AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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DRAFT FUTURE PROGRAM STRATEGY

FOR AGSO'S

MARINE GEOSCIENCE AND PETROLEUM

GEOLOGY PROGRAM

by

P. A. Symonds

AGSO

AUSTRALIAN GEOLOGICAL
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Division of Marine Geoscience & Petroleum Geology

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INTRODUCTION

The Marine Geoscience and Petroleum Geology (MGPG) Program of the Australian Geological Survey Organisation (AGSO; formerly the Bureau of Mineral Resources, Geology & Geophysics) undertakes studies of the geology and resource potential of the continental margin and adjacent ocean basins around Australia and its territories - an area of about 12 million km^2 (about 1.5 times the area of the Australian land mass). The Program, which began in 1985, is also referred to as the 'Continental Margins Program'. It is an important element in the Federal Government's strategy to encourage exploration and development of Australia's offshore petroleum resources.

The Program has three main elements:

- to provide datasets, knowledge, and ideas to aid the sustainable development of Australia's offshore petroleum, and to a lesser extent, mineral resources;
- to help formulate government policy on maritime jurisdiction and on management of non-living resources; and
- to raise the level of understanding of the geological processes that form continental margins.

All three elements have long- and short-term priorities, which relate to the needs of industry, government and the general public. The MGPG's future program seeks to balance the program elements and priorities, with operational logistics, and financial and human resources. On occasion, fully- or partially-funded foreign development assistance projects (e.g. the Philippines survey of early 1992), and co-operative studies with industry and other research organisations, form another component of the Program.

Proposals for the MGPG future program come from within AGSO, and directly from industry, government, or university researchers. They are assessed by the MGPG Future Program Committee against the marine program strategy and discussed with client groups, and may then be included within a portfolio of possible projects. These are prioritised to create a balanced two-year rolling program, which is firmed-up on a six monthly basis.

PETROLEUM RESEARCH STRATEGY

The rationale

At present, about 90% of Australia's petroleum production comes from offshore basins, specifically the Gippsland Basin, Northwest Shelf and Timor Sea. It is widely accepted that any

future large discoveries are also most likely to be made offshore.

Exploration density in Australia remains very low by world standards. Despite this situation, about 5200 million barrels of oil and condensate have already been discovered beneath the 1.7 million km^2 of continental shelf available for exploration. AGSO conservatively estimates that at least a further 2500 million barrels (average estimate) of oil and condensate remain to be found beneath the shelf. About 3 million km^2 of the more remote continental margin remains virtually unexplored, but appears to have a range of basin settings similar to those beneath the shelf. There is a continuing need to maintain and expand the level of exploration effort on Australia's continental margin if this resource potential is to be realised. Reduction of geological risk through provision of improved geological information contributes to this goal.

The MGPG Program's future petroleum strategy is best summarised as '*new basins, new approaches, new ideas*' and has two major thrusts, which are tied to long and short term outcomes:

- *to locate and study new basins in poorly-explored shelf areas, upper-slope areas adjacent to producing/explored shelf areas, and remote, deepwater slope, plateau and terrace areas - a longer term outcome aimed at ensuring future resources.*

- *to develop and apply new approaches and ideas to rejuvenate exploration in areas of declining interest, or where exploration is 'mature' or ongoing - a shorter term outcome aimed at maximising resources in known petroleum provinces.*

Whenever possible, work under the MGPG petroleum strategy is carried out to have an impact on the release of offshore acreage for petroleum exploration.

New basins - future resources

There are substantial areas of the 12 million km^2 legal continental shelf around Australia and its territories that remain largely unknown in terms of their tectonic development, sediment thickness and basin framework. They include some large shallow-water shelf areas, particularly along Australia's northern margin in the east Timor Sea/Arafura Sea/Gulf of Carpentaria region. This area is generally perceived to have low exploration potential, a perception based on limited data of generally poor quality, and old concepts of margin and basin formation, and prospectivity. Such areas require a reassessment in the light of new regional data sets collected using the latest exploration concepts.

Also, vast sedimentary basins, some of considerable thickness and structural complexity, containing indicative exploration leads, have been recognised in reconnaissance seismic data, including AGSO data. These occur in deepwater, beyond the frontier of conventional offshore exploration activity. Such basins are generally thought to be inaccessible and to be uneconomic at current oil prices.

Elsewhere in the world, notably in the Gulf of Mexico and in the Campos Basin, Brazil, deepwater exploration is increasing. The significance of this exploration is that it has confirmed

the capacity of the exploration industry to explore in and produce from deepwater e.g. in the Green Canyon area of Gulf Mexico oil is being produced in 684m of water using a floating/subsea completion system which can probably be operated in 1200m water. In late 1989 Shell Offshore Inc carried out exploration drilling with riser in 2328m of water.

With steadily improving technology, several Australian deepwater areas appear to hold significant medium- to long-term potential, which may prove attractive through the 1990's and into the 21st century. This is particularly true for large areas adjacent to producing parts of the continental shelf, for example, the Kangaroo Syncline of the eastern Exmouth Plateau, adjacent to the Rankin Platform area of the Northwest Shelf, and slope areas adjacent to the Gippsland Basin of southeastern Australia. When international economies improve, exploration in water depths between 500 and 1500 m around Australia should be considered viable (Fig. 1).

Approaches

The first step in the implementation of this part of the MGPG petroleum strategy requires the collection of regional seismic data over Australia's unexplored/poorly-explored areas using AGSO's dedicated research vessel R/V *Rig Seismic*. These data should then be supplemented by coring and dredging in an effort to 'ground-truth' seismic interpretations. A better understanding of the tectonic evolution, basin framework and petroleum potential of Australia's poorly-explored areas will also result from new ideas developed to explain better-explored, shallower water margin/basin provinces in adjacent or conjugate positions. For example, new concepts such as the detachment model of continental extension, and regional palaeogeographic studies, contain strong predictive elements which can be used to improve the geological understanding of whole sectors of the Australian margin.

Where?

The chronology in which any newly discovered basins will be explored by industry will undoubtedly be controlled by economic factors. Such factors place priority on where to apply this 'new basins' strategy. MGPG program should have three priorities, broadly following those of industry:

1. To study new basins beneath the shelf before those in deeper water. It is these areas which will be of greatest interest to the exploration industry. Possible areas to be considered are: the east Timor Sea/Arafura Sea/Gulf of Carpentaria area because of it's shallow-water location and lack of exploration. This priority has been further enhanced by AGSO's 1990 Arafura survey, which discovered a thick ?Triassic and Permian section north of the Goulburn Graben, the present focus of exploration in the region. Other poorly-explored shelf areas requiring further investigation occur off Carnarvon (Gascoyne Sub-basin, southern Carnarvon Basin) and off eastern Tasmania (Fig. 2).

2. To study upper slope areas (200-500m water depth) adjacent to explored/producing regions with proven resources, because of the existing infrastructure, knowledge base, and greater potential. Some of these areas lie adjacent to the Northwest Shelf region, for example the Kangaroo Syncline adjacent to the Rankin Trend, the inner Scott Plateau adjacent to the Scott Reef Trend, and possibly the Rowley Sub-basin adjacent

to the offshore Canning Basin. Another area of potential interest is the region adjacent to the Otway and Gippsland Basins off southeastern Australia (Fig. 2). Whether any of these areas require a full regional framework study in their own right has yet to be determined. Many of them will be investigated to some extent as a result of data collection and studies related to projects over the adjacent shelf basins as part of the 'new approaches/new ideas' strategy (see below).

3. To explore the large area of deep-water plateaus and ridges around Australia. These are not of high interest to exploration companies at the present time, but it is these areas that have the potential to provide the resources of the future. It will take a large investment in time and effort to collect the necessary data to understand the geological framework and basin distribution beneath these generally remote features. Deep-water areas that have substantial petroleum potential are: the western flank of Lord Howe Rise, the southern Kerguelen Plateau, and to a lesser extent the South Tasman Rise and West Norfolk Ridge (Fig. 2). The Exmouth Plateau is known to be prospective, particularly for gas. Other potential areas are the northern Scott Plateau, Wallaby (Cuvier) Plateau, Cascade (East Tasman) Plateau, Mellish Rise, the western Great Australian Bight Basin, areas adjacent to the Otway and Sorell Basins, New Caledonia Basin, Rowley Terrace, eastern Naturaliste Plateau, Kenn Plateau, and the Cato Trough. Some of these areas also require investigation as part of MGPG's 'law of the sea and seabed boundaries' strategy.

Recommendation

Given the considerations outlined above, the main goals of the MGPG Program over the next five years related to the 'new basins' strategy (Fig. 2) should be:

- *to provide the regional framework in the most prospective parts of the east Timor Sea/Arafura Sea/Gulf of Carpentaria region.*

- *to develop a new understanding of basin distribution and petroleum potential in upper slope areas of the inner Scott Plateau, the Rowley Terrace, and the Kangaroo Syncline (adjacent to the Rankin Platform) as part of a major study of the Northwest Shelf region.*

- *to commence a study of regional framework and basin distribution on the shelf off eastern Tasmania, and on the upper slope adjacent to the Otway Basin, as part of a major regional study of the basin system off southeastern Australia.*

- *to collect new data over some of the most prospective remote, deep-water areas off eastern Australia, such as the southwestern Lord Howe Rise, Kenn Plateau, and South Tasman Rise. The selection of which of these that should be studied will probably be largely controlled by other MGPG Program priorities.*

New approaches and new ideas - reduced exploration risk

The MGPG Program aims to reduce exploration risk in previously and currently explored areas by applying new techniques, and by studying basin- and margin-wide architecture and prospectivity. The MGPG Program can assist the exploration process and improve exploration efficiency by collecting deep-seismic and geological data on long regional lines which cross permit areas, and by tying existing exploration wells to these lines. These surveys need to target critical gaps in industry information, as well as acquiring information (e.g. deep structural data) that can improve regional exploration models.

There is increasing recognition that old models of margin evolution incorporating a single phase of rifting leading eventually to continental breakup and dispersal by seafloor spreading do not explain the complex episodes and arrangement of structures observed on rifted margins. Many margins exhibit several rift/sag phases which can be related to a variety of different extensional styles and transport directions. These primary margin and basin forming structures can then be reactivated both before and after break-up in a variety of tectonic settings. Understanding the time-variant, three-dimensional, finite deformation field responsible for the development of extensional terranes, and the resulting complex arrangement of structural styles and related depositional systems, is crucial to the development of play types and exploration approaches within basins.

Virtually all of Australia's petroleum resources occur in structural and structural/stratigraphic traps formed by reactivation of basin-forming and basement structures (Etheridge & others, 1991: *Geological Society of Australia Abstracts* 30, 132-133), particularly in the Carnarvon, Gippsland and Bonaparte Basins. At least six significant reactivation events have been recognised since the Late Triassic. In most cases the structures reactivated were those that were formed during the initial stages of basin development. This reactivation may produce structuring in the overlying sequence, influence the distribution of sedimentary facies and induce spatial variations in subsidence rate. Reactivation of primary fault arrays creates plumbing systems within the basin that may provide hydrocarbon migration paths from deeply-buried source facies to higher-level reservoirs in the overlying thermal subsidence sequence. This highlights the need to understand the deep structural architecture of margins and their basins.

Approaches

The 'new approaches/new ideas' part of the MGPG's petroleum program will be pursued in two main ways:

- by integrating new regional data, collected using R/V *Rig Seismic*, with existing exploration industry data. The R/V *Rig Seismic* data are designed to complement those gathered by industry, by targeting critical gaps in information and by collecting data sets that enhance regional understanding of basin development. Much of the MGPG's petroleum effort will be concentrated in this area. For example, regional deep-seismic profiles for studying primary basin-forming architecture, linkages between major structural elements, and regional control on the distribution of source and seal facies in relation to the 'kitchen' areas; and high-resolution seismic, sidescan sonar, bottom sampling and DHD (direct hydrocarbon detection- 'sniffing') data for

examining structural and depositional effects resulting from Tertiary reactivation, and their influence on petroleum generation, migration and entrapment.

- by conducting regional reviews, compilations and reinterpretations of well data, existing potential field data etc., to form a regional knowledge base from which to move in new directions and create testable models and ideas. For example, regional biostratigraphic studies based on sequences of samples from offshore wells, cores and dredges, in addition to relevant onshore wells and outcrops, would substantially increase the reliability of age determinations, palaeogeographic interpretations, formation identification and the timing of significant structural and stratigraphic events; and the re-processing and re-display of gravity (both marine and SEASAT) and magnetic (both marine and airborne) data, particularly as images, will aid understanding of the regional structural framework. When the new satellite Geodetic Mission high-resolution gravity data becomes available in the near future, they will have a big impact on the way MGPG petroleum studies are planned and conducted. The dataset will be an invaluable aid to designing deep-seismic surveys and will permit the mapping of major structures, as defined on widely-spaced regional seismic lines, throughout whole basin systems.

Where?

Because the 'new approaches/new ideas' part of MGPG's petroleum program is aimed at reducing exploration risk and rejuvenating activity in previously explored areas, its main focus will be on the shelf/upper slope basins off northern, western and southern Australia - that is, the major exploration regions. The Perth Basin off southwestern Australia has been the subject of recent MGPG studies, leaving the Northwest Shelf basins and the Otway, Bass and Gippsland Basins off southeastern Australia as the priority regions for future study over the next five years (Fig. 3).

Northwest Shelf:
The Northwest Shelf is clearly the first region that should receive concentrated study because of its importance to Australia's future petroleum production. Despite the considerable exploration effort in the region during the last 10 years there remain enormous gaps in understanding of critical aspects of basin evolution. For example, the nature of the primary, Palaeozoic basin-forming mechanisms that have controlled all future development of the Northwest Shelf basin system, and the part that these mechanisms played in the development of the whole continental margin province, are not understood; and the nature of the linkages between many basin elements is largely unknown.

Major scientific objectives of the Northwest Shelf study are:

- to determine the regional structural framework of the Northwest Shelf by examining the boundaries between major structural elements.

- to determine the deep-crustal structure of the basins of the Northwest Shelf and their relationship to the development of the continental margin and adjacent Argo, Gascoyne and Cuvier Abyssal Plains.

- to assess the effect of deep structure on the development of the major fields and petroleum plays in the region, and in particular the structural and depositional effects resulting from Mesozoic and Tertiary reactivation of these deep structures.

- to improve knowledge of the depositional processes responsible for filling the basins, and the regional source, reservoir and seal potential of the main megasequences.

Southern/southeastern margin - Otway, Bass and Gippsland Basins:
Although the southeastern Australia margin contains the highly-productive Gippsland Basin, the considerable exploration effort made in the adjacent Bass, Otway and Sorell Basins has so far produced only disappointing results. Exploration is continuing but there appears to be considerable pessimism about the chances of significant discoveries being made particularly outside the Gippsland Basin. Nonetheless, the southeast Australian margin is still Australia's premier petroleum province with its strategic location near the major population centres, and with the Gippsland Basin producing about 60% of Australia's oil and condensate.

Major issues that need to be resolved in this region are:

- the tectonic development of Australia's southern/southeastern margin, and its influence on basin distribution and framework.

- the deep-crustal structure of the Otway, Bass and Sorell Basins and its relationship to margin development.

- the effect of deep structure on the development of major fields, prospects and petroleum plays in the region, and in particular any structural and depositional effects resulting from Cretaceous and Tertiary reactivation of these deep structures.

- the regional structural framework of the southeast Australian basin system and linkages between major stuctural elements, and the basins themselves.

- the style and age of the various phases of basin formation from initiation to late stage reactivation.

- the factors that have made the Gippsland Basin so much more prospective than other basins in the region.

Recommendation

The main goals of the MGPG Program over the next five years related to its 'new approaches/new ideas' petroleum strategy should be (Fig. 3):

- *to complete a regional structural study of the northwest Australian continental margin and the major basins of the Northwest Shelf (from the Exmouth Sub-basin in the south, to the Calder Graben in the north), in order to provide new insights into basin evolution and petroleum generation as an aid exploration in the region.*

- *to commence an integrated regional study of the southern/southeastern Australian margin and the Otway, Sorell, Bass and Gippsland Basins, in order to provide new insights into basin evolution and petroleum migration as an aid to exploration in the region.*

MINERALS RESEARCH STRATEGY

The rationale

The Minerals (Submerged Lands) Act 1981 was declared in 1991 and provides Australia's framework for the offshore exploration and exploitation of minerals. As in the case of petroleum resources, the MGPG Program has a responsibility to provide advice and basic information to government to facilitate the formulation and implementation of policies, and the effective management of Australia's offshore mineral resources.

Currently there is no significant offshore mineral exploration activity around Australia; however, there are mineral sand exploration leases over shallow shelf areas off northern and central New South Wales, and placer diamond leases on the shelf off the Kimberleys in Western Australia. There is also an increasing interest in extracting construction materials from the inner shelf off major population centres, particularly Sydney. The impetus for this type of activity will undoubtedly increase in the future, as available onshore resources dwindle, and the exploitation of such deposits will probably become more widespread and extend into ever increasing water depths. At the moment, the focus of activity is on the shallow inner-shelf zone because of the relative ease of extraction and small transport distances; that is, within the 3 nm jurisdiction (Coastal Waters) accorded the Australian States under the Offshore Constitutional Settlement and within the inner part of the recently extended territorial sea (now 12 nm - note: the Commonwealth has jurisdiction over resources beyond 3 nm, but in some cases, such as with petroleum and minerals, the States are involved in administration of resources beyond 3 nm as members of Joint Authorities).

Approach

The offshore mineral resources of interest to the MGPG Program fall into two categories:

- shallow-water, shelf resources such as placer-type deposits of diamonds, gold, heavy-mineral sands etc., phosphates as crusts, pavements and nodules, and deposits of construction materials such as sand and gravel.

- deep-sea resources in the form of polymetallic nodules and crusts which contain Ni, Cu and Co.

Recommendation

The MGPG Program should, on an opportunity basis in conjunction with other projects:

- *undertake studies of shallow water, shelf resources; and*

- *continue studies of deep-sea, polymetallic resources, particularly in the Cocos-Keeling and Christmas Islands areas of the Indian Ocean and in the Cape Leeuwin nodule field off southwestern Australia.*

Currently, the development of a dedicated minerals program is on hold because of the lack of specific funding for such a program.

LAW OF THE SEA AND SEABED BOUNDARIES

The rationale

The MGPG Program has an important responsibility in relation to the establishment and management of Australia's seabed jurisdiction by providing government with technical advice, information and expertise on seabed morphology, geology and resource potential.
This responsibility occurs in three main areas:

- definition of the 'legal' continental shelf around Australia and its territories.

- areas involved in seabed boundary negotiations and delimitation with adjacent coastal states.

- areas under consideration for the creation of marine parks and reserves.

The importance of this role was emphasised by the 1992 Review of the Continental Margins Program undertaken at the instigation of the AGSO Advisory Council. This review recommended, amongst other things, that: "AGSO develop a five year strategic plan to complete data acquisition related to Australia's Maritime Boundaries", and that "discusssions be held with DASET and other appropriate agencies on their forward programs with a view to gathering baseline data in areas that may be considered for new marine parks or protected areas".

Australia's 'legal' continental shelf

The area of the Australian legal continental shelf (LCS) is approximately 12 million km^2, and eight regions of this LCS, totalling more than 3 million km^2, extend beyond the 200 nm line: A - Lord Howe Rise/Norfolk Ridge, B - Macquarie Ridge, C - South Tasman Rise, D - Great Australian Bight, E - Naturaliste Plateau, F - Exmouth/Wallaby Plateaus, G - Argo Abyssal Plain, and H - Kerguelen Plateau (Symonds & Willcox: *AGSO Journal,* 11, 11-36). A precise

foot-of-continental-slope line (based on echo sounder or seismic profiles rather than contoured bathymetry) presently can only be defined for about 15- 20% of these regions, and an outer edge-of-margin line based on the sediment thickness formula cannot be constructed for any of them. However, it should be pointed out that the sediment thickness formula can probably only be used to increase the area of LCS in region D,in the Great Australian Bight.

Regional bathymetric and seismic profiles at a spacing of 60 nm or less are required across the areas of margin extending beyond 200 nm where a precise foot-of-slope and sediment thickness line cannot be constructed. Although the collection of seismic data may not result in an increase in the area of LCS that can be claimed, with the possible exception of the Great Australian Bight, it will allow an assessment to be made of the resource potential of these remote regions.

Where?

Regional bathymetric and seismic data for the purpose of LCS definition are required in the following regions - the northern, northwestern and southwestern margins of the Exmouth Plateau; the northern and western margins of the Wallaby (Cuvier Plateau) and probably around the adjacent Zenith Seamount (outer Wallaby Plateau); central Great Australian Bight south of the Ceduna Terrace; around much of the southern two-thirds of the South Tasman Rise; the southwestern and eastern margins of the Lord Howe Rise; the northwestern and northeastern margins of the West Norfolk Ridge; the southern Macquarie Ridge; and around much of the southern Kerguelen Plateau (Fig. 4). The collection of data for this purpose will probably need at least eight normal R/V *Rig Seismic* cruises (about 3000 line km of data per cruise). The use of a high-speed seismic streamer would speed up the data collection and reduce the number of cruises required in very remote, poorly-known areas such as the Kerguelen Plateau.

Recommendation

During the next five years the MGPG Program should collect new data relevant to the definition of Australia's LCS in the following areas (Fig. 4):

- *the southwestern Lord Howe Rise and West Norfolk Ridge, in conjunction with a 'new basins' and 'seabed boundary' study (Note: work scheduled to be undertaken in November-December1992);*

- *the South Tasman Rise, in conjunction with a 'new basins' study, possibly involving French co-operation;*

- *the Wallaby Plateau as part of a 'new approaches/new ideas' study, possibly involving co-operation with French organisations.*

Seabed boundary negotiations

Australia has still to complete seabed boundary negotiations with Indonesia and New Zealand. Regional surveys and framework studies may be required in some of the areas to be negotiated to ensure that the Australian Government can be provided with appropriate and timely

information and advice on their morphology and resource potential. It is difficult to predict when these datasets will be required; however, during 1993 negotiations with Indonesia are expected to progress, and negotiations with New Zealand may commence.

Where?

The areas requiring data for delimitation purposes are around Christmas Island, over the southern Lord Howe Rise and West Norfolk Ridge, and possibly over the northern Scott Plateau (Fig. 4). A Christmas Island morphology and resource survey was carried out in January/February 1992, and a regional framework study of the southern Lord Howe Rise/West Norfolk Ridge region is scheduled for late 1992.

Recommendation

During the next five years the MGPG Program should:

- *collect, if necessary, new data in areas where seabed boundary negotiations are required.*

Marine parks and reserves

Advice on the morphology and resource potential of areas under consideration for national parks and reserves will normally be based on existing data. However, depending upon advice from DASET and other agencies, there may be some need for dedicated surveys in particular areas.

MARINE PROCESSES AND ENVIRONMENT

The rationale

The 1992 AGSO Advisory Council Review of the Continental Margins Program recommended that "any work in the marine environmental field unrelated to marine protected areas should be as a result of an explicit Government decision or clearly be funded from external sources". However, there is a view being put to the Richard's Review of AGSO that the MGPG Program should include marine processes and enviromental components, albeit with specific funding. Clearly, understanding the geoscientific aspects of Australia's offshore environment is an important function, particularly in the area of Commonwealth jurisdiction beyond 3 nm.

It is has been demonstrated that marine sediments of the continental margin contain the signature of changes in climate, sea level and ocean productivity, which not only provide a legible record of the past, but which help to unravel environmental problems that concern society at the present time. That is, they can provide a baseline by which to judge the significance of modern, man-induced global change. In addition, seafloor sediments are the sink for many industrial and urban wastes, and are capable of recording the extent of degradation of

the marine environment from man-made sources. Offshore resource exploration is likely to expand, and there is a need to provide input to industry with respect to the depositional processes that produce such deposits and the likely impact of their exploitation. There is a need to develop models to explain the nature and distribution of sediments that now lie beneath the shelf and slope, within an evolving palaeogeographic and palaeoclimatic setting that is peculiar to Australia - currently many such models are imported, with varying degrees of applicability to the local situation. Such work also has impact on the minerals strategy and in the availabililty of facies models and modern analogues for use in petroleum exploration.

Approach

AGSO's R/V *Rig Seismic* is able to sample sediments, either by dredging or coring, in all water depths, and it is capable of imaging the surface of the seafloor and its subsurface, to build up a regional picture, at varying resolution using side-scan sonar, and single and multichannel seismic reflection techniques. The vessel is equipped to analyse a variety of inorganic elements and organic compounds both in sediments and in the water column. R/V *Rig Seismic* is unique in the Australasian region in that it's direct hydrocarbon detection (DHD) system gives it the capacity to carry out continuous, underway, real-time sampling and analysis of seawater in shelf water depths. In addition, facilities are available at AGSO's laboratories in Canberra to use a variety of analytical techniques, including grainsize analysis, petrography, biostratigraphy and stable isotope geochemistry to name a few.

Because of the man-power requirements involved in this type of work, MGPG's Marine Processes and Environment sub-program is ideally suited to a high level of co-operative research with other Australian and overseas institutions. Indeed, given AGSO's manpower constraints, such an approach is essential to maintain the momentum that is required to accomplish the sub-program's tasks. Such co-operation has already commenced with the signing of an agreement between AGSO and the Japanese National Oil Corporation (JNOC), and involving Sydney University, for the joint study of modern carbonate depositional processes and facies development of the southern Queensland shelf and southern Great Barrier Reef; as part of AGSO's involvement with the Co-operative Research Centre for Antarctic and Southern Ocean Environment at the University of Tasmania in sedimentological and palaeoclimate studies of the Antarctic and southern Australian continental margins; for studies of the NSW shelf with Sydney University and the Sydney Water Board.

Obviously, MGPG process-oriented studies related to resource exploration are largely limited to those where the resulting sedimentary deposits can be sampled and imaged by the technology onboard R/V *Rig Seismic*, or on very rare occasions by ODP (Ocean Drilling Program) technology. It is essential to establish more precisely where active Australian explorers feel there is the greatest need for improved process models. This can only be achieved by better communication with company explorationists.

There is also a need to make contact with other federal and state government agencies whose jurisdiction involves the marine environment. An example would be the Great Barrier Reef Marine Park Authority. While their concerns are often biological or oceanographical, they do require input from the geological community. Over the next five years the marine program

should attempt to make AGSO their first point of contact on environmental matters that have a geological perspective.

What/where?

Australia is suitably placed to undertake world-class marine environmental research with both its eastern and western margins extending from the tropics to temperate climates. The conjugate margins of southern Australia and eastern Antarctica present contrasting natural laboratories to study cool-water marine depositional processes, palaeoclimate and palaeoproductivity. A compelling philosophy, therefore, would be to utilise this north-south variability to undertake studies of modern processes and palaeoclimate from a range of different environments extending from the tropics to the polar regions. Results from the recent ODP leg off northeastern Australia have demonstrated that a high-resolution record of late Quaternary sedimentation exists on the upper continental slope, and that the impact of climatic change is preserved in great detail within these sediments. While coring these relatively thick sediments can only be achieved by programs such as ODP, it is feasible to core similar age sediments elsewhere on the continental margin, which still preserve a legible climatic and environmental signal, using conventional techniques. Initially, the strategy of the Marine Processes and Environment sub-program will be to concentrate on developing sedimentological and climatic models of the continental margin for the late Quaternary, but also extending this in time as the opportunity arises. The intention is to locate and sample those parts of the Australian and Antarctic margins where a high-resolution record of lāte Quaternary sedimentation and palaeoclimate exists, from a variety of environments ranging from 10°S to 70°S latitude. This, coupled with high-resolution seismic data, could form the basis for selecting potential ODP sites to extend the record back into the Tertiary.

In addition to studies aimed at investigating regional variability, there are some specific locations around the Australian margin where unique combinations of processes and environmental factors have produced natural laboratories for analysing palaeoclimate and sealevel change. An example is the Gulf of Carpentaria/Arafura Sea area (Fig. 5), and several proposals have been received from Australian and USA organisations for co-operative programs to examine climate and sealevel change in this region.

Another facet of the program is intended to broadly encompass environmental geochemistry. This will focus on environmental signals, both past and present, that have come about naturally, as a consequence of changes in the hydrosphere over time, or as a result of human activities. An example of the former is the JGOFS (Joint Global Ocean Flux Study) program, which will attempt to document variations in ocean chemistry and productivity as a consequence of climatic change, whereas studies of the NSW shelf would be an example of the latter. The NSW shelf is an area where there are important resource and environmental management issues: seabed construction materials, mineral sands, waste disposal (sewerage outfalls, contaminated run-off, heavy metals), recreational and fishing use. Understanding the sediment dynamics and geochemical processes in this region is crucial for the future management of the region. Environmental concerns are likely to arise and change rapidly in this region, and the MGPG Program needs to adapt its techniques and build up its knowledge base if it is to be able to respond quickly to such change.

Over the past seven years some six hundred cores have been collected as part of AGSO's Continental Margins Program and this data base continues to grow. This represents an invaluable source of data on sedimentary processes on the Australian margin, and on the climatic and sea level variations preserved within the cores. While most of these cores have been sampled for routine analysis, many of them would be amenable for more detailed analyses of ocean/climate and sedimentological history. These cores form an important database that should be addressed, not only by AGSO, but by scientists from a diversity of backgrounds and specialities. In this way the maximum use of this database can be achieved.

Recommendation

Providing that specific funding is made available, the main goals of the MGPG Program over the next five years related to the Marine Processes and Environmental strategy should be (Fig. 5):

- *to conduct sedimentary process and environmental studies along the east Australian margin. This has already commenced with the co-operative studies involving JNOC in the northern sector of the shelf, and the Sydney Water Board/Sydney University/NSW Geological Survey in the central sector of the shelf near Sydney.*

- *to conduct a co-operative modern process, palaeoclimate and sealevel studies on the northern Australian shelf.*

- *to participate in sedimentological and palaeoclimatic studies on the southern Australian and the Antarctic margins with the Co-operative Research Centre for Antarctic and Southern Ocean Environment.*

- *to conduct co-operative studies in regions of southeast Australia to provide information on sediment dynamics and geochemical cycling of pollutants as a basis for environmental management.*

OCEAN DRILLING PROGRAM

The MGPG Program has been strengthened by Australian involvement in the multi-lateral Ocean Drilling Program (ODP) through a consortium arrangement with Canada. The MGPG Program provides funding to support Australia's ODP membership, and scientists to participate on Australian, Consortium, and international ODP/JOIDES committees and panels. Under ODP, the D/V *JOIDES Resolution* has undertaken six drilling legs off Australia and the Australian Antarctic Territory, including the northwest Australian margin in 1988, and the northeast Australian margin in 1990. Most of these legs involved MGPG scientists, and were an important part of the MGPG work program. Thirty six Australian scientists have been directly involved in drilling in the Australian region, as well as about two hundred and fifty international scientists. This research effort represents a massive increase in our knowledge of the geology of Australia's maritime jurisdiction. It is unlikely that any of this scientific drilling would have

occurred without the pre-drilling surveys carried out by the MGPG program.

ODP drilling provides otherwise unobtainable insights into the geological processes and framework, resource potential, and past environments of Australia's offshore territory. In the deep water beyond the shelf it provides the only means of obtaining direct information on the rock-types at depth beneath the sea floor. ODP drilling has the potential to impact on all MGPG program strategies and should continue to be supported and encouraged within the future program.

PROJECT PORTFOLIO

The MGPG project portfolio as it stood at September 1992 is given in the Appendix, and contains over forty individual projects. The core of the MGPG program for the next five years will be chosen largely from these projects, or combinations of them. Projects will be added to the portfolio from time to time as proposals are received and reviewed. Other projects, largely externally driven, will occasionally arise, and will need to be considered in the development of the two-year rolling program. Such projects are likely to consist of foreign development assistance studies, and co-operative studies with industry and other research organisations.

Appendix

MARINE GEOSCIENCE AND PETROLEUM GEOLOGY PROJECT PORTFOLIO

A1. PETROLEUM - NEW BASINS

Categories: Poorly explored *shelf* (0 - 200m);
Upper slope *adjacent* to producing/explored shelf area (200 - 500m);
Remote *deep* water slopes, plateaus & terraces (> 500m).

Project Number	Title	Theme *	Project type	Strategy category#	Prior-ity	Status *
121.	Western Arafura - basin framework study of Calder and Goulburn Grabens region - link up existing Timor Sea and Arafura Sea deep seismic (+ Goulburn Graben-Arafura-Tanimbar transect 6)	B	Ship Deep seismic	Shelf	High	FP
121.	Basin framework and hydrocarbon potential of Gulf of Carpentaria	B	Ship Deep/ con seismic	Shelf	Medium	FP
121.	Basin development and hydrocarbon potential of the southern Carnarvon Basin including the Exmouth Sub-basin	A	Ship Deep/ con seismic	Shelf	Medium	FP
121.	Basin framework of the east Tasmanian shelf and slope	D	Ship Deep/ con seismic	Shelf (deep)	Medium	FP
121.	Kenn Plateau - regional framework and basin development	E	Ship Deep seismic	Deep (Tectonic)	Low	FP
121.	South Tasman Rise/East Tasman (Cascade) Plateau - regional framework and basin development (Co-operation with French)	D,H	Ship Deep seismic Swath mapping Sampling	Deep (Tectonic)	Low	FP
121.	Basin development and hydrocarbon potential of the eastern Exmouth Plateau adjacent to the Rankin Trend	A	Ship Deep seismic	Adjacent	Medium	

* Abbreviation given at the end of this Appendix.
\# Strategy category relates to the words shown in italics at the top of each section of the portfolio listing.

A2. PETROLEUM - NEW APPROACHES AND NEW IDEAS

Categories: *Basin architecture* - primary and reactivation structuring
Tectonic and margin development
Maturation history
Trapping mechanisms
Basin fill - nature of source, reservoir and seal facies
Integrated *regional* study - tectonics, biostratigraphy, palaeogeography, maturation history

Project Number	Title	Theme *	Project type	Strategy category#	Prior-ity	Status *
121.34	Northwest Shelf region tectonic development, basin architecture and petroleum systems	A	Integrated regional study	Regional	High	WP
121.22,36,39	Basin development and hydrocarbon potential of the Bonaparte Basin - Sahul Platform/Malita Graben including JDZ area, or around edge of JDZ	A	Ship Deep seismic	Basin architect	High	FP,WP
121.28	Basin development and hydrocarbon potential of the Browse Basin and adjacent margin	A	Ship Deep seismic	Basin architect	High	FP,WP
121.	Tectonic evolution of the southern Australian margin - 6-8 deep structural transects from the Naturaliste Plateau to South Tasman Rise to develop an extensional model and test concepts of propogating/ multi-stage rifting and breakup.	D	Ship Deep seismic	Tectonic	High	
121.	Regional structural framework of the southeast Australian basin system - inter-relationship of the Bass Strait basins: Gippsland/Bass (Boobyalla)/ Otway (Torquay & King Is.)	D	Ship Deep seismic refraction	Basin architect	High	FP
121.	Regional structural framework and basin development of the Perth Basin (follow-up to previous cruises - deep structure and test models. Combine with the Onshore Seismic Group to study whole basin and Darling Fault.		Ship Deep seismic	Basin architect	High	FP
121.19,28, 36,39	Northwestern margin crustal transects - deep structure and collisional processes (Petrel SB-Malita Graben-East Timor transect 5; Vulcan SB-Ashmore Plat-West Timor transect 4; Browse-Scott Plat-Argo Abyssl Plain transect 3) plus necessary strike tie lines	A,B	Ship Deep seismic	Tectonic	High (Medium?)	FP,WP

Project Number	Title	Theme *	Project type	Strategy category#	Prior-ity	Status *
121.	Northern margin flexural study - model the collision along the northern margin of Australia and analyse its effects on reactivation, maturation and petroleum migration history of the margin.	B	Regional modelling;AGSO/ company seismic geohistory source rock evaln	Tectonic	High (Medium?)	
121.17	Regional structural framework of offshore Canning Basin (SNOWS 3) (+ Canning Basin-Rowley Terrace - Argo Abyssal Plain transect 2)	A	Ship Deep seismic	Basin architect (Adjacent)	Medium	FP,WP
121.	Petroleum trapping mechanism in the Barrow-Dampier Sub-basins	A	Ship HR seismic	Trapping Maturation	Medium	FP
121.17	Structural framework and petroleum potential of the Barrow-Dampier Sub-basins. Cooperative study with industry involving aeromagnetic and seismic relationships	A,H	100,000km of 1.5km spaced aeromag. lines; company seismic	Basin architect	Medium/ High?	WP
121.36	Structure framework and petroleum potential of the JDZ area, Bonaparte Basin	A,H	Aeromag. lines 1.5km spaced; AGSO/company seismic data	Basin architect	Medium	
121.??	Margin development, breakup and collisional history, and foreland development of the northern Scott Plateau, Roti Basin, Ashmore Platform and west Timor Trough	A,B	Ship Deep/con seis sampling	Tectonic (Deep)	Medium	FP,WP
121.	Margin development and breakup history of the N Exmouth Plateau, Rowley Terrace and Scott Plateau	A	Ship Deep/con seis sampling	Tectonic (Adjacent /deep)	Low	
121.	Structural framework of the Otway (slope) Basin and its relationship to the ocean/continent boundary	D	Ship Deep seismic ?sampling	Basin architect (tectonic)	Medium	FP
121.	Stratigraphy and source rock potential of the Bremer Basin and Ceduna depocentre.	D	Ship Sampling HR seismic	Basin fill	Medium	FP
121.	Tectonic evolution of the southwest Australian margin - relationship of Naturaliste Plateau, Diamantina Zone and AAT discordance, to southern margin tectonics and seafloor spreading (Co-operation with French)	D,H	Ship	Tectonic Deep seismic Swath mapping Sampling	Medium	FP
121.	Heatflow and maturation history of NW Australian margin. Heatflow stations along transects in conjunction with carbonate coring program from shelf to abyssal plain. (Heatflow in basins and on outer margin is very poorly known and is an important input to maturation studies)	A,B	Ship Heatflow coring	Maturation (Environment)	Low	FP

Project Number	Title	Theme *	Project type	Strategy category#	Prior-ity	Status *
121.	Volcanic margin development and breakup history of the Wallaby Plateau, Wallaby Saddle and Bernier Platform	A	Ship Deep/con seis Sampling	Tectonic (Deep)	Low	FP
121.	Framework study of eastern Papuan Basin - test structural models and the prospectivity of the Late Cretaceous section	B,G	Ship Deep seismic	Basin architect. (adjacent)	Low	FP

B. LAW OF THE SEA AND SEABED BOUNDARIES

Categories: Legal continental shelf (*LCS*) definition
Seabed boundary definition

Project Number	Title	Theme *	Project type	Strategy category#	Priority	Status *
121.??	Northern Scott Plateau/Roti Basin area - morphology, geological framework and petroleum potential (Seabed boundary defn. with Indonesia)	F	Ship Con. seismic dredging bathymetry	Seabed	High	FP,WP
121.30	Southern Lord Howe Rise & West Norfolk Ridge - morphology, geological framework and petroleum potential (Continental shelf defn. and seabed boundary defn. with NZ)	F	Ship seismic bathymetry dredging	LCS Seabed	High	FP,WP
121.	South Tasman Rise - morphology, geological framework and petroleum potential (continental shelf defn.) dredging	F	Ship seismic bathymetry	LCS	Medium	FP
121.	Outer margin of the Wallaby and Exmouth Plateau - morphology, geological framework and petroleum potential (continental shelf defn. - 350nm cutoff applies to some of this area)	F	Ship seismic bathymetry dredging	LCS	Medium	FP
121.	Southern Kerguelen Plateau - morphology, geological framework and resource potential (continental shelf defn. - may require 2-3 cruises)	F	Ship seismic bathymetry dredging	LCS	Medium	FP
121.	Central New Caledonia Basin and its margins - morphology, geological framework and petroleum potential (continental shelf defn. May not need full cruise for LCS purposes)	F	Ship seismic bathymetry dredging	LCS	Medium	FP
121.	Central Great Australian Bight (deep Ceduna Sub-basin) - morphology, geological framework and petroleum potential (continental shelf defn., particularly using sediment thickness)	F	Ship seismic bathymetry dredging	LCS	Medium (Low?)	FP?
121.	Macquarie Ridge - morphology, geological framework and resource potential (continental shelf defn. & seabed boundary defn. with NZ - probably not essential because distance limits generally apply)	F	Ship seismic, bathymetry dredging	LCS (Seabed)	Low	

C. PROCESSES AND ENVIRONMENT

Categories: Facies and process studies to understand *environmental* change
Facies and process studies to understand *resource* accumulations
Oceanography and water *chemistry*
Man-induced changes of the marine environment

Project Number	Title	Theme *	Project type	Strategy category#	Prior-ity	Status *
121.29	The effects of sea level, climate and tectonics on facies development of tropical and temperate carbonates off NE Australia (cooperative study with JNOC)	C (part G,H)	Ship HR seismic sidescan boomer sampling	Environment Resource	High	FP,WP
121.37	Nature and distribution of ocean outfall plumes, particularly off Sydney (provide baseline studies and geotechnical expertise to aid the siting of future outfalls on the shelf	C,G	Ship DHD sampling	Man-induced	High	FP,WP
121.37	Sedimentary facies and processes, and environmental change on the southeast Australian shelf	C (part G,H)	Ship HR seismic sidescan boomer sampling	Environment Man-induced (Resource, chemistry)	High	WP
121.33	Antarctic margin - facies and palaeoclimatic change (co-operation with Antarctic and Southern Ocean CRC)	C,H	Ship HR seismic Coring	Environment	High	FP,WP
121.	Gulf of Carpentaria/Arafura Sea - modern processes within an epeiric sea, and climate and sealevel change. (possible collaboration with Sydney Uni., USGS and Lamont)	C,H	Ship HR seismic Sampling Sidescan	Environment (Resource)	Medium	FP
121.	Amplitude and timing of Neogene sealevel change from the carbonate platforms of the Marion Plateau	C	Ship HR seismic Sampling	Environment	Medium	
121.	Facies development on the temperate carbonate margin of the South Tasman Rise/East Tasman Plateau (including a biogeochemical study of a high productivity margin related to the Antarctic Convergence, with potential for a distinct palaeoclimate record) (partly funded through JGOFS; co-operation with Antarctic/Southern Oceans CRC)	C,H	Ship HR seismic Sampling	Environment	Medium (Low?)	
121.	Sahul Shoals/Cartier Trough - carbonate facies, palaeoclimate, and collision	C,A	Ship HR seismic Sidescan Coring,heatflow	Environment	Medium (Low?)	FP?

Project Number	Title	Theme *	Project type	Strategy category#	Prior-ity	Status *
121.	Malita shelf valley -eustatic and neo-tectonic controls on shelf processes	C,A,H	Ship HR seismic	Environment	Medium (Low?)	

Abbreviations:

HR Seismic- high-resolution seismic
DHD- direct hydrocarbon detection, 'sniffing'.
Con seis- conventional exploration seismic (6-8 second record length).

Themes:

A Northwest Shelf evolution - passive margin to foreland basin
B Basin framework of Australia's northern margin
C Facies and process studies as an aid to exploration and understanding environmental change
D Tectonic development of Australia's southern/southeastern margin
E Frontier basin framework off eastern Australia
F Law of Sea and seabed boundary studies
G Add on program - externally funded
H Co-operative studies with industry, universities etc.

Status:

FP Future Program proposal/documentation is available
WP AGSO work program document has been prepared. On draft program.

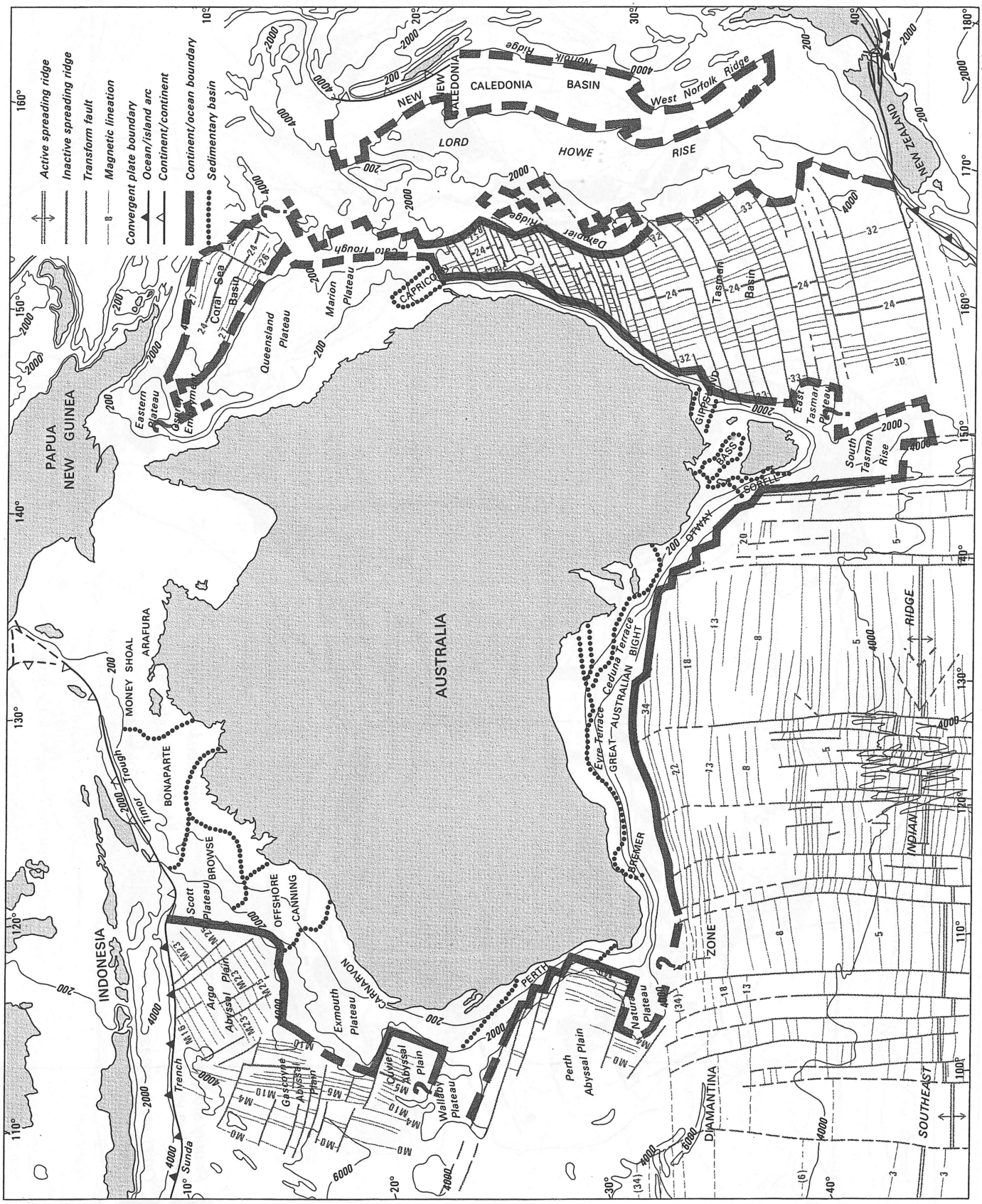

Figure 1. Generalised bathymetry and seafloor spreading anomalies of the Australian region. Also shows the major basin systems beneath Australia's continental margin.

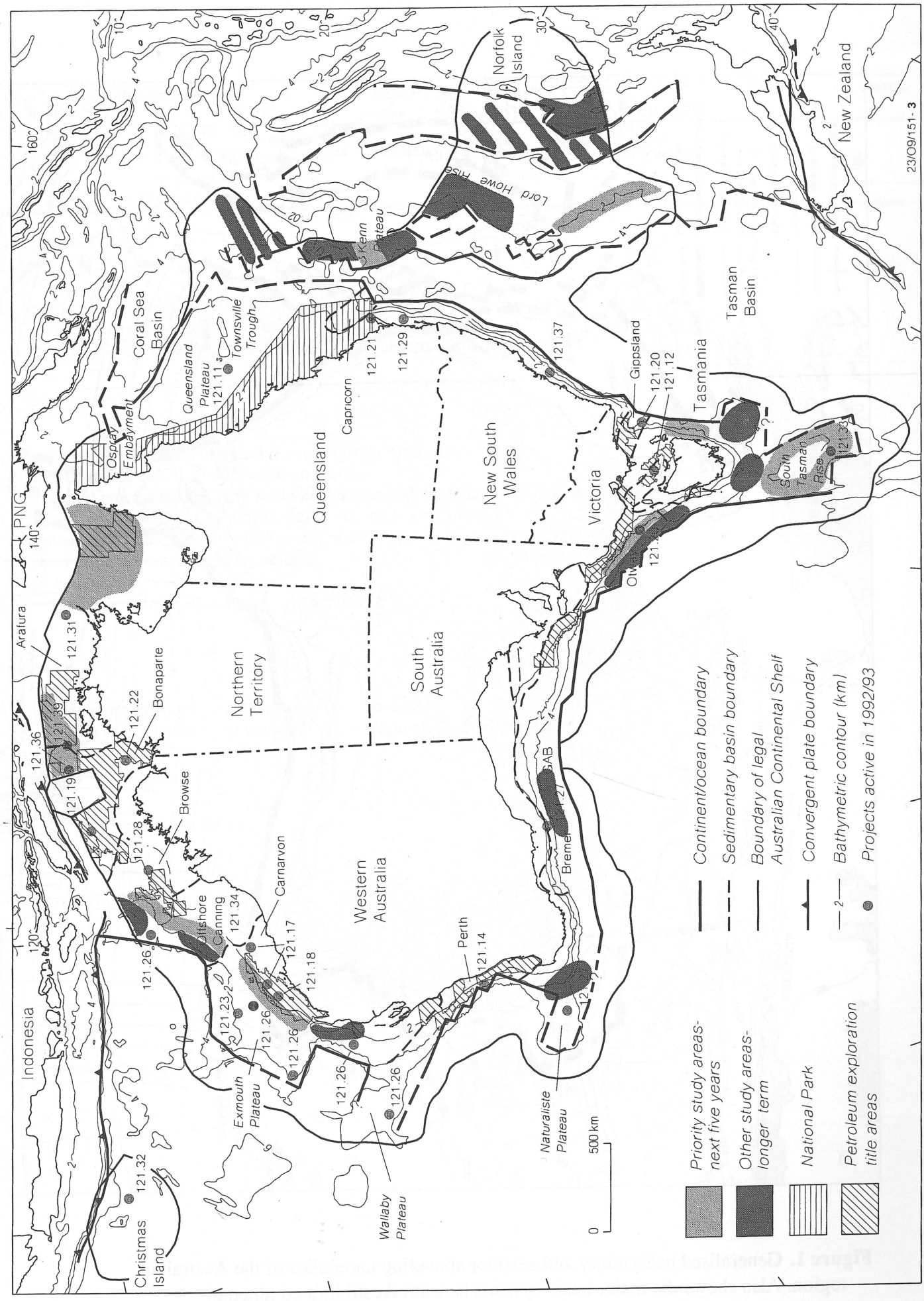

Figure 2. Distribution of study areas related to the MG & PG Program's 'new basins' petroleum strategy.

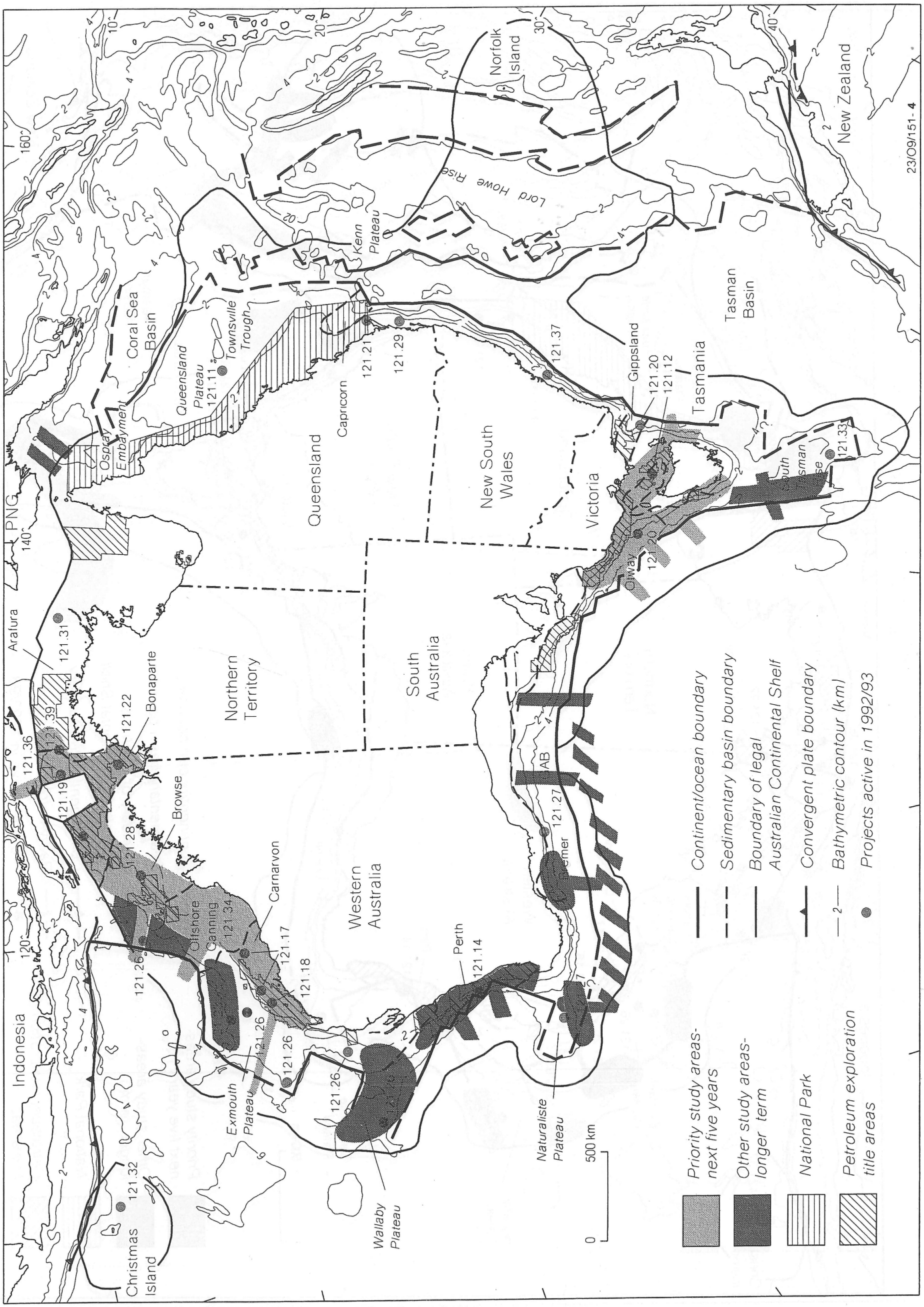

Figure 3. Distribution of study areas related to the MG & PG Program's 'new approaches/new ideas' petroleum strategy.

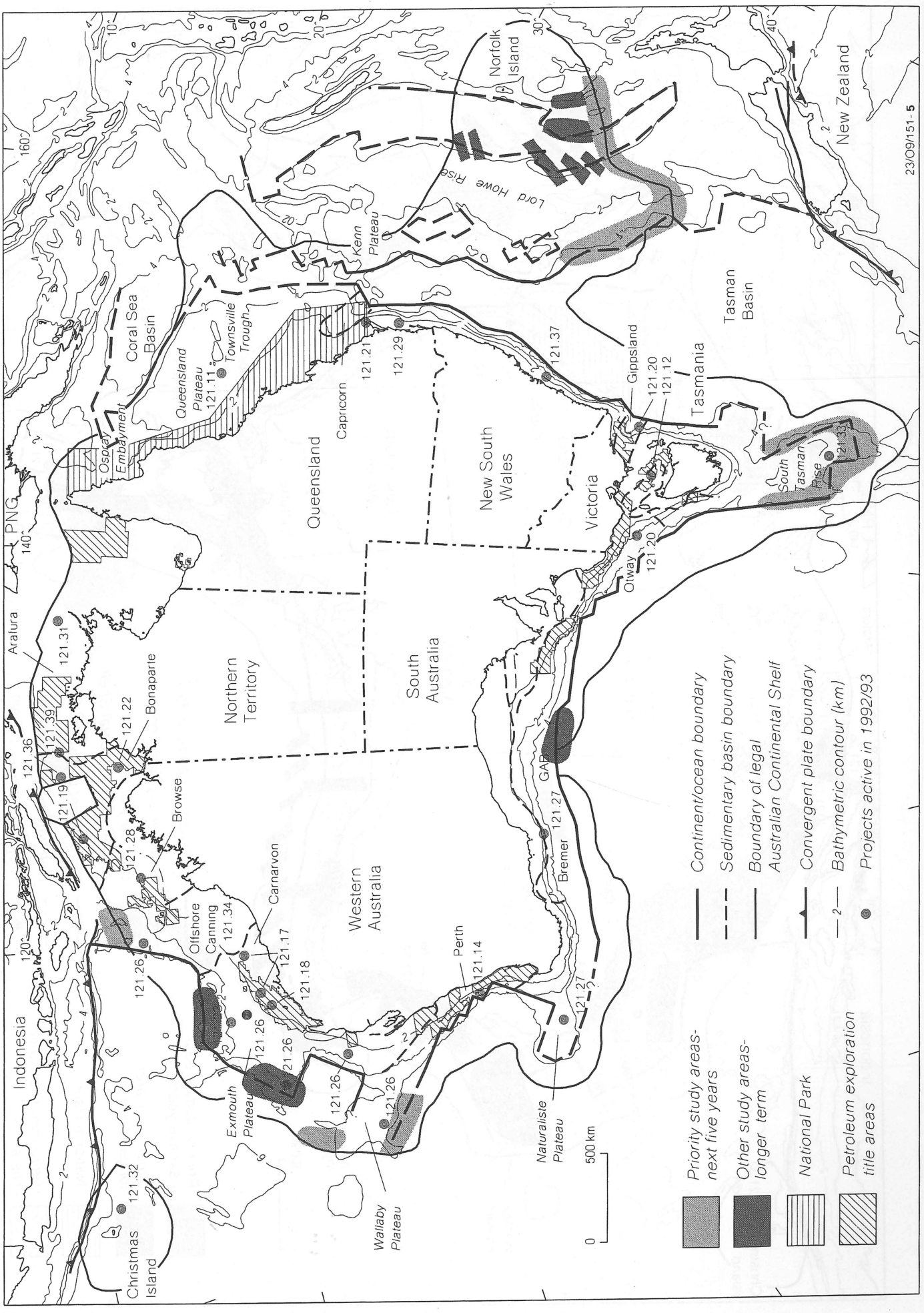

Figure 4. Distribution of study areas related to the MG & PG Program's 'Law of the Sea and seabed boundary' strategy.

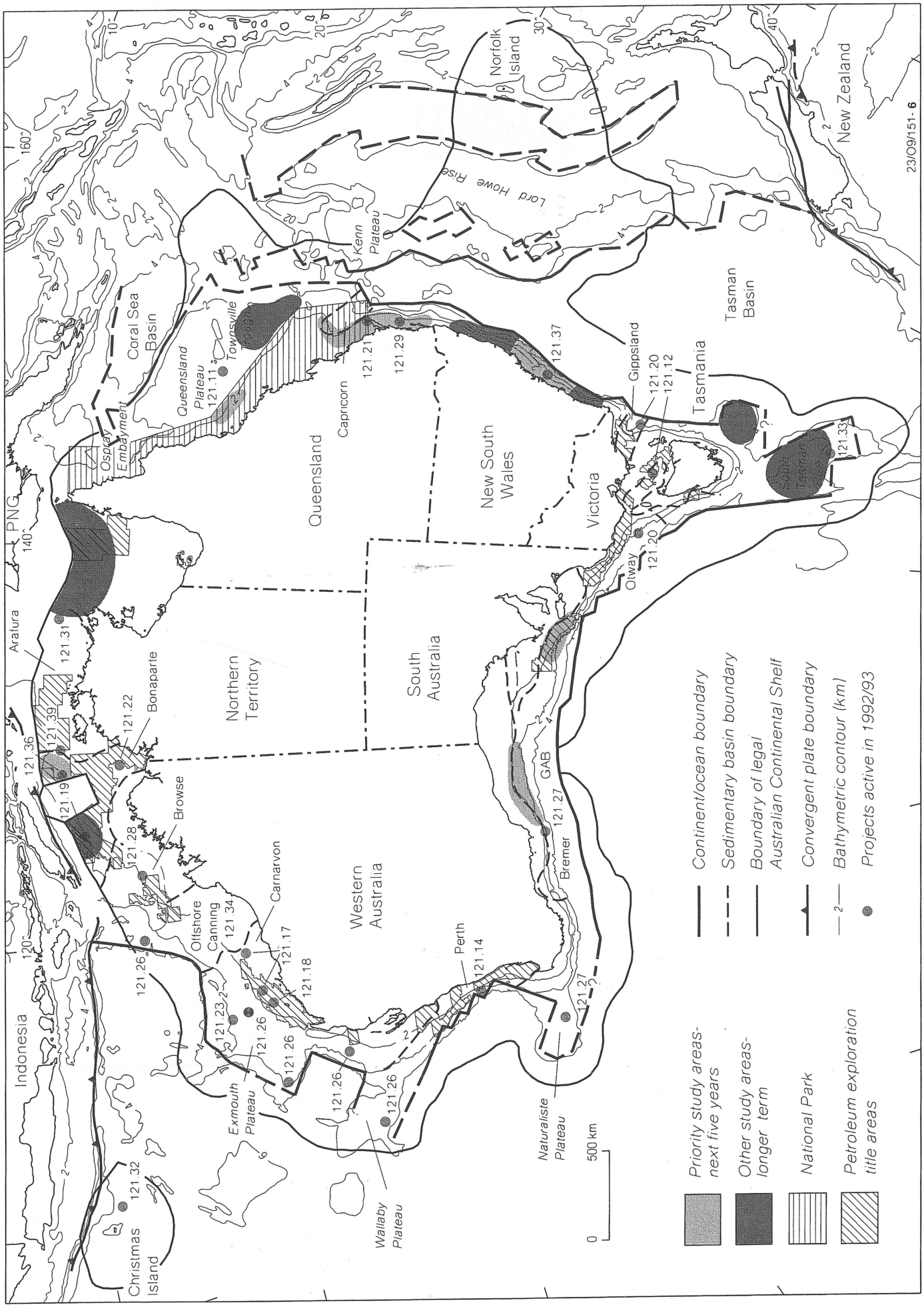

Figure 5. Distribution of study areas related to the MG & PG Program's 'marine processes and environment strategy.