction on its record of 'fostering and promoting all aspects of minerals research and petroleum research', and its thorough and consistent work in 'monitoring and evaluating research projects in respect of which the Institute has allocated financial assistance'.[102] Under its guidelines, MERIWA was obliged to assist researchers to reach appropriate industry sponsors to partially fund a project in return for the solutions to a particular problem. Since the first days of WAMPRI, the institute's sub- committees had played an important role: they possessed specialist industry knowledge and could ascertain the value of a research proposal and its funding eligibility. As Rex Baker recalled of his role as chair of the WAMPRI advisory committee: 'We formed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subcommittees because they seemed to make sense at the time. It's interesting to note that they are still essentially the same; they haven't changed in twenty years.'[103] Without doubt, the specialist help offered by the subcommittees played a crucial role in cementing the institute's reputation as a responsible grants body.

MERIWA facilitated many projects in which the benefits flowed both ways – to the researchers as well as to industry. The researchers' responses to the work performed by the institute indicate that their access to specialist advice – together with the opportunity to participate in the industrial domain – was appreciated. Particularly valuable was the novel cooperative relationship established between the industry and academia, ensuring that the needs of both were met. To help cultivate this relationship, WAMPRI and MERIWA always demanded clear details on all aspects of each project from the applicants. As one prolific researcher, Professor Jeff Dunn, claimed:

> What WAMPRI did was to require that a proposal was developed in which all these things were spelt out, and the proposal had to meet the satisfaction of both parties. WAMPRI also ensured ongoing interaction between both parties, through regular meetings, reports.[104]

Dr Dunn, Dr Terry Smith and their co-workers at Curtin University's Departments of Applied Chemistry and Chemical Engineering worked intermittently over fifteen years to understand all the factors which influenced the flash smelting of nickel sulphide concentrates carried out at the Western Mining Corporation's flash smelter in Kalgoorlie, discussed in more detail in Part 2, Chapter 6. The team received, from the first grant in 1982, to the last in 1997, some $300,000 in concurrent value for their projects. The projects attracted widespread media coverage in the national press, particularly because the new technique in metal smelting reduced costs and had 'worldwide applications in energy conservation'. According to Dunn, the research 'opened up areas of fundamental studies into the chemistry of sulfide minerals'.[105]

Left: Photographs from a project on the Triassic palynostratigraphy of the Dampier Sub Basin, commenced in February 1999. (1) *Multiplicisphaeridium dendroidium* Morbey 1975. (2-4) *Bartenia helbyi* Burger 1996. (5-6) *Bartenia communis* Helby 1987a. (7) *Circulisporites* sp. (8-9) *Cymatiosphaera* spp. (10-12) *Lecaniella* sp.A. (13-16) *Schizosporis* sp.A. (17-18) *Quadrisporites horridus* Hennelly 1959 ex Potonie and Lele 1961. (19-20) *Pilasporites crateraformis*. (Project M313).

Another multiple grant recipient, Professor David Groves, from the Department of Geology and Geophysics at The UWA, concurred with Dunn on the significance of the institute:

> MERIWA has played a most important role in research in the State. Without [its] existence, only four of the fourteen projects completed by my group of researchers would have been funded from other sources … [MERIWA has] helped develop a superior research culture related to the mining and exploration industry in the State.[106]

Reflecting the diversity of the work supported by MERIWA, Groves' work was in the area of exploration geology, aiming to 'produce high-quality documentation of as many significant gold deposits in the Eastern Goldfields Province of the Yilgarn Block as possible'. The mapping documentation preserved important information for the exploration industry, allowing the major sponsoring companies – such as CRA Exploration, Geopeko, and Dominion – to prolong the life of mines. In return for the funding they provided, the sponsors received an information 'database to which they could add their own data to derive a superior database of Yilgarn gold deposits'.[107]

All researchers attest to the responsiveness of the industry to proposals and – when appropriate – providing samples for their research.[108] Professors Bob Alexander and Bob Kagi of the School of Applied Chemistry, Curtin University, received support for a number of projects, and Alexander testified that the pair had 'developed productive ongoing relationships with a number of our industry sponsors', with MERIWA's assistance in administering grants and organizing sponsor seminars. In general, the work of Alexander and Kagi has been in the hydrocarbons area, aimed at

> the use of molecular hydrocarbon fossils to correlate crude oils with their source rocks. In some cases the molecular fossils of land plants which have changed through geological time with changes in climate, have made it possible to establish the geological age of the source rock from which the oil was derived.

Alexander and Kagi's work gained national recognition 'through to the present level where [their] research is internationally recognized'.[109] The main benefit to the industry has been the establishment of the principal sources of crude oils in the Western Australian petroleum basins. In 2000, Alexander and Kagi were the recipients of the Lewis G. Weeks Gold Medal for their contribution to petroleum exploration in Australia, made possible by their MERIWA-supported work.

MERIWA's publication of research results has been a key factor in enabling research to gain the recognition it has deserved. David Groves believed that the institute's contribution in this area was significant, 'particularly in editing the final report and ensuring a high-quality product'.[110] The institute was obliged by legislation to disseminate the results of research it funded and maintain a collection of all reports in the Department of Mines – but publication was not similarly prescribed. In order to maximize industry's access to research which could potentially solve important problems, however, all research results and project details have been published in both microfiche and hard copy. Since 1994, moreover, MERIWA has employed a project coordinator to manage its publications and, in 1998, it began publication of reports on CD-ROM. Generally, reports are made public at the conclusion of the research project. In a few instances, an 'embargo' period of up to twelve months has been invoked before results became public property, and therefore available to companies other than those funding the research project. As former Executive Officer John Roberts explained: 'They [the sponsors] get the commercial benefit in the first place, while doing the project and possibly for an additional twelve months.'[111] In this way, the institute was able to ensure that research partly funded by Western Australian taxpayers offered benefits to diverse companies.

In 1991, complementing its work of facilitating contact between established researchers and industry, MERIWA introduced top-up doctoral scholarships for postgraduate students at the State's tertiary institutions. These scholarships consist of a research fund of $5,000 for project maintenance and a personal stipend of another $5,000 per year, for a maximum of three years. As Dr Colin Branch recalled, the scholarship scheme had an interesting beginning:

> In the late eighties, the interest earned on investments was becoming an embarrassment. MERIWA was meeting its own administration costs, but what to do with the surplus?… This situation allowed the Board to commence a new initiative that meets the requirements of the legislation by setting up these scholarships for leading young doctoral students as top-up scholarships to encourage them to continue their research in WA. That's why they are important to us as an organization.[112]

The introduction of these top-up scholarships underlined the institute's commitment to supporting the work of emerging, younger researchers producing original and valuable research results applicable to Western Australian industry. According to Dr Carl Brauhart, a researcher in economic geology, the financial incentive was not the only reason candidates applied: 'There is also a degree of prestige in successfully applying for such an award.' Researchers were free to

Disharmonic folds in chert bands in the lower Mount McRae shale at the Mount Whaleback Mine, Newman. The focus of the researchers' study was the timing and genesis of iron deposits. (Project M242)

maintain the independence of their projects, as Brauhart emphasized: 'MERIWA [was] happy to let me get on with things once my scholarship was underway.' Brauhart also reflected that funding from MERIWA allowed him to consider a significant change in career direction, adding that 'in hindsight, this is the luckiest break I have had in my career'. For Brauhart, the scholarship project led directly to full-time employment with its major sponsor, Sipa Resources.[113]

Advantages from postgraduate work flowed in many directions. Typically, researchers spend the first half of their scholarship meeting research costs. In Brauhart's case, MERIWA funding 'lifted the research budget over the life of the project from $20,000 to $30,000'. This was important because it expanded the breadth of the research: Brauhart's project in economic geology was concerned with mapping the sulfide deposits of the Pilbara, and the extra $10,000 received from MERIWA more than doubled the amount of geochemical and isotopic analysis that I could perform and meant that we achieved complete geochemical coverage over the project area, rather than relying on a few 'representative' areas. This made the difference between a reasonable project and a great project.[114]

Minister for Mines Gordon Hill (left) with the first Supplementary Scholarship awardees, Marisa Ioppolo (Energy Research) and Clive Milham (Minerals Research) at the presentation ceremony on 21 March 1991.

Some postgraduate research related to, or formed part of, a larger MERIWA-funded project, enabling recipients to use a top-up scholarship to add value to existing projects. Ron Hackney, a PhD student in the Department of Geology and Geophysics at the University of Western Australia, applied for the scholarship while working on a project led by Professor Chris Powell exploring the possibilities of deep exploration techniques for Hamersley iron ore. Reflecting the flexible application of the scholarships, Hackney has used the funds provided by MERIWA to cover the expenses involved with fieldwork. This was especially useful in unanticipated emergencies, such as when an extra research trip became necessary after earlier plans were disrupted by poor weather.[115] The results of Hackney's research were important to geologists because they had a direct bearing on the interpretation of other geological and geophysical data. The results were of benefit to government as well as industry, with the

Department of Land Administration using Hackney's satellite-based navigation survey data in its final adjustment of a network of survey points across the State.

A project conducted by another scholarship recipient, Andrew Webb at the Department of Mechanical and Materials Engineering, University of Western Australia, involved researching the applicability of hydrogen energy, an area of work that is rarely explored in Australia. Webb recorded:

> I was interested in researching hydrogen energy as a renewable, non-polluting energy source. The safe and effective storage of hydrogen is a vital element if this alternative energy source is to be effective. The materials used in the manufacture of these materials are abundant in WA so by manufacturing and value-adding this would be of great economic benefit to WA and the nation as a whole.[116]

The MERIWA scholarship allowed Webb, who was pioneering such research at his university, to purchase the equipment necessary to undertake materials testing; the personal stipend enabled Webb to dedicate more time to the study.

The diversity of projects supported by MERIWA is reflected in a project on renewable energy conducted by Dr Stephanie Jennings at Murdoch University (and later at Western Power's Sustainable Energy Branch). Jennings used scholarship funds to develop a computerized design tool for solar and wind energy power supplies in isolated applications, contributing to superior system design and operations. In 1995, with assistance from MERIWA, Jennings also had her work appraised and reviewed by internationally-renowned researchers attending the International Solar Energy Research Society conference in Harare, Zimbabwe, in 1995. As Jennings explained the application of her work:

> Having since worked in the field and seen numerous solar-genset-battery systems in remote communities, I can see the design errors and their consequences. I have since used this tool in my work to design new systems for remote Aboriginal communities.[117]

Clearly, there were immense benefits for researchers in establishing and maintaining contact with established workers in a particular field, and the building of bridges between public, private, and academic sectors was a task at which MERIWA excelled. As Hackney commented, 'perhaps the most important MERIWA contribution has been encouraging and facilitating links between industry and academia'.[118] Brauhart also underlined the value of this powerful connection:

Minister for Mines George Cash (centre) with MERIWA's 1995 scholarship winners Christopher Warris and Emer O'Gara, 22 February 1995.

> I am aware that MERIWA supports my industry to the tune of many millions of dollars, and, based on the difference that $20 000 has made to my project, I can only imagine that MERIWA's indirect contribution to our State far outweighs the millions spent to support this fine institution.[119]

The Minerals and Energy Research Institute of Western Australia has grown in stature over the past two decades, and this growth has reflected the expansion of the minerals and energy industries and their need for specific and practical research to overcome challenges. Over this period, more than 220 projects with a total cash value of $30 million were managed and successfully completed through WAMPRI and MERIWA, and the results have been used extensively. In 2001 alone, thirty projects were under management worth $7 million, with most of the research being carried out in Western Australian

universities and at the CSIRO. As Colin Branch observed, these projects have facilitated the growth and progressive development of the intellectual and professional base in this State:

> Many academic research careers and reputations have been enhanced internationally by involvement with successive MERIWA projects, with the added bonus that initial junior collaborators and post-doctoral research assistants have subsequently become senior researchers in their own right.[120]

MERIWA's supplementary scholarships to PhD students had also encouraged more students to become involved in minerals and petroleum research, and the achievements of recipients had further contributed to the enhancement of Western Australia's international reputation as a centre of excellence for minerals and petroleum research and innovation.

Branch believed that the institute's fundamental processes had been a significant factor in its success. He pointed out that research priorities had not been applied to the distribution of MERIWA funds, with the germination of ideas coming from elsewhere. Researchers, he noted, 'are the ones with some sort of research idea; they know that if they want MERIWA support it has got to be an applied one that industry will respond to.' Therefore, 'they will generally tailor their ideas to what they believe to be the needs of industry.' In other cases, a company may approach a researcher noting a particular difficulty encountered in its operations; the 'problem' then becomes a research opportunity, involving perhaps a group of interested companies seeking matching MERIWA funds for the initiative.[121] It was significant, too, that the institute had not found it necessary to refuse a worthwhile project application due to a lack of State Government funds, although the size of individual grants was limited by annual appropriations in the State budget, ranging from a few thousand dollars to a maximum of $100,000. Projects deemed worthy of support but not funded in one year were simply carried over and reconsidered in the next, so long as they had sufficient industry sponsorship. According to Branch, projects that were refused funding focused on research that fell outside the institute's legislative boundaries. Typically, however, projects coming before the Board for final consideration were well presented because they had already encountered a number of hurdles, including discussions between the researchers and members of one of MERIWA's specialist subcommittees, and then review by the institute's major advisory committee. From the early 1990s, moreover, the institute had been 'very active in assisting those researchers who may be trying perhaps for the first time to meet with

industry, to help refine their ideas to ensure that industry will provide them with a contribution'.[122]

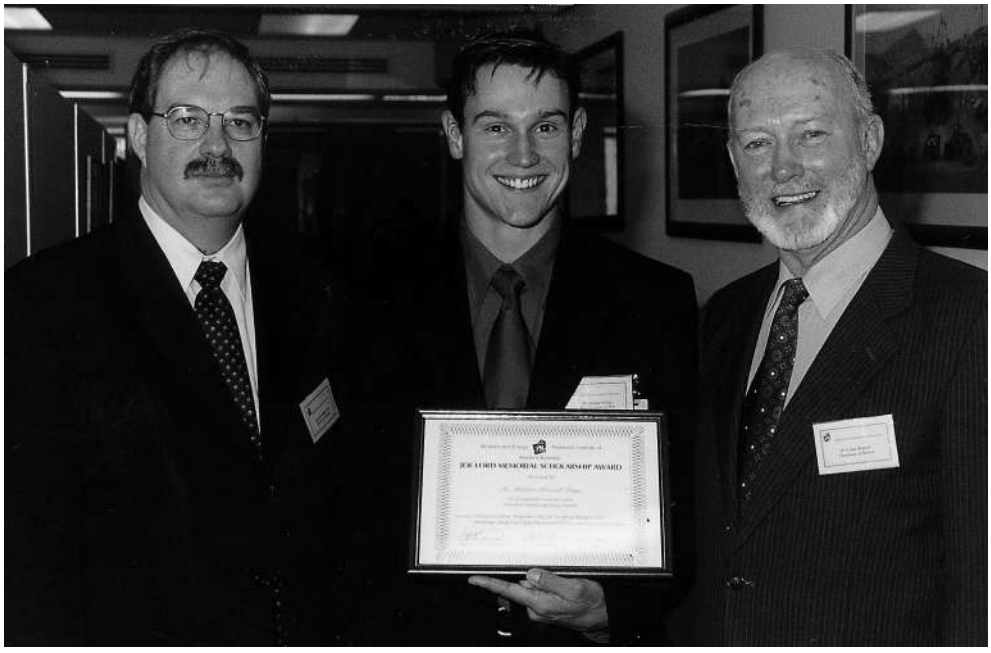
The institute faces global challenges in the twenty-first century, especially increasing competition in the mining industry. The quest of capital has driven major global mining companies to outsource exploration and research. MERIWA has attempted to counter this trend by arguing that the 'long-term wealth and success of the organization lies in continued research and exploration and not just in the short-term position of the "bottom line"'.[123] The future for MERIWA, according to board member Rex Baker, is dependent on an expansion of the amount of research it facilitates. Patently, too, the future development of the institute also depends on increasing financial support from its client industries and the State Government. While outsourcing has driven research overseas or outside Western Australia, Baker was convinced that there were still needs that local-based industry would be happy to see provided for from within the State:

> I think the industry in Western Australia would support the capacity to undertake large and often complex research projects locally, and not necessarily be limited by what is quite a small amount of money available through MERIWA.[124]

Baker predicted that the institute would reflect on its past style and achievements to evaluate its prospects and set its path for the future. It was possible that changing industry needs and research institute capabilities could precipitate the evolution of MERIWA into a larger scale organization capable of facilitating world-class research on a global scale. Baker continued:

> There's a new and better role for MERIWA… We've got to keep our minds open about how MERIWA could change... I think it should change... We can continue to spend our annual allocation on small-to-medium sized projects, but I keep wondering whether that is what the industry really needs... I think the budget should be measured in millions of dollars in keeping with the prospect of satisfying much more of the industries' research needs locally in Western Australia.[125]

In the view of Dr Colin Branch, the key to maintaining long-term economic benefits was to expand and sustain the intellectual property residing in Western Australia. Through MERIWA, the minerals and petroleum industries had supported Perth-based research resulting in world-leading developments in remote sensing, computer software and virtual imaging. International industries, however, seek the best expertise wherever it may be found, and MERIWA



Presentation of the inaugural Joe Lord Memorial Scholarship award, 16 May 2001.
The scholarship was sponsored by the WA School of Mines, Outokumpu (Black Swan Nickel), Normandy Mining Ltd, Wesfarmers Coal Ltd and Delta Gold Ltd, and those pictured are Deputy Premier Eric Ripper, Alasdair Grigg (awardee) and MERIWA chairman Dr Colin Branch.

would keep striving to attract this expertise to Western Australia so that the State would be valued for both its natural and its intellectual resources. To achieve this outcome on behalf of the State Government, MERIWA sought to position itself to attract international attention through increasing the State's intellectual capital in relation to the occurrence, extraction and processing of mineral and energy resources.[126] A priority for the institute was to establish better communications between the international industry and local research and development institutions, especially through conferences, workshops and seminars, where researchers could highlight their achievements. MERIWA recognized the need to continually review and extend its strategies so that, through its activities, Western Australian researchers could operate more effectively in the minerals and petroleum 'global village'.

TWO

THE MERIWA EFFECT

2:1

The MERIWA effect

Knowledge is a resource, as much as a rich nickel province or an offshore gas field. In the social and political arenas, however, it is difficult to promote the idea that an investment in research can yield outstanding returns – that the 'knowledge resource' augments and expands our mineral and hydrocarbon potential. It is tempting for governments to undertake investments with an immediate political return; a new freeway or building, for example, can be seen by voters as tangible benefits of government initiative. The benefits of research are more difficult to demonstrate. In view of this, it is especially commendable that successive Western Australian governments have supported the work of MERIWA, that the institute's original goals have been adhered to, and that this has been successful in bringing many benefits to the resource industries – and ultimately, to all Western Australians.

While the MERIWA board has been responsible for all policy issues and the management and control of its budget, investigatory work and consideration of the merit and appropriateness of research proposals have always been carried out by the Minerals Research Advisory Committee (MRAC). With thirteen members and twelve deputy members, MRAC represents the broad base of academia and industry; the detailed examination of projects is evaluated by one of its five subcommittees, the members of which receive no fee.

In 2001, studies relevant to mineral and petroleum exploration made up almost half of MERIWA's research projects, with the balance spread between

mineral processing, environmental, mining engineering and energy-related projects. Mineral exploration projects have covered such diverse fields as remote sensing of chemical changes, often known as alteration haloes around mineral deposits, gold ore deposit characteristics, geochemical exploration using mobile metal ions, and geophysical exploration using electromagnetic, magnetic, and induced polarisation techniques. All of these projects yield data, ideas or techniques that are rapidly taken up by the majority of exploration groups, especially the smaller companies that cannot carry out their own in-house research. It is often these smaller groups that apply new research results quickly and are more innovative in their approach to exploration, resulting in higher success rates.

Petroleum-related projects have included detailed, geographically limited studies as well as broader studies of widespread interest to the industry. Research fields cover a wide spectrum of disciplines, including stratigraphic and tectonic evolution of basins, petroleum geochemistry, palynology, and seismic processing. The research has included studies in all the major sedimentary basins of Western Australia, including the North West Shelf.

In the mineral processing field, MERIWA-funded research has investigated aspects of platinum group element mineralogy of nickel sulphide ores, mineralogy of arsenical gold ores, thickener technology, and selective flotation of Mt Weld phosphate ore. Once again, the spread of research topics benefits the entire mining industry, and results are rapidly transferred to interested parties throughout the size spectrum of industry participants.

Mining engineering projects also cover a wide spectrum of activities. Published reports have discussed findings on mine safety, mining hygiene and tailings disposal, groundwater supply and recharge in the Eastern Goldfields, open pit blasting issues, monitoring systems for open pit wall deformation, and underground testing of electronic distance measuring equipment.

The environmental area has also been well addressed by MERIWA research, particularly in the field of mine revegetation. Some early benchmark research on revegetating mine dumps in Kalgoorlie, with subsequent follow-up research, has provided guidelines for revegetation and dust abatement programs throughout the arid zones of the State. Such studies have included germination and propagation characteristics of a range of native plants, and some disease problems that are relevant to both arid area and coastal wetland environments. These studies again make vital information available to the smaller operators that do not have the resources to investigate these important issues in-house.

The Western Australian Chamber of Minerals and Energy believes that the global mining industry – and the Australian mining industry in particular – is

Hovercraft showing personal safety equipment, 1994. This was used during a project researching saline tailings disposal, a report on which was presented in March 1998. (Project M241)

faced with challenges not previously experienced in modern history. It suggests that funding for mining development has been significantly eroded by the industry's apparent lack of competitiveness in the equity markets. This is a consequence of the advent of the so-called 'new economy'. The industry is not currently seen in its true light by the investment community, equity markets, and prospective new professionals entering university for the first time. In more recent times, the industry has failed to attract sufficient school leavers to the mining disciplines to support industry and its management into the future. This is a phenomenon that is not exclusive to the Australian mining industry, but one that has been felt throughout the world. The Chamber of Minerals and Energy believes there is little doubt the industry will contain, and eventually overcome, the many adverse factors threatening it. In the meantime, it is important to ensure that it remains relevant and continues to strive to build resource businesses to ensure a long-term future. It is here that the chamber argues that technology is vital. More than ever, it is important to ensure that sufficient funding is provided to maintain development and research, and that research bodies are supported. The chamber acknowledges that MERIWA's

history of supporting minerals and energy research in Western Australia has provided enormous benefits, and member companies have been among the beneficiaries.

In general, MERIWA research activities are confined to collaborative, focused projects that are clearly of direct relevance to the resources industry. Some of these projects are discussed in the ensuing chapters, which survey the work of the institute's subcommittees on Mining and Engineering (Chapter 2), Geoscience (Chapter 3), General (Chapter 4), Hydrocarbons (Chapter 5) and Mineral Processing (Chapter 6). Project numbers or references to research reports are appear in parentheses throughout the text.*

*MERIWA managed alternative energy research projects until 1 July 1995 when these activities were transferred to the Alternative Energy Development Board (AEDB) established in the Office of Energy, as recounted on p.45. Legislative changes have not yet been enacted to allow AEDB to operate autonomously, and funding by government is still provided through MERIWA. As MERIWA has no management role in the alternative energy projects supported by AEDB, this aspect of MERIWA'S activities is omitted from this history.

2:2

Understanding vast forces

Even with modern technology, mining can be a hazardous occupation, and a significant proportion of the research supported by MERIWA has been dedicated to making the industry as safe as possible. Some projects have also addressed issues related to broader questions of health and safety, affecting the wider community.

Consider the vast forces at work in the geology of a mine: the millions of tonnes of rock, the possibility of movement and the effect of mine workings. These forces have to be understood if mining is to be carried out with a maximum amount of safety, and the science of geomechanics is applied to this task. In the early 1980s, rockbursts became a particularly worrying hazard associated with underground mining. While rockfalls are non-violent falls of loose rock due to gravity, rockbursts are violent failures of brittle rock stressed to their threshold. Such violent seismic events can result in considerable damage and threaten the lives of mine personnel.

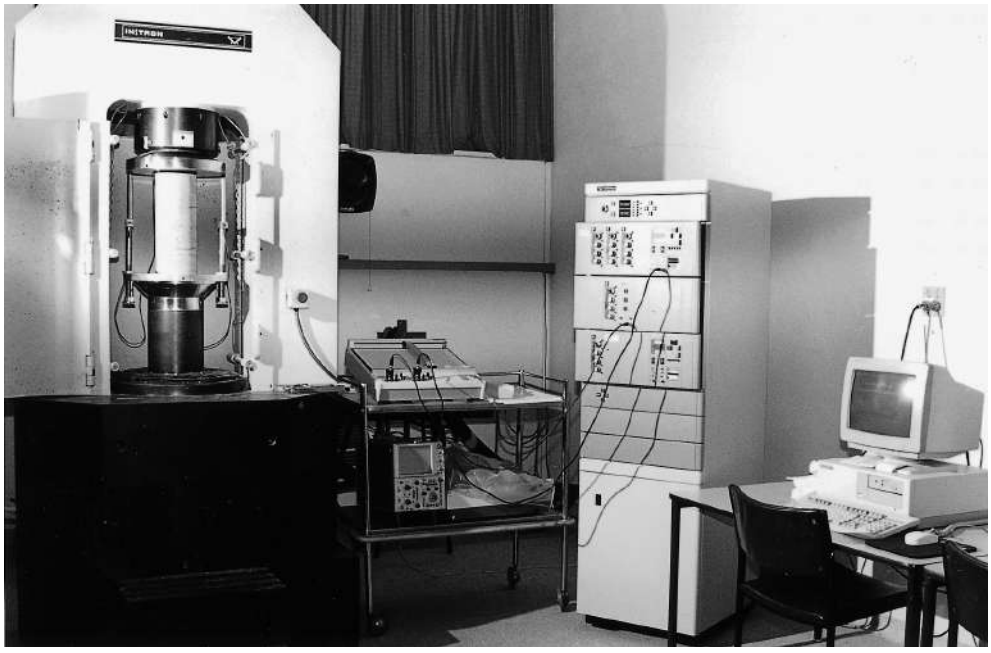
One of MERIWA's earlier research projects investigated the behavioural characteristics of Eastern Goldfields rocks when exposed to high stresses under controlled conditions in the laboratories of the Western Australian School of Mines. Such experiments, however, can only be carried out on relatively small rock specimens which tend to give higher strength values than is the case for rock in a mine. It follows that as the specimens increase in size, the strength properties become more closely aligned with that of rock in situ. The research project examined this issue, as well as the behaviour of rock specimens as they

failed. (Report 80) The results tested the 'burst proneness' of porphyry and basaltmafic specimens from the Long Shaft nickel mine at Kambalda, and of dolerite samples from the Mt Charlotte gold mine at Kalgoorlie. The research report concluded that the strength of rock specimens of 150mm or more in diameter approximates to the strength of intact, *in-situ* rock.

By the mid-1990s, rockbursts were much more prevalent and serious as more underground mines were sunk to deeper levels, where the rocks were more highly stressed. Short courses and seminars on the general topic of seismicity in mines were held, and an increasing number of seismic monitoring systems were installed in Australian mines. Following this, the Australian Centre for Geomechanics at the University of Western Australia attracted industry and MERIWA sponsorship for a continuing Australia-wide project studying 'mine seismicity and rockburst risk management'. (Project M328) Seismic events have been monitored at the Mt Charlotte, Big Bell, Darlot and Junction mines in Western Australia's Eastern Goldfields. The project's long-term goal is to develop a flexible and adaptable system for assessing the hazard and damage potential of mining areas, allowing engineers to minimize the risk in burst-prone areas by improving ground support, minimizing the exposure of mineworkers, and adopting more appropriate mining systems.

Another continuing project of major significance to the safety of underground miners deals specifically with the minimization of rockfall fatalities. This has attracted sponsorship from twelve mining companies and MERIWA, and entails the collection and collation of information on rockfalls from mine-sites, consultant files and regulatory authorities. The causes of rockfalls are analysed and a standard data collection form has been designed. This work, carried out at the Australian Centre for Geomechanics, will lead to a better understanding of the causes of rockfalls and the associated hazard to mineworkers. (Project M341)

Another mine safety project proposed to examine the corrosion of rock reinforcement elements, such as rock bolts used in underground excavations. Falls of ground in Western Australian mines have often been shown to result from the failure of the ground support elements, due mainly to corrosion. It was anticipated that this work, carried out at the Western Australian School of Mines with the support of the Western Australian Corrosion Research Group at Curtin University of Technology, would lead to design and operational guidelines for the better use and monitoring of rock reinforcement systems. (Project M333) The total value of this and the two geomechanics projects on mine safety mentioned above was $1.23 million, with MERIWA's contribution being $224,000.



A rock testing machine with control console, used in a study of the mechanical properties of Goldfields rocks during 1990. (Project M149)

Another project dealing with occupational safety and health issues related to the protection of hearing in noisy working environments. This involved the development of an 'ear defender' at The University of Western Australia's Department of Mechanical Engineering. This 'ear defender' can be adjusted to selectively cancel out noise frequencies generated by mechanical equipment while ensuring that the frequencies of warning signals and person-to-person communication remained unaffected. A prototype ear defender was successfully developed providing reduction in tonal noise transmission and periodic impact noise. This novel development was expected to be of great value to people working in environments with high levels of machine noise. (Report 167)

Occupational health and safety was also the central interest in a study of the inhalation of a radioactive isotope radon at mineral sands mining sites. Examining the hazard of thorium inhalation for employees, this project involved the design and construction of a 'thoron-in-breath unit' for use at five processing sites, where sixty-two employees were tested. (Report 117) As a result, six employees with high recordings in their lungs were sent to the Australian Radiation Laboratory in Melbourne for more extensive testing, and two were assessed as receiving an average annual internal radiation dose above

the existing standard. Both had worked in the dry separation plant for more than fifteen years, and it was assumed that most of their inhaled dose had occurred prior to 1986, when detailed assessments of intake commenced.

Projects of community interest are typified by the study of blast vibration and 'airblast overpressure' in the Eastern Goldfields, carried out at the Western Australian School of Mines. (Report 53) One study related to the effects of blasting operations on the residential and business community in Kalgoorlie/Boulder. It resulted in the development of blasting techniques and monitoring systems which allowed for the continuous operation of the Super Pit, a large open cut mine close to residential areas. It is also important for community reasons to ensure that saline tailings at gold mines are disposed of in an environmentally-acceptable manner. A project dealing with this issue examined all aspects of the behaviour of gold tailings at a number of sites, with the objective of establishing an economically viable decommissioning and rehabilitation strategy acceptable to the community and regulatory authority. The project addressed such issues as the physical properties of the tailings, depositional techniques, the impact of tailings storage on groundwater conditions and the resistance of storage to erosion. The research work was carried out by the Geomechanics Group at UWA and the Western Australian Geological Survey, under the aegis of the Australian Centre for Geomechanics. It involved a combination of laboratory, field consolidation and evaporation experiments and site investigations at both active and decommissioned sites. (Report 189). The study demonstrated that many of the potential environmental problems associated with tailings storage can be prevented by good design and efficient management, the essential features of which were clearly defined in the final report.

In the area of industrial efficiency and competitiveness, two projects are worthy of special mention. The first relates to the study of subsidence in the strata overlying the coal seams extracted in the Collie Basin and the other to the factors influencing the safe tow-out of the large 'Concrete Gravity Structures' required by the offshore oil and gas industry from our casting basins at Bunbury and Jervois Bay. In the Collie Basin, the Permian sediments overlying the coal seams are very weak and contained a number of aquifers. Consequently only partial extraction 'room and pillar' methods were being used for operational and safety reasons. However, due to pressure for the development of more efficient mining systems there was a need to have a better understanding of the effect that higher extraction systems would have on strata behaviour. A trial extraction panel was therefore designed employing a method which could increase the coal mined by from 35 per cent to 80 per cent with existing mining

equipment. This research work recorded strata subsidence over numerous coal extraction panels using conventional surveying techniques on the surface and measuring the displacement of anchors located at various depths in carefully positioned boreholes. These *in-situ* measurements were complemented by carefully designed laboratory experiments employing a newly purchased centrifuge at UWA. The primary aim of the research work was to develop a composite model based on *in-situ* measurements as well as empirical, mathematical and physical modelling techniques so that surface and sub-surface subsidence effects could be predicted above the higher extraction mining panels. This objective was achieved by the researchers and allowed for the successful extraction of coal beneath a dual carriage haul road and pipeline whilst minimizing water inflow into the mine. (Report 156) Despite the fact that underground coal mining has been discontinued in WA, the research work is valuable within a world context since its findings enhanced our understanding of the subsidence processes occurring in weak strata overlying high extraction coal panels.

Another area of important research for the local construction industry servicing the offshore oil and gas sector is the study of factors influencing the safe towing of concrete Gravity Based Structures (GBS) through the narrow shallow channels leading to the ocean from 'casting basins' at Bunbury and Jervois Bay. The first of these projects, carried out by UWA's Centre for Oil and Gas Engineering, focused on developing a preliminary guide for designers on the required still-water 'under keel clearance' (UKC) and still-water 'water plug height' (WPH) of air lifted concrete GBS with skirts for float-out through very shallow water in a calm sea. (Report 185). Only one GBS has so far been constructed in Western Australia, the Wandoo B platform at Bunbury, before being successfully towed to the open sea through a 2.5 km dredged channel. The draft of the structure was 10.74m which gave a bottom clearance of 1.45m, and although the structure collided with the seabed during the tow it sustained no damage. The other location for a casting basin is Jervois Bay, where the channel to the open sea will be approximately 5 km long, with a water depth of 14.7m. The physical limitations at both these locations influence the size of Concrete Gravity Structures (CGS) that can be built in WA. This problem is compounded by the deep 'skirt' requirements of structures required for the North West Shelf due to the soft calcareous sediments on the seabed. One solution to this problem, which is the subject of further research, is to increase the under-keel clearance during tow-out using air cushions in the 'skirt' compartments. However, this may increase the instability of the structure during tow-out as a result of the structure's dynamic response to the waves running into the channel from the open sea.

Wandoo B-Platform being towed out of Bunbury Harbour as modelled in a Mining and Engineering Sub-Committee project, 1997. (Project M291). Courtesy of Mobil and SKS Corporate Photographers.

Researchers sponsored by MERIWA have also worked offshore in a project related to the wellbeing of marine life, involving North West Shelf hydrocarbons. Most North West Shelf crude oils are highly volatile, a characteristic not shared by most of the northern hemisphere oils on which internationally accepted toxicity tests protocols were developed. Because of this volatility, the values obtained from toxicity tests are significantly affected by the evaporation of highly volatile and less toxic components of the test solutions during measurement. Company staff and regulatory agencies use results from these tests to estimate environmentally-safe levels of toxicant exposure to the marine environment. The purpose of this project was to improve the accuracy of these estimates by developing a standard approach that negated product instability and a protocol for assessing likely environmental impacts of weathered oils. (Report 220)

Another area of industry concern addressed by this work related to the biodegradability of drilling muds. Before this study commenced, test procedures then in use gave variable and often erroneous results. All previous work on this problem involved Northern Hemisphere test organisms and conditions. There were no test protocols for tropical organisms of specific relevance to the North West Shelf and there was also a lack of biodegradation test protocols for tropical conditions. The project successfully addressed those deficiencies.

2:3

The ground beneath our feet

Understanding the ground beneath our feet is a continuing task, with the disciplines embraced by geoscience making an impressive contribution to this knowledge. It is a quest that is particularly challenging in Western Australia because surface indications have been largely obscured by geological events.

MERIWA's geoscience subcommittee presides over grants that assist current exploration, but also take a longer view. Geoscience projects supported by the committee generally fall into one of three categories. The first of these is 'tactical research' projects directed to immediate problems of mineral exploration, the application of new approaches and ideas that would not normally be followed by industry in its day-to-day exploration activities. Secondly, the institute supports projects examining strategic concepts, such as the development of new models for mineral occurrences and background geoscience investigations providing basic input for exploration models, and the preparation of information essential for future discoveries. In the third category are a number of projects aimed at achieving a more developed understanding of mineral behaviour and analytical techniques, essential in advancing the effectiveness of mineral exploration.

Some of the projects which can be included in the first category, tactical research, examined the application of helium in uranium exploration (Report 4), and the application of lead isotopes in gold and base metal exploration. (Reports 2 and 11) Others have studied electromagnetic techniques and the

applications of structural geology in mineral exploration, (Reports 24, 29, 72, 102, and 146); and the uses of trace element geochemistry. (Reports 14, 18, 22, 153, 184 and 206) A group of projects explored the uses of mineralogy and geochemistry in exploration for a number of materials. (Reports 32, 43, 67, 123 and 176)

The discovery of new mineral deposits is vital for the long-term viability of the mining industry. However, the discovery of new deposits is not easy in Western Australia as much surface rock is extremely altered and leached by weathering so that surface expressions of mineral concentrations are lost. For this reason, it is necessary to explore using geophysical and geochemical techniques. One method employs chemical signatures produced by the dispersion of target elements away from potential ore deposits by the movement of ground waters. MERIWA has actively supported geophysics projects including the application of electromagnetic techniques in exploration, led by John Coggan of the Western Australian School of Mines. (Report 72) New work in this area includes innovative concepts to provide images of important structural boundaries and geometries in mineral-rich ranges, such as iron ore in the Hamersley (Project M282) and gold in the Yilgarn. (Project M349) MERIWA has also supported a number of projects on geochemical exploration. Among the prime examples are projects on mobile metal ions led by Dr Alan Mann, director of the Geochemistry Research Centre. (Reports 153, 184 and 206) In this research, it was found that loosely held trace elements in regolith materials (part of the blanket of weathered rock and soil) defined sharp geochemical anomalies to pinpoint hidden minerals.

The Geochemistry Research Centre has carried out a number of projects with the support of MERIWA. Eleven companies were involved in work related to the existence and potential usefulness of soil anomalies derived from the painstaking extraction of metals from soils. This led to a better understanding of soil anomalies, effectively a valuable tool in exploration. (Report 206) The centre's findings were later confirmed by a Canadian research group, and the technique developed is now used in more than twenty countries. Research on lead isotope applications for gold and base metal exploration by a research group at the University of Western Australia, led by Dr David Groves, showed that large base metal occurrences were characterized by uniformity in their lead isotopes compared with surrounding host rocks, so that the lead isotopes could be used to detect a likely base metal occurrence. (Reports 11 and 22)

An interesting technique used in exploration for some minerals is the monitoring of gases. Studies of mercury vapour have been used in gold exploration and, similarly, helium detection has been applied in uranium exploration with varying amounts of success. The testing of helium as an exploration method for

Michael Spurge, of the CSIRO's Division of Mineralogy, sampling water for helium analysis from an abandoned stock well in 1982. (Project 17)

uranium in Western Australian conditions by a CSIRO group, led by Dr Charles Butt, was an important MERIWA-sponsored contribution. (Report 4) The decay of uranium to lead releases helium, and a high concentration of helium in the soil indicates the presence of uranium or thorium in the rocks below. The CSIRO research involved innovative sample testing using a mobile mass spectrometer. Conclusions from the study – that the technique had significant problems standing in the way of its use in routine exploration – serves as a fine example of those situations where a negative conclusion can be extremely valuable in defining future exploration strategies.

In a different vein, MERIWA has supported research on adding value to ores through processing – and has also assessed the potential uses of by-products. One sponsored project demonstrated the presence of platinum elements in Kambalda nickel ore. (Report 18) Platinum group elements such as platinum and paladium are high value products, and the recovery of these elements, in addition to the nickel, has the potential to add value to the ore.

Strategic research – taking 'a longer view' – has formed a major component of some MERIWA supported projects. These include investigations in a number

of sub-disciplines for prospective areas. Strategic research into the application of databases on the characteristics of mineral deposits and the modelling of mineral occurrences has received support, and projects focused on understanding element behaviour during the weathering processes have also been strongly supported by industry and MERIWA. (Reports 67, 106 and 206) Experimental and analytical studies of mineral behaviour and the migration and concentration of gold and other elements have also been important avenues of research. One examined the exfoliation of vermiculite, which greatly expands when heated, making it very useful as insulation. (Report 23)

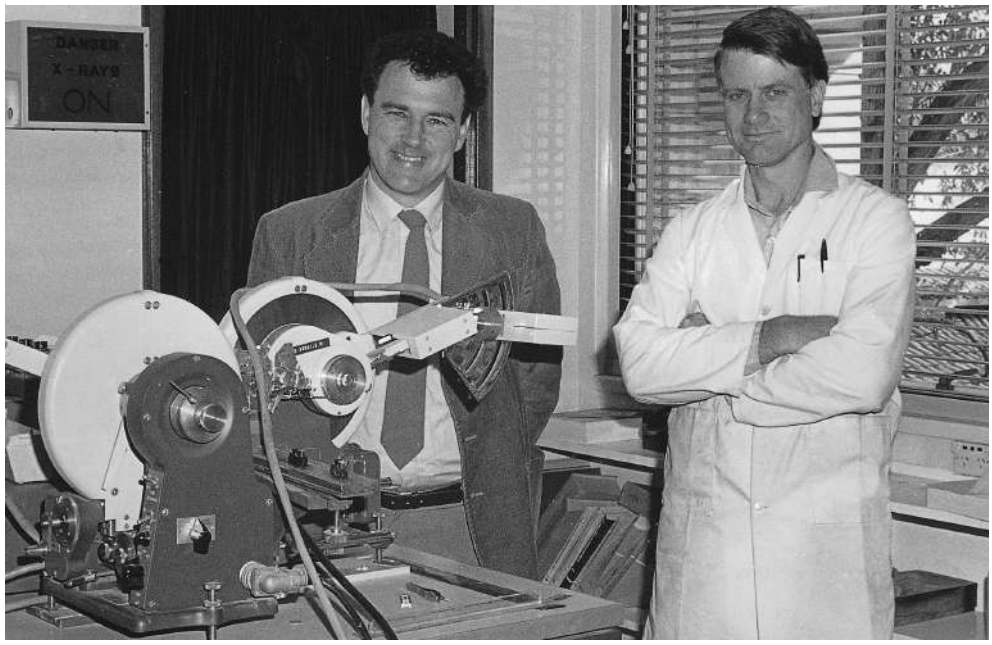
There have been a number of projects studying the importance of geology on mineral occurrences, such as the project on large-scale shear zones and their control of gold mineralization. While the location of gold deposits in shear zones is well known, the reason for this has not been adequately explained. (Report 122) Another example of the value of detailed geological investigations for mineral exploration is a study of the stratigraphy and structure of the State's nickel deposits, which led to a clear understanding of the origin of nickel sulphide ores as released components of high magnesium lava flows, and helped formulate ideas on further exploration. (Reports 32 and 68)

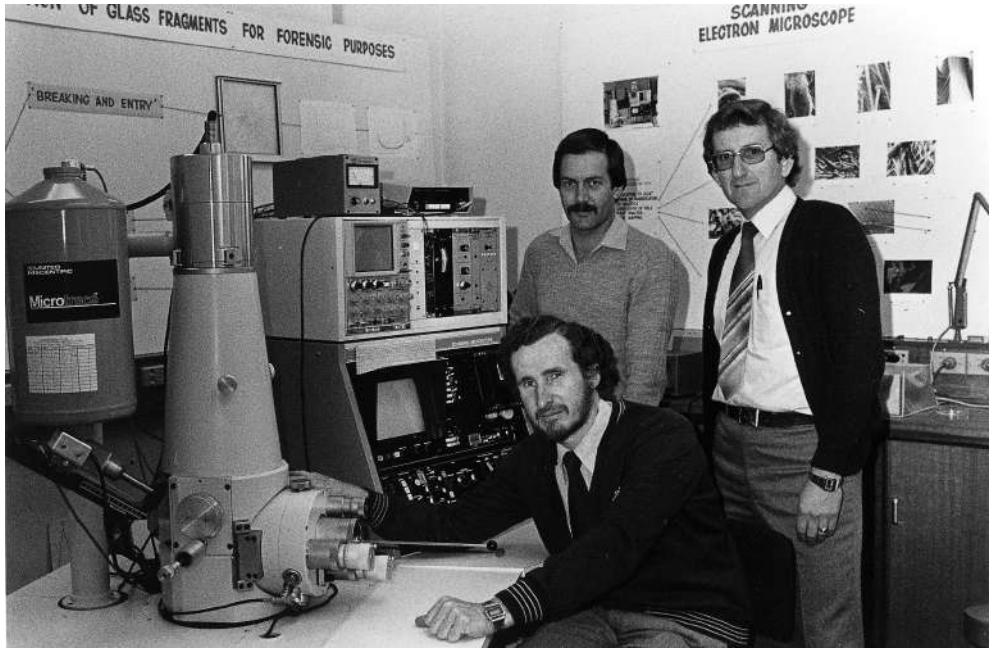
The use of databases to collate and classify information on all aspects of known mineral deposits to assist in the generation of models for further exploration has been the theme of a number of projects. Studies have also been completed on the timing of mineralizing events in the Yilgarn and Pilbara regions. It had been understood that there was widespread volcanic activity in the Yilgarn approximately 2.7 billion years ago. Research work sponsored by MERIWA found that there was also an episode of such activity about three billion years ago in the Murchison at Golden Grove, and in the Twin Peaks and Tallering greenstone belts – all areas of attractive mineralization. (Report 27) It is a measure of the widespread importance of geoscience that such a time scale has great relevance to contemporary exploration.

An indication of the importance of MERIWA for the future is indicated through a project that demonstrates the increasing role of information and communications science and technology to the resources industry. Improved exploration and exploitation of mineral resources will evolve from the better management and use of data, and the interaction of all geological, geochemical and geophysical data will inevitably lead to better interpretations of 'what's there'. A MERIWA-sponsored project led by Dr Simon Cox, of the CSIRO, is addressing this issue, with the research group working on the development of eXploration and Mining Markup Language (XMML), which provides a uniform format for the transfer of technical data in geoscience and mining – an electronic

Top: Associate Professor Robert Gilkes (left) and Dr Brian Smith in the laboratory of the Department of Soil Science and Plant Nutrition at the University of Western Australia in 1983. (Project 33)

Bottom: Arie van Riessen, David Vowles (seated) and Keith Terry (right) pictured during their study of a semi-micro analytical technique in mineral exploration and ore genesis studies, 1982. (Project 14)





lingua franca. (Project M340) Because it is based on XML, the data format of the World Wide Web, with other commonly employed derivatives, exploration and mining data can be managed using standard web interfaces. The project has brought international recognition to Dr Cox and his group, and Cox plays a major role in the OpenGIS Consortium, the global body working for wide access to data, which has more than 250 members drawn from industry, academia and government.

It is MERIWA's charter to support research in the mining industry and also to provide the mechanism for researchers and industry to work closely together. The wide variety of industry-supported geoscience projects over the years is testimony to its success. Since 1984, a total of fifty-two geoscience projects have been successfully completed, with funding of more than $6 million; significantly, more than two-thirds of the cost has been contributed by industry. This level of industry support highlights the value companies place on research, and also underlines the importance of the role MERIWA plays in coordinating, as well as supporting, practical research relevant to the mineral industry.

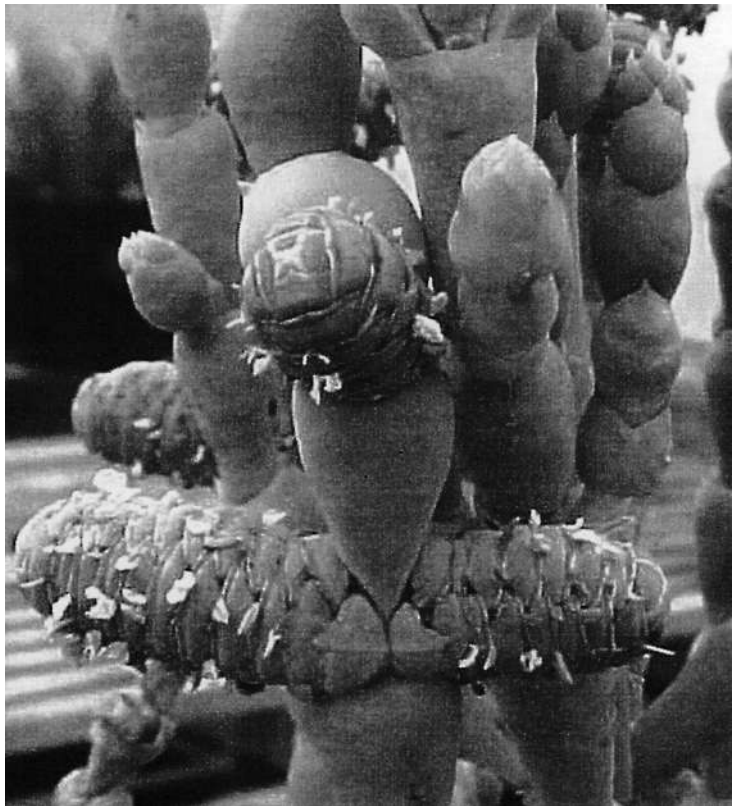
2:4

Restoring a reputation

In the past, the mining industry has been perceived to be indifferent to environmental issues and to have contributed to the degradation of the Australian landscape. While this may have been so, its record in recent decades in ameliorating the effects of mining, in preserving the fragile Australian ecology, has been impressive – though often overlooked.

In many cases, environmental research sponsored by resource companies, often with the support of MERIWA, has had benefits far beyond the immediate area of concern. The institute has dealt with a wide range of research projects over the past twenty years. The majority have covered a broad spectrum of environmental and rehabilitation issues, and there have also been a number of significant occupational health and waste management projects. The general subcommittee of the institute has recommended thirty-five research projects for government support, and has examined many more. This has resulted in a total allocation of almost $1.5 million of MERIWA funds attracting more than twice that amount from industry sources – a leverage of more than two dollars from industry for every government dollar. Due to the unique nature of Western Australian flora, a majority of mining rehabilitation issues are specific to the State. MERIWA sponsorship has therefore made a significant contribution to the development of a local research base for the local mining industry.

There has been wide 'cross-fertilization' with other research organizations, the Botanic Gardens and Parks Authority being a good example. The institute



The characteristic opposing inflorescences in *Tecticornia verrucosa*, showing the free bracts and exerted anthers and stigmas of the tiny triads of flowers. This plant was studied as part of research into the rehabilitation of salt affected mining lands, completed in 2002. (Project M312)

has contributed to about ten projects undertaken by the authority, covering a wide range of topics. Restoration and regeneration are of paramount importance in temperate Australian ecosystems, and direct financial assistance from organisations such as MERIWA has resulted in research and development providing significant breakthroughs. About half of the institute projects in this field have been concerned with mining rehabilitation and associated issues such as seed germination. (Reports 66, 94, 112, 121, 158 and 163; and Project M321) Some have applied techniques which appear bizarre to an outsider, such as the use of smoke to promote the germination of 'recalcitrant species' (the terminology used to describe those species that are difficult to restore) and to improve germination in others. (Report 174)

Restoration of plant species and communities around closed mines requires an understanding of the germination characteristics of species to optimize recruitment from topsoil and broadcast seeds. Finding cost-effective ways to generate plants on and off a mine site is also important. For many species, rehabilitation has been hampered by inherent seed dormancy characteristics, which have posed problems that are difficult or impossible to overcome using

conventional methods, and costly using advanced methods such as *in vitro* propagation. Work carried out in South Africa in 1993 suggested that smoke was a factor in bringing seeds out of dormancy for many plant species which occur in similar habitats in Australia. It was later demonstrated that smoke was also, potentially, a key agent in the promotion of germination for many native Western Australian plants. Apart from offering obvious horticultural benefits, this new and exciting procedure has been shown to be a simple and effective process for the propagation of native plants which had not responded at all, or only at very low germination rates, with conventional procedures. In this project, at least three hundred species in field and glasshouse studies responded significantly to the use of smoke, with the average improvement in germination ranging from 40 per cent to 100 per cent for a wide range of germinable seeds and up to 400 per cent for a range of recalcitrant species.

Fire plays a role in another restoration solution involving that most ubiquitous of outback plants, spinifex. These grasses dominate the vegetation cover at the Argyle Diamond Mine, but were absent from rehabilitated areas. The company's objective to return these key ecological species to disturbed areas provided researchers with an opportunity to study the restoration ecology of endemic grasses which dominate vegetation across an estimated 22 per cent of the Australian mainland. It was found that vegetative propagation methods applied to resprouting and/or clonal species provided a simple and cost-effective method of generating greenstock for restoration, and the methods have since been adapted for other grasses. In the MERIWA-sponsored project, an examination of topsoil revealed significant levels of stored seed reserves, which are triggered to germinate by the passage of fire. Further examination of post-fire seedling recruitment suggested that the removal of mature vegetation provides the predominant germination stimulus. When combined with possible additive effects, including the influx of nutrients and smoke residues to the soil following fire, this results in the establishment of seedlings in numbers often equivalent to, or well in excess of, plant densities that existed before the area was disturbed. Seeder species were found to produce large numbers of seeds with seed production tightly regulated by seasonal conditions, predominantly the magnitude and timing of rainfall events. A method was developed which determined high viability of seed from the Argyle site. This was successfully applied to other spinifex species and provided the first reliable and accurate means of establishing the viability of seed through germination in species previously reluctant to germinate – an important factor in maintaining the diversity of the spinifex species. It appears that this was the first time molecular-based genetic markers were used to delineate genomic boundaries within spinifex grasslands

to identify the extent of the local provenance. Genetic variability within the populations and species was also ascertained, while information used to design collection techniques for propagation material ensured the continuation of that diversity. (Report 200)

A study of ways to produce plants for mining restoration, particularly native heath plants, is an example of the involvement of MERIWA in a key initiative using leading edge technology. (Project M321) If this is successful, it will help in revegetation of mine sites. Another research project has examined the rehabilitation of salt-affected land around mining sites, using a native shrub which could play a significant role in checking the spread of the salinity. One of the most serious environmental problems facing Australia is the destruction of farming land by salt encroachment and solutions have proven to be elusive. While mining takes up only a tiny proportion of the Australian landmass, the industry has not ignored its responsibilities in studying salinity issues, and may yet make a significant contribution to the more widespread problem of land degradation. (Project M312)

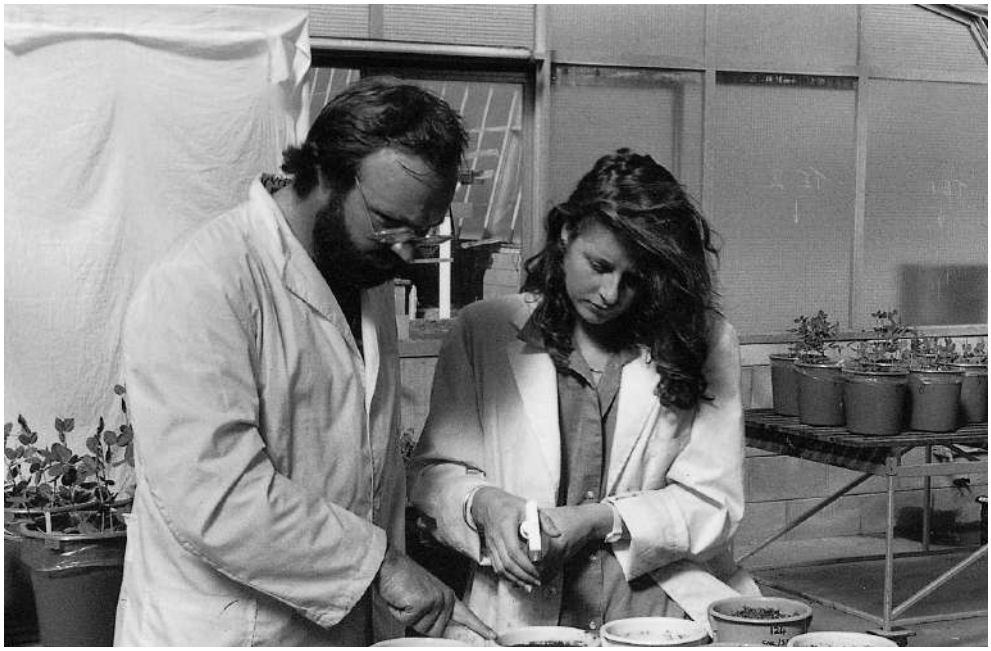
Rehabilitation requires propagation material for a wide range of species and clonal selections on a scale not likely to be achieved using current propagation technologies. The research group has established an international reputation in the use of tissue culture for propagation of recalcitrant native Australian plants, and has developed the first stages of the final frontier in plant propagation in bringing a specialist type of embryogenic technology to Australia. A well-established mass propagation tool used successfully overseas for a broad range of forestry and horticultural applications, this technology has the potential to revolutionize traditional approaches, particularly for species difficult to propagate in particular habitats. Through its use, greenstock and seed may be provided for large scale plantings, overcoming such problems of limited seed and lack of species selection, and eliminating dormancy problems associated with seed propagation for many key species required for land rehabilitation.

Another direction for research which has attracted a number of projects is understanding the biology, ecology and the control of the spread of *Phytophthora*, induced dieback disease in mining and rehabilitation areas in the south of the State. One study examined the biology and ecology of *Phytophthora citricola* in native plant communities affected by mining. *P.citricola* (Sawada root rot) is well established in plant communities in south-western Australia, particularly in the sandplains north and south of Perth and the jarrah forest. *P.citricola* has frequently been isolated from dead and dying jarrah seedlings on rehabilitated bauxite-mined pits in the jarrah forest, and from a host of species from the northern sandplains. A survey showed that *P.citricola* is positively associated with forest roads, with recovery of *P.citricola* declining

Atriplex semibaccata seedlings alongside the smaller *Rumex vesicarius*. The management of *R. vesicarius* was significant in the rehabilitation of mine sites. (Project M332)

away from the road into the adjoining forest. *P.citricola* readily produces oospores, which enable it to survive in the absence of host material, and over extended dry and hot periods in situ. The efficacy of phosphonate against *P.citricola* was examined using *Banksia prionotes*, and successfully inhibited lesion development in all isolates tested. (Report 151)

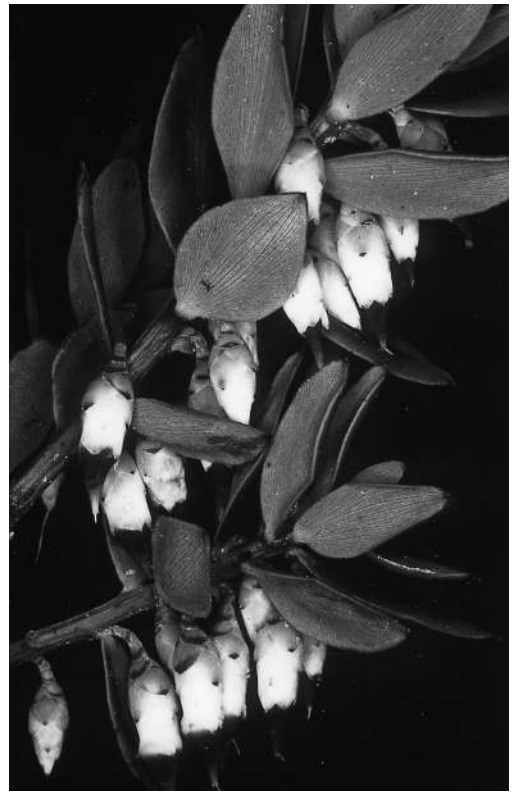
Yet another project found that identification of species of *Phytophthora*, other than *P.cinnamomi*, by traditional morphological means can take between four weeks and several months. This work developed isoenzyme procedures and protocols which discriminated between Western Australian field species of *Phytophthora*, and compared the isoenzyme method of identification with the traditional method of accuracy, turnaround time and cost per sample. The report sets out methods developed to improve the accuracy of identification of species of *Phytophthora* and to increase the sensitivity of detecting species of *Phytophthora* in samples retrieved from exploration tenements. It also describes methods to determine the levels of sampling necessary to achieve given degrees of certainty for detecting *Phytophthora* when present, and to reduce the number of 'false negatives' for the disease. (Report 175)



David Newsome and Jenny D'Arcy-Evans attend seedlings grown in soil mixes incorporating iron oxide wastes in 1989. A detailed report on the utilisation of wastes from synthetic rutile plants was completed in 1994. (Project M122)

Waste management is another area for which the mining industry has, on many occasions in the past, attracted criticism. Companies are now considerably more sophisticated in the ways they store and handle residues from mineral processing, and have contributed significantly to research projects that improve their practice. In some cases, the waste can be employed beneficially in other industries. An example of this can be drawn from the synthetic rutile industry, a significant success story in Western Australia in recent years. Mineral sands miners in this State have reached a high level of expertise in upgrading ilmenite to synthetic rutile, and are now the biggest producers of synthetic rutile in the world. However, the direct reduction technology produces about 250,000 tonnes of iron oxide annually, one of two types of waste, the other being a neutralized acid effluent. Both contain microcrystalline iron oxides, with gypsum and calcite being important constituents of the neutralized acid effluent. The small crystal size of these wastes, and hence large surface area, along with low heavy metal content and a substantial capacity to retain phosphorus, make them suitable ameliorants for sandy soils where leaching of phosphorus is an environmental problem. Glasshouse experiments showed

Three plant species forming part of a study into the post-mining re-establishment of native heaths, completed in 1992. *Clockwise from top: Andersonia involucrata*, *Conostephium pendulum* and *Lysinema ciliatum*. (Project M129)



that the addition of 5 per cent to 10 per cent wastes to sandy soils greatly reduced leaching of fertilizer phosphorus and consequently increased plant growth by up to 60 per cent. Field experiments at five locations demonstrated that additions of 5 per cent of iron oxide wastes to sandy topsoils increased the effectiveness of phosphate by 60 per cent at Eneabba and 10 per cent at Capel. Additions of 10 per cent of neutralized acid effluent increased the effectiveness of phosphate fertilizer by 40 per cent at Gingin and 30 per cent at Vasse. Heavy metal contents of plants were well below those considered hazardous to animals and no environmental hazards should develop from the application of these wastes to well-drained soils. These results offer considerable promise in employing wastes to improve soils, although their use may be constrained, to some extent, by transport costs. (Report 84)

Another product of direct reduction technology in the mineral sands industry also has potential. Further work on the neutralized acid effluent stream from processing showed that it precipitates to produce gypsum containing iron and manganese. The aim of the project was to measure the effectiveness of this material as a sulphur fertilizer in high rainfall sandy areas. 'Ironman gypsum' pellets, as they have been named, enabled residues of sulphur to remain in the soil for at least two years. Annual applications would result in the good early supply of sulphur from residues of the previous year, and sustained release from the fresh pellets would support production to the end of spring and carry over into the following autumn. The pellets proved to be more effective than naturally-occurring fine gypsum. Results of this research showed that the persistence of the Ironman gypsum pellets would make it suitable in situations where reapplication of fertilizer is not possible in spring because of soggy conditions. (Report 179)

In more recent years, issues associated with occupational health in the mining industry have been studied. An example of this type of work examined the sampling methods used to determine dust levels both above and below ground, and made recommendations for improved procedures and revisions to industry standards based on the project's results. (Report 195) Another aimed to use historical sets of X-rays taken throughout miners' lives to contribute to the understanding of the relationship between exposure to silica, the occurrence of silicosis and the occurrence of lung cancer. (Project M289)

These studies are only a small proportion of the projects successfully completed under the watch of MERIWA's general subcommittee in the past twenty years, but indicate the exceptional contribution that has been made to the Western Australian mining industry.

2:5

Another Great Barrier Reef

The first research project approved by what was then WAMPRI could hardly have been more successful. Sponsored by thirty-one oil and mineral exploration companies, it produced a surplus sufficient to finance several other projects. This is believed to be a record among the more than two hundred projects sponsored by WAMPRI and MERIWA, and was an emphatic indicator of the institute's great potential. The applicant, Dr Phillip Playford, was a leading figure in mining exploration in Western Australia, and his series of projects examining the Devonian and Carboniferous carbonates of the Canning and Bonaparte Basins, off the far north coast of Western Australia, produced results which have won worldwide recognition. The support offered to that first application enabled an American carbonate specialist, Dr Charles Kerans, to carry out research under local supervision. The report that resulted from this had widespread implications for the petroleum and mineral exploration programs carried out in the Canning and Bonaparte Basins, and has led to considerable success. An associated project, carried out in the early 1990s with MERIWA support, examined tectonic, structural and other features of zinc and lead mineralization in the Lennard Shelf area of the Canning Basin. A number of researchers were involved in this, and the project yielded important new information which again had significant implications for exploration. (Report 12)

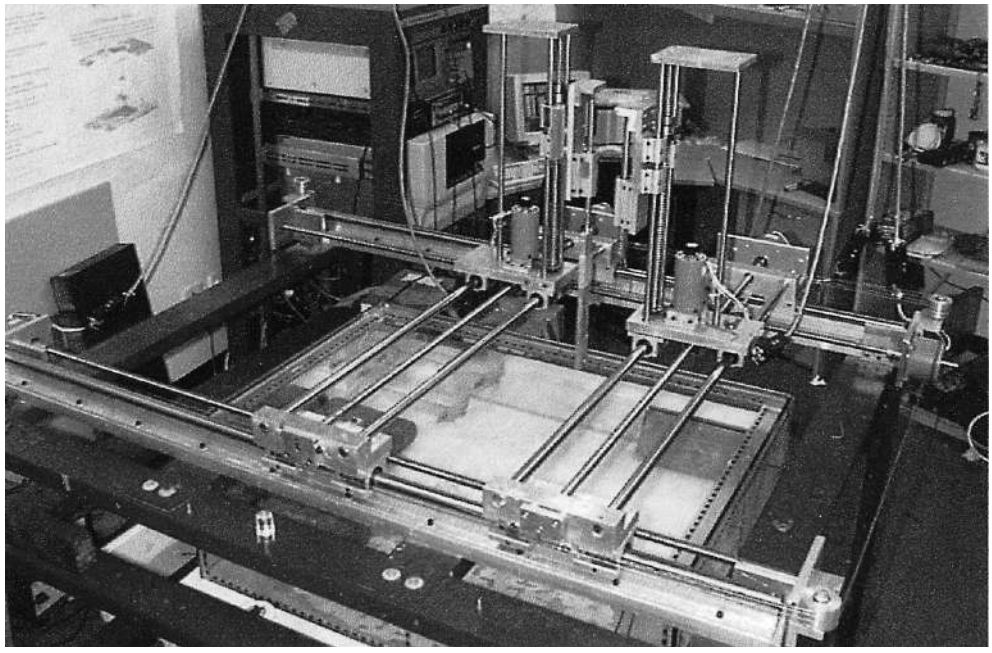
This research has confirmed that the reefs exposed in the Canning Basin are the best preserved example in the world of an ancient reef belt, and have

become known as the 'Devonian Great Barrier Reef', seen by even cautious scientists as one of the natural wonders of the world. Results of their research attracted worldwide attention, the reports becoming textbook material in some American universities. A number of excursions into the area have been arranged for scientists throughout the world, including one in 2002. The petrology of the reefs is very important to oil and mineral explorers, with oil having been found in rocks in the Blina area and zinc-lead deposits associated with this geology have been mined at Cadjebut, Pillara, Goongewa and Kapok, not far from Fitzroy Crossing. Playford believed that WAMPRI Project 1 played an important role in stimulating exploration in the area, helping in the work that led to several discoveries. The project was also important to WAMPRI because it firmly established its worth to the mining and petroleum industries. The flow-on benefits of a project approved two decades ago is demonstrated by the continued publication of maps and reports on the area.

MERIWA has also played a distinguished role in other areas of hydrocarbon and minerals research. The Petroleum and Environmental Organic Geochemistry Research Centre, formed at Curtin University in the 1970s, is recognized as having achieved international stature, with the most productive applied research group in this field in Australia. Two of the leaders of this program, Professor Bob Alexander and Professor Bob Kagi, have emphasized that WAMPRI and later MERIWA have been major supporters of this research since its inception. The institute's support has provided an important incentive for industry to continue its contributions, and has been a major factor in the rate of development, overcoming significant delays caused by intermittent funding.

Money provided by MERIWA has been used to apply new molecular marker technology to increase understanding of the source rocks and petroleum in North Western Australia, and has helped unravel the accumulation and degradation events that have influenced crude oil accumulations. Recent research involving changes in land plant markers over geological times has led to the introduction of molecular stratigraphy to precisely relate markers in crude oils with those in rudimentary sequences. When found in sediments, biomarkers can provide a 'fingerprint', enabling the determination of the geological age at which the sediment was deposited. Studies of biomarker distribution in crude oils and sediments have enabled, among other results, the recognition of sea-level and climate changes over geological time. (Reports 138, 188 and 218; and Project M336)

Over two decades, the Petroleum and Environmental Geochemistry Research Centre has graduated sixteen doctoral and many more bachelor



A seismic physical modelling system at Curtin University of Technology, Perth. This was part of a long-term project commenced in August 1993 and completed early in 2002. (Project M343)

degree students – some from overseas countries, providing a welcome disseminating influence. The centre has also attracted postdoctoral research fellows from Australia and overseas to undertake research projects related to crude oil exploration and production in offshore Western Australia. Graduates from the centre now occupy senior positions in the petroleum industry, in the CSIRO, and in Australian, American and British universities.

Geophysics is another field associated with geology that has received significant support from MERIWA. The Department of Exploration Geophysics at Curtin University is the most prominent producer of geophysicists in the Southern Hemisphere, and much of its success is attributed to the support of MERIWA. (Reports 10, 114, 152, 164 and 203) Professor Norman Uren, head of the department, and Associate Professor Brian Evans have pointed out that, in the past thirty-three years, more than 450 science degrees have been awarded – despite the fact that there were no funds for postgraduate programs in the 1970s. Since those early days, grants from a number of sources – and, in particular, from MERIWA – have given the department its impressive research stature. MERIWA grants totalling more than $750,000 have flowed into the

department, and the institute also provided equipment grants. Many Master of Science candidates have been graduated in recent times, and the higher degrees made possible through the significant financial support offered by MERIWA have benefited not only Australia, but more than thirty other countries from which the graduates have come.

Western Australia has become the focal point for the national oil and gas industry, with many producing fields, mostly offshore. The North West Shelf has overtaken the Bass Strait as Australia's biggest source of hydrocarbons, creating a significant export industry. The technology employed in production and the processing of natural gas is of the highest order. The Department of Mineral and Petroleum Resources has noted that, in the two decades since MERIWA's establishment as WAMPRI, mineral and petroleum production in Western Australia has increased in value from $2.7 billion to more than $25 billion. While MERIWA cannot take credit for this dramatic growth, its research has contributed significantly to most areas of the resources industry, with exploration being the focus of almost half of its projects.

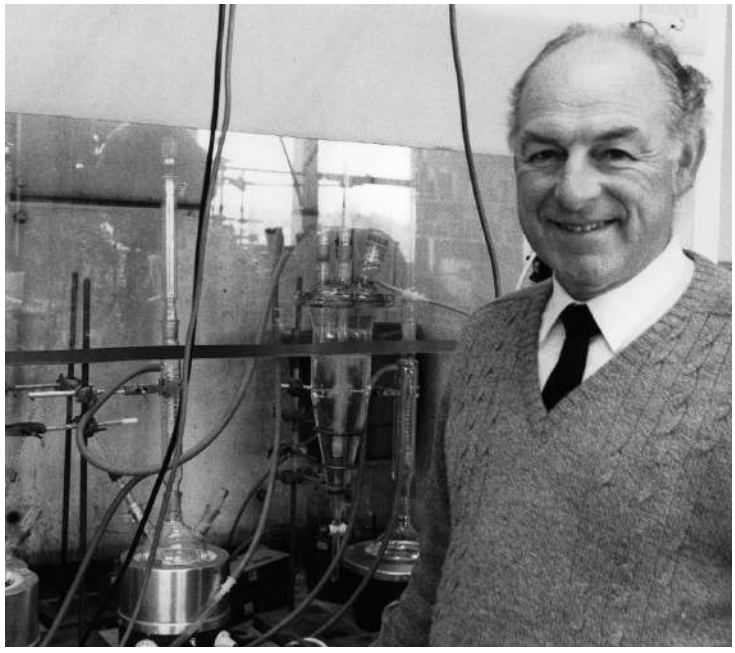
2:6

The end result

Mineral processing is the end result of years of exploration, drilling, marshalling capital and commissioning a mine. It involves many high-level skills and great precision to apply industrial processes in treating hundreds of thousands of tonnes of ore, with tolerances fine enough to produce a few kilograms of precious material. In the case of gold, for example, treatment plants extract metal that makes up only three or four parts per million of the rock in which it is found. In many mines, the objective is a return of two grams per tonne – two parts per million – bringing technical and scientific challenges that, when met, reflect great credit on Western Australian miners.

Mineral processing can be defined as the phase in which the mineral content of ore is enhanced by means of physical, chemical and/or pyro-metallurgical processes. One process that has made the extraction of tiny quantities of gold possible requires the most prosaic of materials. The 'carbon-in-pulp' (CIP) technology involves the use of activated carbon for the treatment of pulps containing dissolved gold. (Report 2) The capacity of activated carbon to adsorb precious metals from solution has been known for 150 years. However, it was not until the 1950s that the US Bureau of Mines developed a technique for stripping loaded carbon of its gold cyanide using a hot sodium hydroxide/sodium cyanide solution, and the first major CIP plant was not commissioned until two decades later.

Activated carbon suitable for gold recovery is made from nutshells, fruit pits, bituminous coal, petroleum residues, wood or carbonaceous material – hardly



Professor Ian Ritchie with apparatus used to investigate the production of iron oxide pigments from reduced ilmenite in 1984–85. (Projects 46 and 64)

the stuff of rocket science. Nevertheless, the carbon required in a CIP plant needs to be hard, and abrasive resistant and, perhaps surprisingly, the preferred source is coconut shells. After repeated use, carbon loses its potency, which can be reactivated by heating the carbon in kilns closed to the atmosphere for twenty minutes or more at temperatures of 600-900°C. Research work sponsored and coordinated by MERIWA and carried out at the A.J. Parker Centre at Murdoch University examined such issues as the best conditions for loading gold on activated carbon; the adsorption mechanism of gold on carbon; contamination of carbon by calcium, magnesium and silica; and the control of copper in gold electrowinning. (Reports 5, 113 and 180)

Since the launch of the A.J. Parker Centre, nine of its projects have benefited from MERIWA funding of $577,000, with a total cash value of $3.2 million. The first of these brought together four gold producers with an interest in processing gold ores containing cyanide-soluble copper. Some of the gold projects have been structured in modules to allow ten companies flexibility in funding to suit their individual needs. The modules provided the sponsors with a major review of refractory ore treatment, and an evaluation of sensors used for cyanide and oxygen control and methodologies for measuring leaching performance and optimizing reagent use. The project enabled technology transfer to be taken to a new level with the delivery of specialized training courses and seminars for industry professionals.

The Mineral Processing Subcommittee has allocated more than $1.7 million of State Government funds to support a total of forty research projects over the past twenty years. Industry sponsorship brought in a further $3.5 million, giving MERIWA a financial leverage of $2 from industry sources for every government dollar. While the work of this subcommittee over those two decades has embraced the processing of most minerals mined in Western Australia, the bulk of approved projects related to gold, nickel and aluminium. The remaining projects dealt with the operation and control of equipment and the processing of iron ore and mineral sands. (Reports 15 and 19)

Another exciting area of research related to the operational characteristics of the Kalgoorlie nickel smelter. This is one of only four operational flash furnaces in the world for the treatment of nickel sulphide concentrates. Nickel flash smelting involves blowing fine, dried nickel sulphide concentrate and silica flux with oxygen enriched air into a hot, hearth-type furnace. Unfortunately, the smelting of nickel in this way requires a great deal of energy, and the first of three MERIWA projects in this field dealt with the chemical reactions and thermodynamic conditions prevailing during the flash smelting process. (Report 1) It examined the heat capacity of a range of fluxing materials in order to ascertain the energy released during the ignition reaction and the relationship between ignition reaction and product quality. The work was extremely successful since, for the low cost of $21,500, with a contribution of $8,000 from industry, the research findings led to energy savings at the Kalgoorlie smelter of approximately one million dollars per year.

Two other projects also led to operational improvements at the flash smelter. The first of these was designed to evaluate, with the aid of physical models, some of the parameters influencing the furnace operation which would be virtually impossible to investigate *in situ*, such as the design of the burner and flow patterns in the furnace. (Report 7) This work extended the knowledge gained in the previous research program by utilizing more precise analysis of the factors influencing the kinetics and energetics of the ignition reaction. The second research project involved the design and construction of a pilot-scale jet reactor which could be operated under conditions more closely approaching those in the smelter shaft. (Report 39)

Further projects relating to the smelting of nickel concentrate examined the ignition process, (Report 87) and the effects of the mineralogical composition of the concentrate and its particle size on the ease of smelting. (Report 149) All nickel deposits contain violarite, pentlandite, pyrrhotite and pyrite with violarite and pyrite being the most reactive. Consequently, deposits with dominant quantities of violarite and pyrite minerals, such as those in

Western Australia, are relatively easy to smelt. It was also suggested that the stoichiometry (the weight relationship between compounds) of the mineral phases also affects the ease of smelting – a fact confirmed in this study. There was a bonus, too, for the study concluded with another interesting finding: that particle size has a greater effect on the reactivity of the mineral than does its stoichiometry, so that any adverse effect of the latter can be alleviated by further grinding of the concentrate. All five of these smelting-related projects were carried out at the Western Australian Institute of Technology (now Curtin University of Technology).

Many MERIWA-sponsored research projects related to problems associated with the economic extraction and processing of local ores. Two related to the subject of 'process mineralogy', combining the skills and knowledge of an extractive metallurgist and a mineralogist to develop a better understanding of how the mineralogy of local gold ores affected the efficacy of the mineral processing system. These projects, carried out at the WA School of Mines, investigated the mineralogical characteristics of a wide range of arsenical ores in order to learn more about the nature and form of the gold in arsenopyrite and other sulphides. (Reports 51 and 97) A wide range of processing options were also tested including roasting, ultrafine grinding, pressure oxidation, chlorine oxidation and bacterial leaching. The results of these tests were examined alongside the mineralogy of the ores, with a view to identifying the preferred processing path for the various ores.

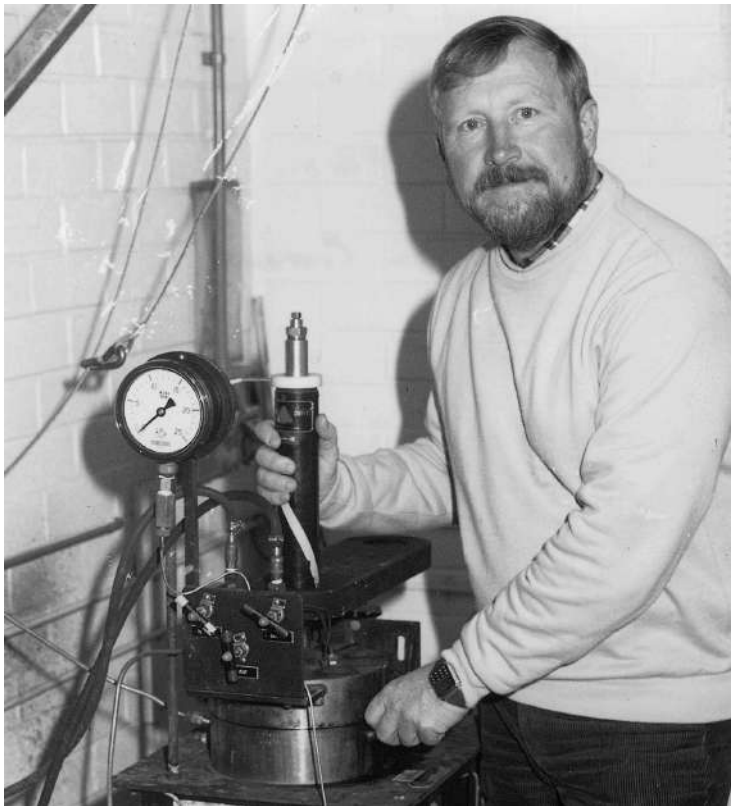
In recent times, increasing attention has been directed to improving the Bayer process, by which alumina is produced from bauxite. The Western Australian industry produces nearly a quarter of the world's alumina, valued at about $2 billion a year. The spectacular growth of the industry has been accompanied by research of international stature, demonstrating that, when an industry reaches 'critical mass', considerable technological advances are possible. An example is the research carried out at the A.J. Parker Cooperative Research Centre for Hydrometallurgy, now regarded as the most advanced centre of its kind in the world. Complementing this is crystallization research at Curtin University, also internationally recognized, and the two have received considerable support from MERIWA and the alumina industry.

One area of intense study is the precipitation of 'gibbsite', a key step in the alumina refining process (there are more than 350 gibbsite precipitators in Western Australia). Five research projects dealing with 'gibbsite precipitation' have been sponsored and coordinated by MERIWA since 1994, involving a total sponsorship of $1.12 million, of which the institute provided $375,000. (Projects M255, M255A and M256; and Reports 204 and 215) The most recent of these

Dr Terry Smith (right) and research assistant Rob Duggan examine a smelter furnace model during research into flash smelter shaft operations in 1983. (Project 27)

projects was jointly sponsored by MERIWA and the Australian Mineral Industry Research Association (now known as AMIRA International Ltd.). AMIRA, a national research funding body established by leading figures in the mining industry, has cooperated with MERIWA on many ventures. The latest gibbsite studies involved an investment of $240,000 from four industry sponsors and $30,000 from MERIWA to investigate the relationship between gibbsite precipitation and the hydrodynamics of the precipitator. The computational fluid dynamics associated with the simulations for this study were carried out at CSIRO, Melbourne. The research findings will undoubtedly lead to significant improvements in precipitator design, operation and control. These five research programs were carried out at the School of Applied Chemistry, Curtin University, and at the A.J. Parker Centre.

Another project involving both AMIRA and MERIWA sponsorship provides a good example of research dealing with equipment design and instrumentation. (Report 3) In the Bayer process, bauxite ore is treated with hot caustic soda to dissolve the alumina but leave iron oxides and coarse silicates in suspension. Thickeners are used to separate 'red mud' solids from the aluminate liquor, and



Dr Ian Corrans, supervisor of a study into the recovery of gold from leached calcine residues in 1986. (Project 72)

the efficient operation of these thickeners is a key factor in the overall process. An instrument known as a nephelometer provided an effective means of monitoring the levels of suspended solids in the overflow from the thickener. These liquors are, however, so corrosive that repeated immersions of the nephelometer resulted in the thin boro-silicate glass windows cracking within a few weeks. This research project was carried out at the CSIRO laboratories and resulted in the identification of a far superior material as a replacement for boro-silicate. The most suitable was a fluorinated ethylene – propylene copolymer (FEP) and its use led to a much more resilient instrument for assessing the quality of the thickener overflow liquors. Professor Gordon Parkinson of Curtin University, who was responsible for the gibbsite projects, believed that in addition to the significant advances in understanding the complex Bayer process, the grants stimulated research training with ramifications far beyond the original scope of the research projects, with broader benefits to Western Australia and the nation.

NOTES

EXPLANATORY NOTES

- Unless otherwise indicated, all interviews, questionnaire responses and documentary material cited below are held by MERIWA.
- 'Report' refers to the published reports of WAMPRI/MERIWA research projects.

1 The information in this chapter is substantially based on information contained in Ken Spillman, *A Rich Endowment: Government and Mining in Western Australia 1829-1994*, University of Western Australia Press, Nedlands, 1993, and Ken Spillman, 'Western Australia's Mining Heritage' (leaflet), Department of Mines of Western Australia, Perth, 1990.

2 Questionnaire response from Hon. Peter Jones.

3 ibid.

4 Questionnaire response from Sir Charles Court.

5 John McIlwraith and Richard Woldendorp, *Hamersley Iron: Twenty Five Years*, Hamersley Iron, Perth, 1991, p. 21.

6 Alex Kerr, 'The Economic and Social Significance of Western Australian Mining Developments', in R.T. Prider (ed.), *Mining in Western Australia*, University of Western Australia Press, Nedlands, 1979, p. 298.

7 Questionnaire response from Hon. Peter Jones.

8 Spillman, *A Rich Endowment*, p. 212.

9 Interview with John de Laeter by Jasmina Brankovich, 13 September 2000.

10 ibid.

11 ibid.

12 ibid. Note that one of the ideas that de Laeter returned with later materialized in the establishment of Technology Park at Curtin University.

13 ibid.

14 Interview with Professor Odwyn Jones by Jasmina Brankovich, 29 August 2000.

15 Interview with John Roberts by Jasmina Brankovich, 29 August 2000.

16 Jones interview, 29 August 2000.

17 De Laeter interview, 13 September 2000.

18 ibid.

19 Jones interview, 29 August 2000.

20 'A Proposal for the Establishment of the Mining and Petroleum Research Institute', School of Mining and Mineral Technology, Western Australian Institute of Technology, Perth, August 1978.

21 Jones interview, 29 August 2000.

22 'A Proposal for the Establishment of the Mining and Petroleum Research Institute'.

23 ibid. See also Dr Peter E. Power to the Minister for Mines, Andrew Mensaros, 4 September 1978; MERIWA file 67.

24 Power to Mensaros, 4 September 1978.

25 Questionnaire response from Hon. Peter Jones.

26 Joe Lord typescript used to inform groups in Perth of Power's proposal, found in Power's personal correspondence, p. 3.

27 De Laeter interview, 13 September 2000.

28 Questionnaire response from Hon. Peter Jones.

29 *West Australian*, 3 November 1979.

30 Lord typescript, p. 3.

31 *WAPD*, 13 August 1980, v. 228, p. 352.

32 *WAPD*, 28 November 1980, v. 231, p. 4391.

33 Lord typescript, p. 3.

34 *WAPD*, 25 March 1981, v. 232, p. 137.

35 Questionnaire response from Hon. Peter Jones.

36 *WAPD*, 25 March 1981, v. 232, p. 136. See also *WAPD*, 19 March 1981, v. 232, p. 13.

37 ibid., p. 137.

38 ibid.

39 ibid. See also *Mining and Petroleum Research Act 1981* (No. 2 of 1981), S.5.

40 *WAPD*, 28 April 1981, v. 233, p. 1203.

41 *WAPD*, 25 March 1981, v. 232, p. 137.

42 'A Proposal for the Establishment of the Mining and Petroleum Research Institute', p. 3.

43 *Mining and Petroleum Research News*, v. 1, no. 1, August 1982, p. 1.

44 Questionnaire response from Hon. Peter Jones.

45 ibid.

46 ibid.

47 J. Brunner, 'The Prospect for Mining', in R.T. Appleyard (ed.), *Western Australia into the Twenty First Century: Economic Perspectives*, St George Books, Perth, 1991, p. 255.

48 WAMPRI, *Annual Report*, 1981/1982, p.2.

49 *WAMPRI News*, vol.2, no.1, 1983, p.1.

50 Jodie Gysen, Corporate Communications, Department of Minerals and Energy, memo to the *West Australian*, 'Obituary for Joseph Henry Lord', 15 January 1999; MERIWA file 67.

51 De Laeter interview, 13 September 2000.

52 Roberts interview, 29 August 2000.

53 De Laeter interview, 13 September 2000.

54 Interview with Dr Colin Branch by Jasmina Brankovich, 29 August 2000.

55 *Report of the Review Committee into the First Five Years of Operation of the Western Australian Mining and Petroleum Research Institute*, WAMPRI, Perth, 1987, p.2.

56 Branch interview, 29 August 2000.

57 *Report of the Review Committee*, p. 35.

58 *WAMPRI News*, v. 6, no. 1, 1987.

59 *Report of the Review Committee*, passim. See also WAMPRI Report 1.

60 *WAMPRI News*, v. 6, no. 2, 1987.

61 Interview with Rex Baker by Jasmina Brankovich, 16 October 2000.

62 ibid.

63 See Chapter 2.

64 Questionnaire response from Professor Jeff Dunn, Director, Instrumentation Center, University of Toledo.

65 ibid.

66 Questionnaire response from Professors Bob Alexander and Bob Kagi, Petroleum and Environmental Organic Chemistry Research Centre, Curtin University.

67 Dr Tony Bagshaw, Research Coordinator, AMIRA International, 'AMIRA & MERIWA', 24 October 2001; MERIWA file 67.

68 *WAMPRI News*, v. 2, no. 1, February 1983.

69 *WAPD*, 12 November 1987, v. 267, p. 5762.

70 *Minerals and Energy Research Act 1987* (No. 89 of 1987), preamble.

71 *Minerals and Energy Research News*, v. 7, no. 1, March 1988.

72 Budget figures supplied by MERIWA.

73 Interview with Bob Hannaford by Jasmina Brankovich, 8 October 2000

74 Branch interview, 29 August 2000.

75 Baker interview, 16 October 2000.

76 MERIWA became a constituent part of the Department of Minerals and Energy in July 1992; after a change of government, the old order was restored later the same year.

77 Reports 43, 47, 78 and 82.

78 Report 68.

79 Report 42.

80 Reports 41, 58 and 86.

81 Reports 50 and 55.

82 Report 72.

83 Report 36.

84 Report 53.

85 Report 80.

86 Report 101.

87 Report 63.

88 Reports 35, 37 and 62.

89 This important work is covered in more detail in Part 2, Chapter 6. See also Reports 39 and 87.

90 Report 92.

91 Reports 46, 51, 59, 87.

92 Reports 34, 38 and 67.

93 Report 105.

94 Report 54.

95 Reports 44, 45 and 66.

96 Reports 52 and 91.

97 Report 79.

98 Baker interview, 16 October 2000.

99 *Minerals and Energy Research News*, v. 15, no. 2, July 1997.

100 'Science and Technology Policy Discussion Paper – Comments Submitted by Minerals and Energy Research Institute', 6 December 1995.

101 See Part 1, Chapter 3.

102 *Minerals and Energy Research Act 1987*, S.5.

103 Baker interview, 16 October 2000.

104 Questionnaire response from Jeff Dunn.

105 ibid. See also Reports 1, 7 and 39.

106 Questionnaire response from David Groves.

107 ibid.

108 Questionnaire response from Bob Alexander.

109 ibid.

110 Questionnaire response from David Groves.

111 Roberts interview, 29 August 2000.

112 Branch interview, 29 August 2000.

113 Questionnaire response from Carl Brauhart.

114 ibid.

115 Questionnaire response from Ron Hackney.

116 Questionnaire response from Andrew Webb.

117 Questionnaire response from Stephanie Jennings.

118 Questionnaire response from Ron Hackney.

119 Questionnaire response from Carl Brauhart.

120 Branch interview, 29 August 2000.

121 ibid.

122 ibid.

123 *Minerals and Energy Research News*, v. 18, no. 1, February 2000.

124 Baker interview, 16 October 2000.

125 ibid.

126 Branch interview, 29 August 2000.

APPENDICES

1. WAMPRI Ministers, Board Members and Executive Officers
2. WAMPRI Minerals and Petroleum Advisory Committees
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4. MERIWA Ministers, Board Members, Executive Officers and Secretariat
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WAMPRI

1 : Western Australian Mining and Petroleum Research Institute (WAMPRI)

MINISTERS

NAME	TENURE
Hon. Peter Jones, MLA	1981 – 1982
Hon. Peter Dowding, MLC	1982 – 1983
Hon. David Parker, MLA	1983 – 1988

BOARD OF DIRECTORS

NAME	TENURE
J. H. Lord [Chairman]	1981 – 1988
W. E. Ewers	1981 – 1988
P. L. Wall	1981 – 1984
R. E. Butters	1984 – 1988

EXECUTIVE OFFICERS

NAME	TENURE
J. F. Johnston	1981 – 1983
M. C. Kirk	1983 – 1984
J. S. Partington	1984 – 1988

Western Australian Mining and Petroleum Research Institute (WAMPRI)

2 : MINERALS AND PETROLEUM ADVISORY COMMITTEE

Members and Deputy Members

1981/1982

MEMBER	DEPUTY MEMBER	REPRESENTING
S. R. Baker *[Chairman]*		Minister
Dr I. O. Jones		Minister
J. R. May	J. Roberts	Minister
B. J. O'Leary		Minister for Resources Development
W. T. Peart	J. C. Lenzo	The Confederation of Western Australian Industry (Inc.)
T. S. Ivankovich	C. Wyatt	The Chamber of Mines of Western Australia (Inc.)
Dr K. C. Short	G. Dann	Australian Petroleum Exploration Association
Prof. P. G. Harris	Prof. A. T. Morkel	The University of Western Australia
Prof. A. J. Parker	Dr E. J. Grimsey	Murdoch University
Dr T. Pyle	N. F. Uren	Western Australian Institute of Technology
A. J. Gaskin	Dr D. R. Hudson	Commonwealth Scientific and Industrial Research Organisation

1982/1983

MEMBER	DEPUTY MEMBER	REPRESENTING
S. R. Baker *[Chairman]*		Minister
Dr I. O. Jones *[Deputy Chairman]*		Minister
J. R. May	J. Roberts	Minister
B. J. O'Leary	A. D. Giles	Minister for Resources Development
J. C. Lenzo	W. T. Peart	The Confederation of Western Australian Industry (Inc.)
T. S. Ivankovich	L. K. Slade	The Chamber of Mines of Western Australia (Inc.)
Dr K. C. Short	J. C. Parry	Australian Petroleum Exploration Association
Prof. P. G. Harris	Prof. A. T. Morkel	The University of Western Australia
Dr E. J. Grimsey	Dr D. M. Muir	Murdoch University
Dr T. Pyle	N. F. Uren	Western Australian Institute of Technology
A. J. Gaskin	Dr D. R. Hudson	Commonwealth Scientific and Industrial Research Organisation

Western Australian Mining and Petroleum Research Institute (WAMPRI)

2 : MINERALS AND PETROLEUM ADVISORY COMMITTEE

Members and Deputy Members

1983/1984

MEMBER	DEPUTY MEMBER	REPRESENTING
S. R. Baker *[Chairman]*		Minister
Dr I. O. Jones *[Deputy Chairman]*		Minister
J. R. May	J. Roberts	Minister
B. J. O'Leary	A. D. Giles	Minister for Resources Development
J. C. Lenzo	W. T. Peart	The Confederation of Western Australian Industry (Inc.)
T. S. Ivankovich	L. K. Slade	The Chamber of Mines of Western Australia (Inc.)
Dr K. C. Short	J. C. Parry	Australian Petroleum Exploration Association
Prof. P. G. Harris	Prof. A. T. Morkel	The University of Western Australia
Dr E. J. Grimsey	Dr D. M. Muir	Murdoch University
Dr T. Pyle	N. F. Uren	Western Australian Institute of Technology
Dr D. R. Hudson	Dr E. H. Nickel	Commonwealth Scientific and Industrial Research Organisation

1984/1985

MEMBER	DEPUTY MEMBER	REPRESENTING
S. R. Baker *[Chairman]*		Minister
Dr I. O. Jones *[Deputy Chairman]*		Minister
B. J. O'Leary		Minister
J. R. May	J. Roberts	Minister
A. D. Giles	R. E. Marshall	Minister for Resources Development
J. C. Lenzo	J. A. Davis	The Confederation of Western Australian Industry (Inc.)
C. J. D. Williams	L. K. Slade	The Chamber of Mines of Western Australia (Inc.)
J. C. Parry	M. White	Australian Petroleum Exploration Association
Prof. P. G. Harris	Prof. A. T. Morkel	The University of Western Australia
Dr E. J. Grimsey	Dr D. M. Muir	Murdoch University
Dr T. Pyle	N. F. Uren	Western Australian Institute of Technology
Dr D. R. Hudson	Dr D. F. A. Koch	Commonwealth Scientific and Industrial Research Organisation

Western Australian Mining and Petroleum Research Institute (WAMPRI)

2 : MINERALS AND PETROLEUM ADVISORY COMMITTEE

Members and Deputy Members

1985/1986

MEMBER	DEPUTY MEMBER	REPRESENTING
S. R. Baker *[Chairman]*		Minister
Dr I. O. Jones *[Deputy Chairman]*		Minister
B. J. O'Leary		Minister
J. R. May	J. Roberts	Minister
A. D. Giles	R. E. Marshall	Minister for Resources Development
J. C. Lenzo	J. A. Davis	The Confederation of Western Australian Industry (Inc.)
C. J. D. Williams	L. K. Slade	The Chamber of Mines of Western Australia (Inc.)
J. C. Parry	M. White	Australian Petroleum Exploration Association
Prof. P. G. Harris	Prof. A. T. Morkel	The University of Western Australia
Dr E. J. Grimsey	Dr D. M. Muir	Murdoch University
Dr T. Pyle	N. F. Uren	Western Australian Institute of Technology
Dr D. R. Hudson	Dr D. F. A. Koch	Commonwealth Scientific and Industrial Research Organisation

1986/1987

MEMBER	DEPUTY MEMBER	REPRESENTING
S. R. Baker *[Chairman]*		Minister
Dr I. O. Jones *[Deputy Chairman]*		Minister
J. R. May	J. Roberts	Minister
N. Goodall	Dr J. Limerick	Minister for Resources Development
J. C. Lenzo	J. A. Davis	The Confederation of Western Australian Industry (Inc.)
A. E. O'Meara	L. K. Slade	The Chamber of Mines of Western Australia (Inc.)
J. C. Parry	M. White	Australian Petroleum Exploration Association
Prof. P. G. Harris	Prof. A. T. Morkel	The University of Western Australia
Dr E. J. Grimsey	Dr D. M. Muir	Murdoch University
Dr T. Pyle	Dr R. T. Pidgeon	Curtin University of Technology
Dr D. F. A. Koch	Dr D. R. Hudson	Commonwealth Scientific and Industrial Research Organisation

Western Australian Mining and Petroleum Research Institute (WAMPRI)

2 : MINERALS AND PETROLEUM ADVISORY COMMITTEE

Members and Deputy Members

1987/1988

MEMBER	DEPUTY MEMBER	REPRESENTING
S. R. Baker *[Chairman]*		Minister
Dr I. O. Jones *[Deputy Chairman]*		Minister
J. R. May	J. Roberts	Minister
J. C. Lenzo	J. A. Davis	The Confederation of Western Australian Industry (Inc.)
Dr J. Limerick	C. F. A. Daffen	Minister for Resources Development
A. E. O'Meara	L. K. Slade	The Chamber of Mines of Western Australia (Inc.)
J. C. Parry	M. White	Australian Petroleum Exploration Association
Prof. P. G. Harris	Prof. A. T. Morkel	The University of Western Australia
Dr E. J. Grimsey	Dr D. M. Muir	Murdoch University
Dr T. Pyle	Dr R. T. Pidgeon	Curtin University of Technology
Dr D. F. A. Koch	Dr D. R. Hudson	Commonwealth Scientific and Industrial Research Organisation

Western Australian Mining and Petroleum Research Institute (WAMPRI)

3 : SPONSORING COMPANIES 1981–1988

Aberfoyle Exploration Pty Ltd
Aberfoyle Resources Ltd
ACET Limited
ACE-T Pty Ltd
Afmeco Pty Ltd
Agnew Mining Company
Alcoa of Australia Ltd
Alliance Petroleum International Ltd
Allied Eneabba Ltd
Amax Australia Limited
Amoco Australia Petroleum Company
Ampol Exploration Limited
Anaconda Australia Inc.
Asarco Australia Ltd
Ashton Mining Limited
Associated Minerals Consolidated Limited
Austamax Resources Ltd
Australian Aquitaine Petroleum Pty Ltd
Australian Consolidated Minerals Ltd
Australian Occidental Petroleum Inc.
Australian Oil & Gas Corporation Ltd
Australis Mining NL
Aztec Exploration Limited
Battle Mountain (Australia) Inc.
Billiton Australia
Bond Corporation Pty Ltd
BP Minerals Australia
Bridge Oil Ltd
Broken Hill Proprietary Co Ltd
Cable Sands (WA) Pty Ltd
Carpentaria Exploration Company Pty Ltd
Carr Boyd Minerals Ltd
Central Norseman Gold Corporation Ltd
Chamber of Mines of Western Australia (Inc.)
Chevron Exploration Corporation
CNW Oil (Australia) Ltd
Confederation of Western Australian Industry (Inc.)
CRA Exploration Pty Ltd
Croesus Mining NL
CSBP & Farmers Ltd
CSR Limited
Cultus Pacific NL
Dallhold Resources Management Pty Ltd
Dominion Gold Mines NL
Elf Aquitaine Petroleum Australia Pty Ltd
Endeavour Resources Limited
Esso Australia Limited
Forrestania Gold NL
Getty Development Company Limited
Golconda Limited
Gold Fields Exploration Pty Ltd
Gold Resources Pty Ltd
Goldfields Exploration Pty Limited
Greenbushes Tin Ltd
Gulf Canada Resources Ltd
Gulf Oil Australia Pty Ltd
Haefeli-Lysnar Survey Equipment Company
Hamersley Iron Pty Limited
Home Energy Company Ltd
Home Oil Australia Limited
Homestake
ICI Australia Operations Pty Ltd
International Energy Development Corporation of Australia Pty Ltd
Kalgoorlie Mining Associates
Kufpec Australia Pty Ltd
Marathon Petroleum Australia Ltd
Minatome Australia Pty Limited
Mineral By-Products Pty Ltd
Miralga Mining NL
Mobil Oil Australia Pty Limited
Mt Newman Mining Co Pty Ltd
Newmont Holdings Pty Ltd
North Kalgurli Mines Ltd
Oakwood International Petroleum NL
Ocelot International Pty Ltd
Otter Exploration NL
Pancontinental Mining Ltd
Petroleum Securities Pty Ltd
Pioneer Concrete Services Ltd
Placer Exploration Ltd
Pontoon Oil & Minerals NL
Ranger Oil (Australia) Limited
Reynolds Australia Mines Pty Ltd
Seltrust Mining Corporation Pty Ltd
State Energy Commission
Stockdale Prospecting Ltd
The Griffin Coal Mining Company Ltd
The Shell Company of Australia Limited - Metals Division
Toleco Resources Pty Ltd
Total Mining Australia Pty Ltd
Uranerz Australia Pty Ltd
Vamgas Limited
Vickers Hoskins
Weaver Oil & Gas Corporation - Australia
West Australain Petroleum Pty Ltd
West Coast Holdings Ltd
Western Australian School of Mines
Western Collieries Ltd
Western Mining Corporation
  Exploration Division
  Kalgoorlie Nickel Smelter
  Kambalda Nickel Operations
  WMC Engineering Services Pty Ltd
Westralian Sands Ltd
Whim Creek Consolidated NL
Whitestone Petroleum Australia Ltd
Woodside Offshore Petroleum Pty Ltd
Worsley Alumina Pty Ltd
Yom Oil Ltd

MERIWA

4 : Minerals and Energy Research Institute of Western Australia (MERIWA)

MINISTERS

NAME	TENURE
Hon. Jeff Carr, MLA	1988 – 1990
Hon. Gordon Hill, MLA	1990 – 1992
Hon. George Cash, MLC	1992 – 1995
Hon. Kevin Minson, MLA	1995 – 1996
Hon. Norman F. Moore, MLC	1996 – 2000
Hon. Eric Ripper, MLA	2000 – 2001
Hon. Clive Brown, MLA	2001 –

BOARD OF DIRECTORS

NAME	TENURE
J. H. Lord	1988 – 1990
W. E. Ewers	1988 – 1989
R. E. Butters	1988 –
A. R. Billings	1988 –
R. A. N. Douglas	1989 – 1993
C. D. Branch *[Chairman]*	1990 –
S. R. Baker	1993 –

EXECUTIVE OFFICERS

NAME	TENURE
J. S. Partington	1988 – 1988
M. E. J. Seal	1988 – 1990
R. H. Hannaford	1990 – 1998
J. Roberts	1998 – 2000
D. Milton	2000 –

SECRETARIAT

NAME	TITLE	TENURE
R. R. Connolly	Publications Officer	1989 – 1994
G. Davies	Secretary to E.O.	1991 –
J. Muhling	Project Coordinator	1994 – 1997
P. Smith	Project Coordinator	1997 –

Minerals and Energy Research Institute of Western Australia (MERIWA)

5 : MINERALS RESEARCH ADVISORY COMMITTEE

Members and Deputy Members

to 30 JUNE 1988

MEMBER	DEPUTY MEMBER	REPRESENTING
S. R. Baker *[Chairman]*		Minister
Dr I. O. Jones *[Deputy Chairman]*		Minister
J. R. May	J. Roberts	Minister
A. E. O'Meara		Minister
Dr J. Limerick	C. F. A. Daffen	Minister for Economic Development and TradeJ.
C. Lenzo	W. S. Sashegyi	The Confederation of Western Australian Industry (Inc.)
R. W. Bourne	L. K. Slade	The Chamber of Mines of Western Australia (Inc.)
J. C. Parry	M. White	Australian Petroleum Exploration Association
Prof. P. G. Harris	Prof. A. T. Morkel	The University of Western Australia
Dr E. J. Grimsey	Dr D. M. Muir	Murdoch University
Dr T. Pyle	Dr R. T. Pidgeon	Curtin University of Technology
Dr B. J. J. Embleton	Dr D. R. Hudson	Commonwealth Scientific and Industrial Research Organisation

1988/1989

MEMBER	DEPUTY MEMBER	REPRESENTING
S. R. Baker. *[Chairman]*		Minister
A/Prof. I. O. Jones *[Deputy Chairman]*		Minister
J. R. May	J. Roberts	Minister
A. E. O'Meara		Minister
Dr J. Limerick	C. F. A. Daffen	Minister for Economic Development and Trade
Dr B. J. J. Embleton	Dr D. R. Hudson	Commonwealth Scientific and Industrial Research Organisation
Prof. P. G. Harris	Prof. A. T. Morkel	The University of Western Australia
Dr E. J. Grimsey	A/Prof, D. M. Muir	Murdoch University
A/Prof. T. Pyle	A/Prof .R. T. Pidgeon	Curtin University of Technology
J. C. Lenzo	W. S. Sashegyi	The Confederation of Western Australian Industry (Inc.)
R. W. Bourne	L. K. Slade	The Chamber of Mines of Western Australia (Inc.)
J. C. Parry	M. White	Australian Petroleum Exploration Association

Minerals and Energy Research Institute of Western Australia (MERIWA)

5 : MINERALS RESEARCH ADVISORY COMMITTEE

Members and Deputy Members

1989/1990

MEMBER	DEPUTY MEMBER	REPRESENTING
S. R. Baker *[Chairman]*		Minister
Prof. I. O. Jones *[Deputy Chairman]*		Minister
J. R. May	J. Roberts	Minister
A. E. O'Meara		Minister
Dr J. Limerick	C. F. A. Daffen	Minister for Resources
Dr B. J. J. Embleton	Dr D. R. Hudson	Commonwealth Scientific and Industrial Research Organisation
Prof .C. McA. Powell	Prof. A. T. Morkel	The University of Western Australia
Dr E. J. Grimsey	A/Prof. D. M. Muir	Murdoch University
A/Prof. T. Pyle	A/Prof. R. T. Pidgeon	Curtin University of Technology
J. C. Lenzo	W. S. Sashegyi	The Confederation of Western Australian Industry (Inc.)
R. W. Bourne	L. K. Slade	The Chamber of Mines and Energy of Western Australia (Inc.)
J. C. Parry	M. White	Australian Petroleum Exploration Association

1990/1991

MEMBER	DEPUTY MEMBER	REPRESENTING
J. Roberts *[Chairman]*		Minister
Prof. I. O. Jones *[Deputy Chairman]*		Minister
Dr D. Nairn		Minister
A. E. O'Meara		Minister
R. Marshall	C. F. A. Daffen	Minister for State Development
Dr B. J. J. Embleton	Dr D. R. Hudson	Commonwealth Scientific and Industrial Research Organisation
Prof. C. McA. Powell	Prof. A. T. Morkel	The University of Western Australia
Dr E. J. Grimsey	A/Prof. D. M. Muir	Murdoch University
A/Prof. R. T. Pidgeon	Dr H. M. Ang	Curtin University of Technology
W. S. Sashegyi	J. C. Lenzo	The Confederation of Western Australian Industry (Inc.)
R. W. Bourne	G. R. Arcus	The Chamber of Mines and Energy of WA
P. Botten	E. Kopsen	Australian Petroleum Exploration Association

Minerals and Energy Research Institute of Western Australia (MERIWA)

5 : MINERALS RESEARCH ADVISORY COMMITTEE

Members and Deputy Members

1991/1992

MEMBER	DEPUTY MEMBER	REPRESENTING
J. Roberts *[Chairman]*		Minister
Prof. I. O. Jones *[Deputy Chairman]*		Minister
Dr D. Nairn		Minister
A. E. O'Meara		Minister
R. Marshall	C. F. A. Daffen	Minister for State Development
Dr B. J. J. Embleton	Dr D. R. Hudson	Commonwealth Scientific and Industrial Research Organisation
Prof. C. McA. Powell	Prof. A. T. Morkel	The University of Western Australia
Dr E. J. Grimsey	A/Prof. D. M. Muir	Murdoch University
A/Prof. R. T. Pidgeon	Dr H. M. Ang	Curtin University of Technology
W. S. Sashegyi	J. C. Lenzo	Chamber of Commerce and Industry of WA
R. W. Bourne	G. R. Arcus	The Chamber of Mines and Energy of WA
P. Botten	E. Kopsen	Australian Petroleum Exploration Association

1992/1993

MEMBER	DEPUTY MEMBER	REPRESENTING
J. Roberts *[Chairman]*		Minister
Prof. I. O. Jones *[Deputy Chairman]*		Minister
Dr D. Nairn		Minister
A. E. O'Meara		Minister
R. Marshall	C. F. A. Daffen	Department of Resources Development
Dr R. Hill	Dr A. Ord	Commonwealth Scientific and Industrial Research Organisation
Prof. C. McA. Powell	Prof. A. T. Morkel	The University of Western Australia
Dr E. J. Grimsey	A/Prof. D. M. Muir	Murdoch University
A/Prof. R. T. Pidgeon	Dr H. M. Ang	Curtin University of Technology
W. S. Sashegyi	J. C. Lenzo	Chamber of Commerce and Industry of WA
R. W. Bourne	G. R. Arcus	The Chamber of Mines and Energy of WA
P. Botten	E. Kopsen	Australian Petroleum Exploration Association

Minerals and Energy Research Institute of Western Australia (MERIWA)

5 : MINERALS RESEARCH ADVISORY COMMITTEE

Members and Deputy Members

1993/1994

MEMBER	DEPUTY MEMBER	REPRESENTING
J. Roberts *[Chairman]*		Minister
Prof. I. O. Jones *[Deputy Chairman]*	Dr C. F. Swindells	Minister
Dr D. Nairn	R. Grogan	Minister
A. E. O'Meara	W. Aldridge	Minister
R. Marshall	Dr D. Martin	Department of Resources Development
Dr R. Hill	Dr A. Ord	Commonwealth Scientific and Industrial Research Organisation
Prof. C. McA. Powell	A/Prof. R. J. Gilkes	The University of Western Australia
A/Prof. D. M. Muir	Dr N. Stockton	Murdoch University
Prof. R. T. Pidgeon	Prof. J. Warren	Curtin University of Technology
W. S. Sashegyi	G. Lye	Chamber of Commerce and Industry of WA
G. Johnson	P. Fairclough	The Chamber of Mines and Energy of WA
A. Padman	Dr J. Gorter	Australian Petroleum Exploration Association

1994/1995

MEMBER	DEPUTY MEMBER	REPRESENTING
J. Roberts *[Chairman]*		Minister
Prof. I. O. Jones *[Deputy Chairman]*	Dr C. F. Swindells	Minister
Dr D. Nairn	R. Grogan	Minister
A. E. O'Meara	W. Aldridge	Minister
R. Marshall	Dr D. Martin	Department of Resources Development
Dr R. Hill	Dr. A Ord	Commonwealth Scientific and Industrial Research Organisation
Prof C. McA. Powell	Prof. R. J. Gilkes	The University of Western Australia
A/Prof. D. M. Muir	Dr N. Stockton	Murdoch University
Prof. R. T. Pidgeon	Prof. J. Warren	Curtin University of Technology
W. S. Sashegyi	G. Lye	Chamber of Commerce and Industry of WA
G. Johnson	P. Fairclough	The Chamber of Mines and Energy of WA
A. Padman	Dr J. Gorter	Australian Petroleum Exploration Association

Minerals and Energy Research Institute of Western Australia (MERIWA)

5 : MINERALS RESEARCH ADVISORY COMMITTEE

Members and Deputy Members

1995/1996

MEMBER	DEPUTY MEMBER	REPRESENTING
J. Roberts *[Chairman]*		Minister
Prof. I. O. Jones *[Deputy Chairman]*	Dr C. F. Swindells	Minister
D. Tucker	R. Grogan	Minister
Dr R. Blanks	P. Baillie	Minister
Prof. P. Garnett	A/Prof. J. Cross	Minister
R. Marshall	Dr D. Martin	Department of Resources Development
Dr A. Ord	Dr C. Butt	Commonwealth Scientific & Industrial Research Organisation
Prof. C. McA. Powell	Prof. R. J. Gilkes	The University of Western Australia
A/Prof. D. M. Muir	Dr N. Stockton	Murdoch University
Prof. R. T. Pidgeon	Prof. J. McDonald	Curtin University of Technology
W. S. Sashegyi	G. Lye	Chamber of Commerce and Industry of WA
G. Johnson	J. Aberdeen	The Chamber of Mines and Energy of WA
A. Padman	Dr J. Gorter	Australian Petroleum Exploration Association

1996/1997

MEMBER	DEPUTY MEMBER	REPRESENTING
J. Roberts *[Chairman]*		Minister
Prof. I. O. Jones *[Deputy Chairman]*	Dr C. F. Swindells	Minister
D. Stribley	R. Grogan	Minister
Dr R. Blanks	P. Baillie	Minister
Prof. P. Garnett	A/Prof. J. Cross	Minister
Dr D. Martin	J. Ridgway	Department of Resources Development
Dr A. Ord	Dr C. Butt	Commonwealth Scientific & Industrial Research Organisation
Prof. C. McA. Powell	Prof. R. J. Gilkes	The University of Western Australia
Dr N. Stockton	Dr S. La Brooy	Murdoch University
Prof. R. T. Pidgeon	Prof. J. McDonald	Curtin University of Technology
W. S. Sashegyi	G. Lye	Chamber of Commerce and Industry of WA
G. Johnson	J. Aberdeen	The Chamber of Mines and Energy of WA
A. Padman	Dr J. Gorter	Australian Petroleum Exploration Association

Minerals and Energy Research Institute of Western Australia (MERIWA)

5 : MINERALS RESEARCH ADVISORY COMMITTEE

Members and Deputy Members

1997/1998

MEMBER	DEPUTY MEMBER	REPRESENTING
J. Roberts *[Chairman]*		Minister
Prof. I. O. Jones *[Deputy Chairman]*	Dr C. F. Swindells	Minister
D. Stribley	R. Grogan	Minister
Dr R. Blanks	P. Baillie	Minister
Prof. P. Garnett	A/Prof. J. Cross	Minister
Dr D. Martin	J. Ridgway	Department of Resources Development
Dr A. Ord	Dr C. Butt	Commonwealth Scientific & Industrial Research Organisation
Prof. C. McA. Powell	Prof. R. J. Gilkes	The University of Western Australia
Dr N. Stockton	Prof. M. Nicol	Murdoch University
Prof. R. T. Pidgeon	Prof. J. McDonald	Curtin University of Technology
W. S. Sashegyi	D. Milton	Chamber of Commerce and Industry of WA
G. Johnson	J. Aberdeen	The Chamber of Mines and Energy of WA
K. Spence	Dr J. Gorter	Australian Petroleum Exploration Association

1998/1999

MEMBER	DEPUTY MEMBER	REPRESENTING
Prof. I. O. Jones *[Chairman]*		Minister
P. Dowd	Dr C. F. Swindells	Minister
D. Stribley	R. Grogan	Minister
Dr R. Blanks	P. Baillie	Minister
Prof. P. Garnett	A/Prof. J. Cross	Minister
Dr D. Martin	J. Ridgway	Department of Resources Development
Dr A. Ord	Dr C. Butt	Commonwealth Scientific & Industrial Research Organisation
Prof. C. McA. Powell	Prof. R. J. Gilkes	The University of Western Australia
A/Prof, P. May	Prof. M. Nicol	Murdoch University
Prof. R. T. Pidgeon	Prof. J. McDonald	Curtin University of Technology
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8 : Published Reports

MINERALS AND PETROLEUM RESEARCH

MINERALS EXPLORATION

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
4	17	Helium surveys of the Manyingee and Bennett Well uranium deposits, WA	C. R. M. BUTT, M. J. GOLE	Apr '84
6	26	Sedimentary and tectonic development of the Bangemall Basin and implications for mineral exploration	R. G. CHUCK	Sep '84
11	23	Genetic concepts as aids to development of gold exploration models: Lead isotope constraints on source and genesis of Archaean gold deposits in Western Australia	D. I. GROVES, N. DAHL, N. J. McNAUGHTON	Feb '85
13	4	Development of exploration concepts for Sn-Ta Pegmaties: Use of host rock associations and alteration haloes	L. F. BETTENAY, G. A. PARTINGTON, D. I. GROVES	Apr '85
14	33	Mineralogy and geochemistry of the weathered zone over some Archaean base-metal deposits in Western Australia	B. H. SMITH, R. J. GILKES	May '85
16	14	Semi-micro analytical technique in mineral exploration and ore genesis studies	K. W. TERRY, A. VAN RIESSEN, D. C. LEE	Jul '85
18	7	Nature, distribution and recovery of platinum group minerals in Kambalda nickel ores	D. R. HUDSON, P. CROMELLIN, M. A. CHAN	Jul '85
22	62	Trace-element and lead isotopic compositions of pyrites as guides to gold and base-metal mineralization – a pilot study	N. DAHL, N. J. McNAUGHTON, D. GROVES	Jul '86

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
23	57	The exfoliation of vermiculite	J. G. DUNN, L. MEAGHER, L. J. WARREN	May '86
24	36	Coincident loop and in-loop transient electromagnetic interpretation for sheet conductors	J. H. COGGON	Feb'87
26	20	Petrography of Collie coal, Collie Basin, Western Australia	K. K. SAPPAL	Sep '86
27	24	Correlation of acid volcanics in the Archaean of Western Australia	R. T. PIDGEON	Nov '86
29	41	The application of drill hole electromagnetic techniques for delineation of conductive mineralization	E. H. CLARKE, J. H. COGGON	Jan '87
30	30	U--Pb geochronology, geothermometry and petrology of the main areas of gold mineralisation in the 'Wheat Belt' region of W.A	C. R. M. BUTT, M. J. GOLE	Jun '85
32	38	The Agnew nickel deposit, Yilgarn Block, WA – stratigraphy, structure, geochemistry and origin	S. J. BARNES, M. J. GOLE, R. E. T. HILL	Jun '87
38	51	Mineralogy of Darling Range bauxite	R. J. GILKES	Nov '88
42	73	Holocene sedimentation and heavy mineral accumulation, Minninup shoreline, Geographe Bay	L. B. COLLINS, N. T. HAMILTON	Apr '89
43	65	Exploration significance of regional and local scale hydrothermal alteration patterns in greenstone belts	M. E. BARLEY, D. I. GROVES	Feb '89
47	61	The structural development and controls on mineralisation of the northern sector of the Norseman – Wiluna Belt, Western Australia	B. EISENLOHR	May '89
61	82	Correlation of the Fortescue Group	D. R. NELSON, A. F. TRENDALL, J. R. DE LAETER	Apr '90
67	90	Mineralogy of Darling Range bauxites in relation to chemical reactivity – new ore types	M. G. AYLMORE, R. J. GILKES	May '91
68	79	The refinement of extrusive models for the genesis of nickel deposits: implications from case studies at Honeymoon Well and the Walter Williams Formation	M. GOLE, R. HILL	Nov '90
72	71	Comprehensive interpretation of drill hole electromagnetic data	J. COGGON, K. FLEMING	Mar '91
78	95	*Merigold*: a database for Archaean gold deposits in the Yilgarn Block	N. M. S.ROCK, C. KNOX-ROBINSON, M. R. WHEATLEY, T. HALLAM, D. I. GROVES	Oct '91
82	M123	The geochemistry of Archaean gold ores from the Yilgarn Block of Western Australia: implications for gold metallogeny	C. S. PERRING, D. I. GROVES, J. N. SHELLABEAR	Nov '91

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
102	M143	Advanced structural interpretation using magnetic data	Q. LAI, J. COGGON, R. KEELE	Nov '93
106	M178	Geochemistry, mineralogy and hydrogeochemisty of the Ambassador multi-element lignite deposit, Western Australia	G. B. DOUGLAS, D. J. GRAY, C. R. M. BUTT	Mar '93
109	M203	Controls on mineralization and tectonic development of the central part of the northern Yilgarn Craton	J. B. BEESON, D. I. GROVES, J. R. RIDLEY	Jun '93
122	M121	The nature of large scale shear zones and their relevance to gold mineralization, Yilgarn Block	B. N. EISENLOHR, D. I. GROVES, J. LIBBY, J. R. VEARNCOMBE	Dec '93
123	M202	Vanadium distribution in the Shephards Discordant Zone, Windimurra Complex, Western Australia	M. M. HABTESELASSIE	Feb '94
142	M154	Exploration and deposit models for gold deposits in amphibolite/granulite facies terranes	J. R. RIDLEY, D. I. GROVES, S. G. HAGEMANN	Feb '95
145	M201	Tectonic, structural and depositional controls on zinc-lead mineralization on the Lennard Shelf, Canning Basin	J. R. VEARNCOMBE, S. L. DORLING, M. C. DENTITH, A. W. CHISNALL, J. N. CHRISTENSEN, N. J. McNAUGHTON, P. E. PLAYFORD, M. J. RAYNER, A. R. REED	Mar '95
146	M83	Induced polarization characteristics of gold mineralization	A. W. MANN, J. COGGON	May '93
153	M219	Mechanism of formation of mobile metal ion anomalies	A. W. MANN, L. M. GAY, R. G. BIRRELL, J. G. WEBSTER, K. L. BROWN, A. T. MANN, D. B. HUMPHREYS, J. L. PERDRIX	Sep '95
157	90	Mineralogy of Darling Range bauxites-forms of A1 in pisolitic ore	R. J. GILKES, B. SINGH	Oct '95
165	M194	Improved resource evaluation using geoscientific information systems – a pilot study	C. KNOX-ROBINSON, D. I. GROVES, D. C. ROBINSON, M. R. WHEATLEY	Jun '96

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
176	M243	Primary geochemical and isotopic dispersion haloes in Archaean lode-gold systems: Assessment of alteration indices for use in district and mine-scale exploration	P. EILU, J. MIKUCKI	May '96 Oct '96
181	M244	Assessment of base-metal prospectivity in sedimentary basins based on the association between hydrocarbon and metalliferous brine migration: A feasibility study based on the Fitzroy Trough/Lennard Shelf, Western Australia	B. RASMUSSEN, B. KRAPEZ, D. I. GROVES	Nov '97
184	M267	Soil geochemical anomalies – their dynamic nature and interpretation	A. W. MANN, A. T. MANN, D. B. HUMPHREYS, S. E. DOWLING, S. STALTARI, L. MYERS	Nov '97
193	M195	Systematic documentation of Archaean gold deposits of the Yilgarn block	F. VANDERHOR, D. I. GROVES	Mar '98
198	M311	Gold solubility in neutral-alkaline solutions	A. W. MANN, A. T. MANN, S. STALTARI	Nov '98
199	M242	Timing and genesis of Hamersley BIF-hosted iron deposits: a new palaeomagnetic interpretation	Z. X. LI, W. GUO, C. McA, POWELL	Mar '00
205	M322	Mapping the Panorama VMS-style alteration and host rock mineralogy, Pilbara Block, using airborne Hyperspectral VNIR-SWIR data	T. CUDAHY, K. OKADA, K. UEDA, C. BRAUHART, P. MORANT, D. HUSTON, T. COCKS, J. WILSON, P. MASON, U. F. HUNTINGTON	Dec '99
206	M323	Comparison of Mobile Metal Ion (MMI) geochemistry and conventional geochemistry at mineralized sites in different geological, climatological and regolith settings.	A. MANN, R. BIRRELL, T. FOSTER, S. STALTARI	
216	M303	Texture-based enhancement and classification of aeromagnetic data	M. DENTITH, S. SHI, D. COWAN	Feb '00

HYDROCARBON EXPLORATION

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
3	3	Petroleum geochemistry of Canning and Bonaparte Basins	R. ALEXANDER, R. I. KAGI, S. ROWLAND	1983
9	28	Petroleum geochemistry of potential source rocks from the Canning Basin	R. ALEXANDER, M. CUMBERS, R. I. KAGI	Nov '84
10	39	The seismic performance of shaped charges	N. F. UREN, B. J. EVANS	Jun '85
12	1/50	Petrology of Devonian and carboniferous carbonates of the Canning and Bonaparte Basins	C. KERANS	Mar '85
20	44	Petroleum geochemistry of the Canning Basin	R. ALEXANDER, K. M. CUMBERS, B. HARTUNG, R. I. KAGI	Sep '85
41	63	Multidimensional seismology – papers	B. J. EVANS (Editor)	Mar '89
50	60	Petroleum geochemistry of the Canning Basin: thermal history	R. ALEXANDER, R. I. KAGI, K. M. CUMBERS, C. A. LEWIS, W. VAN BRONSWIJK, A. ZUHAAR	Jul '89
55	84	Lower Cretaceous deposition in the southern North West Shelf	N. B. THOMPSON, R. M. HOCKING, L. B. COLLINS, J. W. K. VOON, M. F. MIDDLETON	Apr '90
58	88	The recognition and suppression, of seismic multiples offshore North West Shelf, Australia	G. HEAL, B. EVANS	Jun '90
69	M112	Evaluation and development of non-destructive core analysis using X-ray computed tomography	L. COSHELL, J. SCOTT, A. M. KNIGHTS, B. J. EVANS	Dec '90
86	M125	Seismic/Lithology	C. JUHLIN	Mar '92
114	M184	Thermal properties of Western Australian sediments	M. F. MIDDLETON, M. LENNANE,	Sep '93
128	M150	Phase behaviour studies for optimizing hydrocarbon liquid production from the North West Shelf gas condensate fields	T. J. EDWARDS, R. D. TRENGOVE, D. BURGE, R. MURRAY, S. UNSTEAD	Jul '95

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
133	M181	The geometry and Phanerozoic history of the Darling Fault and associated structures in the Perth Basin	M. DENTITH, A. LONG, J. SCOTT, I. BRUNER	Sep '94
138	M220	A biomarker study to correlate oils and source rocks from the Carnarvon Basin	B. G. K. VAN AARSSEN, R. ALEXANDER, R. I. KAGI	Dec '94
152	M252	Influence of anisotropy on depth conversion	P. N. OKOYE, N. F. UREN	Aug '95
159	M225	Subtle faults/fractures and coal seams	B. J. EVANS	Jun '96
164	M221	Attenuation of seismic multiples	N. F. UREN, B. M. HARTLEY	Apr '96
170	M260	Tectonic and stratigraphic evolution of the Carnarvon Basin, Northwest Australia	N. DRISCOLL, G. D. KARNER	Aug '96
188	M251	Plant biomarker study for oil source rock correlation in the Carnarvon Basin	B. G. K. VAN AARSSEN, R. ALEXANDER, R. I. KAGI	Jul '97
197	M274	3-D seismic expressions of fault systems	D. SHERLOCK, B. EVANS	Aug '98
203	M275	Determination, interpretation and correction for seismic anisotropy	P. N. OKOYE, N. F. UREN	Sep '99
213	M319	Jurassic calcareous nannofossil biostratigraphy of the North West Shelf and Timor Sea areas	R. W. HOWE	Dec '00
218	M306	Oil-Source correlation using molecular sequence stratigraphy	B. G. K. VAN AARSSEN, R. ALEXANDER, R. I. KAGI	Apr '00
219	M297	Evaluating trap integrity on the northwest shelf of Australia using hydrodynamic analysis	C. OTTO, A. HENNIG, J. UNDERSCHULZ, V. ROY, G. O'BRIEN	Dec '00
224	M343	Physical modelling study of sleipner west CO_2 sequestration Stage 1 – Modelling the sleipner west overburden	B. EVANS, J. McKENNA	Jan '02

MINING AND PETROLEUM ENGINEERING

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
8	31	The contribution of the extractive industries to the Western Australian economy	K. CLEMENTS, R. W. FRASER	Oct '84
28	45	The development of a railhead gauge for ore haulage railways	T. W. RILEY	Dec '86
31	54	Use of Electronic Distance Measuring (EDM) equipment in underground surveying	J. E. MAISEY, R. LYSNAR	Mar '87
33	16	On-line control of hydrocyclones	A. GUPTA, H. EREN	Jul '87
34	68	An improved nephelometer window for corrosive environments	P. G. SMITH, J. D. SWIFT	Dec '87
35	74	Influence of pore pressure variation on sandstone behaviour and its contribution to subsistence and strata behaviour interpretation in the Collie Basin	A. W. EVANS, M. A. KAWECKI, H. NIKRAZ	Jul '88
36	58	Repair of fatigue damage in welded joints	T. PYLE, P. H. TOWNEND, M. PITRUN	Aug '89
37	37	The development of a load monitoring, display and reporting system for shovels	P. VAN MANEN, T. W. RILEY	Aug '88
48	91	Agitator design for leaching	T. PYLE, D. ALLEN	Jun '89
53	94	Measurement and control of blast vibration and airblast overpressure in the Eastern Goldfields of Western Australia	D. P. BLAIR, T. N. LITTLE	Jan '90
62	76	Corrosion of bus superstructure components	T. PYLE, P. H. TOWNEND.	Apr '91
63	86/ M115	Factors that affect splice strength in conveyor belts	J. G. DUNN, R. E. PRICE	May '90
79	M174	Preliminary study of radon in underground mines in Western Australia	G. S. HEWSON, P. J. TIPPET, B. H. O'CONNOR, M. I. RALPH, S. EVANS	Sep '91
80	M149	Mechanical properties of Goldfields rocks with particular emphasis on an examination of the influence of sample size on laboratory strength measurements	S. KRAMADIBRATA, I. O. JONES, S. J. D. COX	Oct '91
98	M146	Groundwater recharge studies in the Kalgoorlie region	J. TURNER, M. ROSEN, N. MILLIGAN, M. SKYLASH, L. TOWNLEY	Jul '93
101	M177	Application of small format terrestrial photogrammetry in monitoring open pit mine wall stability	C. F. SWINDELLS, D. FARMER, B. MONTGOMERY	Feb '93

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
136	M198	Ageing characteristics of conveyor belt splices	J. G. DUNN, R. D. ENTWISTLE, R. E. PRICE	Oct '94
140	M226	An investigation of the controls on shallow subsidence in the Collie Basin	C. R. D. GOLDSMITH, S. J. BRICE, A. W. EVANS	Feb '95
143	M218	Mid-shaft cage arrestor	P. G. ROWE	Nov '95
154	M217	Groundwater supply to the mining industry in the WA Goldfields	J. V. TURNER, et al.	Mar '96
156	M165	Subsidence prediction in the Collie Basin	I. J. MISICH, A. W. EVANS	Oct '97
167	M210	Development of adaptive based active noise control ear defenders for the resource industries	J. PAN, M. P. NORTON, R. PAUROBALLY, H. PENG, C. BAO	May '96
171	M169	The prediction of dynamic stress in structures due to air- and structure-borne sound and vibration	M. P. NORTON, D. G. KARCZUB	Nov '96
185	M291	Model research program for hydrodynamic response of an air lifted GBS in limited water depth	A. HILL, E. SOW	Dec '97
186	M236	Integrated monitoring systems for open pit wall deformation	X. DING, M. TSAKIRI, S. B. MONTGOMERY, C. F. SWINDELLS, R. J. JEWELL	Jun '98
189	M241	Research into saline-tailings disposal and decommissioning	T. NEWSON, M. FAHEY	Mar '98
190	M269	Precise determination of isentropic exponent and speed of sound in hydrocarbons and natural gases	D. J. PACK, D. FAWCETT, T. J. EDWARDS, K. FRIDAY, K. MEIER	Dec '97
201	M287	Selection of corrosion resistant steels for use in oil and gas flowlines	D. CLOVER, B. KINSELLA, S. BAILEY, R. de MARCO	Jul '99
207	M268	An integrated study of foundation systems on calcareous sediments	M. F. RANDOLPH, P. G. WATSON, M. F. BRANSBY, M. FAHEY	Oct '99
223	M341	Toward the elimination of rockfall fatalities in Australian mines	Y. POTVIN, P. NEDIN, M. SANDY, K. ROSENGREN, M. ROSENGREN	Dec '01

MINERAL PROCESSING

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
1	2	The flash smelting of nickel sulphide concentrates	J. G. DUNN	1983
2	10	Carbon-in-pulp gold processing technology	M. RUANE	1983
5	35	Fouling studies on C.I.P. carbons and prospects for gold recovery using ion exchange resins	I. SMITH, W. HINCHCLIFFE, J. W. HOSKING, D. M. MUIR	Mar '84
7	27	Flash smelter shaft operations	J. G. DUNN, T. M. SMITH	Jul '84
15	46/64	Investigation of the production of iron oxide pigments from reduced ilmenite	A. C. BAX, I. M. RITCHIE	Jun '86
17	15	The application of chloride hydrometallurgy to upgrading dirty base metal sulphide concentrates and processing nickel matte in Western Australia	D. M. MUIR, D. J. PASS	Jul '85
19	29	Corrosion of metallic iron from reduced ilmenite	J. B. FARROW, I. M. RITCHIE	Jul '85
25	67	Gold deposition during the roasting of pyritic gold concentrates	J. G. DUNN, R. BAILEY	Oct '86
39	53	Flash smelter operating variables	T. N. SMITH, J. G. DUNN, J. C. MACKEY, L. R. STEVENSON	Nov '88
46	72	The recovery of gold from leached calcine residues (with a literature review of the technology of extraction of gold from refractory ores)	I. J. CORRANS, J. HAYES	Mar '89
51	87	Mineralogy and processing characteristics of arsenical gold ores	J. P. VAUGHAN, S. BACIGALUPO-ROSE, R. DUNNE	Sep '89
54	80	Selective flotation of Mount Weld phosphate ore	W. Q. GOND, A. PARENTICH, L. H. LITTLE, L. J. WARREN	Feb '90
59	78	Relationships between mineralogy, roasting, and extraction of gold from refractory pyritic and arsenopyritic gold ores and concentrates	J. G. DUNN, J. GRAHAM, J. AVRAAMIDES	Apr '90
87	M141	Ignition studies in flash smelting	T. H. SMITH, J. G. DUNN, M. B. WILD, L. C. MACKEY	Apr '92
92	M102	The solubility of cobalt in fayalite slags and factors affecting cobalt recovery	E. J. GRIMSEY	May '92
97	M136	Mineralogy and processing characteristics of arsenical gold ores – phase 2	J. P. VAUGHAN, I. J. CORRANS	Dec '92

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
105	M128	Upgrading ultrafine iron ore	J. G. DUNN, L. J. WARREN, P. K. WEISSENBORN	Apr '93
113	M191	Control of copper in gold electrowinning	J. AVRAAMIDES, I. M. RITCHIE, S. JAYASEKERA, J. L. ZHENG	Sep '93
115	M186	The study of heteropolytungstates for heavy liquid mineral separations	B. J. SMITH, D. L. KEPERT, V. A. PATRICK	Aug '93
125	M185	Studies on column flotation of sulphide ores of Western Australia – Also refer Report 141 Supplement	R. TUTEJA, D. SPOTTISWOOD, V. MISRA, T. SIEFKEN	Feb '94
135	M192	Pyrolysis and extraction of gold from refractory sulphide concentrates – Supplementary Report	T. M. SMITH, B. VERBAAN, M. D. GIBBS, D. SHI, M. B. WILD	Aug '94 May '97
141	M185	Modelling and simulation of flotation columns – Supplement to Report No. 125	R. K. TUTEJA	Sep '94
144	M207	Manufacture of alumina wear tiles using WA raw materials	R. J. STEAD, D. ALECU, R. PENNIFOLD, K. J. O'RIELLY, A. NG, B. O'CONNOR, B. LATELLA, J. CARTER	Mar '95
149	M205	The effect of stoichiometry on the ignition behaviour of synthetic iron-nickel sulphides	J. G. DUNN, A. C. CHAMBERLAIN	Jun '95
180	M238	Gold processing technology	S. LA BROOY, A. C. BAX	Mar '97
183	M279	Improving thickener technology	R. R. M. JOHNSTON, J. D. SWIFT, T. NGUYEN, K. SIMIC, J. B. FARROW	Jun '97
192	M272	Reducing the corrosion wear of steel grinding media	J. AVRAAMIDES, B. KINSELLA	Oct '98
194	M258	Recovery of silicon metal from dross	J. BROSNAN, B. SNOW	Apr '98

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
202	M285	Activated carbon recovered from wastes of synthetic rutile operations in Western Australia	P. DONECKER, K. HARRISON, P. McCORMICK, J. HARROWFIELD, C. HALAIS	Jul '99
204	M278	Fundamentals of gibbsite precipitation	C. VERNON, H. WATLING, D. LAU, M. BROWN, G. PARKINSON, A. ROHL, J. LOH, S. FREIJ, J. GALE	Mar '99
215	M305	Relationship between hydrodynamics and gibbsite precipitation	D. ILIEVSKI, M. RUDMAN, D. BEDELL, G. METCALFE, M. SCHIBECI	Mar '99

REHABILITATION AND ENVIRONMENTAL

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
21	21	The pre-mining assessment of a coal mining lease north of Esperance, WA	P. VAN der MOEZEL, D. T. BELL	Dec '85
44	66	Abatement of dust in the Kalgoorlie region by revegetation of overburden stockpiles	M. FLETCHER, C. MALCOLM, A. PETERSEN, B. JENNINGS, D. BURNSIDE	Mar '89
45	43	Plant and soil ecology of natural areas and rehabilitated minesites near Eneabba	D. T. BELL, B. LAMONT	Mar '90
52	M118	Exchange rates and commodity prices: the Australian case	L. A. SJAASTAD, The Economic Research Centre, University of Western Australia	Jan '90
66	98	Rehabilitation of mining affected flora	K. A. MENEY, K. W. DIXON, J. S. PATE, I. R. DIXON	Sep '90
84	M122/ M208	Utilisation of wastes from synthetic rutile plants	R. GILKES, I. KANABO, A. MOSQUERO-PARDO, D. NEWSOME, D. WEATHERLEY	May '94

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
91	M179	Gold and the exchange rates	L. A. SJAASTAD	May '92
93	M127	The establishment of wetland plants	J. M. FLETCHER, et al	Sep '92
94	M129	Post-mining re-establishment of native heaths (Epacridaceae)	K. DIXON, G. NIELSSON	Oct '92
108	M156	Factors affecting seed germination in goldfields species of *Eremophila*	G. S. RICHMOND, J. E. D. FOX, J. M. OSBORNE	Jun '93
110	M135	Mine waste management in arid areas	B. JENNINGS, E. G. BARRETT-LENNARD, B. J. HILLMAN, M. EMROSE	Dec '93
111	M148	Propagation of forest and heath understorey species: *Hibbertia*	A. SCHATRAL, J. E. D. FOX	Jun '93
112	M193	Integrated conservation of rare flora	M. ROSSETTO, K. W. DIXON, E. BUNN	Sep '93
116	M163	Solidification of toxic wastes (with a literature review of the chemical fixation and solidification of hazardous wastes)	J. H. KYLE, S. SKRYPSKI-MANTELE, T. R. BRIDLE	Jan '94
117	M211	Retention and excretion of thorium by mineral sands industry employees	K. W. TERRY, G. S. HEWSON	Jul '93
121	M158	Propagation and post-mining establishment of native rush and sedge species	K. MENEY , K. DIXON, J. PATE	Dec '93
147	M204	Soil microbiology for revegetation, incorporating field inoculation with VA mycorrhizal fungi	D. A. JASPER	Jun '95
151	M188/ M247	Biology and ecology of *Phytophthora citricola* in native plant communities affected by mining	F. BUNNY, B. SHEARER	Jul '95
158	M200	The impact of smut diseases on rushes and sedges in pre- and post-mining situations	K. WEBSDANE, K. DIXON, K. SIVASITHAMPARAM	Dec '95
162	M249	The relationship between respiratory disease and the particle size of dust inhaled by mine workers (Literature Review)	G. S. HEWSON, K. W. TERRY	Mar '96
163	M214	Post-mining recovery of native heaths (*Epacridaceae*)	B. HUTTON, K. DIXON, K. SIVASITHAMPARAM	May '96
174	M235	Smoke enhanced germination of native species for minesite rehabilitation	K. W. DIXON, S. ROCHE, K. MENEY, B. VON PERGER	Nov '96
175	M227/ M254	Rapid identification of species of *Phytophthora*	S. A. CARSTAIRS, M. J. C. STUKELY	Nov '96

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
179	M237	Fertilizer value of a limed gypsum by-product from mineral sands processing	R. SUMMERS, M. CLARKE, T. POPE	Apr '97
187	M224	Salt tolerant plants for goldfields revegetation	I. BENNETT, D. EYRE, B. DUFF	Apr '98
191	M250	Mycorrhizal associations of plants in the eastern goldfields	D. A. JASPER, S. MERCER	Aug '97
195	M249	Characterization of inhaled dusts on mine sites	K. W. TERRY, G. S. HEWSON, M. B. ROWE	Aug '98
208	M277	Assessment procedures and end point criteria for arid mine waste rock dumps	D. BREARLEY, J. OSBORNE, I. RIGHT	May '00
209	M280	The potential of the fungicide phosphite to control *Phytophthora cinnamomi* in native plant communities associated with mining	G. HARDY, B. DELL, I. COLQUHOUN, J. McCOMB	Dec '00
214	M309	Cyanide waste management: Minimizing environmental and economic impacts	P. MAY, G. HEFTER, P. LOTZ, R. SCHULZ, K. MURRAY, P. LYE	Jul '00
217	M317	The transport of near surface salts in hyper-saline gold tailings and the implications for dust generation by wind action	S. J. ZEGELIN, J. N. CARRAS, F. J. COOK, K. RILE, D. E. SMILES	Jan '01
220	M290	Improving the precision of ecotoxicity testing protocols for crude oils and drilling fluids	L. EVANS, Y. TSVETNENKO, J. WOODWORTH	Oct '00
221	M270	The role of nutrient cycling in the sustainability of young plant communites	M. C. L. TODD	Mar '00
225	M312	Rehabilitation of salt affected mining lands using the native halophytic shrub *Halosarcia*	T. COLMER, D. JASPER	Apr '02

8 : Published Reports

ALTERNATIVE ENERGY RESEARCH

ALTERNATIVE ENERGY PUBLICATIONS

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
56	E104	New approaches for preparing thin films of amorphous siliconfor photovoltaic applications	G. T. HEFTER et al	Jun '90
57	E138	Electrochemically induced nuclear fusion	T. QUICKENDEN, T. GREEN	Feb '90
60	E114	Upgrading and evaluation of sludge derived oil as a diesel fuel	T. R. BRIDLE	Apr '90
64	E116 E162	A Western Australian wind atlas and ATLAS program Supplement	S. J. DEAR et al	Aug '90
65	E110	Development of a simulation package for remote area power supply systems	T. L. PRYOR, A. A. LIM	Nov '90
71	E106	Small-scale wind-powered electric generators	C. V. NAYAR. et al	May '91
73	E107	Commercial development of an advanced power conditioner for solar systems	S. J. PHILLIPS	May '91
74	E117	Solar and wind powered compressed air water pumping system	SYSTEMS INTELECT	May '91
75	E157	Substantial energy reduction in solar powered refrigerators	W. L. JAMES, J. MANUEL	Jul '91
76	E171	Solar powered reverse osmosis desalination	G. HO, D. G. HARRISON	Aug '91

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
77	E160	Further investigations into electrochemically induced nuclear fusion	T. I. QUICKENDEN, T. A. GREEN	Aug '91
81	E108	Development of a low-cost energy-efficient remote area power supply	S. J. PHILLIPS, W. L. JAMES	Dec '91
83	E183	Investigation of the use of neodymium iron boron magnets in wind turbine generators	T. S. CRAWFORD, G. P. HILL	Mar '92
85	E164	Shadeglass	S. P. PAOLINO	Mar '92
88	E189	Motorized solar tracker module	J. HALL	Jun '92
89	E195	Suntracker	G. MOORE	Mar '92
90	E134	The effect of thermal mass of a structure in energy efficient commercial (airconditioned) buildings	G. F. BAVERSTOCK	Feb '94
95	E152	Wind/solar/diesel/battery hybrid energy system	C. V. NAYAR, S. J. PHILLIPS	Dec '92
96	E161	Amorphous silicon thin films and devices	J. C. L. CORNISH et al	Nov '92
99	E199	Energy efficient anaerobic treatment of brewery wastewater	M. NEWLAND et al	Feb '93
100	E209	Tidal power generation – demonstration project	P. WOOD	Jan '93
103	E109	Surface modified electrode for state-of-charge determination of lead-acid batteries	P. SINGH et al	Feb '93
104	E176	Medium to high power photovoltaic and wind-based standalone energy supply	S. WROBLEWSKI	Feb '93
107	E180	Perth regional landfill gas resource assessment	S. BATEMAN et al	Feb '94
118	E213	Hydrocool thermoelectric refrigeration system	J. SEARLS, G. ATTEY	Sep '93
119	E192	Wind resource assessment issues in Western Australia	S. DEAR	Sep '93
120	E198	Efficient solar and off-peak powered freezer with eutectic storage	W. JAMES, J. MANUEL	Jan '94
124	E193	Towards more efficient electric power generation in SECWA remote systems	D. REMMER, M. DYMOND	Apr '94
126	E219	Comparative analysis of domestic energy consumption in three sub-divisions in Kingsley, WA	N. D'CRUZ, D. PHILIP	Jan '94
127	E208	Development of wind turbine technology	T. S. CRAWFORD, S. PHILLIPS	Feb '94
129	E197	Investigation of power transients in fuel cells for power conditioning design	W. JAMES et al	Mar '94
130	E202	Solar powered reverse osmosis desalination – development	G. E. HO, D. G. HARRISON	Jul '94
131	E222	Hydrocool vacuum panel thermal insulation	G. ATTEY, S. EDWARDS	May '94

REPORT No.	PROJECT No.	TITLE	AUTHORS	YEAR
132	E188	Drive optimisation for a solar pumping system	W. LAWRANCE, L. LANGRIDGE	May '94
134	E203	Cold fusion studies on heavily deuterated electrodes	T. I. QUICKENDEN, T. A. GREEN	Jun '94
137	E215	Investigation into advanced power electronic techniques	C. V. NAYAR, L. J. BORLE	Nov '94
139	E220	Optimization of amorphous silicon thin film devices	P. J. JENNINGS, J. C. L. CORNISH	Jan '95
148	E223	Maximum power point tracking remote area power system controller	J. HALL	Jul '95
150	E196	Measurement and prediction of speed of sound with application to gas flow metering in Australian natural gases	T. J. EDWARDS et al	Jul '95
155	E206	Reduction of harmonic distortion and associated energy losses in industrial applications	W. LAWRANCE, W. MIELCZARSKI	Aug '95
160	E224	Grid interactive power electronics in energy efficiency and renewables	U. DUETSCHLER	Sep '95
161	E233	Development of a 20 kW low-speed high-torque permanent magnet wind generator	B. BRIX et al	Mar '96
166	E229	Wind powered water pump development and demonstration	R. WHITE	May '96
168	E216	The use of artificial neural networks in the control of hybrid power generation systems	E. GRAY, K. CHEOK, T. PRYOR	Aug '96
169	E231	Advancement of current control techniques	D. BAKER, C. NAYAR, L. BORLE, A. RUSCOE	Sep '96
172	E239	Solar powered desalination for remote areas	G. E. HO, D. G. HARRISON	Apr '97
177	E228	Research and demonstration: Optimized hybrid energy system	S. PHILLIPS, K. KOTTATHRA, U. DUETSCHLER, G. YAO	Nov '96
182	E237	Amorphous silicon solar cells	G. HANN, J. CORNISH, G. HEFTER, P. JENNINGS, C. LUND, F. ZHU	Jul '97
196	E232	Reduction of harmonic distortion in three phase fluorescent lighting systems	W. LAWRANCE, W. MIELCZARSKI.	Aug '98

9 : Current Projects

as at June, 2002

PROJECT NO.	TITLE OF PROJECT	APPLICANTS
M282	Resolution of subsurface structure of Hamersley Province by multi-channel seismic reflection	C. McA. POWELL, P. A. CAWOOD, M. DENTITH
M288	Development of an electro-chemical corrosion probe for use in oil and gas flowlines	S. BAILEY, B. KINSELLA
M289	Radiographic silicosis and lung cancer in Kalgoorlie miners	N. de KLERK, A. W. MUSK
M304	Genetic stratigraphic analysis of the Hamersley group	M. E. BARLEY, B. KRAPEZ
M313	Triassic palynostratigraphy of the Dampier Sub Basin	D. HAIG
M321	Somatic embryogenesis and synthetic seed technology for mine restoration with emphasis on native heaths	K. DIXON
M328	Mine seismicity and rockburst risk management	Y. POTVIN, R. JEWELL
M329	Stress measurements from cored rock	E. VILLAESCUSA
M331	Shallow water tow-out issues in WA-based construction of concrete gravity structures for offshore oil and gas production	K. P. THIAGARAJAN, B. F. RONALDS
M332	Management of *Rumex vesicarius L.* on rehabilitated mine sites in the Goldfields of Western Australia	J. OSBORNE, A. SCHATRAL
M333	Corrosion of rock reinforcement in underground excavations	E.VILLAESCUSA

PROJECT NO.	TITLE OF PROJECT	APPLICANTS
M335	Application of trace fossil studies to depositional facies analysis and stratal surface identification: Middle Jurassic - Lower Cretaceous deltaic, estuarine and shallow marine systems, NW Shelf	F. BURNS, A. GEORGE
M336	Molecular stratigraphy research for oil-source rock correlation	R. ALEXANDER, R. KAGI
M338	Cretaceous & Neogene reactivation & inversion history of the Northern Carnarvon Basin & the role of basement highs in the distribution of Cretaceous & Neogene strain in the Carnarvon Basin & Browse Basin/Timor Sea	M. KEEP
M339	Using seismic anisotropy to characterize seal and reservoir properties in the NW Shelf of WA	P. N. OKOYE, M. UROSEVIC
M340	XMML - online data transfer for the exploration and mining industry	S. COX
M342	Development of a new seismic fracture mapping technique	B. EVANS, M. LUO
M344	Nutrient absorption capacity of neutralised acid effluent and blends	B. McLOUGHLIN, D. VON HORN
M345	Automated measurement of phase behaviour in North West Shelf petroleum & natural gas fluids using advanced microwave technology	T. EDWARDS, T. G. MANN
M346	Upper crustal structure of the Laverton Tectonic Zone adjacent to major gold deposits from seismic reflection profiling	M. DENTITH, B. GOLEBY
M347	Trace fossils and their application to high resolution sequence stratigraphy and associated cement distribution: Middle Jurassic to Lower Cretaceous Interval, North West Shelf	F. BURNS, A. GEORGE
M348	Development of tantalum-silicon photovoltaic devices	J. LIVINGSTONE, J. HENRY
M349	Dynamic testing of ground support elements	E. VILLAESCUSA
M350	Selective herbivory by kangaroos in mined land	B. LAMONT
M354	The occupational health risk of melioidosis in the mining industry	T. INGLIS, K. HOWARD
M355	Mine seismicity and rockburst risk management	Y. POTVIN, M. HUDYMA

10 : Supplementary Scholarship Awards

MINERALS AND PETROLEUM RESEARCH

NAME	YEAR AWARDED	UNIVERSITY
Clive MILHAM	1991	The University of Western Australia
Joseph KNIGHT	1992	The University of Western Australia
Yadran MARINOVICH	1993	The University of Western Australia/Murdoch University
Katherine MALATT	1994	Curtin University of Technology
Jialong ZHENG	1994	Murdoch University
Emer O'GARA	1995	Murdoch University
Christopher WARRIS	1995	The University of Western Australia
Carl BRAUHART	1996	The University of Western Australia
Yumin QIU	1996	The University of Western Australia
Matthew JEFFREY	1996	Curtin University of Technology
Thomas RIDSDILL-SMITH	1997	The University of Western Australia
Anthony GARTRELL	1997	The University of Western Australia
Richard HIGGINS	1997	The University of Western Australia
April PICKARD	1998	The University of Western Australia
Philip HECKLEY	1998	WA School of Mines/Curtin University of Technology
Ronald HACKNEY	1999	The University of Western Australia

NAME	YEAR AWARDED	UNIVERSITY
Karl BRENNAN	1999	Curtin University of Technology
Eric MAY	2000	The University of Western Australia
Grace ZAWKO	2000	The University of Western Australia/Botanic Gardens and Parks Authority
Joanna KELLY	2001	The University of Western Australia
Troy THOMPSON	2001	Curtin University of Technology
Alasdair GRIGG *	2002	The University of Western Australia
Daniel HELM	2002	WA School of Mines/Curtin University of Technology
James HOS	2002	The University of Western Australia

* Joe Lord Memorial Scholarship, to commemorate MERIWA's 20th anniversary, sponsored by contributions from Wesfarmers Coal Limited, Outokumpu (Black Swan Nickel Pty Ltd), Normandy Mining Ltd, Delta Gold Limited and the WA School of Mines.

ALTERNATIVE ENERGY RESEARCH

NAME	YEAR AWARDED	UNIVERSITY
Marisa IOPPOLO	1991	Curtin University of Technology
Jacob PERAHIA	1992	Curtin University of Technology
Andrew WEBB	1993	The University of Western Australia
Stephanie JENNINGS	1994	Murdoch University

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