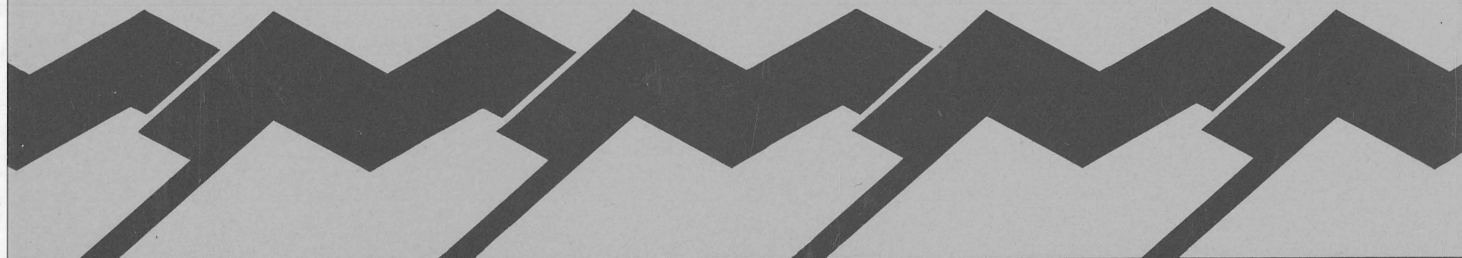
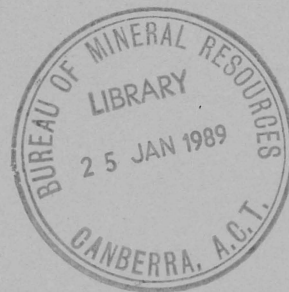


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SUBMISSION TO THE REVIEW OF
MARINE SCIENCE AND TECHNOLOGY

by

David A. Falvey

Division of Marine Geosciences & Petroleum Geology

1988/41
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SUBMISSION TO THE REVIEW OF MARINE SCIENCE AND TECHNOLOGY

MARINE GEOSCIENCE AND THE EXPLORATION FOR PETROLEUM

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SUBMISSION TO THE REVIEW OF MARINE SCIENCE AND TECHNOLOGY

MARINE GEOSCIENCE AND THE EXPLORATION FOR PETROLEUM

BACKGROUND

Supply and Demand for Petroleum Liquids

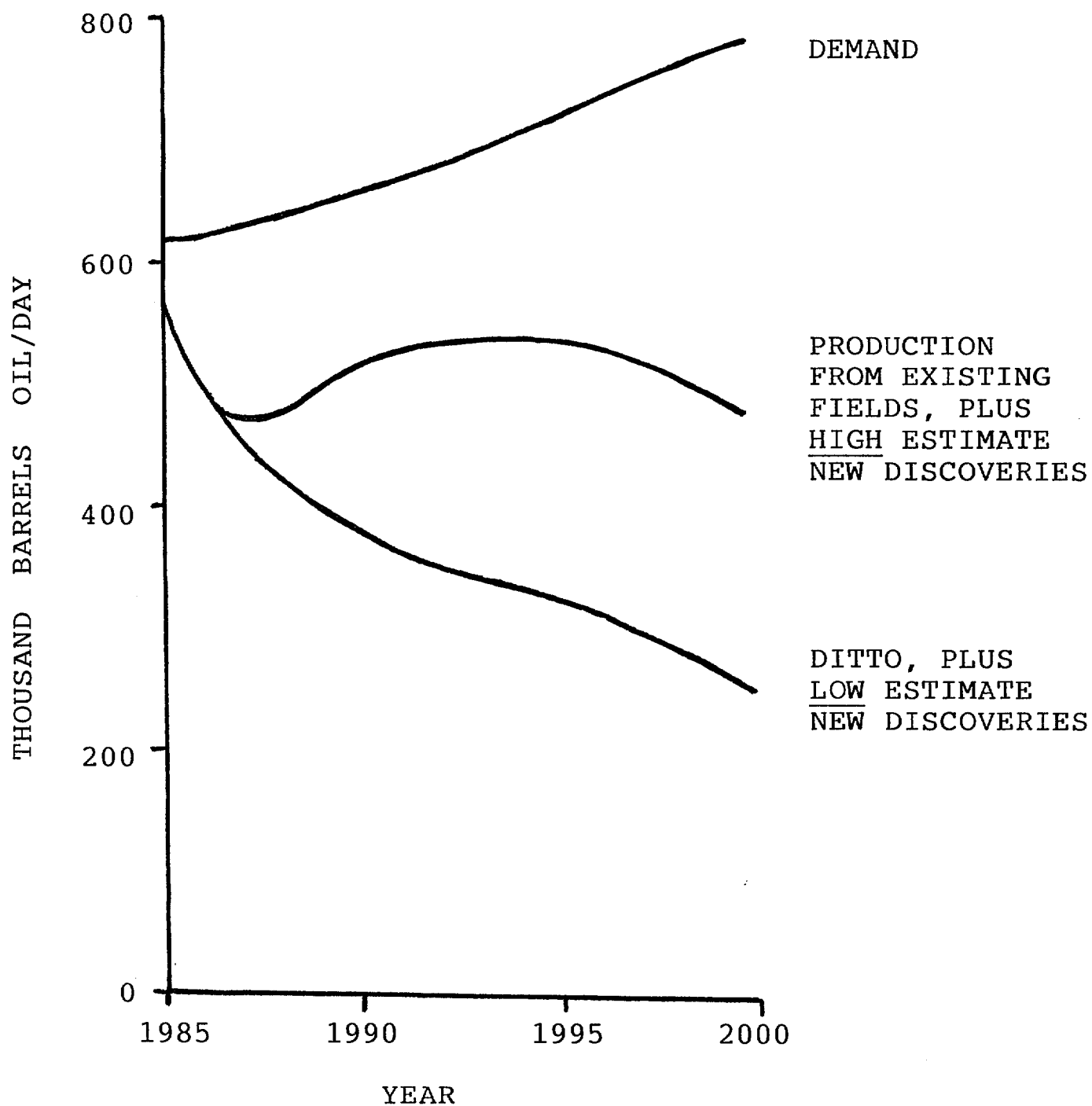
An underlying reason for maintaining and further developing a strong marine geoscience sector in Australia lies in the substantial contribution it makes to continued effective petroleum exploration. Further discoveries are required to meet the continuing demand for petroleum liquids (for road, sea and air transportation in particular). It is presumed that world demand will grow, albeit slowing, over at least the next 20 to 30 years.

This demand outlook must be contrasted with the outlook for supply. (The current world oversupply of oil is brought about by excess production capacity, rather than excess of reserves.) Petroleum resources are non-renewable on a human timescale and of finite, although unknown magnitude. On a global scale, a real diminishing availability of cheap and widely available oil is inevitable. It will become more elusive and more costly to find, and will be discovered in smaller and smaller pools. The projected supply/demand imbalance is certain to drive disproportionate increases in price through the early part of the next century.

Australia's supply/demand projection is illustrated in Figure 1. The supply predictions are based principally on production from currently known fields. To this is added high and low probability estimates of future discoveries of conventional petroleum accumulations of types already known to occur or thought to exist in particular areas, based on existing geological knowledge. These forecasts are therefore conservative and clearly take no account of oil which may be found in currently unexplored basins, or in explored basins in geological settings not currently known to hold oil. In other words, the forecasts take no account of the role of innovative geological science in finding new basins, geological settings and models of petroleum occurrence. These projections are, however, a legitimate basis for economic planning:

PROJECTED PRODUCTION AND DEMAND

OIL/CONDENSATE/LPG



SOURCE: ENERGY 2000

FIGURE 1

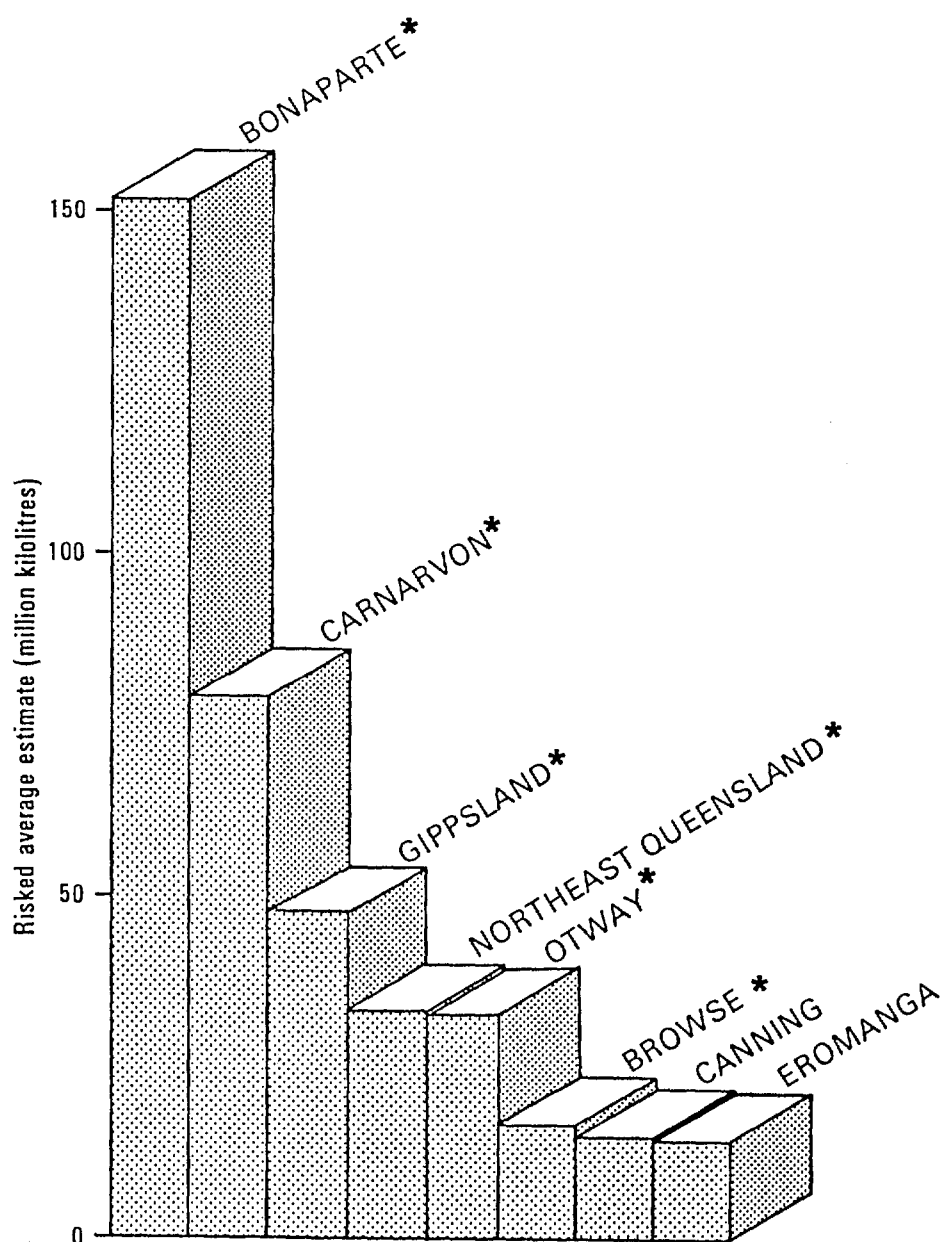
- . Assuming the low estimate prediction to the year 2000 and using the present low world oil price, Australia's balance of payments deficit on oil imports alone would increase by about \$4 billion per year.
- . Government revenues from petroleum royalties, levies and taxes would fall by almost \$2 billion per year over the same period.
- . Assuming the more optimistic higher estimate of new discoveries would lead to the balance of payments deficit growing by about \$2 billion per year, and Government revenue falling by about \$500 million per year.

The underlying thesis of this Submission is that, at the very least, innovative programs of geoscientific surveys and research will contribute, or act to lift the balance of probability from a lower to a higher level of new petroleum discoveries. There is a real probability that such research may lead to new discoveries which exceed the higher estimate case.

In order to focus such research and survey programs it is important to note that almost 90% of Australia's current oil production is from offshore or continental margin sedimentary basins. BMR's current risked average estimate of the undiscovered reserves in Australia's eight most prospective basins is shown in Figure 2. The first six of these basins are offshore, and contain more than 90% of the currently forecast undiscovered reserves. Even allowing for the uncertainties of such forecasts, they provide a valid direction where geoscientific research and surveys might best act to lift the level of new discoveries, and clearly that is offshore. This conclusion is supported by the simple fact that Australia's onshore area is a little over 7 million sq kms, compared with an offshore jurisdiction of almost 12 million sq kms, or about 62% of the total (Figure 3).

On the balance of area and prospectivity, at least three quarters of Australia's petroleum related strategic geoscientific research and survey effort should be directed offshore, together with research and development of related exploration and survey technologies.

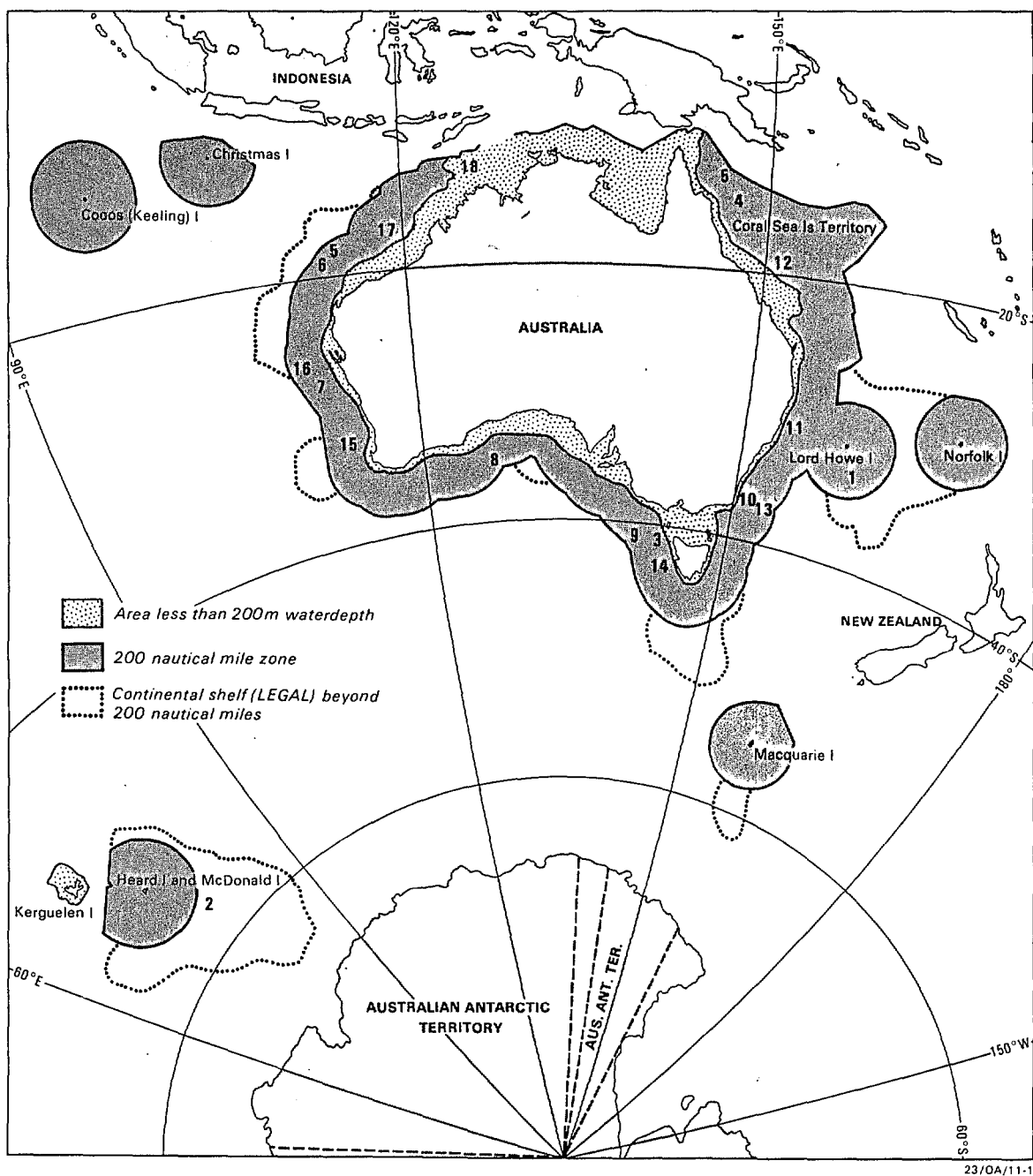
SUMMARY OF PROBABLE UNDISCOVERED PETROLEUM
LIQUIDS IN AUSTRALIA'S 8 MOST PROSPECTIVE BASINS



* Offshore basin

SOURCE: "Australia's Petroleum Potential"
BMR, 1988

FIGURE 2



- Areas of study by BMR's *Rig Seismic* under the continental margins program. (* Completed)

FIGURE 3

With these policy objectives in mind the Federal Government announced a new BMR research program in the 1983-84 Budget context. Known as the "Continental Margins Program", it involves strategic offshore surveys and research, and is carried out by BMR's Division of Marine Geosciences and Petroleum Geology.

- . The first research cruise under the Continental Margins Program was carried out in January 1985. The program is well established and constitutes a significant and increasingly effective component of the petroleum related research, surveys and resource assessment activities of Government.
- . The BMR research and seismic survey vessel, Rig Seismic, is now well set up and has charter options for a further 10 years.
- . Australia is on the point of joining Canada in consortium membership of the Ocean Drilling Program.

Organisation and Conduct of Petroleum Exploration

In Australia, the exploration industry is overwhelmingly private, with only the SAGASCO Resources and the Gas and Fuel Corporation of Victoria being State Government owned. Exploration and development is administered by seven state/territory authorities onshore and in coastal waters and by seven "Designated Authorities" (on behalf of the Commonwealth) offshore. Offshore exploration and development falls within the jurisdiction of the Petroleum (Submerged Lands) Act. The Petroleum Division of the Department of Primary Industries and Energy administers exploration through each Designated Authority, with technical advice from the Petroleum Branch of BMR's Resource Assessment Division. BMR's Division of Marine Geosciences and Petroleum Geology carries out geoscientific research and surveys, which form the basis of advice to Government on longer term strategies, as well as providing technical incentives to the exploration industry.

Exploration companies acquire the right to explore through a permit issued by a state/territory authority or Designated Authority. Applications are competitive and judged on the work program offered, or, in a few cases offshore, cash bidding. After a permit is granted that company (more

commonly, a previously established joint venture between a number of companies) will hold a guaranteed tenure for a fixed term, provided the work program is carried out.

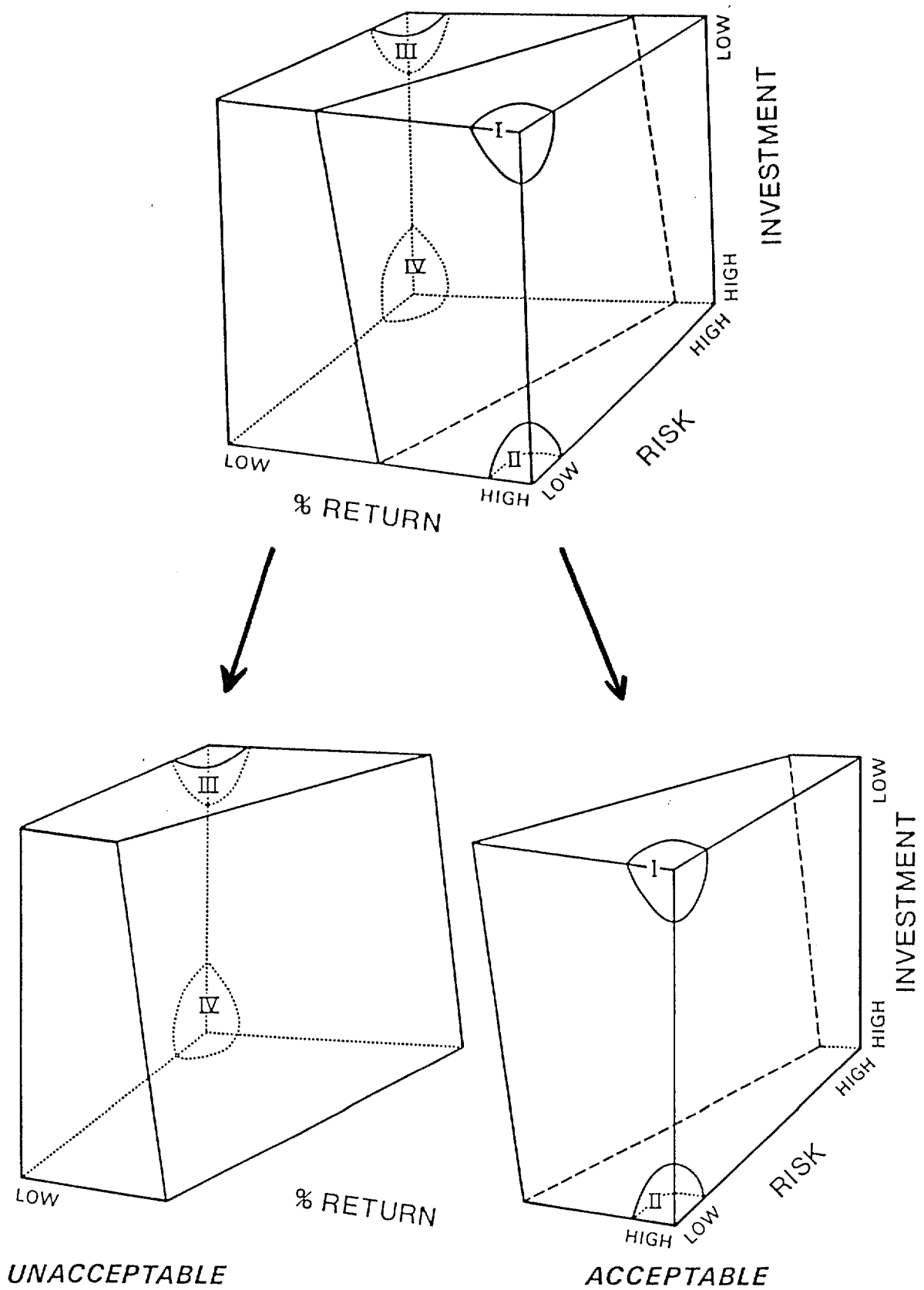
In preparing a work program or cash bid for a permit, a company or joint venture will assess the area offered in terms of the probability of finding oil (geological risk), the investment required to search for and, if successful, then develop the resource (cost) and the nett income generated from any success (return). Figure 4 shows the framework within which this evaluation takes place. Companies tend to develop a portfolio of exploration ventures which are a mix of the high risk/high cost/high return (usually offshore) and the low risk/low cost/medium return (overwhelmingly onshore). The low risk/low cost/high return ventures have long since disappeared. Companies have various corporate strategies, involving different mixes of ventures. Taken together with fluctuations in cash flow caused by oil price variations, this leads to a dynamic industry.

Geological science is the basis of the risk analysis shown in figure 4, and that requires basic geological and geophysical data. One of the roles performed by BMR's Continental Margins Program is to make available such data in relatively unexplored areas or to provide innovative data in conventionally explored areas. The absence of relevant data leads to a default higher risk assessment. Availability of BMR data, therefore, acts on balance to promote exploration through reducing risk assessments.

Expenditure on offshore exploration in Australia has averaged about \$400 million per year over recent years (although it has been lower recently). By comparison, the well head value of present offshore production at the world parity price is approximately ten times this amount. Typical joint venture expenditures on the various phases of an offshore exploration/development program in a single permit area are:

. pre bid analysis	\$10k - \$100k
. cash bid (if relevant)	\$ 1m - \$ 10m
. seismic phase	\$ 1m - \$ 5m
. drilling (per well)	\$ 5m - \$ 15m
. development	\$50m - \$500m

Petroleum Exploration Risk Categorisation



Source: Strategic Planning for Exploration Management
IHRDC, 1983

FIGURE 4

Companies normally spend less than 1% of their exploration budgets prior to gaining tenure over an exploration permit.

In the wider Asian/Pacific region there are some differences in the conduct of exploration when compared with Australia. In Asia in particular, exploration is dominated by national, or state-owned oil companies, who have certain statutory rights. Commonly, all exploration is a joint venture with the state enterprise. Such joint ventures may act to increase the Government's share of nett revenue at the expense of the companies share. However, in the case of Indonesia and Malaysia in particular, generally perceived prospectivity is higher and thus assessed risk lower. In PNG and the Pacific islands, offshore oil prospectivity remains moderate to low or non-existent. In such cases, Governments have offered tax advantages in order to promote exploration. In addition, foreign development assistance and/or World Bank loans have been used to obtain and promote acquisition of regional geoscientific data that might lift prospectivity assessments.

Role of Research in Exploration

Clearly there is no hard and fast distinction between geoscientific research and the initial stages of "wildcat", or frontier exploration. Consequently, most major oil exploration companies support research, either through their "in house" research divisions, by private contract, or (to a much lesser extent) through Government/University research. In Australia, the major oil exploration companies have in-house research divisions and rely on their overseas affiliates for new ideas. The role of "exclusive" geoscientific research is to provide the company with a competitive advantage in the assessment of risk and in the conduct of exploration.

The role of Government funded "public" marine geoscientific research is to promote effective and efficient exploration by the industry within the national jurisdiction, in order to achieve an economically realisable production output and facilitate national economic planning through the fullest possible understanding of future resource potential. Availability of data will, in general, act to decrease the risk assessment on frontier areas and promote increased investment in exploration. Such an objective is of paramount importance in countries where only limited research is conducted in that country by the major oil companies.

This important strategic objective is covered by a range of marine science and technology activities:

- . research requiring regional marine geoscientific surveying and mapping, using more or less conventional data acquisition, processing and analysis techniques.
- . research into improved geophysical and geological data acquisition systems, designed to improve resolution and detection of subsurface features (specifically relevant where special regional data acquisition problems may be inhibiting exploration).
- . research into improved analytical and interpretive techniques, methods and models of geological and geotectonic processes relevant to understanding petroleum generation and habitat.

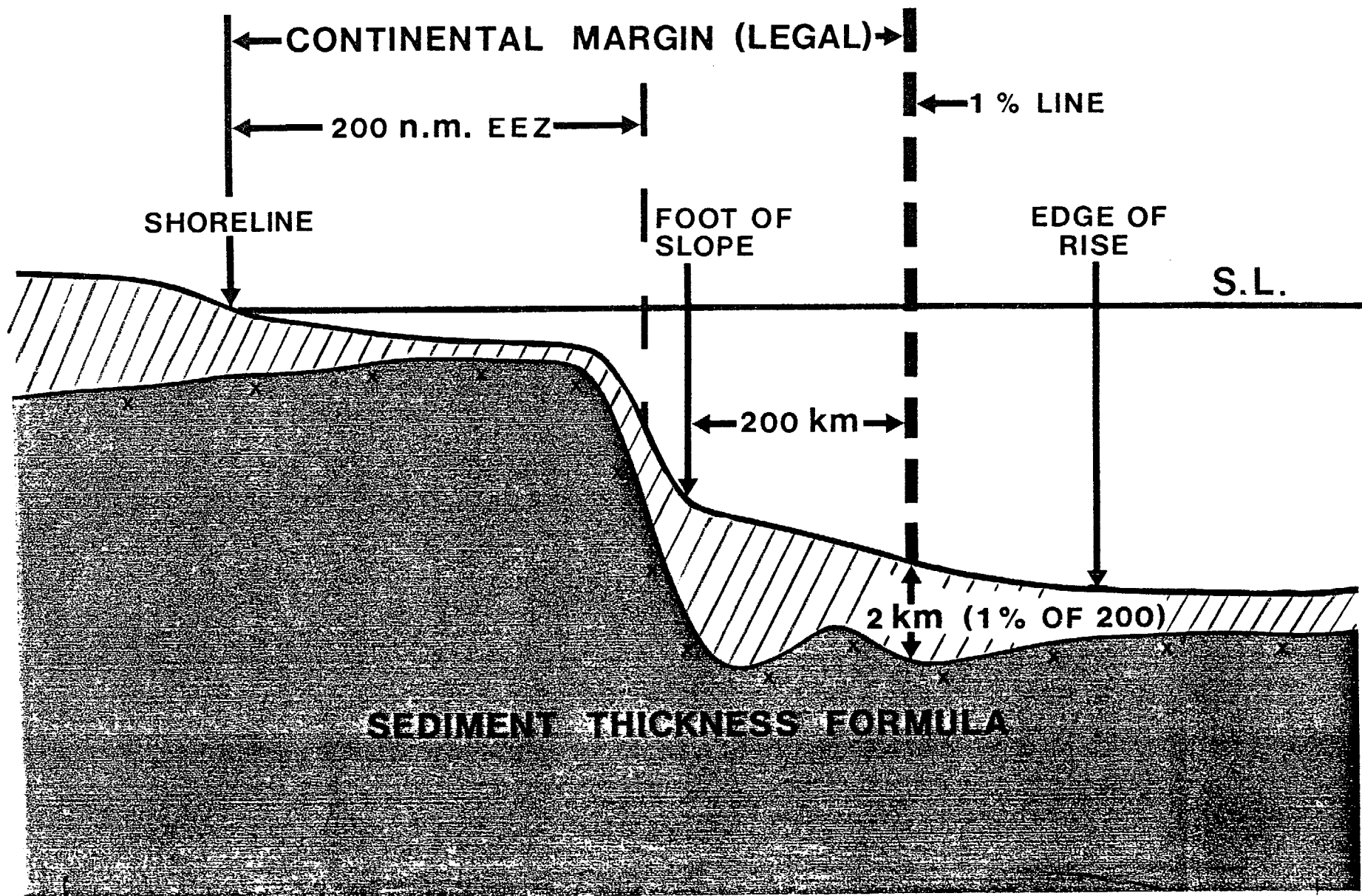
The real return on this type of strategic research is less in short term sale of products than in the long term increase in national wealth and Government revenues from enhanced petroleum production.

Jurisdiction and the Law of the Sea

In 1982 an international agreement was reached covering jurisdiction over the seabed resources of the world's oceans through the United Nations Convention of the Law of the Sea. Australia has signed the Convention but has yet to ratify it. Accordingly, Australia is legally entitled to declare a 200 nautical mile Exclusive Economic Zone (EEZ). Australia must also define the distribution and limits of the Legal Continental Shelf (LCS). This concept involves natural prolongations of the continental margin which may extend beyond the EEZ. Such extensions to the margin involve defining sediment thickness and base of slope morphology. Good bathymetric and sediment thickness data are essential in these determinations, as illustrated in Figure 5.

Australia has not yet declared an EEZ, but its area, plus that of the extended LCS, is likely to be almost 12 million sq km; at least 60% larger than the area of the continent. Eight regions of the Legal Continental Shelf are currently identified which extend outside the EEZ (Figure 3).

FIGURE 5



Difficulties arise in defining seabed boundaries when the EEZ and LCS of adjacent states overlap. The position of the seabed boundary is then subject to negotiation. A negotiated seabed boundary separates Australia from Indonesia (now including the area adjacent to East Timor, but not adjacent to Christmas Island), Papua New Guinea and the French Territories of New Caledonia and Kerguelen. Negotiations are scheduled, or will be required with Solomon Islands, New Zealand and the Antarctic Minerals Convention.

The Continental Margins Program provides the essential data for defining both negotiated seabed boundaries and the boundaries of the Legal Continental Shelf, as well as determining the resource potential of both the Exclusive Economic Zone and Legal Continental Shelf.

BMR'S CONTINENTAL MARGINS PROGRAM

Objectives

This program is an important element in the Federal Government's strategy to encourage the exploration for and development of Australia's offshore petroleum resources, in order to maximise oil self sufficiency as far as possible into the next century. The program has a current commitment of up to ten years (subject to appropriate reviews). The program objectives are:

- . To develop a knowledge and understanding of the geological framework of the continental margins around Australia and its territories, in order to more effectively promote exploration for petroleum by industry.
- . To identify the petroleum and mineral resource exploration potential of the offshore area and to provide the basic information necessary for the formulation of independent advice to the Federal Government on offshore resource development.
- . To develop models of the geological processes which have formed the continental margin and led to economic accumulations of petroleum and minerals.

Program Strategy

The CMP strategic plan emphasises the development of innovative geoscientific research programs, which enhance the prospects of finding new petroleum. Projects are developed in three areas:

- . In sedimentary basins currently considered to have moderate to good prospectivity, and which are consequently being actively explored (e.g. Gippsland Basin) the CMP aims at specific problem solving, through the acquisition of the kind of geological and geophysical data that is not routinely collected by industry: deep crustal seismic, shallow high resolution seismic and seabed geology and geochemistry. This provides for a more flexible examination of new geological models and petroleum play concepts, and so acts to enhance conventional exploration strategies, and contribute to increased petroleum exploration efficiency.

- . In sedimentary basins previously explored, but with no active exploration (e.g. Perth Basin) the CMP aims to reassess regional resource potential, redefine conventional exploration strategies, reassess and, where possible, reduce prospectivity risk assessments and promote renewed exploration. This is achieved principally through regional seismic and geological framework studies.
- . In frontier areas, not so far explored by industry (e.g. Kerguelen Plateau) the CMP aims, through reconnaissance studies, to assess long term resource potential and formulate the technical basis of Australia's Law of the Sea claim.

Program Organisation

The program is managed and operated by BMR's Division of Marine Geosciences and Petroleum Geology. The Division has 87 scientific and technical staff and is organised into four elements:

- . Operations Unit (52 staff): responsible for shipboard operations management, data acquisition, data processing and engineering services.
- . Projects Unit (25 staff): responsible for project formulation, supervision, interpretation and publication of results.
- . Products Unit (6 staff): responsible for drafting, marketing and promotion of program products.
- . Management Unit (4 staff): responsible for overall divisional and program coordination.

The staff of the Division consists of 38 scientists and research scientists, 42 science and engineering technical officers, 5 drafting staff and 2 clerical staff. General administrative services, including staffing, purchasing, library services, workshop facilities, etc. are provided centrally by BMR.

Program Formulation and Consultation

The program is implemented through a series of strategic projects defined around one or two successive shipboard operations. These projects are conducted in a specified area of the continental margin and are designed to

carry out specified, problem-oriented, data collection. Projects, addressing the objectives and strategy, are formulated up to 2 or 3 years ahead of cruise start. Exploration problems, issues and priorities emerge from industry through conference presentations, industry forums and individual discussions.

- . Project options and outlines are drawn up within the Marine Division as a basis for further discussion.
- . The Division Chief and senior scientific staff attempt to consult each major domestic offshore explorer annually, either in their offices, or at APEA and PESA national conferences
 - individual and confidential discussions have proved much more effective than open forum discussions.
- . As far as practical forward program in currently and previously explored areas is linked to anticipated acreage releases
 - this requires consultation with DPIE Petroleum Division and State Mines Departments.
- . Program in frontier areas is deliberately diverse and aimed at the progressive acquisition of data required to maximise our offshore jurisdiction.

Projects last an average of 2 years after cruise completion. As far as practical, an appropriate and designated product range defines the conduct of each cruise/project, subsequent data processing, analysis and interpretation. Projects are not open ended.

Facilities

The cruise program is carried out on R/V Rig Seismic, a seismic/research vessel with a dynamic positioning capability, chartered and equipped by BMR. The ship was built in Norway in 1982 and is operated for BMR by the Federal Department of Transport and Communications. Funding and staff provided are sufficient to operate the ship at sea for 180 days per year. Scope for up to a further 90 operational days exists, subject to allocation of additional resources. The current staff responsible for vessel management and data acquisition is 18 (plus 9 in engineering support

services). Details of the vessel, together with a listing of the greater than \$4 m of scientific survey equipment are shown in Attachment 1.

Key data collected by R/V Rig Seismic include conventional and high resolution multichannel seismics, gravity, magnetics, and vibro, piston and gravity cores and dredges. On board geochemical, sediment and palaeontological laboratories provide for x-ray analysis, porewater extraction, chemical analysis, age dating and petrological descriptions of rocks and sediments collected on appropriate cruises.

In BMR, seismic processing, sediment and rock analysis, palaeontological analysis and geochemical studies are conducted in specifically equipped laboratories. The current staff involved in data processing is 25.

- . The Seismic Processing Centre represents a \$2.0 m investment based on a Vax 11/785 computer with two array processors, 32 megabytes of memory and specialised commercial seismic processing software. The Centre has the capability of annually processing 12 000 km of marine seismic data and 500 km of land seismic data. To date more than 25 000 km of marine seismic data have been processed and made available through the BMR copy service. The Centre also provides facilities for interactive seismic modelling and interactive velocity interpretation.
- . The Non-Seismic Processing and Database Facility is in the process of moving to a microVax based system. It provides for all navigation, gravity, magnetic and bathymetric data processing and storage.
- . The Sedimentology Laboratory provides specialised unconsolidated sediment analysis and image analysis as aids to determining facies variation on cored and dredged samples.
- . The Palaeontology Laboratory provides microfossil processing, including scanning electron microscope facilities, aimed at providing age control on samples dredged or cored from the margin.
- . The Geochemical Laboratory provides for analysis of pore water, the molecular composition of light hydrocarbon gases in marine sediments and the determination of organic and inorganic carbon in dissolved and solid phases. The laboratory also has a capacity to carry out limited radiometric dating.

Current Program Activity

For 1988/89 the CMP consists of the following projects (with manpower noted in brackets):

Project		Scheduled Completion
131.03	Carbon cycling in east Australian continental margin sediments and its control on the formation and distribution of Quaternary phosphorite (0.5)	Dec. 88
131.06	Exmouth Plateau Project (3.0)	Dec. 88
131.07	Basin framework and resource potential of the North Perth Basin (1.0)	Dec. 88
131.08	Structural evolution of the southern Australian continental margin (4.0)	June 89
131.10	Structure, stratigraphy and kinematic development of the northeast Gippsland Basin, the southern NSW Continental Margin and the conjugate margin on the Lord Howe Rise (2.0)	Dec. 89
131.11	Structure, stratigraphy, evolution and regional framework of the Marion Plateau, Townsville Trough and Queensland Plateau (5.0)	1990
131.12	Deep basin and crustal structure of the Gippsland and Bass Basins (1.0)	1990
131.13	Geological framework and hydrocarbon resource reassessment of the West Tasmanian Margin plus preliminary investigations in the Tasmania Basin (2.5)	1990
131.14	Geological framework and hydrocarbon resource reassessment of the South Perth Basin (4.0)	1990

- 131.16 Deep crustal structure and stratigraphy of the 1991
Kerguelen Plateau incorporating results from ODP (1.0)
- 131.20 Hydrocarbon gas geochemistry of the Otway and 1990
Gippsland Basins (1.0)

Data and interpretations obtained from some of these projects are expected to be substantially augmented by drillhole data obtained through the Ocean Drilling Program (discussed below) in relevant areas.

In addition to the above, Marine Division has primary responsibility for the Tripartite Geoscience Project of BMR Component 140 (Overseas Basins), and the offshore East Antarctica Project of Component 350 (Antarctic Offshore Basins). Both of these projects are dependent on external funding and involve only minor effort in 1988/89. Principal objectives of the two projects are:

1. 140.01: under programs of foreign aid, to assist developing nations in the Asian/Pacific area to understand the geological framework and resource potential of their offshore areas with a view to promoting resource exploration, and
2. 350.01: to develop an understanding of the general geological and environmental framework and petroleum resource potential of the continental margin of the Australian Antarctic Territory.

Program Costs

Appropriations in 1988-89 covering the charter and operation of Rig Seismic, data acquisition, processing, interpretation and dissemination are broken down as follows:

	\$ million
. Staff salaries	2.9
. Vessel operations	4.6
. Science operations	1.7
. Plant & Equipment	1.0
. HIFIX operation	<u>0.3</u>
	\$10.5

The functional breakdown of this budget is as follows:

. Vessel operations (only)	\$ 26 000 per day
- plus seismic acquisition	\$ 16 500 per day
.. total, seismic line cost	\$ 350 per km
- or non-seismic acquisition	\$ 12 000 per day
. Seismic processing	\$ 75 per km
. Geoscience interpretation and production	\$380 000 per 30 day cruise operation

Operations beyond the current 180 sea days per year and 12 000 kms of seismic acquisition have been estimated (on-costs) at \$8 500 per day. On a 270 operational sea day program, the average cost of the vessel alone would reduce from \$26 000 per day to \$20 000 per day. The extra scientific and technical staff (ASL) required to run an acquisition and processing program of, say, one extra 30 day cruise per year is 9. The additional ASL to interpret and publish the data from such a cruise is 5. Antarctic on-costs and staff requirements are about 15% higher.

Products and Reporting

The principal program products valued most highly by the petroleum exploration industry are basic data, which can be reinterpreted "in house" in terms of individual corporate strategies.

- . Multichannel seismic reflection digital data and processed record sections.
- . Geological, geochemical and geothermal data.
- . Gravity, magnetic, bathymetric and sidescan sonar data.

Interpretative data are also utilised by industry both as a new venture review and as a check evaluation of prospectivity. These include:

- . Basin folios, reports and records.
- . Written papers in exploration industry journals and technical volumes.
- . Presentations at industry conferences and symposia.

A further important mechanism for reporting projects, whose results are relevant to new acreage releases, is the Basin Workshop. These are usually in the form of one day presentations on the reassessed prospectivity of defined areas. So far, successful workshops have been held covering the Bass, Otway and North Perth Basins. A Great Australian Bight Basin workshop will be held early in 1989.

Ship operations covering 16 projects have been completed to August 1988, and processing of data for eight of the sixteen has already been completed and data released to industry. This has included almost 10 000 digital magnetic tapes and 25 000 kilometres of seismic data displayed on approximately 200 individual record sections. A breakdown of seismic data released for each project is given below:

<u>Projects</u>	<u>Seismic Data (km)</u>	<u>No. of Lines</u>	<u>Approx. No. of Tapes</u>
Bass Basin	2216	10	2200
Lord Howe Rise	940	5	279
Heard-Kerguelen	5600	20	1301
Otway Basin	3304	46	948
Northeast Aust 1&2	4134	49	990
Exmouth Plateau	2720	23	1303
Nth Perth Basin	2445	18	608
Southern Margin	3574	23	833

Product Distribution Policy

Data from areas adjacent to States and Territories are supplied to Designated Authorities at copying cost. These are not for recopying, resale or trade. Data from cooperative programs are supplied free to the cooperating institution under strict written agreement. These are only for internal use. All other data are sold at the list price and under the conditions set out on product advertising brochures.

- . Seismic record sections on film, ranging from \$5 to \$20 per km.
- . Seismic digital field tapes, from \$5 to \$10 per km, plus
- . Digital non-seismic data, from \$300 to \$500 per cruise.

- . Maps, at \$25 each on paper and \$75 each on film.
- . Folios vary according to content, with numbers 1 and 2 priced at \$950 per copy.
- . Records and reports at list price.

Discounts are offered on whole survey and multiple copy purchases. Data over existing permits are supplied to operators upon request at copying cost, covering the limits of the permit only.

Promotion and Marketing Strategy

The principal mechanism for advising industry of the availability of products from the Continental Margins Program is the project brochure, or "flier". A sample brochure on the Southern Margins Project (131.08) is at Attachment 2. This contains a description of the project objectives and outcome; a track map of available data; references and publications; digital, analogue, map and section data and reports available for purchase. It is made available to industry through the DPIE Petroleum Division world-wide mailing list of exploration companies.

- . 11 fliers, covering completed, or partially completed projects from 1985 to 1988 are currently available.
- . Advertising in overseas industry magazines will begin soon.

Marine Division now regularly mounts program and product display booths at relevant industry conferences such as APEA and PESA.

- . It is proposed to mount a similar promotional display at future overseas conferences, such as the American Association of Petroleum Geologists and the European Association of Exploration Geophysicists - this mechanism is intended to promote Australia to the large number of foreign companies not represented domestically.
- . The Basin Workshop, tied to an impending acreage release is also an important promotional tool.

Preparation and presentation of scientific papers reporting the interpretative products of projects is also an important aspect of promotion and product marketing. Such papers are directed towards journals such as APEA, PESA, AAPG, Geophysics, Oil and Gas Journal and the Journal of Marine and Petroleum Geology, to reach the industry audience.

Port calls by Rig Seismic are also used to promote the program, its capabilities and products.

- . Media releases are used to announce results or impending program.
- . Visits to, and inspections of, the ship by industry representatives.

THE OCEAN DRILLING PROGRAM IN AUSTRALIA

The Ocean Drilling Program (ODP) is considered an important adjunct to the Continental Margins Program. ODP is a program of sediment and basement coring in the deep ocean basins and margins of the world. It is the largest and most important international geoscience and marine engineering technology research program of the last decade and will likely remain so to the turn of the century. It provides a major opportunity and challenge to Australian geoscience and related technology. Results of the program are having a major impact throughout the earth sciences and specifically upon petroleum exploration concepts and methods, oceanography and climatology. The program is global in concept, participation and significance. Drilling proposals or projects completed in the Australian region cover the Kerguelen Plateau (around Heard Island), the Exmouth Plateau and Northeast Australia (1990/91) and would potentially cost A\$100-120 m, if drilled commercially. Australia has pursued membership of ODP for ten years and is about to become a consortium member with Canada. The BMR will be the Australian lead agency.

Drilling results obtained through the Ocean Drilling Program will impact directly on BMR's Continental Margins Program. It will provide the essential ground truth testing of seismic data and the new concepts developed from such data. In addition, the Ocean Drilling in the Australian region will substantially advantage a wide range of scientific, technological, commercial and geopolitical areas.

Geoscience Research

- . International scientific cooperation will provide a major stimulus to basic and applied research in geoscience and engineering particularly through the opportunity for Australian scientists to work alongside international researchers and gain first-hand experiences and knowledge using the most up-to-date facilities.
- . It will increase the quality of University research and training, thus providing skilled manpower to support future offshore exploration and development.

Exploration and Technology Transfer

- . The ODP pioneered and established many of the key technological developments necessary for deepwater exploration and future development. These include the wireline packer, downhole telecamera, hot hole logger, multichannel seismic logger and deepwater re-entry systems. These developments and the related drawings and specifications are ODP proprietary items and available only to ODP members. The interested industrial sectors of participating countries have access in addition to being able to actively participate in the R&D and to propose engineering programs. This leads to a more efficient and effective interaction between a country's scientific and technological R&D sectors.

- . Successful petroleum exploration depends upon advanced geoscientific knowledge. Advances in seismic stratigraphy, the understanding of the evolution of continental margins and the gas and oil potential of deep continental margins continue to arise from the ODP. The 20-30 drillholes currently drilled or envisaged for the Australian region will be of inestimable value. In the specific regional context, current and/or anticipated drilling on the Kerguelen Plateau, the Exmouth Plateau and the Queensland Plateau in support of the Continental Margins Program, will provide direct information crucial to Australian exploration and resource assessment.

Oceanography and Climatic Change

- . Drilling in the Australian region will help define the regional climate baseline and variations which will help develop a predictive model of climatic and oceanographic change grounded in fundamental physical and chemical causes. Estimates of future changes in sea level, sea surface temperatures, ocean chemistry, together with climatic variation will output from the model.

Direct Commercial Advantages

- . Drilling in the Australian region have already entailed two port calls in 1988. Each port call would require port services, fuel, provisions and logistic services. A current Canadian estimate of the value of a single port call based on actual experience is \$1 million.

- . Drilling in the Australian region could provide opportunities for offshore survey and service companies, marine engineering and high-tech companies, and marine equipment suppliers. A Canadian estimate of such expenditures is \$1.5 m when the vessel is in the region.

Foreign Development Assistance

- . The Pacific Island Nations have requested, in a letter from the Coordinating Committee for Offshore Prospecting in the South Pacific (CCOP/SOPAC) to the Department of Foreign Affairs, that Australia should join the ODP and, through membership, promote increased drilling in the southwest Pacific. CCOP/SOPAC members consider that this kind of regional stratigraphic drilling acts to enhance exploration.

In addition, membership of ODP will have the effect of focussing a large part of the geoscientific community on problems related to the evolution of the offshore. This increased and focussed effort can only help future petroleum exploration.

PROGRAM ACHIEVEMENTS

The Continental Margins Program has been underway for a little over three years, but it has already effected offshore petroleum permitting and exploration strategies around Australia. The 1982 pilot study for the Continental Margins Program was carried out in the Bass Basin, between Victoria and Tasmania.

- . It was a contract seismic survey costing approximately \$4 m and since BMR data release, over \$100 m has been invested in exploration in the Basin.
- . BMR identified a number of new petroleum plays in a published analysis in 1984, including the Yolla structure, which was drilled by AMOCO in 1985. This was an oil discovery, as yet non-commercial.

In 1985 and 1987, Rig Seismic operations in the Otway Basin (offshore South Australia, Victoria and Western Tasmania) identified new potential petroleum plays.

- . Hydrocarbon seeps were detected in seafloor sediments.
- . New exploration permits in the Basin were recently granted to companies, and new exploration is underway.
- . There has been continued interest in this area, previously considered unprospective, and recent applicants for acreage have quoted BMR data in submissions and presentations. Most of the offshore basin is expected to be under exploration permit by the end of this year.

In 1985 a large new structural trend was discovered extending into Australian waters east of Torres Strait. New petroleum accumulation models were developed from studies undertaken in this area and presented to industry.

- . This new exploration lead has now been drilled in PNG waters as Pandora-1 and is a major gas discovery.

The 1985 and 1987 surveys in the Townsville Trough and Marion Plateau discovered a new sedimentary basin to the east of the Great Barrier Reef Marine Park off Townsville and containing up to 6 km of sediments.

- . Seismic indicators of possible hydrocarbons have been discovered in the eastern part of the basin.
- . There has been strong interest from both overseas and local companies in potential release of permits in this area.

The 1986 Exmouth Plateau project (NW Shelf) ascertained a total thickness of about 10 km of sediment and discovered previously unknown deep petroleum source rocks.

- . Taken together with recent ODP drilling results, a new Triassic reefal play and a new Barrow delta play have been identified.

The 1986 North Perth Basin project has identified three sub-basins and a new range of hydrocarbon plays. As well, the 1986 Great Australian Bight project identified a new group of structures with possible hydrocarbon potential in a previously undrilled area beyond the shelf.

- . Both areas will be offered for exploration permit in 1989.

A considerable amount of new deepwater sediment thickness data has been collected which is applicable to Australia's Law of the Sea claim beyond 200 nautical miles.

- . Exmouth Plateau, off northwest Australia.
- . Great Australian Bight.
- . Deepwater Gippsland Basin.
- . Lord Howe Rise.
- . Australian sector of the Kerguelen Plateau (Heard Island area).

A forthcoming deep seismic program in the Gippsland Basin is expected to outline new petroleum plays beneath those currently being developed in the area. It has strong and well documented support from industry.

FUTURE PROGRAM AND PROJECTED ACHIEVEMENTS

Assuming no significant change in Marine Division's role and in the operating strategy of the Continental Margins Program and/or the Rig Seismic (i.e. 180 ship operational days per year), the following CMP projects form the draft, or indicative program from mid 1989 through early 1991:

- . SE Queensland - Regional (seismic and geology)
- . Sydney Basin - Regional (seismic)
- . Vulcan Graben/Browse Basin - Detailed (geochemistry)
- . Vulcan Graben/Browse Basin - Deep Structure (seismic)
- . NW Shelf - Deep Structure (seismic)
- . NW Shelf - Detailed (geochemistry)
- . Torres Shelf - Detailed (seismic and geology)
- . South Carnarvon Basin - Regional (seismic)
- . Bonaparte Gulf/Timor Sea - Regional/Deep Structure (seismic)
- . Southern Margin - Regional (geology)

These projects will follow on those already in the 1988/89 forward program. However, they will be scheduled to maintain the present mix of 3 or 4 seismic cruises, 1 or 2 geological cruises, and 1 geochemistry/ geological cruise per year, as well as to take account of the timing of new acreage releases and changes in areas and emphasis of exploration interest and activity. Expected short-term benefits of the 1989/90 program are:

- . The identification of new structures and the development of new play concepts on the North West Shelf should substantially contribute to Australia's long term self-sufficiency. Further, new frontier area studies offshore southeast Queensland and central New South Wales (emphasising new deep penetration seismic techniques and high resolution seismic methods) may markedly upgrade the petroleum potential of areas close to major east coast population centres.
- . The development of new geochemical techniques for both frontier and prospect exploration, for example in the Browse Basin and Vulcan Graben, will substantially increase exploration efficiency.

ADVANCED TRAINING

A major spin-off of the Continental Margins Program is in the tertiary and technical education fields. Advanced training opportunities for industrial, academic and overseas scientists, engineers and technicians occur within both the Continental Margins Program and the Ocean Drilling Program.

The Continental Margins Program provides an excellent opportunity for cooperative research. The R/V Rig Seismic is one of the world's most modern geoscience research vessels and now provides a comparable seismic capability to many commercial contractors. Possible future semi-commercial use will provide opportunities of short term secondment of industry staff for the duration of a particular project with resultant training in aspects of seismic acquisition, processing and interpretation, and geological analysis. Japanese companies have already used R/V Rig Seismic in testing instrument packages. University participation in the CMP has already been fostered with staff and students from Flinders, Adelaide, Sydney, Macquarie, ANU and Melbourne Universities participating in projects. This will be further encouraged as both a supplement to BMR's limited manpower resources and in the interests of training the marine geoscientists and technicians that Australia will so badly need in the future. Cooperation with ANU is currently being explored in palaeoclimate and global environmental change research. Overseas universities have already recognised the research and training potential of R/V Rig Seismic with students and staff from six foreign institutions participating in cruises in 1986 and 1987. The potential future use of R/V Rig Seismic in Southeast Asia and Southwest Pacific nations will certainly include a training component for nationals of those nations in modern geoscientific practices and techniques.

The Ocean Drilling Program also provides a unique training opportunity for all Australian marine scientists in drilling and downhole logging techniques, and in the development of new innovative technologies. Petroleum industry scientists in particular, would obtain a window on such technologies well before their commercial implementation.

PROGRAM WEAKNESSES

There are two principal sources of weakness in the current Continental Margins Program: (1) resources based weaknesses, and (2) organisational weaknesses.

Resource Weaknesses

The basis of resource based program weaknesses are staff and financial deficiencies. There is increasing pressure on the Continental Margins Program to rapidly release data and interpretive products to the public. Drafting, marketing and promotion are therefore assuming an importance approaching that of data processing. Current delays in data release (up to 12 months) are arising as a consequence of staff shortages in these areas and these are likely to spill over into program cost recovery.

Staff shortages are also affecting the ability of Marine Division to conduct extended scientific studies, such as process studies related to tectonic mechanisms at continental margins and environmental studies related to global environmental change. Similarly, Antarctic studies have been deferred, despite conclusion of an Antarctic Minerals Convention this year. In addition, program development is currently conducted by the same staff who operate the program. Whilst this is appropriate, there is little time available for long-range planning and a desirable level of consultation with industry.

Funding of new initiatives is a second resource-based restriction on appropriate development of the CMP. A number of these initiatives represent the kind of scientific, technical and commercial opportunities that are the objective of this Review. They are detailed in the next section of this Submission, but suffice it to say that they are outside the financial scope of the base level Continental Margins Program.

A second and possibly more serious effect of limits to financial allocations is restrictions on re-equipment of the basic CMP. The most serious example of this problem is in the major seismic program. The current seismic streamer is analogue, limited to 96 data channels and can be extended, practically, to only 3600 m. Modern commercial streamers are digital, with fibre optic transmission, have up to 480 channels and extend

up to 6000 m in length. The cost of such streamer systems approaches \$2 million. Modern sleeve guns also have a greater source band width than the current airguns. The whole seismic system on Rig Seismic will have to be drastically updated within the next 2 years if the CMP is to be expected to deliver the program set by its objectives.

Organisational (Administrative) Weaknesses

Organisational weaknesses arise out of operation of the CMP within a strict public service structure. Assessment of offshore petroleum resources is not conducted in Marine Division, but elsewhere in BMR. Advice to Government would be strengthened if research and assessment were combined in the same Division. Equipment procurement and purchasing under the present structure is also cumbersome and bureaucratic. Financial management and responsibility needs to be decentralised. Future cost recovery targets should be fixed and a clear re-investment policy accepted. In addition, the ability to more easily obtain, use and develop external funds (similar to statutory authorities) is essential to future program development. Management based weaknesses with respect to staffing are cumbersome, costly and time consuming, particularly with respect to temporary or fixed term contract appointments using external funds.

POTENTIAL NEW INITIATIVES

The Marine Division is technically capable of expanding its operation into new research and survey activities which would enhance and strengthen the CMP. Such expanded activities contain significant commercial opportunities downstream. However, program expansion cannot be carried out without increased operational and administrative staff and funding.

Externally-Funded Programs Related to Petroleum Exploration

An average of 90 operational days per year are potentially available for externally-funded programs in addition to the "core" CMP. The options for this extra time include Antarctic margin geoscience, semi-commercial activities around Australia, and foreign development assistance programs in Asian and Pacific waters.

(i) Antarctic marine geoscience: Government consideration of a detailed proposal for a 10 to 12 year, 5 or 6 cruise program along the margin of the Australian Antarctic Territory has been deferred until 1989. This proposal involves increasing the ice-worthiness of the Rig Seismic, providing extra operations funds and staff (16), and increasing the Division's computer capacity to handle the extra data processing load. A regional program of research and reconnaissance surveys of the Antarctic margin is essential if Australia is to have any meaningful or influential participation in the Antarctic Minerals Convention or any voice in resource development and environmental protection of the AAT.

(ii) Semi-commercial activities around Australia: Opportunities for semi-commercial activities, including cooperative surveys and research in conjunction with industry, are limited by the fixed staff numbers in the Operations Section of the Division and the fixed operations budget. Only fully-trained scientific and technical staff can operate the ship and its equipment, and the existing staff are more than fully committed to the current 180 day program. With greater flexibility (e.g. to employ contract staff) it would be possible to take short-term commercial opportunities as they arise, without disrupting core program. Flexibility would be required to transfer some contribution from the joint research trust account to the cost recovery account, in order to contribute directly to cost-recovery as well as provide the extra staff and cover financial costs associated with

the additional (add-on) program. Joint research possibilities include seismic, geochemical and engineering studies.

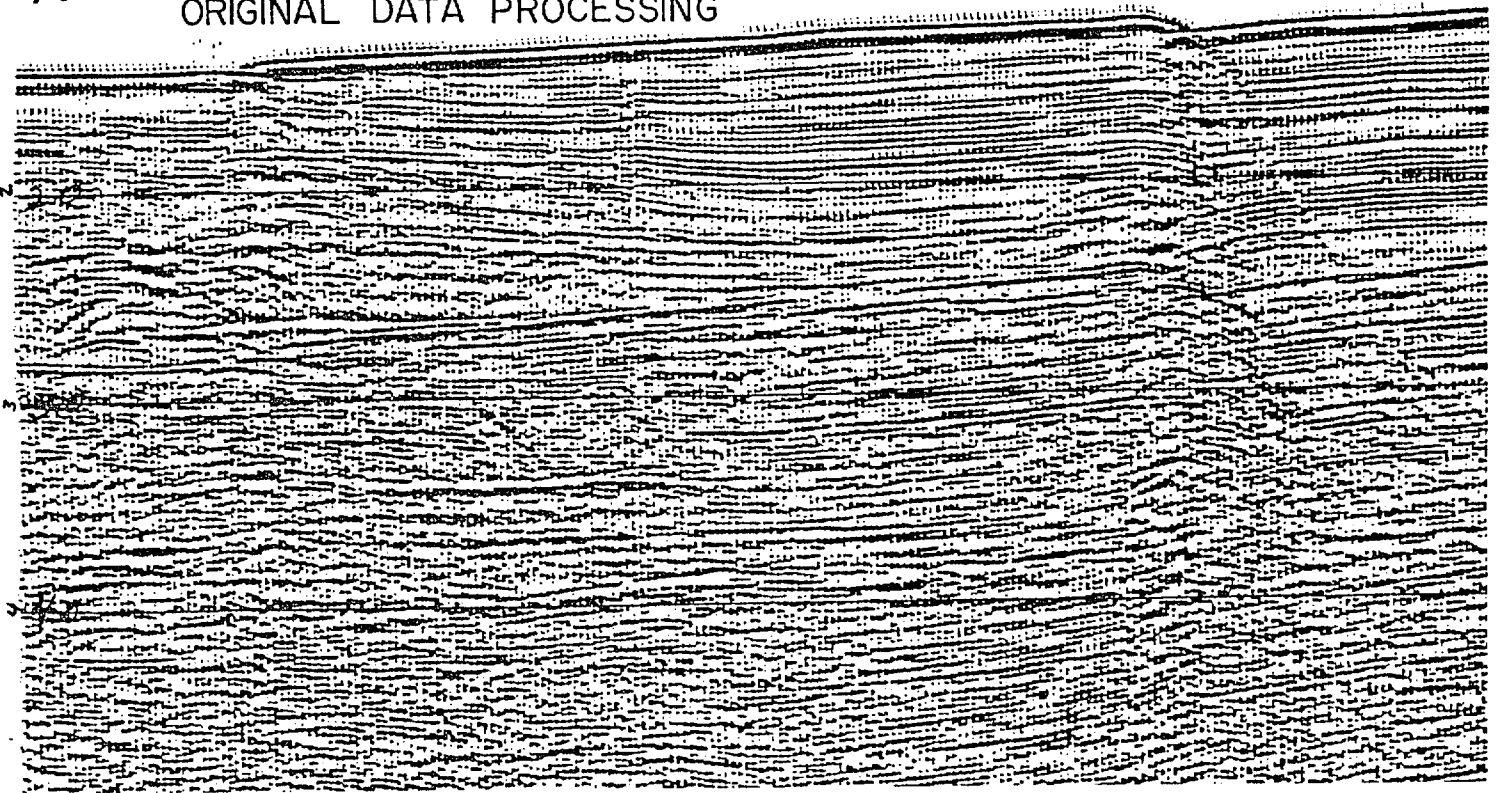
(iii) Overseas foreign development assistance programs: A number of proposals (involving suggested programs in the People's Republic of China, Philippines, Indonesia and PNG) have been canvassed and are currently under external consideration for 1990 and beyond. The suggested programs involve CMP-type regional resource framework studies in unexplored or underexplored basins. They are also a vehicle for advanced training. One potential recipient nation has also indicated that if such a regional program were funded by AIDAB, then Australian exploration companies would get preference in allocation of subsequent permits in that area. Each of these assistance proposals involves funds for additional staff, operations and data processing. A now essentially completed cooperative Australia/NZ/USA resource framework study in the SW Pacific is described in Attachment 3.

Reprocessing of Seismic Data

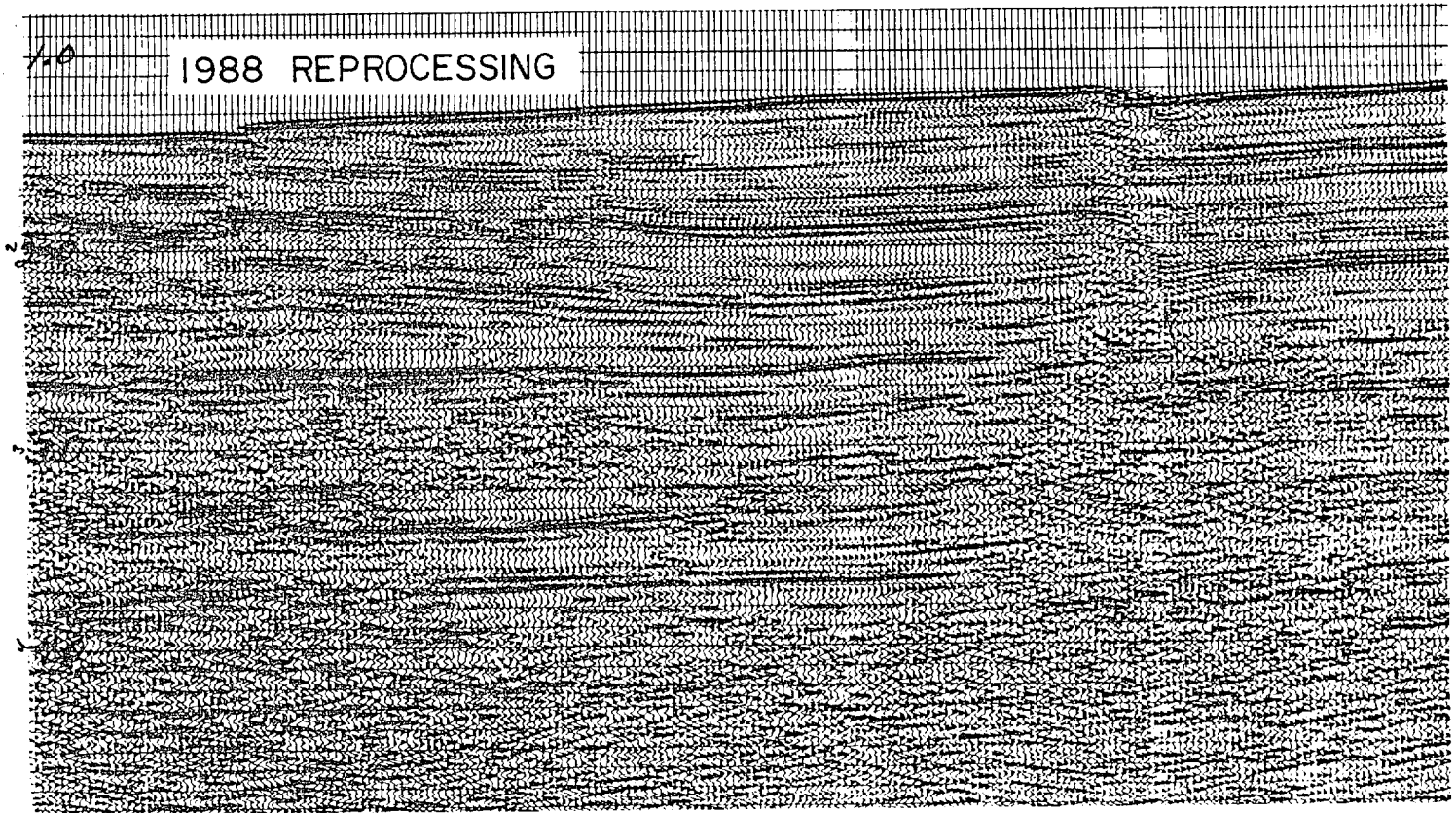
A large quantity of old seismic data (both BMR and industry) is available for reprocessing. In certain areas around the Australian margin, these data would be of considerable interest to industry, provided that they are reprocessed using modern techniques and released in a timely fashion. An example of the effectiveness of modern reprocessing is illustrated in Figure 6. It is estimated that approximately 3000 km of data could be constructively reprocessed each year, requiring 3 extra processing staff. Principal attention would be paid to areas indicated for exploration permitting. This proposal and the preceeding proposed initiatives all require time on the BMR Seismic Processing Centre. As the Centre is fully committed to production requirements of the current CMP, it would be necessary to expand its capabilities to handle additional work. This is seen as occurring in two consecutive stages:

- . through expansion of working shifts from 5 days to 7 days per week, requiring two additional computer operators.
- . through a major upgrade to the hardware, estimated to cost \$1 m. This has been included in the Antarctic marine geoscience proposal. However, in the event that the proposed Antarctic program does not proceed in 1989-90, it may be necessary to raise these funds in some other way.

ORIGINAL DATA PROCESSING



1988 REPROCESSING



Software for processing seismic data improves year-by-year. The top plate shows an example of 1983 processing of South Pacific seismic data. The lower plate is the identical data reprocessed in 1988 with current state-of-the-art software. Vertical and horizontal scales on the two plates are the same.

FIGURE 6

Future Climate Prediction

The recent predictions of irreversible global environmental change are of international concern. National planning in Australia for agriculture, demography and coastal development and urban reconstruction are dependent upon predictable climate and sea level. Climate research should, therefore, be a national priority. The degree to which meaningful and reliable prediction can be made depends entirely upon the quality of the historical record of climate/sea level baseline and variations. Key questions which must be addressed include the carbon dioxide balance between atmosphere and ocean and the relationship between current atmosphere levels and the burning of fossil fuels, as well as recent global warming and sea level changes; and the relation between the shorter term El Nino/Southern Oscillation phenomenon and global climatic change.

Data to answer these questions lies almost entirely within the oceanic sedimentary record, and the Australian region is well located for deciphering this record. Shelf and slope carbonate rocks hold a sensitive record of environmental change, particularly sea level, ocean temperatures and chemistry, atmospheric carbon dioxide, annual and seasonal rainfall, and the periodicity of wet and dry episodes. Some climate studies have been carried out on CMP core material collected from Rigg Seismic. However, a more comprehensive program of climate studies would require 2 additional staff for a comprehensive program of laboratory analysis.

Studies so far carried out around Australia, together with some published data, indicate an essentially random change in sealevel over the past 150 000 years (Figure 7A). The rate of sealevel rise has generally fallen over the last 18 000 years (Figure 7B), but risen marginally in recent years. The real question is the separation of the Greenhouse effect from natural cyclicity. At this stage, there is insufficient historical data to predict this separation and thus reliably estimate the effects of continuing to burn fossil fuels.

Thermogenic Hydrocarbon Seep Detection

In many parts of the world, oil and gas accumulations at depth are known to leak to the surface and release trace amounts of lighter hydrocarbons into surface sediments and seawater. The CMP has included some studies of hydrocarbons in seabed sediments, including the detection of anomalous trace occurrences in the Otway and Gippsland Basins. These results

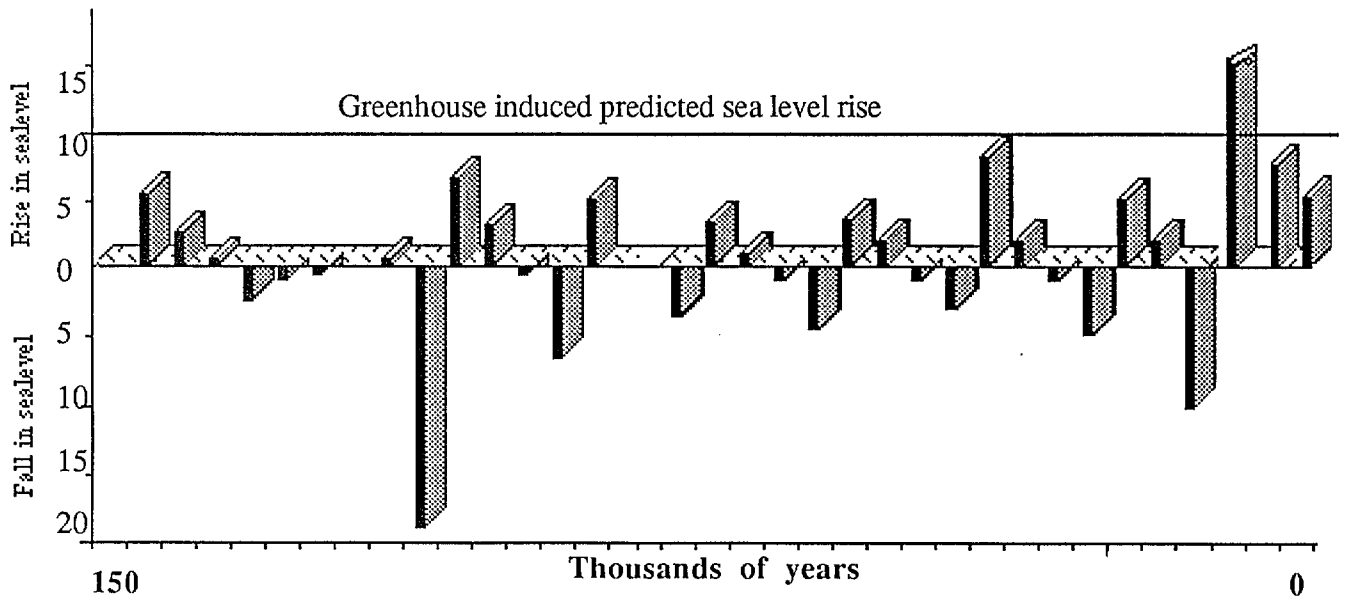


Figure 7A. Rates of sea level change in the past 150,000 years(mm/year).

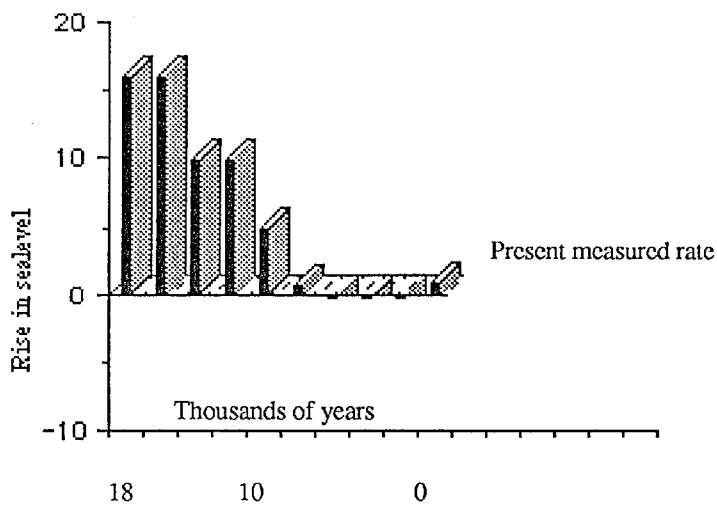


Figure 7B. Rate of sealevel change over the past 18,000 years in northeast Australia(mm/year).

provided encouragement for a number of companies to apply recently for exploration permits in these areas. Detection of hydrocarbon anomalies in seawater, however, requires a more advanced system. Such systems are not yet available commercially; indeed, the whole technique is still in its infancy as an exploration tool. Considerable research is required to establish the validity of the method, including migration path studies, distribution controls, subsurface maturation studies and repeatability experiments.

Once developed, the system could be run either as part of a specific geochemistry cruise, or as a reconnaissance program run simultaneously with underway geophysics. Either way the potential to complement CMP objectives, stimulate exploration and achieve an enhanced measure of cost recovery is considerable, possibly enormous, depending upon how successful the method proves. The estimated cost of developing the equipment is approximately \$250 000.

Towards a Comprehensive Margin Stratigraphy

Petroleum exploration in deeper water is hampered by the paucity of stratigraphic core samples from the continental slope. While acquisition of high quality seismic data is essential in exploration, drillhole control is required for quantitative prospectivity analysis. However, offshore stratigraphic drilling is extremely expensive; the cost of stratigraphic holes being approximately \$5m (or more) per hole in water depths greater than 500 m. A low cost substitute would potentially lead to a vastly improved understanding of the development of the deep continental margin of Australia including the distribution of source, seal and reservoir rocks.

A rotary drill, capable of drilling to 50 m in 2000 m of water, is currently being tested in the USA. The cost of purchase of this equipment and modification of Rig Seismic is estimated at around \$1m. A program of stratigraphic coring could be developed which would provide a more comprehensive offshore database with cost recovery potential.

Improved Assessment of Petroleum Prospectivity

In many sedimentary basins the BMR data is the principal, high-quality framework data set available from which to investigate regional prospectivity and subsequently assess resource potential. In order to

obtain maximum benefit from these data they need to be integrated with existing data sets (primarily previous seismic and drilling data) to yield a comprehensive review and analysis of basin prospectivity. Given the existing staff levels and the large volumes of existing data in some basins, this is often not possible.

The CMP should carry out more comprehensive assessment of the petroleum prospectivity of the areas in which it is working. This could be achieved by much closer involvement of suitable staff from the related basin review function in RAD.

Continental Margin Basin Geothermal and Fluid Database

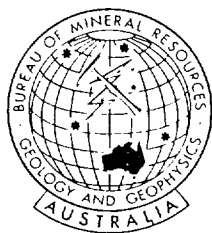
Because of its national role, BMR, and Marine Division in particular, are in a unique position to establish and maintain a national database of all geothermal and fluid information from Australia's offshore region. Initially, this could be constructed using the ODP database from around Australia.

Continental margin sedimentary basins consist of a matrix of sedimentary grains and a dynamic fluid system, which includes water, oil and gas. Burial, compaction, structuring and generation of hydrocarbons (by the maturation of source rocks) mean that evolving basins contain dynamic fluid systems. Studies of such system dynamics will lead to the next breakthrough in predicting oil accumulation and this database will promote its application to the Australian margin as soon as possible. It is estimated that construction of such a database could be achieved by 2 to 3 additional scientific and technical staff.

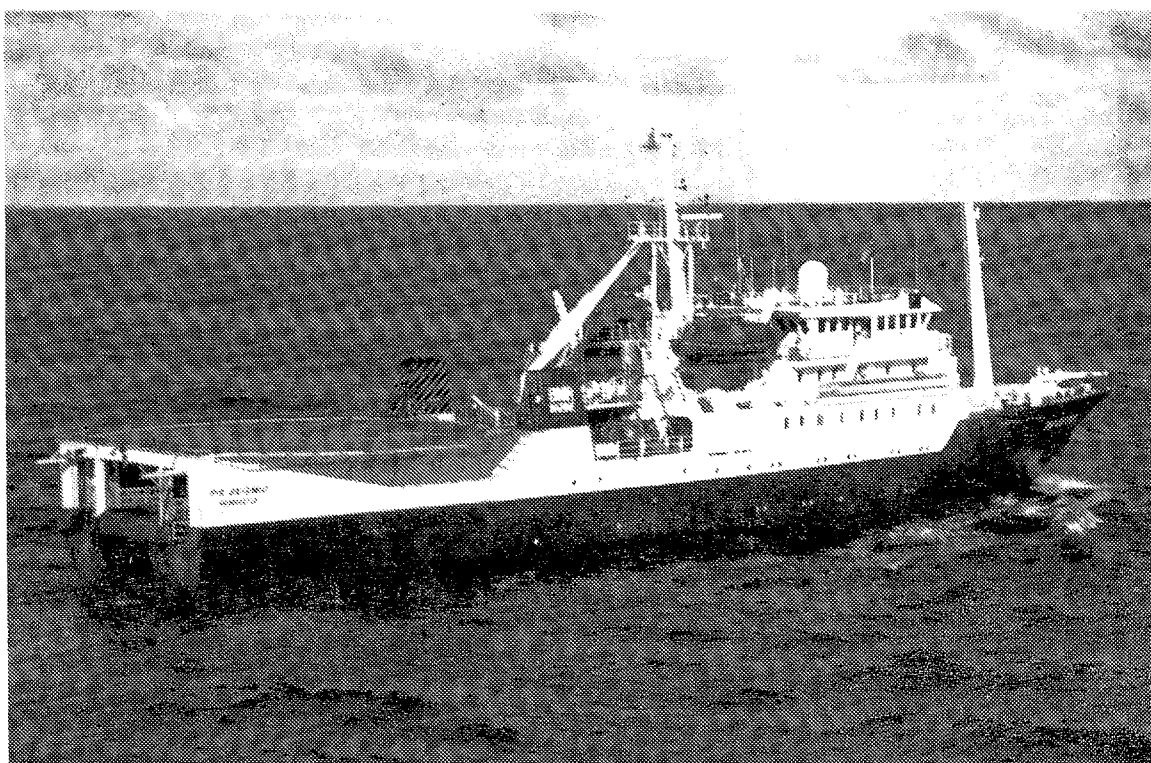
CONCLUSION

The current Continental Margins Program is a soundly based Government initiative, providing a technical response to an indicated fall in Australia's current level of petroleum self-sufficiency. It is therefore recommended that the Review into Marine Science and Technology agree:

- . That the Continental Margins Program be continued along the lines agreed by the Government in March 1988, and strengthened in order both to more effectively achieve its current program and to extend its operations to include extended research activities, more commercially oriented seismic processing, prospectivity assessment and petroleum fluid/geothermal database programs.
- . That cost recovery on industry oriented strategic programs be primarily an indicator of program relevance and not a means of obtaining a significant component of offsetting revenue. The practical target of cost recovery is recommended to be limited to 5% of the total cost of those programs, with revenues in excess of that target being available for investment in advanced technology, which would extend the capacity and relevance of those programs.
- . That AIDAB note the potential of the CMP for export to Southeast Asia and the Southwest Pacific, and the likely benefits of such programs to Australia.



Marine geoscientific research in Australia



Bureau of Mineral Resources, Geology and Geophysics
Division of Marine Geosciences and Petroleum Geology

Department of Primary Industries and Energy



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The Australian Continental Margins Research Program

The Bureau of Mineral Resources, Geology and Geophysics (BMR) is responsible for the Australian Continental Margins Research Program, a major program of strategic geoscientific research in the Australian offshore area. The Program is carried out by the Bureau's Division of Marine Geosciences and Petroleum Geology from the geoscientific research vessel, *Rig Seismic*.

The objectives of the Program are to:

- *develop a knowledge and understanding of the geological framework of the continental margins around Australia and its territories.*
- *identify the petroleum and mineral resource exploration potential of the offshore area under Australian jurisdiction and to provide the basic information necessary for the formulation of independent advice to the Federal Government on offshore resource development.*
- *develop models of the geological processes which have formed the continental margin and led to economic accumulations of petroleum and minerals.*

The Program, which began in 1985, is an important element in the Federal Government's strategy to encourage the exploration for and development of Australia's offshore petroleum resources in order to maximise oil self-sufficiency well into the next century.

At present, 90 per cent of Australia's petroleum production is derived from sedimentary basins of the continental margins (Gippsland Basin, Northwest Shelf, Timor Sea) and it is widely accepted that future large discoveries are most likely to come from offshore basins.

However, the area offshore undergoing active petroleum exploration has contracted over the last 10-15 years, leading to a narrower focus on those offshore basins currently perceived to be 'more prospective' by the exploration industry.

In the long term it will be necessary to encourage exploration in areas now considered 'frontier' (that is, relatively unexplored), but which hold the resources that Australia will need in the next century.

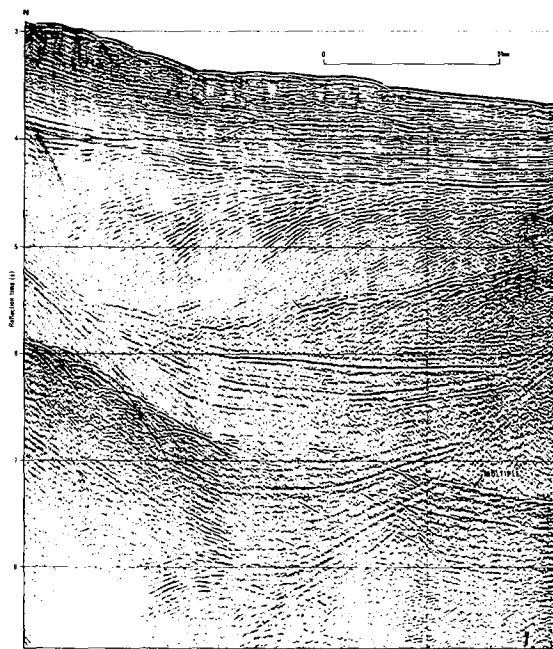
The Program is aimed towards a future expansion of the offshore area undergoing exploration. New geological and geophysical data (such as seismic reflection data) needed for petroleum exploration and prospectivity assessment are acquired on a regional basis from offshore areas under Australian jurisdiction.

The area under investigation is almost 12 million square kilometres. The new data are integrated with existing exploration industry data to provide new basin analyses, which may incorporate new ideas and understanding of petroleum generation and entrapment.

In 1988 and 1989, the Research Vessel *Rig Seismic* will be collecting new scientific data in the Gippsland Basin, the Bass Basin, the West Tasmania Basin, the Perth Basin, the Carnarvon Basin and the Northwest Shelf.

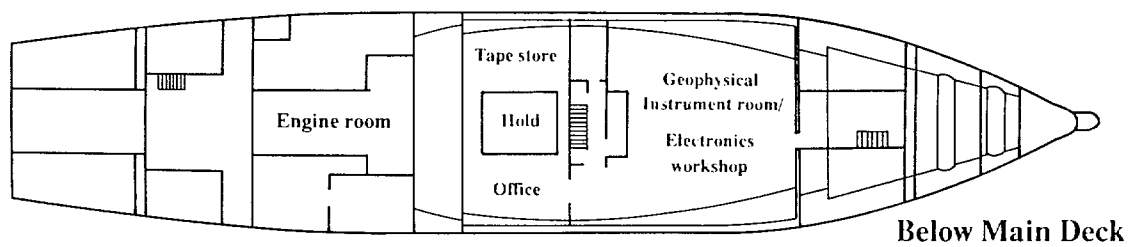
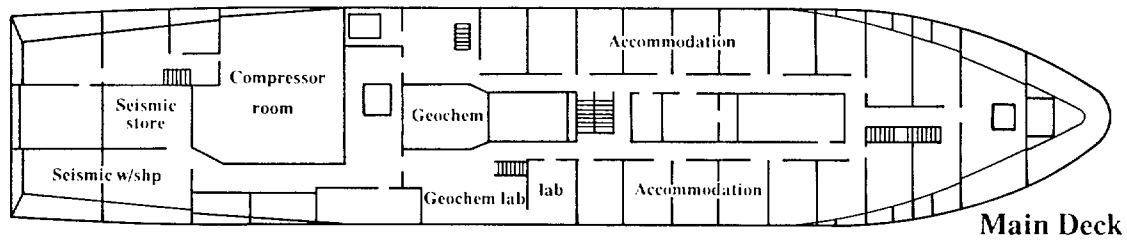
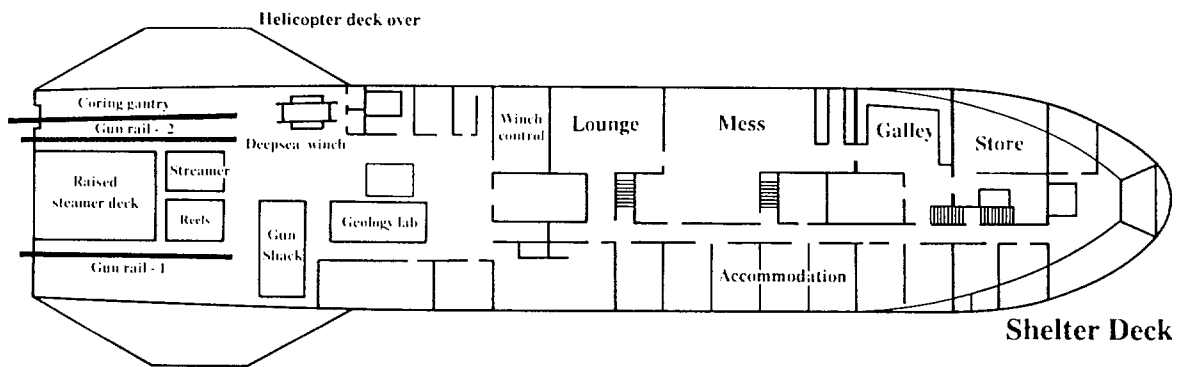
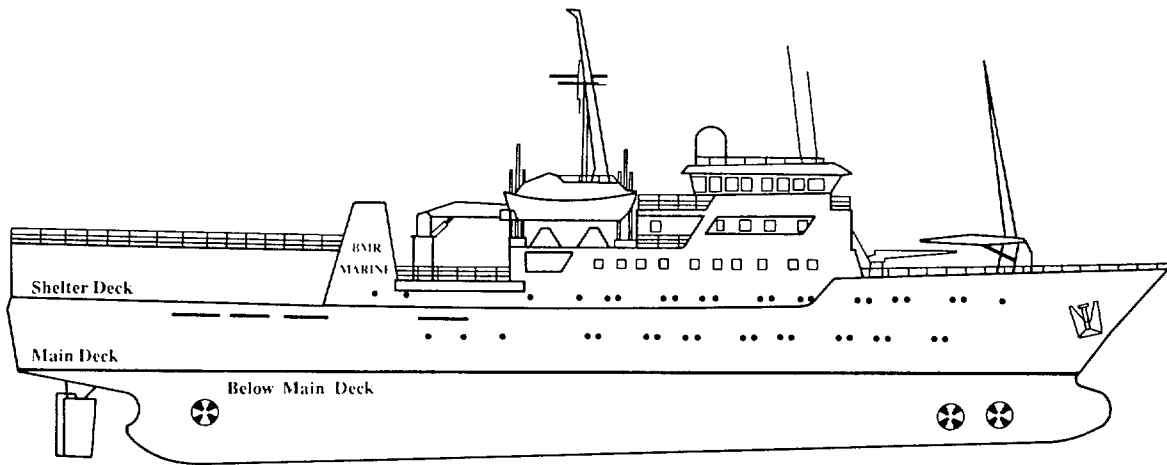
Data from the Program are publicly released as soon as practical after completion of processing, usually within two years of the start of the project. Basin analyses and the reassessments of petroleum prospectivity are publicly released within three years.

It is expected that industry will acquire these data and interpretations, integrate them with their own regional concepts, and reassess large areas of the Australian continental margin as prospective for oil exploration. The Program is aimed at both frontier areas and areas previously explored.



Portion of a stacked seismic section from the continental margin in the central Great Australian Bight, recorded on the RV *Rig Seismic* with a single 26 litre airgun array source and the standard streamer configuration. The section shows five seconds (two-way seismic wave travel time), or about eight kilometres of sediments and possible volcanics beneath the seabed.

RV Rig Seismic



Research Vessel Rig Seismic

R/V *Rig Seismic* is a seismic research vessel with dynamic positioning capability, chartered and equipped by BMR to carry out the Continental Margins Program. The ship was built in Norway in 1982 and arrived in Australia to be fitted out for geoscientific research in October 1984. It is registered in Newcastle, New South Wales, and is operated for BMR by the Federal Department of Transport and Communications.

Gross Registered Tonnage:	1545 tonnes
Length, overall	72.5 metres
Breadth:	13.8 metres
Draft:	6.0 metres
Engines:	Main: Norma KVMB -12 2640 H.P./825 r.p.m.
	Aux: 3 x Caterpillar 564 H.P./482 KVA
	1 x Mercedes 78 H.P./ 56 KVA
Shaft generator:	AVK 1000 KVA; 440 V/60 Hz
Side Thrusters:	2 forward, 1 aft, each 600 H.P.
Helicopter deck	20 metres diameter
Accommodation:	39 single cabins and hospital

Scientific equipment

Teledyne seismic receiving array: 12.5 m, 25 m, 37.5 m and 50 m group lengths, up to 96 channels; the standard configuration is 2400 metres, which may be extended up to 4800 metres active streamer length

Teledyne high resolution seismic receiving array: 12 x 12.5 m, plus 12 x 25 m groups; 450 metres active streamer length

Syntron RCL-2 cable levellers

Texas Instruments 28 x 160 cubic inch airguns in two 14 gun arrays; the normal operating array is 2 x 10 guns, giving a total of 3200 cubic inches (52 litres) normal operating array volume

Seismic Systems S-15 and S-80 high resolution water guns

Air compressor system: 4 x A-300 Price compressors, each providing 300 scfm at 2000 psi (62 litres/min at 14 MPa)

Digital seismic acquisition system designed and built by BMR: up to 120 data channels, 15 bit precision, SFG-Y output at 6250 bpi

Reftek receiver and sonobuoys

Yaesu sonobuoy receiver and Spartan SSQ-57A sonobuoys

Raytheon echo sounders: 3.5 KHz (2 K.W.) and 12 KHz (2 K.W.)

Geometrics G801/803 magnetometer/gradiometer

Bodenseewerk Geosystem KSS-31 marine gravity meter

E.G.&G. model 990 sidescan sonar

Nichiyu Giken Kogyo model NTS-11AU heatflow probe

Australian Winch and Haulage deepsea winch with 10 000 metres of 18 mm wire rope and hydrographic winch with 4000 m of 6 m wire rope

Coring and rock dredging systems (various) and vibracorer

Navigation equipment

Magnavox T-Set Global Positioning System navigator

Magnavox MX 1107RS and MX 1142 transit satellite receivers

Magnavox MX 610D and Raytheon DSN 450 dual axis sonar dopplers

Arma Brown and Robertson gyro-compasses; plus Ben paddle log

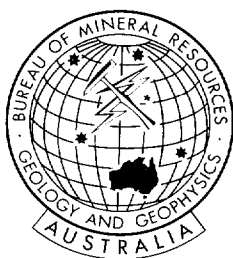
Decca HIFIX-6 radionavigation system, modified for long-range operations

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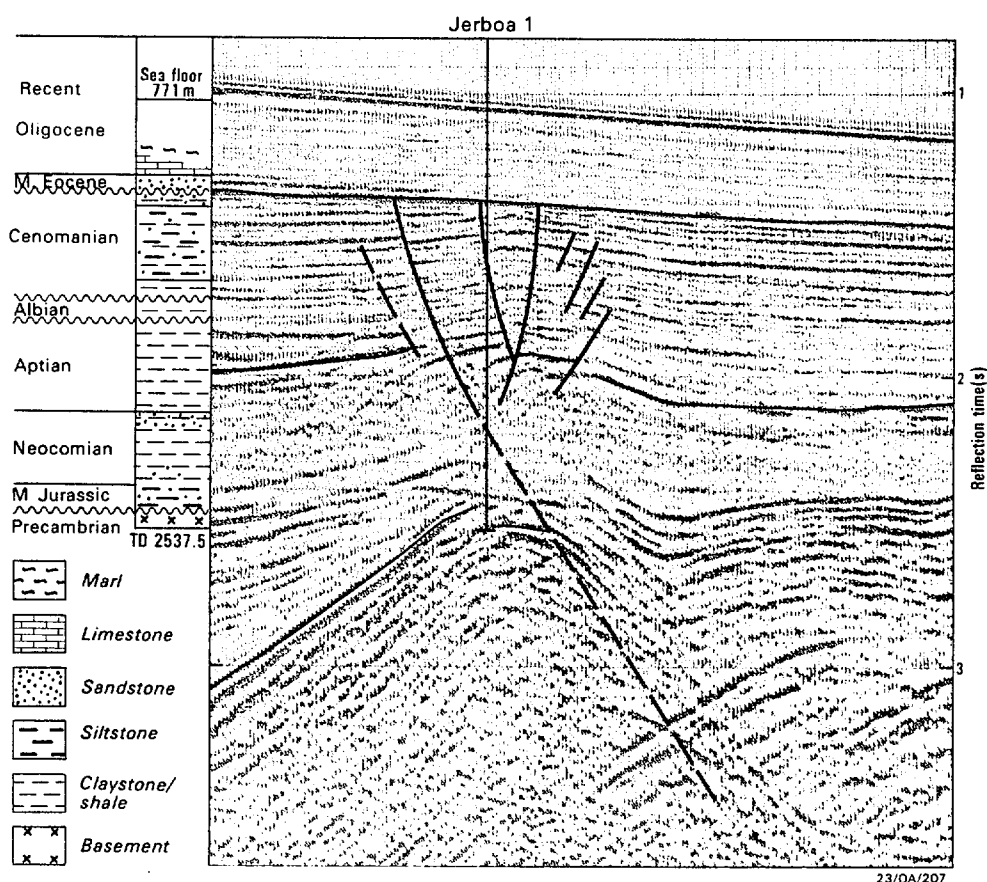


Marine geoscientific research in Australia

The Australian Continental Margins Research Program

Southern Margins Project

Availability of Products - June 1988



Bureau of Mineral Resources, Geology and Geophysics

Division of Marine Geosciences and Petroleum Geology

Southern Margin Project

The region of the Eyre and Ceduna Terraces in the Great Australian Bight was selected for geophysical and geological study because it provides the best opportunity to test new concepts of margin and basin development on the southern margin of Australia, and because most of the margin has been previously subject to only reconnaissance investigation. More than 12500 km of geophysical data were acquired, including 3500 km of multichannel seismic reflection data, principally over the Great Australian Bight (GAB) Basin, Eyre Sub-basin, and Poldia Trough, 11 heatflow determinations were made, and 14 dredge hauls and 20 cores were collected.

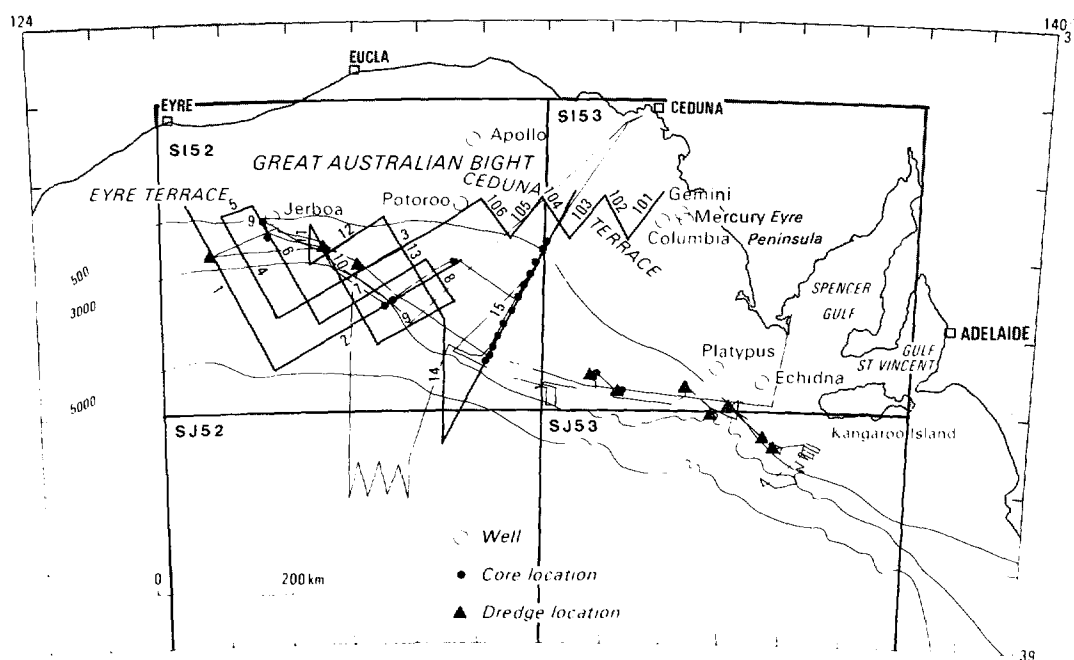
The magnetic data confirm that Late Cretaceous spreading between Australia and Antarctica was directed N-S. However, there is increasing evidence in the seismic data of NW-SE strike-slip faulting in the Cretaceous, beneath the outer margin of the Ceduna Terrace, suggesting that the early continental extension direction may have been in a NW-SE direction.

The Eyre Sub-basin is bounded to the south by a ridge of Precambrian basement which, from the geometry of rotated fault blocks within the basin, probably rests upon a S-dipping primary detachment surface. This basement ridge is at least partly composed of sheared granite, as shown by dredging. The southern flank of the basement ridge, in turn, is a 30 degree S-dipping detachment surface upon which rest rotated blocks of sedimentary rock beneath the continental rise. Sediments in this 'rise basin', south of the Eyre Sub-basin, are 4-6 km thick, and are probably Cretaceous or Tertiary (from tentative correlation with the Otway Basin). They comprise at least nine unconformable seismic sequences, some of which clearly prograde southward.

The very thick (?10+ km) and structured GAB Basin sediments beneath the Ceduna Terrace include a thick prograded sequence characterised by large-scale foreset beds. This unit probably is bounded by Cenomanian and Maastrichtian unconformities (Fraser, A.R., and Tilbury, L.A., 1979, *APEA Journal*, 19(1) 53-65) and thus provides a datum for interpretation of seismic stratigraphy. The sediments of the GAB Basin extend as much as 15 km landward of the shelf break in at least one location, and although very much thinner than in the Ceduna Terrace area, are thus accessible to shelf-depth drilling.

Heatflow values on the Ceduna Terrace are higher than the worldwide average, at around 75 mW/m², and include some anomalously high values which may be related to Tertiary volcanism. Probable intrusive and volcanic rocks are apparent in seismic profiles, and sodic phototephrite lava (undersaturated alkali basalt) was encountered in two dredge hauls. Dredged sediments indicate marginal marine terrigenous sedimentation from Late Cretaceous through to Early Eocene, and pelagic carbonate sedimentation from (limestone and nanno and foram ooze) from Middle Eocene onwards. The youngest sediments dredged were Late Miocene nanno and foram ooze and red-brown mudstone. Cores from the shelf and terraces are mostly pelagic ooze, but those from submarine canyons show an earlier phase of vigorous sediment transport.

This data was acquired on Marine Division surveys 65 and 66, which were carried out using BMR's geoscience research vessel *RIG SEISMIC*, as part of BMR project 9131-08 - Structural Evolution of the Southern Australian Continental Margin.



Geophysical grid for Southern Margin Project including RV *RIG SEISMIC* traverses

Availability of Products

BMR - MARINE SURVEY 65 AND 66 SPECIFICATIONS

Field Data: Vessel: RV RIG SEISMIC
Seismic Digital Seismic Data Tape Format: SEG Y 1600 BPI Phase Encoded
Energy Source: 26.2 litre airgun array *.

Lines 1-15, 105P2, 106
48 Channel, 24 fold recording
Shot Point Interval: 50m
Active Cable Length: 2400m
Sample Rate: 2 msec
Near Trace Offset: 320m

* Line 2P2 and 35km of line 1 were shot using a single BOIT 8.2 litre airgun.

Lines 101-105P2 (Polda trough)
12 channel, 12 Fold recording
Shot Point Interval: 25m
Active Cable Length: 600m
Sample Rate: 2 msec
Near Trace Offset: 320m

Bathymetry Raytheon 3.5kHz & 12.0kHz Precision Depth Recorders with 2kW maximum output.
Gravity Bodenseewerk Geosystem KSS-31 marine gravity meter
Magnetics Geometrics G801/803 proton precession magnetometers
Geology Piston corer, gravity corer, chain dredges, grab sampler
Heat flow Nichiyu Giken NTS-IIAU thermal gradient probe.

Seismic Sections

(If complete survey purchased 25% discount applies)

	Product Code	Price		Product Code	Price
Full scale stacked sections (film only)					
Seismic Line 65/01	M-65S0001F	\$4790.00	Seismic Line 65/05	M-65S0013F	\$ 855.00
Seismic Line 65/02 P1	M-65S0002F	\$ 890.00	Seismic Line 65/06	M-65S0014F	\$3075.00
Seismic Line 65/02 P2	M-65S0003F	\$3495.00	Seismic Line 65/07	M-65S0015F	\$2820.00
Seismic Line 65/101	M-65S0004F	\$ 870.00	Seismic Line 65/08	M-65S0016F	\$1140.00
Seismic Line 65/102	M-65S0005F	\$ 790.00	Seismic Line 65/09	M-65S0017F	\$1950.00
Seismic Line 65/103	M-65S0006F	\$ 810.00	Seismic Line 65/10	M-65S0018F	\$3360.00
Seismic Line 65/104	M-65S0007F	\$ 810.00	Seismic Line 65/11	M-65S0019F	\$1005.00
Seismic Line 65/105 P1	M-65S0008F	\$ 520.00	Seismic Line 65/12	M-65S0020F	\$1995.00
Seismic Line 65/105 P2	M-65S0009F	\$ 720.00	Seismic Line 65/13	M-65S0021F	\$2940.00
Seismic Line 65/106	M-65S0010F	\$1215.00	Seismic Line 65/14	M-65S0022F	\$2835.00
Seismic Line 65/03	M-65S0011F	\$5355.00	Seismic Line 65/15	M-65S0023F	\$6105.00
Seismic Line 65/04	M-65S0012F	\$2745.00			

* All seismic lines are also available as compressed scale sections and are ordered by replacing the 'S' in the product code with a 'C', for example M-65S0001F becomes M-65C0001F.

* Selected lines are being made migrated. For details contact BMR.

Maps

Survey 65 Track Maps, 1:1000000 (3 standard map sheets)	M-65M0001P ⁺ (SI51)	\$ 25.00
	M-65M0002P ⁺ (SI53)	\$ 25.00
	M-65M0003P ⁺ (SI52)	\$ 25.00
Survey 66 Track Maps, 1:1000000 (4 standard map sheets)	M-66M0001P ⁺ (SI51)	\$ 25.00
	M-66M0002P ⁺ (SI53)	\$ 25.00
	M-66M0003P ⁺ (SI52)	\$ 25.00
	M-66M0004P ⁺ (SI53)	\$ 25.00

Survey 65, 1:1000000 Map Sheets (1 sheet in each set)

Bathymetric profiles map	M-65M0004P ⁺	\$ 25.00
Residual Magnetic Anomaly profiles map	M-65M0005P ⁺	\$ 25.00
Free-air Anomaly profiles map	M-65M0006P ⁺	\$ 25.00
Bathymetric posted values map	M-65M0007P ⁺	\$ 25.00
Observed Magnetic Value posted values map	M-65M0008P ⁺	\$ 25.00
Magnetic Anomaly posted values map	M-65M0009P ⁺	\$ 25.00
Observed Gravity posted values map	M-65M0010P ⁺	\$ 25.00

Survey 66, 1:1000000 Map Sheets (1 sheet in each set)

Bathymetric profiles map	M-66M0005P ⁺	\$ 25.00
Residual Magnetic Anomaly profiles map	M-66M0006P ⁺	\$ 25.00
Free-air Anomaly profiles map	M-66M0007P ⁺	\$ 25.00
Bathymetric posted values map	M-66M0008P ⁺	\$ 25.00
Observed Magnetic Value posted values map	M-66M0009P ⁺	\$ 25.00
Magnetic Anomaly posted values map	M-66M0010P ⁺	\$ 25.00
Observed Gravity posted values map	M-66M0011P ⁺	\$ 25.00

⁺ This product has been listed as paper output, film copy is available for \$75 per sheet and is ordered by replacing the 'P' in the product code with 'F'.

Digital Data

Navigation	M-65N0001T	\$ 300.00
1600bpi, 9 track, ASCII, 80 Characters by 10 records per block	M-66N0001T	\$ 300.00
Geophysical Parameters	M-65N0002T	\$ 500.00
(Navigation/minute data)	M-66N0002T	\$ 500.00
Water depth, Magnetics, Gravity		
1600 bpi, 9 track, ASCII, 80 Characters by 10 records per block		

Seismic Data

Field Tapes

Details of tapes upon request. Cost is calculated at \$15 per kilometre (Polda Trough lines \$10 per kilometre) plus a cost of \$80 per tape for copying.

Stack Tapes (If complete survey purchased 25% discount applies)

The stack tape for a particular line can be ordered by replacing the 'F' in the product code for the seismic section with 'T', for example M-65S0004F is replaced by M-65S0004T. The cost is that charged for the seismic section plus a charge of \$80 per tape for copying.

BMR Publications

Willcox, J.B., Stagg, H.M.J., Davies, H.L., & Others RIG SEISMIC Research Cruises 10 & 11 :Structure, stratigraphy and tectonic development of the Great Australian Bight Region Preliminary report BMR Record 1988/13	M-65R0001P	\$ N/A
Revill, K., Roach, I. & Stagg, H.M.J., 1987, RIG SEISMIC Research Cruises 10 & 11 Southern Margin of Australia :explanatory notes to accompany release of non-seismic data BMR Record 1987/39	M-65R0002P	\$ 5.00
Davies, H.L., Clarke, J.D.A., Stagg, H.M.J., McGowran, B., Shafik, S., Alley, N.F., Graham, T., Choi, D. & Willcox, J.B., 1988 Geological results of RIG SEISMIC Cruise 11, Great Australian Bight Basin 1986: BMR Record 1988/16	M-66R0001P	\$ N/A

Conditions of Purchase

(applying to all data including that generated from purchased data)

1. Any publication resulting from the use of the data must give due acknowledgment to BMR.
2. The data may not be published in any form or used in a company prospectus or statement without the permission in writing of the Director, Bureau of Mineral Resources.
3. All data must be kept exclusively for the use of the purchasing company and must not be transmitted to any third party without the permission in writing of the Director, Bureau of Mineral Resources. This restriction does not apply to data resulting from additional processing by the purchasing company in relation to their joint venture partners, provided that those data clearly acknowledge BMR as the source of basic data and copies of the processed data have already been supplied to BMR (see condition 4).
4. In the event of additional processing carried out by or on behalf of the purchasing company, the company is required to supply BMR (Marine Division) with two copies of the final processed data, together with a basic description of the processing sequence. These data must be provided free of charge within six months after completion of processing whereupon they will be kept confidential by BMR for a period of 24 months from the date of receipt.
5. All postage and handling costs are to be paid by the purchaser.

For further information/orders contact:

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Marine Geoscience Research
in the
Southwest Pacific



The Tripartite Program

Introduction . . .

Since 1982, Australia, New Zealand and the United States of America have co-operated in a marine geoscience research program involving the offshore areas of the Southwest Pacific island nations of Cook Islands, Fiji, Kiribati, Papua New Guinea, Solomon Islands, Tonga, Tuvalu, Vanuatu, and Western Samoa.

Many of these small island nations have no natural land-based mineral resources. Most must import, or do without, every kind of mineral resource, at great cost to their economies.

But what they do have, in abundance, is ocean; and under the Law of the Sea, each nation has exclusive rights to the extensive ocean and seabed which surrounds them.

Finding out if their surrounding marine areas - the Exclusive Economic Zones - contain

mineral resources that could be used now or in the future is of great economic and strategic importance to each nation. The answers can only be found after many years of concentrated scientific marine research and exploration.

But it is impractical and uneconomic for small island nations to maintain such complex and expensive research programs requiring high technology equipment, marine research vessels, experienced scientists, and extensive on-shore facilities.

Support is now provided by Australia, New Zealand and the USA, countries who already have well-established research programs and organisations, as part of their foreign aid programs.

This is the Tripartite Program; its results have already surpassed expectations.

Tripartite Program . . .

The Tripartite Program is designed to assess the mineral resource potential and geological framework of the Southwest Pacific region.

The Program followed an arrangement established in 1972 in which New Zealand and island nations form an inter- governmental body, the Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC), to promote the search for underwater resources. Australia is now a member of CCOP/SOPAC.

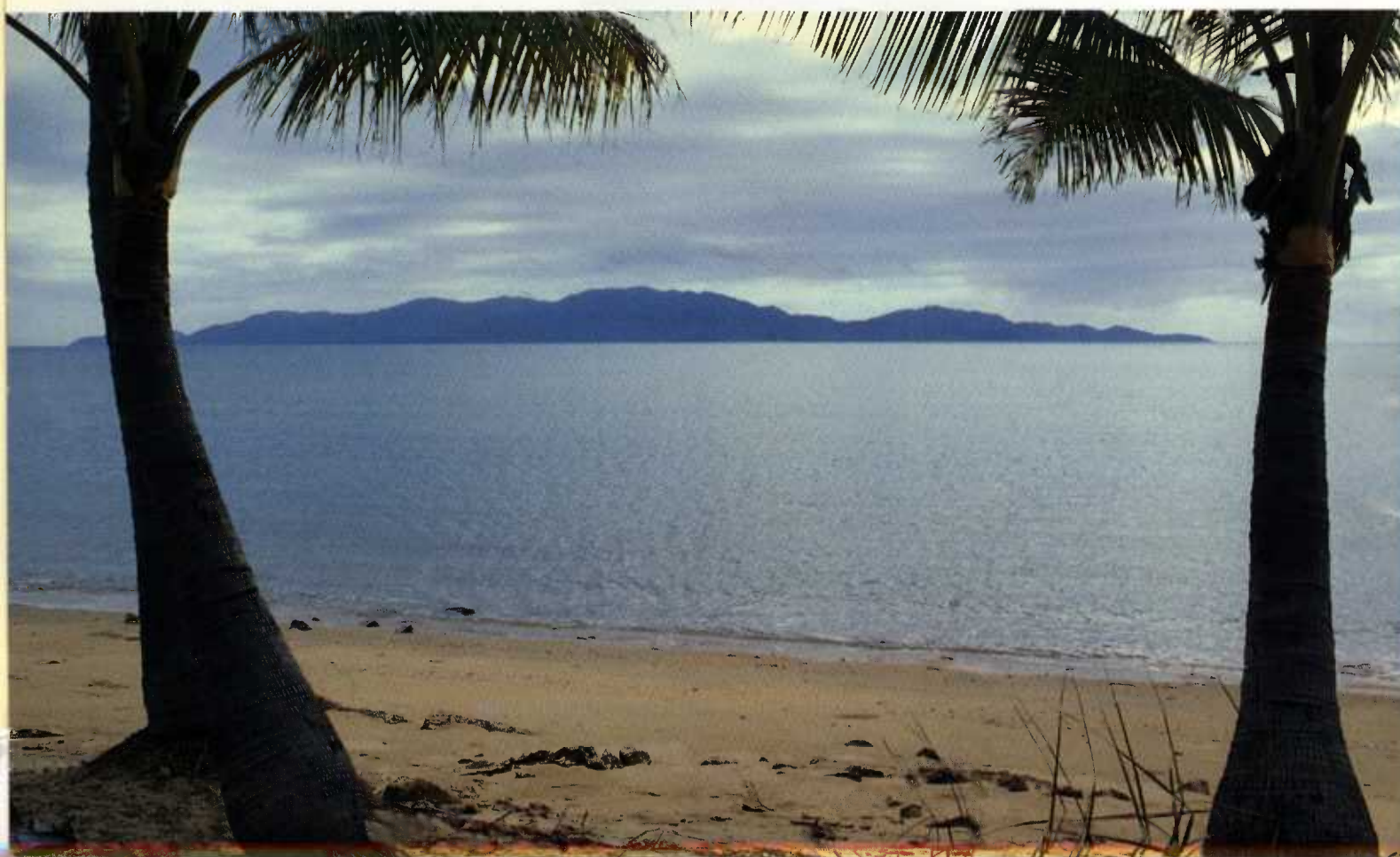
A number of marine surveys were carried out, generally using simple technology, but the knowledge of the seabed in the region remained limited, and the rate of progress was slow.

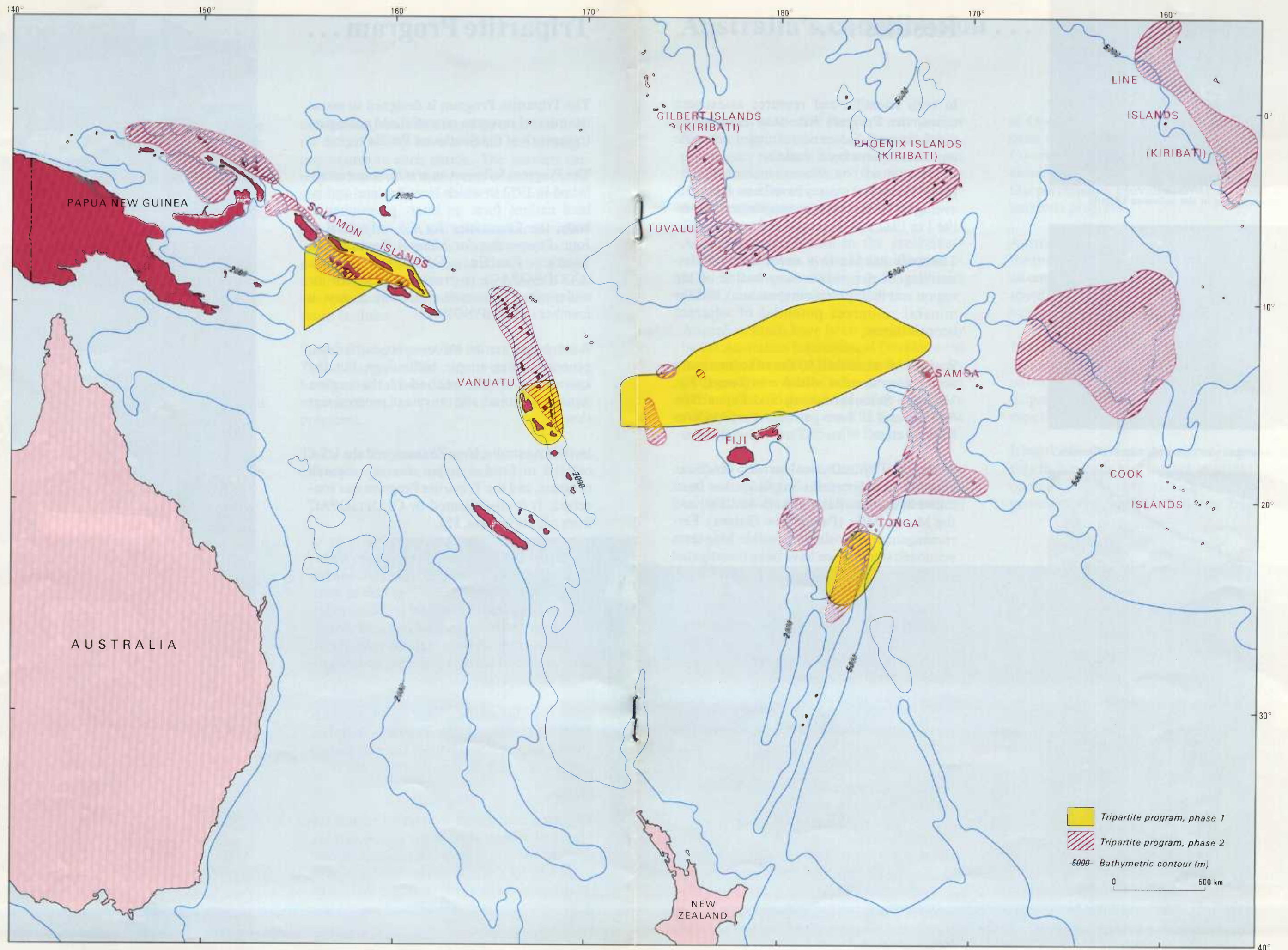
In 1981 Australia, New Zealand, and the USA offered to fund a major marine research program, and the Tripartite Program was conceived. It is co-ordinated by CCOP/SOPAC from offices in Suva, Fiji.

Funding for the program comes from Australia, New Zealand and the USA, and has enabled several high-technology marine geoscience cruises to be undertaken using American and New Zealand research vessels. Scientists from all three nations have played leading roles in the data gathering and data interpretation programs.

A major additional benefit of the Program has been the training of island country scientists, aboard ship and in the laboratory, in marine geoscience and its implications for their countries.

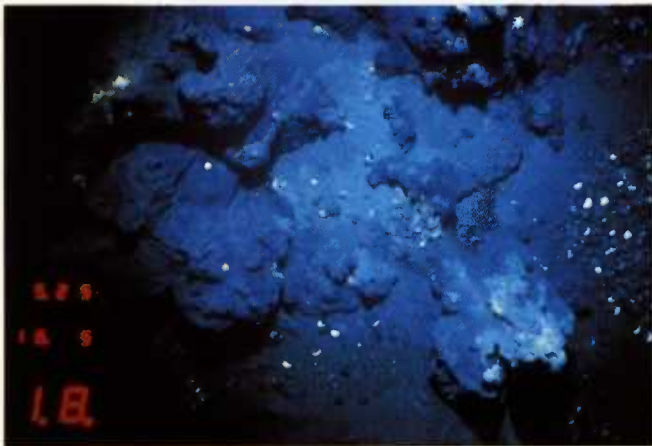
Regular international workshops review the results of recent work in the region and put forward specific projects. A selection is then chosen by CCOP/SOPAC to develop a work program that reflects national priorities and is geographically well-distributed across the region.







Kavachi volcano erupting in the Solomon Islands



Deepsea hydrothermal vent - possible source of metals

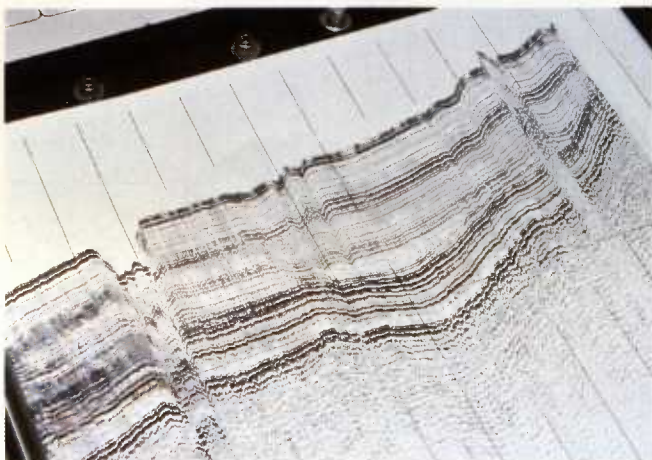


Chart showing strata beneath the sea bed



Deepsea manganese nodules - a major metals source

Results . . .

In both scientific and resource assessment terms, the Program has been enormously satisfying and discoveries of major scientific importance have been made.

Sixteen research cruises have been mounted, averaging 20 days each, in two phases: Tripartite I in 1982 and Tripartite II from 1984-87.

The work has led to a much better understanding of the sedimentary basins of the region and their petroleum potential, and the mineral resources potential of adjacent oceanic basins.

Basins with more than 5000m of sediment are now known to exist offshore in Tonga, Fiji, Vanuatu, Solomon Islands and Papua New Guinea, and all have petroleum prospects as frontier areas.

Evidence of hydrothermal activity, which can give rise to polymetallic sulphides, has been found in the Lau Basin (Tonga and Fiji) and the Manus Basin (Papua New Guinea). Ferromanganese deposits of possible long-term economic significance have been investigated around the Cook Islands, Western Samoa, Kiribati and Tuvalu.

Discoveries include the recognition of hydrothermal vents, with associated unique fauna and an entirely new type of crustal plate boundary in the Manus Basin; and underwater volcanoes of most unusual composition at the junction between three crustal plates in the Woodlark Basin (Solomon Islands).

The exciting results of the Tripartite Program have acted as a catalyst for other research in the area, so that the scientific data base for the region has expanded faster than expected. The data and interpretation efforts are or will be all in the public domain.

Funding for additional work has come largely from civil science budgets of several nations, and in some cases the duration and scope of the cruises have been extended.

Australia's contribution . . .

The seabed of the SW Pacific is essentially a frontier exploration area. In such areas, preliminary research is generally carried out by government agencies, and the more intense research and development falls to privately-funded organisations.

Australia's contribution to the preliminary work is undertaken by the Federal Bureau of Mineral Resources, Geology and Geophysics (BMR) and Australian universities.

Australian funds have been provided largely by the Australian International Development Assistance Bureau (AIDAB). In the five years of the program Australia has provided about \$2.5 million, (75 per cent of which came from AIDAB) representing about 15 per cent of the overall cost of the Tripartite Program.

AIDAB contracts with the BMR to provide and manage the relevant geoscience research services. BMR, AIDAB and the Consortium

of Ocean Geosciences in Australian Universities (COGS) are represented on a National Co-ordinating Committee for Marine Geoscience Programs. This committee seeks scientific participants, provides advice on funds and monitors progress.

Australia has gained substantial benefit from the program. Australian scientists have joined all cruises, eighteen university and seven BMR scientists have gone to sea and a further dozen have taken part in post-cruise laboratory work.

The Tripartite Program embodies a unique and significant planned training program of particular importance for Australian participants, many of whom had little or no marine experience before the Program started.

It has doubled the number of marine geoscientists in Australia and has led to extensive co-operation with internationally-known marine geoscientists in the USA and New Zealand.



The future . . .

The Tripartite Program has been an outstandingly successful program in terms of foreign aid, resource assessment objectives, and marine geoscience research achievements.

It has vastly improved the geoscience data base for the Southwest Pacific, and promoted a substantial increase in international support and prestige for CCOP/SOPAC.

It has provided invaluable training for scientists from the island nations, and broadened the marine geoscience experience of Australian participants.

Further information . . .

Further information on the Tripartite Program may be obtained by contacting:



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