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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

RECORD 1980/73

PETROLEUM EXPLORATION BRANCH

SUMMARY OF ACTIVITIES

1980

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PETROLEUM EXPLORATION BRANCH

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PETROLEUM ASSESSMENT SECTION

The Petroleum Assessment Section has two main functions. The Offshore Subsection is responsible for the provision of the technical advice necessary for the administration of the Petroleum (Submerged Lands) Act and the Basin Assessment Subsection is responsible for the assessment of Australia's undiscovered petroleum resources.

During the year the number of professional staff engaged in carrying out these functions increased from seven to eleven and progress was made with most of the programmed activities.

The acting head of the Section, Dr D.J. Forman, supervised completion of the Minimum Economic Reservoir Size Project which is described further on in this summary. Meetings of Standing Group No. 2 of the National Energy Advisory Committee were attended and a petroleum chapter, updated to 30 June 1980, was prepared for a report on Australia's energy resources.

Basin Assessment Subsection

The Basin Assessment Subsection aims to prepare a region by region assessment of Australia's undiscovered petroleum resources and to forecast future rates of supply from these sources.

A three pronged approach has been taken to achieve this objective:

- (1) Research specific topics of critical importance to understanding the occurrence of petroleum.
- (2) Integrate this research with research and information from other sources, into regional or detailed syntheses, so that those locations where petroleum is likely to have accumulated may be identified.
- (3) Estimate the undiscovered petroleum contained within regions (petroleum resource assessment), examine the economic and technologic conditions under which the petroleum can be exploited, and forecast the future rate of production.

Topical research and regional studies

The source rock study program continued throughout the year with 40 core samples from offshore wells in the Otway Basin, 14 cores from the Darling Basin, and six dredge samples from the Sonne Cruise being submitted to AMDEL for source rock analysis and vitrinite reflectance determination. CSIRO analysed 15 core samples from wells in the Cooper, Eromanga, Darling, and Bass Basins. As part of the Central Eromanga Basin project, 222 cuttings samples from three wells were submitted to Robertson Research for pyrolysis analysis by the Rock-Eval method.

During the year, K. Jackson collaborated with authors from GSQ and CSIRO to present a paper at the APEA conference. The paper incorporates the results of a geochemical study of source rock potential with a facies study of the Denison Trough sediments. The Early Permian Cattle Creek Formation and Reids Dome Beds are generally good, mature source rocks but are probably gas prone. Reservoir rocks are well developed and many occur adjacent to source rocks. The area is rated as prospective with the need now for high quality seismic surveys to define drilling targets, particularly within the Early Permian.

K. Jackson presented a paper on the petroleum potential of the Galilee Basin at the 1980 BMR Symposium. The paper incorporates the results of a petroleum geochemistry study of source rock potential, organic maturation, and oil/source rock correlations. The study shows that the source rock potential of the Late Carboniferous and Permian is variable, but generally poor. The oil reservoired in the Late Carboniferous Lake Galilee Sandstone and recovered from Lake Galilee No. 1 was correlated, by a stable carbon isotope method, with kerogen either in the underlying Devonian or in the overlying Early Permian Jericho Formation. Although reservoirs are likely to occur throughout the Late Carboniferous to Permian sequence, the better source rocks probably occur in the underlying Devonian and in the basal part of the Jericho Formation. Hence the main objectives should be structural or stratigraphic traps containing the Carboniferous and basal Permian sediments. The Aramac Coal Measures form a secondary objective at shallower depths. The sequence of hydrocarbon generation and trap timing are considered favourable. Lack of success to date may well reflect the absence of one or more of the critical exploration factors (e.g. lack of source rock). However, it is believed that, for the main play, many wells were sited off-structure and were not valid tests. The application of improved seismic techniques, allowing mapping below the Early Permian Aramac Coal Measures, is likely to define new, and hopefully more prospective, targets.

A paper on the petroleum potential of the Bass Basin was presented at a Petroleum Exploration Society of Australia Symposium in November (Nicholas and others, in prep.). This paper results from a cooperative study by BMR and CSIRO and gives the results of a petroleum geochemistry study of source rock potential. The Late Cretaceous to Early Tertiary Eastern View Coal Measures are generally good source rocks with potential for generation of both gas and, to a lesser extent, oil. Mature source rocks have only been intersected in the deepest wells drilled, notably Cormorant No. 1, with most wells terminating in immature to transitionally mature sediments. An upper play, consisting of structural traps containing Eastern View Coal Measures and sealed by the Demons Bluff Formation, has been tested with negative results in seven structures. The main play that is now recognised consists of structural and stratigraphic traps, with reservoir, source, and seal all within the Eastern View Coal Measures. The Pelican gas/condensate field is the only discovery in this play, but several other wells have encountered significant hydrocarbon shows. The basin probably has significant potential for further discoveries, but high quality seismic data will be needed to define the drilling targets within the deeper parts of the basin where structure and maturity appear favourable.

All the data obtained as part of the source rock studies project during the current year have been distributed to the relevant State Mines Departments; those which have not yet been interpreted and reported on by BMR are being held on a restricted basis. These data and data from company reports were incorporated into the petroleum source rock data base of the IMAGE computer reference system. Approximately 3300 new entries were made bringing the total number of entries in the data bank to about 4800. A major effort here was the incorporation into the system of the data from the Robertson Research Northwest Shelf study. Operational instructions for the system are now available as a BMR record (DeNardi and Jackson, 1980).

Late in 1979 and early in 1980, drilling for petroleum source rock and for stratigraphic information was undertaken as part of the Section's evaluation of the Darling Basin; all three holes were sited near Ivanhoe in New South Wales. BMR Ivanhoe No. 1 was drilled during October and November 1979 and reached its programmed depth of 300 m. This well was successful in intersecting the fine-grained, clastic rocks of the Lower Devonian Amphitheatre Beds. Fourteen dark coloured cores of shale were selected from this well for source rock analysis by AMDEL. Disappointingly, the results indicate a low source rock potential. A draft report on the petroleum potential of the Darling Basin is near completion. Two other wells, BMR Manara No. 1 and No. 2, encountered technical difficulties and were abandoned before reaching the Devonian objective.

Late in 1980, drilling for petroleum source rocks and stratigraphic information was undertaken in the northeastern part of the Amadeus Basin as part of a developing program to investigate the petroleum potential of the Cambrian and Precambrian sediments around Australia. BMR Rodinga No. 1 and No. 1A, both sited 25 km east-north-east of Mt. Ooraminna, were designed to evaluate the Cambrian Chandler Limestone. The number 1 well had to be abandoned at 65 m but number 1A drilled a complete section of the Chandler and bottomed in Todd River Dolomite at 178 m. The most interesting result here was an oil show encountered between 133.07 m and 134.62 m. Further tests will be required to evaluate the core from this hole in terms of source rock and reservoir rock potential. BMR Rodinga No. 2, sited near Maryvale, had to be abandoned at 12.35 m; this hole was re-sited as Rodinga No. 2A and drilled to a total depth of 50 m, encountering predominantly red shales within the Chandler Limestone. A third well, BMR Rodinga No. 3, was drilled, nearby number 2 and 2A, to a total depth of 31 m with the objective of coring one of the Limestone 'mounds' evident in the area. The final well in this current drilling program is designed to obtain a core of part of the Precambrian Bitter Springs Formation.

The section provided some geological and geophysical input to the Central Eromanga Basin project. Prior to the 1980 field season, the available gravity data over four 250 000 map sheet areas in the central Eromanga Basin were assessed. A fair degree of correlation between gravity and structure is evident throughout the project area, although the existing coverage is sparse. It was recommended that additional gravity data be acquired at 500 m intervals along the new regional seismic traverses, along the 1979 Wilparoo traverses of Delhi, and along two road traverses. Interpretation of seismic data in the Windorah, Canterbury, and Barrolka 1:250 000 map sheet areas commenced. A lithological correlation between petroleum exploration wells in the Warrabin Trough area was compiled; formation tops were picked on the basis of log character and lithology. Vitrinite reflectance values were plotted onto the correlation diagrams.

Typing, tables, references, and appendices were checked, corrected, and proof read for the Canning Basin study which was issued in microfiche form as BMR Record 1979/32. A lithological correlation of 60 wells in the Canning Basin was reduced, corrected, and modified for publication (Gorter and others, in prep).

An uncorrected geothermal map of Australia has been prepared as a BMR Record (Nicholas and Haupt, in prep).

The well data system and a system of references on a number of topics relating to petroleum exploration in Australia were maintained.

Several staff members assisted with contributions to two papers prepared by the department (Department of National Development and Energy, 1980 a & b).

V. Passmore continued to prepare well correlation charts and explanatory notes for Australian basins for the ESCAP Atlas of Stratigraphy, although to a less extent than in previous years. The Browse Basin contribution was completed and issued as a BMR Record.

Geophysical Service International completed reprocessing 500 km of BMR sparker seismic data from the Capricorn Basin and interpretation of the processed sections commenced late in 1980.

Petroleum resource assessment

The most difficult problem encountered in assessments of Australia's undiscovered petroleum resources has been to decide what is the smallest size oil or gas field that could be developed in a particular area. This is referred to as the economic cut off for the area. Given this information we can estimate how much of our undiscovered oil and gas is likely to be economic and then, together with other information, we may estimate the probabilities of finding enough new oil to carry us through the next twenty years - valuable information for energy policy planning and for any company searching for oil and gas in Australia.

Early in 1979, the National Energy Research Development and Demonstration Program approved a grant for the Bureau of Mineral Resources to engage consultants to carry out the 'Minimum Economic Reservoir Size' project. Macdonald Wagner and Priddle Pty Ltd/ Purvin and Gertz Inc. in association were selected to carry out the project which began in July 1979 and was successfully completed in September 1980. It provided BMR and the public with a suite of new computer programs, a summary of cost data, and estimates of the minimum economic reservoir size at seven locations onshore and offshore Australia. The information is contained in two BMR Records, 1980/31 and 1980/58.

Early in the study it became apparent that there is no unique answer to the problem, and that a variety of answers may be obtained according to which facet is emphasised. For instance, apart from differences in geographic location, the minimum economic reservoir size varies with:

the shape of the reservoir that is discovered;

the rate at which individual wells produce petroleum and the number that have to be drilled to develop the field;

the quality of the petroleum;

the costs of exploration, development, production, and transportation;

the availability of markets;

price;

the technology of recovery;

other discoveries in the same region;

the use that may be made of existing pipelines;

the effects of inflation;

the criteria used to evaluate the project;

and the tax credits that are available to the company.

Consequently the computer program that was developed had to be flexible enough to allow these sorts of assumptions to be varied by modifying entered data. The program uses current Federal and State royalty rates and taxes.

Essentially the program calculates the discounted cash flow rate of return (DCF ROR) for the project. Mathematically, DCF ROR is that interest rate which - when applied to calculate the present value of all cash outlays and incomes related to the project - yields a net present value of zero. It was decided that only those petroleum reservoirs that yield a DCF ROR of at least 25 percent will be large enough to be developed. Hence the program has to be run a number of times, each time with modified data, until the 25 percent DCF ROR can be obtained and the minimum economic reservoir size determined. It requires a high level of intervention by the user - which enables the interaction of variables to be assessed, and the relative sensitivity of the minimum reservoir size to these variables to be determined.

The prospects that have been analysed (Fig. 1) comprise examples from a range of petroleum exploration frontiers in Australia. Onshore prospects which were studied lie within the Eromanga and Amadeus Basins in the interior, and the Canning Basin in the northwest. Offshore prospects lie in a range of water depth: the Carnarvon Basin prospect is in conventional water depths; the Bonaparte Gulf Basin prospect is in moderate water depths; the Browse Basin and Exmouth Plateau prospects are in deep water beyond existing production experience.

Assuming that oil would be priced at \$25 a barrel at the nearest metropolitan centre and that natural gas would be priced at \$3.00 per gigajoule, the consultants suggest the following values (Table 1) for the minimum economic reservoir size at the locations shown in Fig. 1.

Table 1
Minimum Economic Reservoir Size

	Oil		Gas	
	G1	10 ⁶ barrels	m ³ x 10 ⁹	10 ¹² cubic feet
Eromanga Basin	2.1	13	4.3	0.15
Amadeus Basin	7.7	48	4.8	0.17
Canning Basin	2.6	16	19.3	0.68
Bonaparte Gulf Basin	36.7	231	-	-
Carnarvon Basin	10.7	67	38.2	1.35
Exmouth Plateau	160	1009	-	-
Browse Basin	73	459	-	-

The subsection commenced revision of the various computer programs that have been written for petroleum resource assessment. A new computer program, PBPSIM, has been written to replace the SIMULAT program for the prospect-by-prospect method of estimating petroleum resources. PBPSIM uses Monte Carlo simulation and includes detailed comments explaining the operation of the main program and 12 subroutines. The new features of the program are: 1) operation on a wider variety of data distributions; 2) automatic validation of input data; 3) conversion of temperature data from degrees Fahrenheit or Celsius to degrees Rankin; and, 4) calculation of statistics describing the distributions generated by simulation. Data entry has been simplified and some output reports reformatted. The basic program is operational and its structure will easily allow it to be expanded to include consideration of implicit and explicit partial data dependencies. E.L. Smith is preparing a record to document and explain the program.

A project to review the results of petroleum exploration to 31 March 1980 and to assess the petroleum resources of the Exmouth Plateau, was completed as an 'in confidence' BMR record (Nicholas, in prep). The prospect-by-prospect method was used to assess the resources of a number of prospects.

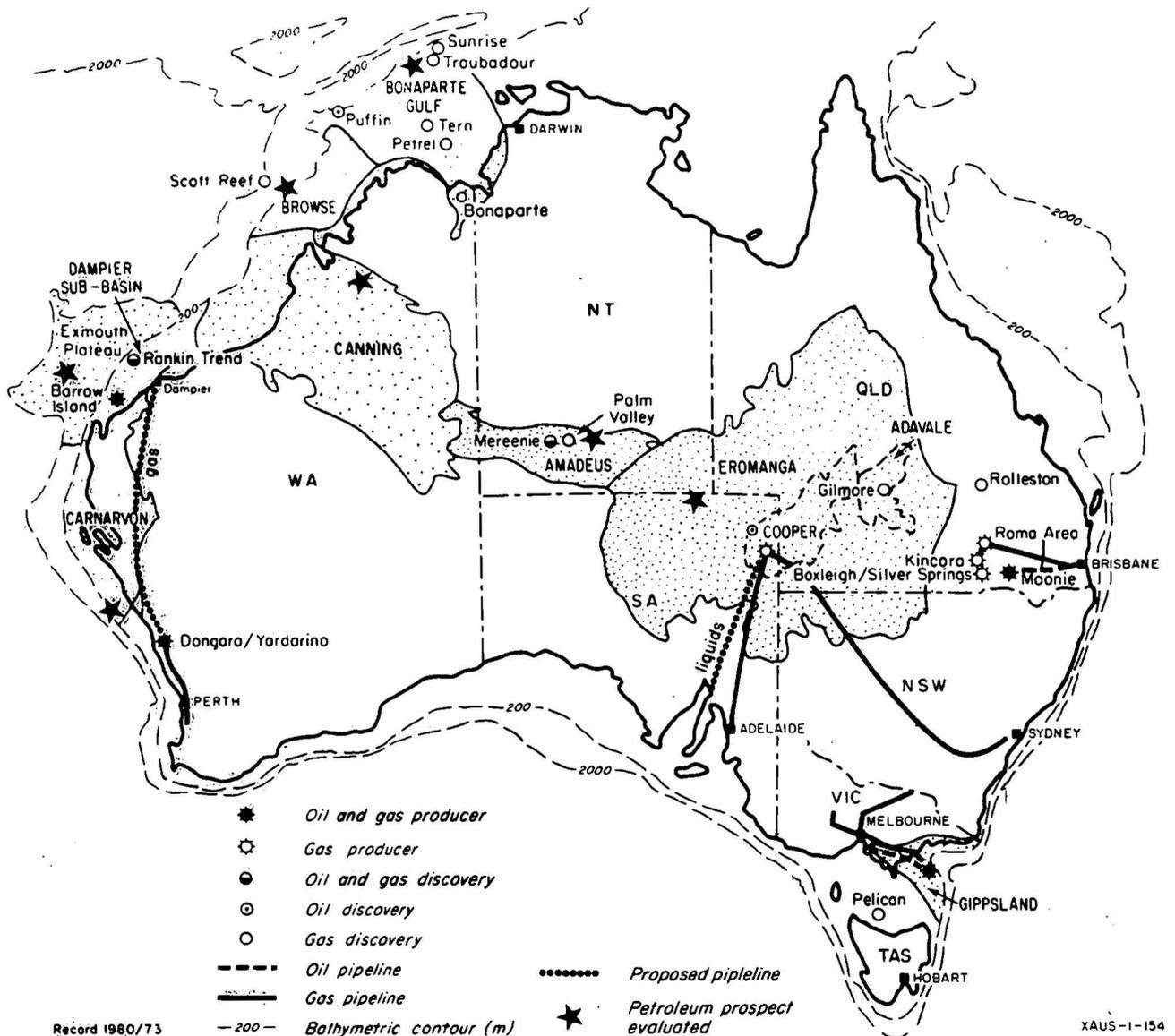


Fig. 1 Petroleum prospects evaluated, and location of petroleum resources

Offshore SubsectionPetroleum (Submerged Lands) Act

The receipt, examination, indexing, and storage of data and reports received under the Act continued during the year. Applications to carry out operations under the Act and final reports on operations performed in offshore title areas were examined and technical comments were prepared. A register of current offshore permits was maintained, and quarterly and annual reports for those permits were studied and commented on as necessary.

Technical comments and recommendations were prepared for Oil and Gas Division and the Northern Territory Department of Mines and Energy on applications for new permits offshore Australia. About 60 applications were dealt with during the year. Comments were also prepared on applications for renewal of offshore permits. Officers of the Subsection were involved in studies of the Tuna and Barrow Island oil fields in connection with applications for 'new oil'. Two offshore and two onshore drilling operations in Western Australia were visited during the year.

During the twelve months ended 31 October 1980, sixteen exploratory wells were drilled in offshore Australia; all these wells were new-field wildcats (see Table 2 and Fig. 2). Fourteen of the wells were drilled in water adjacent to Western Australia and two (Swan No. 2 and Mt Ashmore No. 1B) in waters adjacent to the Northern Territory. The average depth of wells off Western Australia was 4043 m and the average depth of wells off the Northern Territory was 3360 m. In total 63 321 m of drilling was completed with an average depth of 3958 m for the sixteen wells drilled.

Five development wells were completed on the Mackerel 'A' platform and four development wells were completed on the Tuna 'A' platform; both platforms are in the Gippsland Basin, Victoria.

Five wells, Resolution No. 1, Scarborough No. 1, Vinck No. 1, Eendracht No. 1, and Zeepard No. 1, were drilled in deep water on the Exmouth Plateau, Western Australia by the dynamically positioned drillship, Sedco 472, for Esso Exploration and Production Australia Inc. and Hematite Petroleum Pty Ltd. Phillips Australian Oil Co. also drilled a well, Mercury No. 1, on the Exmouth Plateau with the dynamically positioned drillship, Sedco BP/471. Five of the wells were plugged and abandoned after encountering minor gas shows. A substantial gas field was discovered at Scarborough No. 1; but in these water depths the field is uneconomic and the well was plugged and abandoned.

Brecknock No. 1, Buffon No. 1, and Barcoo No. 1 were drilled in the Browse Basin by Woodside Petroleum Development Pty Ltd. Barcoo No. 1 and Buffon No. 1 were plugged and abandoned after encountering minor gas shows; Brecknock No. 1 had significant gas shows but a planned production test was aborted due to technical problems. Gas and condensate were recovered during the testing program, but in these water depths the gas field is uneconomic and the well was plugged and abandoned. Two other wells, Walcott No. 1 and Parker No. 1, were drilled by Woodside Petroleum Development Pty Ltd in the Dampier Sub-basin. Both wells were plugged and abandoned after encountering minor gas shows.

Jerboa No. 1 was drilled in the Eyre Sub-basin of the Great Australian Bight Basin by Esso Exploration and Production Australia Inc. Although the well encountered potential seal and reservoir rocks no hydrocarbons were encountered and the well was plugged and abandoned in Precambrian basement.

Two wells, Swan No. 2 drilled by Citco Australia Petroleum Limited in the Vulcan Sub-basin of the Bonaparte Gulf Basin and Phoenix No. 1 drilled by BP Petroleum Development Australia Pty Ltd in the offshore Canning Basin, were temporarily suspended for possible later re-entry.

Lesueur No. 1, drilled by Australian Aquitaine Petroleum Pty Ltd in the Bonaparte Gulf Basin, encountered a number of hydrocarbon shows. After an extensive testing program the well was plugged and abandoned.

Mount Ashmore No. 1B was drilled by Woodside Petroleum Development Pty Ltd on the Mount Ashmore feature, a large dome shaped structure in the northern Browse Basin. No hydrocarbons were encountered and the well was plugged and abandoned.

During the year 36 seismic surveys were carried out in waters adjacent to Western Australia, Northern Territory, Victoria, Queensland, and Tasmania. Five of these surveys involved magnetic and gravity readings in addition to seismic recording, and three surveys involved only seismic and magnetic surveying. Total survey coverage was about 43 500 km of seismic, 8000 km of magnetic, and 5000 km of gravity traverse. 3D seismic surveying was introduced to Australian waters for the first time, in surveys for Hematite Petroleum Pty Ltd and Esso Exploration and Production Inc., in the Gippsland Basin.

The Subsection continued to give technical advice to the Northern Territory Designated Authority on offshore operations. In February an officer of the Subsection inspected Swan No. 2 offshore drilling operation in Northern Territory waters and reported to the Northern Territory authorities.

Officers of the Subsection also continued to act as technical advisers on petroleum exploration to the Papua New Guinea Government. In March an officer inspected an onshore drilling operation, Kiunga No. 1, on behalf of the PNG authorities.

During the year the Subsection became involved in providing technical advice to the Government of Fiji. Inspection visits were made on behalf of the Fiji authorities to two offshore drilling operations in Fijian waters. An officer of the Subsection inspected Chevron Overseas Petroleum's Bligh Water No. 1 well in April, and again in May. He inspected Great Sea Reefs No. 1 well drilled by the same company in July.

Table 2
Offshore Exploration Drilling Operations,
Completed 1 November 1979 to 31 October 1980

Operator	Well	Total Depth (m)	Status
Esso Exploration and Production Australia Inc.	Resolution No. 1	3884	P & A
	Scarborough No. 1	2360	P & A
	Vinck No. 1	4600	P & A
	Eendracht No. 1	3410	P & A
	Jerboa No. 1	2538	P & A
	Zeepard No. 1	4215	P & A
Woodside Petroleum Development Pty Ltd	Brecknock No. 1	4300	P & A
	Walcott No. 1	4381	P & A
	Parker No. 1	4737	P & A
	Barcoo No. 1	5109	P & A
	Buffon No. 1	4787	P & A
	Mount Ashmore No. 1	2655	P & A
Phillips Australian Oil Co.	Mercury No. 1	3812	P & A
Australian Aquitaine Petroleum Pty Ltd	Lesueur No. 1	3589	P & A
BP Petroleum Development Australia Pty Ltd	Phoenix No. 1	4880	P & A
Citco Australia Petroleum Limited	Swan No. 2	4064	P & A

Petroleum Search Subsidy Act

The Subsection met requests by visitors and BMR officers for information on and access to PSSA reports and other material. Assistance was given to the Australian Government Publishing Service with respect to customers' requests for copies of PSSA material. With the advertising of new offshore title areas and the renewed interest in onshore Australian exploration the work load in this area has continued to increase.

Archives

The Subsection continued its role of technical adviser to Australian Archives on the storage and retrieval of petroleum search magnetic tapes and other petroleum data. Officers from Australian Archives in Sydney and Canberra visited the Subsection for discussions in March. An officer from Auditor General's Office discussed Archives' petroleum storage role with the Subsection in July.

Offshore Index

The offshore index was converted from the INFOL system to the Hewlett-Packard IMAGE system during the year and satisfactory trials were conducted. The scope of data covered by the offshore index is being increased and is to be implemented on an improved version of the IMAGE system that provides increased storage capacity. When this has been completed the index will be useable following input of the required data.

Core and Cuttings Laboratory

During the year samples were received from a total of 160 operations including offshore company wells, BMR drill holes, and other sources. These samples amounted to 1921 metres of core and 19 189 cuttings samples. All receipts were checked and discrepancies resolved. The information on the year's drilling operations was recorded on index, accession, and summary cards and on registers and well files.

Material from a total of 192 wells (including a backlog) were registered during the year. The total of registered samples now held in the laboratory is 1 256 263 samples, representing 2480 km of drilling.

BMR personnel made 168 visits to the laboratory. Representatives from 22 consulting organisations and oil and mining companies made 37 visits. Officers from 13 universities, government authorities, and State (government) departments made 53 visits. A total of 7709 metres of core and 36 259 cuttings samples from 350 BMR stratigraphic holes and company exploration wells were provided for examination. 232 metres of core and 4627 bags of cuttings were sampled for destructive analysis. Reports on the results of destructive analyses were received and indexed.

During the year available compactus shelf space for newly registered samples was filled, with the result that 2164 cartons of registered samples are being kept in temporary storage until the installation of new compactus units in portion of the 1974 extension to the laboratory.

The shelving in the receivals area of the laboratory was reorganised to make more working space available. Routine maintenance of machinery, laboratory equipment, and instruments was carried out or arranged.

Twenty eight thin sections of rock were made on request for BMR officers, bringing the total made and stored at the laboratory to about 6000. Diamond cutting saws were used to slab 545 metres of core, and many surface samples were also cut to size for analytical work. Many thousands of cuttings bags, core bags, and boxes were supplied to BMR drilling parties, and some 1800 pre-typed labels were sent to companies engaged in offshore drilling.

Several groups of students visited the laboratory with their lecturers to examine material stored, to receive instruction in petroleum industry procedures and techniques, and to study methods of storage and documentation of subsurface geological samples.

PETROLEUM TECHNOLOGY SECTION

During the year under review, the Section carried out its established functions, with the exception of the PVT laboratory, which still has no staff and was therefore unable to operate. Other groups were understaffed to some extent and were not able to fulfil completely all appropriate functions.

Mr J.A.W. White, Chief Petroleum Technologist, spent considerable time on the technical aspects of "new oil" pricing submissions in respect of several onshore and offshore petroleum discoveries. Several meetings of the BMR oil shale committee were convened and chaired during the year.

A visit was made to Singapore in December on behalf of the Papua New Guinea Government to inspect a drilling rig being prepared for operations by Gulf Oil Company in the Western District of Papua New Guinea. Later, two inspection visits were made to the Kiunga No. 1X well which was drilled with this rig.

Inspection visits were also made to Mount Ashmore No. 1 well and Swan No. 2 well on behalf of the Northern Territory Government and to Great Sea Reefs No. 1 and Bligh Water No. 1 on behalf of the Fiji Government. The latter two visits were under the auspices of the Australian Development Assistance Bureau.

Several meetings of the Oil Advisory Committee were convened and attended by Mr White. The Oil Advisory Committee is a statutory body set up under the Petroleum (Prospecting and Mining) Ordinance 1954-1966 and has the function of advising the Minister responsible on any scientific or technical matters arising in connection with the exploration for and production of petroleum in the Northern Territory.

During periods of absence of the Head of the Branch, Mr White acted in his stead. He also attended the 1980 Australian Petroleum Exploration Association Annual Conference in Surfers Paradise and the second Petroleum Equipment Exhibition in Sydney.

Many ad hoc enquiries from organisations and individuals were handled.

Industry and Economics Group

Petroleum Economics and Statistics

Material prepared in response to questions from industry, the public, and Parliamentary enquiries has continued to be updated and revised. In addition, quarterly assessments of the recoverable reserves of crude oil, condensate, plant products, liquefied petroleum gas (LPG), and natural gas, together with cumulative production and remaining recoverable reserves were prepared and published in the relevant Petroleum Newsletters Nos. 78, 79, 80, and 81 (currently in preparation). There have been numerous requests for comment from the Department in respect of Foreign Investment applications where these concern petroleum exploration and development companies, titles, etc.

Petroleum and drilling engineering comments were prepared on several drilling projects on the Exmouth Plateau and in the Northern Territory offshore area and assistance was given with matters concerning royalty payments with respect to Bass Strait offshore production.

The annual collection of petroleum exploration, development, and production expenditure and geological and geophysical activities was undertaken, and the results will be published in Petroleum Newsletter No. 82 (in preparation). They are being further analysed and will be published in detail in the Petroleum chapter of the Australian Mineral Industry Annual Review, 1979. The increase from the various Divisions of the Department for information and/or statistics, noted in 1979, has continued through 1980.

In summary, the results of this survey show that there was an increase of 124 percent in exploration drilling expenditure in 1979 over 1978; this was mainly due to the increase in offshore exploration drilling expenditure brought about by the start of drilling operations on the Exmouth Plateau using three dynamically positioned drill vessels, costing some \$120 000 per day each to operate. Overall twenty one offshore wells were drilled in 1979, one fewer than in 1978; metres drilled, however, increased significantly from 56 900 in 1978 to 76 954 in 1979. In onshore exploration drilling the number of wells fell from 31 in 1978 to 30 in 1979 but, the metres drilled onshore increased from 54 655 to 61 845. Geological and geophysical exploration activity in 1979 in terms of crew months of work together with a comparison with 1978 are given in Table 3. There was a noticeable increase in the level of these activities in 1979, with the exception of aero and land magnetic survey work.

Table 3
Level of Geological and Geophysical Activity, 1979

Survey	Unit of Work	1978	1979
Land Seismic	Crew months	35.66	55.04
Marine Seismic	Crew months	21.11	15.79
Gravity Surveys	Crew months	2.41	5.05
Geological Surveys	Crew months	3.5	130.3
Magnetic Land	Line km	nil	nil
Aero	Line km	5048	nil
Shipborne	Line km	3053	8540

Total petroleum exploration expenditure in Australia in 1979 was \$226.3 million; reflecting an increase in exploration expenditure of 94.2 percent over 1978 when the expenditure was \$116.5 million.

The Section prepared for publication and distribution the following documents:-

- (i) The Petroleum Newsletter (Quarterly) Nos. 77, 78, 79, and 80, including monthly drilling rig activity and quarterly statistics.
- (ii) A breakdown of petroleum exploration, development, and production in Petroleum Newsletter No. 78 and in the Petroleum Chapter of the AMI Annual Review.
- (iii) Statistics, and information on petroleum exploration, production, and resources, etc. in Australia for various publications such as World Oil, Oil and Gas Journal, year books, and pamphlets.
- (iv) The Petroleum Exploration and Development Titles Map and Key showing the position as at 1 January 1980 was published. The map showing the position as at 1 July 1980 is in preparation.

A library of index cards containing details on each well drilled is maintained for quick reference, as is reference material on the corporate structure of individual companies engaged in petroleum activities. An index to articles of interest in the various industry and professional journals is maintained on a subject and author basis.

Petroleum Technology Laboratory

Staffing, training and development of new equipment techniques were some of the primary interests of the laboratory for the year. Dr Jackson, geochemist in charge of the source rock group was promoted to another position in the Basin Assessment Subsection, while

Dr C. Boreham joined the group in June as a geochemist. Two further overseas trainees, one from Indonesia and the other from Malaysia, each spent three months mainly with the petrophysical laboratory. In equipment, the head space canned cuttings analyzer was completed and put into routine service while a reliable technique for clay cation exchange capacity of sedimentary samples was developed for petrophysical studies in the important area of reservoir formation damage. The PVT equipment for reservoir fluid analysis studies was still not in operation during the year because of staff limitations and deferment of private leasing arrangements.

Petroleum and Source Rock Geochemistry Group

Detailed source rock studies covering the Taroom Trough, the Galilee Basin and the Georgina Basin comprised a significant part of the years work. The Galilee and Georgina Basin studies were an extension and completion of 1979 work. Source rock studies on the Georgina Basin will form part of the overall BMR Georgina Basin project; similar studies are about to be commenced on samples from industry wells drilled in the area of the BMR central Eromanga Basin project. The Taroom Trough work is a new but related study to the Queensland Denison Trough study of 1978-79 in an active exploration area.

The laboratory conducted other minor source rock work including the following; source rock potential of samples from the Amadeus Basin for the Basin Assessment Subsection; analysis of a sample from a gas discovery well (Woodada-2) in Western Australia, including total organic carbon and oil (stain) analysis; geochemical profiles from a core sample taken in a Georgina Basin well (Mirrica No. 1); and examination of 'oil stains' in a core sample from the McArthur Basin. The Amadeus Basin work involved the investigation of the source potential of the Chandler and other prospective formations, and included analysis of oil from a stained core in the BMR Rodinga No. 1 well.

Expansion of new equipment for the laboratory continued throughout the year. The principle development was the head space analyzer designed to measure the light range (C₁-C₄) hydrocarbons and source characteristics of samples of canned cuttings taken throughout a well; the equipment was made operational and a total of 446 samples (11 wells) were analyzed. This work, done with the cooperation of industry in collecting the samples from newly drilled wells, enables a broader aspect to be applied to our geochemical analysis.

Further equipment work was also carried out during the year on the fixed and programmed temperature pyrolyzers; the former unit, now operational, was utilized in studying the diagenesis of ancient and modern sediments. Additional CO₂ measurement apparatus is still being incorporated via a sample splitter and a thermal conductivity detector into the programmed temperature pyrolyzer before it is completely operational. The "Leco" organic carbon analyzer was also put into full service during the year with the addition of a new detector unit enabling rapid sampling and throughput.

A variety of other minor work comprised the following; further studies related to hydrocarbon product seepages in downtown service stations; flash point tests on a hydrocarbon-type screw worm lure for the Department of Health; chromatographic analysis of oil samples for the Baas Becking Geobiology Laboratory in connection with biological enhanced recovery tests; and analysis of gas and oil content of drilling mud and formation fluid samples from a bore drilled for the Toolebuc oil shale study and a PNG exploration well. The laboratory also completed the incorporation of all laboratory derived source rock information into the "Image" data retrieval system and with assistance of staff in the Reservoir Engineering Subsection, developed a computer program for the output from the canned cuttings analysis.

An increasing part of the work during the year involved discussion with other BMR officers, of various source rock parameters measured from geochemical studies. Dr Jackson gave lectures on the application of geochemistry to exploration to the Canberra College of Advanced Education as part of the geology course there; essentially the same presentation was written up for BMR 79. Dr Jackson also presented the results of the 1978-79 laboratory study on the Denison Trough to the Australian Petroleum Exploration Association conference in March in conjunction with data and authors from CSIRO and the Queensland Geological Survey.

Petrophysics

As a result of infill drilling by International Oil in the Moonie field during 1979, the laboratory carried out petrophysical studies of core material from two new wells, Moonie 35 (South Moonie) and Moonie 36 (North). Because of severe formation damage problems on completion of Moonie 35, the studies centered on flow tests in core material from that well using various indigenous and introduced fluids, plus examination of contained clays to identify the source of damage. This work was assisted considerably by a course presented by Dr Davies (USA), in the "PESA" distinguished lecture series, on production of hydrocarbons from reservoir sandstones, which was attended by Mr Duff.

The newly discovered Waroon gas field in Queensland was the subject of a special core study, involving gas recovery tests, electrical resistivity and clay studies. The latter two tests involved development of techniques for measuring core electrical properties at overburden pressures and utilizing a new clay evaluation method to determine the cation exchange properties of clays in reservoir rocks. The latter technique is a useful adjunct to formation damage studies where certain clays are suspected of causing blockage of pores; the method was also utilized in the Moonie study described previously.

Two additional special core studies undertaken involved gas recovery tests by water drive on core from a low permeability gas reservoir in the Cooper Basin (Wilpinnie No. 1) and some initial test work on coals from two Australian collieries to determine gas recovery characteristics for mine safety and as a possible energy source. A helium type porosimeter

is being developed for these studies in order to measure the complex porosities of coals. A further special study involved fluid permeability measurements of algal-matt samples from the (Fyshwick) environmental tank operated by the Baas Becking laboratory.

A variety of routine core samples (613 plugs including 35 whole core) were tested, most of which were conventional analyses (porosity, permeability and density) for other branches within BMR and one State Geological Survey. Porosity and permeability by whole core analysis on the Mt Whelan No. 2 carbonate samples from the Georgina Basin was completed; this work formed part of an article in the BMR Journal by Dr Bruce Radke and Mr P. Duff on the carbonates of that area. Another interesting whole core study was carried out on material from the newly discovered Woodada gas field in the Perth Basin. Production from this field is principally from fractures requiring the whole core approach for proper analysis; it should be noted that BMR currently has the only equipment of this type in Australia.

In drilling fluid studies, four treated bentonites sampled from an old (mined) deposit near Miles, Queensland were analyzed and found to have reasonably good quality. A sample of drilling mud containing traces of hydrocarbons, taken from the Toolebuc oil shale drilling project was also analyzed.

Two trainees, Mr E. Seah from Malaysian National Oil Company (Petronas) and Mr H. Adim from an Indonesian State company (Lemigas), were able to participate in much of the work described previously enabling them to obtain a broad cross section of petrophysical (and some geochemical) training.

The results of some of the work in the petrophysical laboratory were presented in lectures by Mr Duff and Mr McKay during the year. Mr Duff lectured to the Australian Clay Mineral Society in Melbourne on the effects of clays in hydrocarbon reservoirs while Mr McKay (with Mr White) gave a talk to the Australian Institute of Energy on points with respect to the Moonie and Barrow Island oilfields, with emphasis on possible enhanced oil recovery. Mr McKay gave two lectures to geology students of the Canberra College of Advanced Education on general petrophysical, geochemical and drilling topics. Mr Duff also gave three one day lectures to BMR field drilling crews on the testing and usage of bentonitic drilling muds utilizing API test equipment in the laboratory.

Reservoir Engineering Subsection

The government's 'new oil' pricing policy involved the subsection in considerable technical appraisals during the year. As a consequence, the group carried out engineering and geological assessments on wells in the Bowen-Surat, Carnarvon and Gippsland Basins. Basic data examined in appraising the extent and relationships of reservoirs included mud logs, completion coregraphs, wire-line logs, and both pressure and recovery details from formation interval tests.

Quarterly assessments of Australia's initially recoverable, produced, and remaining reserves of crude oil, condensate (and plant products), liquified petroleum gas (LPG), and natural gas were prepared and published in the relevant Petroleum Newsletter Nos. 79, 80, 81, and 82 (currently in preparation). Summaries of the reserves were also released as 'News Releases'. Australia's estimated economic petroleum reserves as at 30 June 1980 are given in Table 4.

Table 4
Economic Petroleum Reserves as at 30.6.80

	Initial Reserves	Cumulative Production	Remaining Reserves
Crude Oil	$516.99 \times 10^6 \text{ m}^3$	$229.57 \times 10^6 \text{ m}^3$	$287.42 \times 10^6 \text{ m}^3$
Condensate	$43.23 \times 10^6 \text{ m}^3$	$4.65 \times 10^6 \text{ m}^3$	$38.58 \times 10^6 \text{ m}^3$
LPG	$103.65 \times 10^6 \text{ m}^3$	$22.99 \times 10^6 \text{ m}^3$	$80.66 \times 10^6 \text{ m}^3$
Natural Gas	$369.37 \times 10^9 \text{ m}^3$	$57.40 \times 10^9 \text{ m}^3$	$311.97 \times 10^9 \text{ m}^3$

The monitoring of oil production from Gippsland Basin and Barrow Island fields has been enhanced by the computer plotting of monthly statistics. The programs were developed by members of the subsection.

Detailed reservoir engineering studies were carried out on the Pelican, Hapuku, Tuna, and Petrel fields. Parameters defined in the comprehensive studies were:

- effective pay thickness
- areal extent
- porosity
- hydrocarbon saturation
- shaliness
- permeability

In addition wire-line log interpretation was carried out on Flathead, Ooraminna, Lesueur, Kincora, and Barrow Island wells.

The economics of utilizing remotely located gas by conversion to an easily transported product has been studied by monitoring the technology of methanol, ammonia, and urea production. Economic technical advice was given to the Petroleum Assessment Section's 'minimum economic size reservoir' project.

Mathematical developments in reservoir descriptions are being monitored from technical journals and other publications. In particular the conformal mapping technique which purports to replace numerical reservoir simulation by an analytical approach is being studied closely.

Numerous routine and ad hoc enquiries including support for the NEAC and AMEC standing groups involved the supplying of reservoir information, reserve estimates (in energy and/or volume units) and reserve classification (economic, sub-marginal, and paramarginal).

Messrs D.G. Bennett and M.H. Ellis visited the Mackerel Platform, Barry Beach Marine Terminal, Longford Gas Processing Plant, and several oil service companies on an introductory tour of oil related industries at Sale, Victoria.

Mr L.E. Kurylowicz attended a 5-day AMF course on 'Advanced Formation Evaluation' in Adelaide.

Messrs I. Donald and M.H. Ellis attended departmental courses in management and report writing respectively. Also they gave a three day course on the use of the Hewlett Packard 9825A calculator to BMR personnel. Mr M.H. Ellis presented a lecture on wire-line log applications to 3rd year students at the CCAE.

Dr S. Ozimic vacated the Petroleum Technologist Class 2 position in February to take up a NERDDC grant position for three years. Mr D.G. Bennett has since been promoted into a Class 2 position and Mr R. Bresnehan was promoted into a Senior Technical Officer Grade 2 position in September.

Drilling Engineering Subsection

Plant and Equipment

On completion of the 1979 Bowen Basin seismic and McArthur River field parties the remaining two of the four A.E.C. Leyland 1000 gallon water tankers still mobile were returned to Canberra and were disposed of. They were replaced with new 8.63 kl (1900 gallon) water tanks on Mack 6 x 6 chassis. All Mayhew drilling units plus drilling and camping equipment from other parties were returned to the A.C.T.

The "Gemco" 210B drilling unit, support vehicles, camping and drilling equipment were stacked in Darwin; the drilling unit was over-hauled by a private contractor.

During the interfield season, slow rotation gearing for the running of air-hammers was designed, assembled and mounted on the Mayhew drilling units; all drilling rigs were over-hauled and repaired by BMR personnel in the workshop at Fyshwick.

One Gardner-Denver WXH air compressor was completely overhauled and reconditioned by a private contractor at Fyshwick.

Workshop (Fyshwick, A.C.T.)

The interior of the workshop brick walls were painted; the general working benches and power saw are still to be relocated.

The Department of Housing and Construction carried out the necessary machining of parts for repairs and modifications to plant and equipment; private enterprise carried out work for minor repairs and overhaul.

Vehicles and Plant

The current vehicle and plant strength is:

- 5 - Mayhew-1000 Drilling Rigs mounted on Mack R6-85 8 x 6 RS chassis
- 5 - 1900 gallon water tanks mounted on Mack 6 x 6 RM6866RS chassis
- 1 - 600 gallon water tank mounted on International 1600 chassis in Brisbane

(The chassis for disposal and the tank to be transferred to a new chassis).

- 1 - "Gemco" 210B "Tandem Trailer" mounted auger/diamond drill rig
- 4 - 6 tonne, 4-wheel drill trailers (one for disposal) A.C.T.

Drilling operations

In the year ending 31 October 1980, the Drilling Subsection provided fourteen drilling parties in support of various BMR field activities. Drilling and diamond coring operations took place in the A.C.T. and N.S.W., diamond over-coring in W.A. for stress measurements, drilling and diamond coring in the Georgina Basin (Qld), Amadeus Basin (N.T.), and Darwin/Pine Creek areas (N.T.), seismic shot hole drilling in N.S.W., and seismic shot hole drilling and heat flow holes in the Eromanga Basin (Qld). Personnel were also provided for the Barrier Reef drilling program, using a Geological Branch rig. The 5 Mayhew 1000 drills, one Gemco 210B and a portable drilling unit were used to carry out these operations.

Table 5 summarises the drilling and coring activities during the period, 1 November 1979 to 31 October 1980.

Technical Services

During the year a number of drilling, coring, and period contracts for the supply of replacement parts, drilling bits, diamond core-heads and other consumable stores were prepared or revised by the Drilling Subsection and forwarded to the contracts board.

Table 5. Summary of BMR Drilling Operations, 1 Nov. 1979 to 31 Oct. 1980

BRANCH AND SECTION	PROJECT AREA OF OPERATION			NO. OF HOLES	METRES		DRILLED & CORED
		FROM	TO		DRILLED	CORES	
<u>GEOLOGICAL METALLIFEROUS</u>	PINE CREEK BARRY SPRINGS McKINLAY (NT) MAGELA	22.7.80	23.10.80	18	411.46	119.50	530.96
<u>SEDIMENTARY</u>	GEORGINA BASIN (QLD)	20.6.89	12.8.80	6	78.80	377.60	456.40
	AMADEUS BASIN (NT)	20.8.80	21.10.80	5	43.80	293.35	337.15
	BUNYAN (NSW)	18.2.80	4.3.80	3	44.50	64.90	109.40
		27.11.79	19.12.79	2	34.50	28.00	62.50
	ENGINEERING HYDROLOGY (ACT)	22.1.80	20.6.80	25	572.21	190.20	762.41
<u>GEOPHYSICAL</u>							
<u>REGIONAL</u>	(WEST AUST) STRESS MEASUREMENTS	18.2.80	17.3.80	10	84.45	17.37	101.82
<u>SEISMIC</u>	BOWEN BASIN (QLD)	26.10.79	1.11.79	182	7062.00		7062.00
	GOULBURN (NSW)	21.4.80	1.5.80	14	378.00		378.00
	GEORGINA BASIN (QLD)	14.7.80	30.10.80	1281	49937.85	23.90	23.90 49937.85
<u>PETROLEUM EXPLORATION</u>							
<u>BASIN ASSESSMENT SECTION</u>	(IVANHOE (LAKE CARGELLIGO (NSW) (MANARA (OWEN DOWNS	3.11.79	29.11.79)	5	143.80	636.70	780.50
		7.3.80	15.5.80)				
TOTALS		1.11.79	30.10.80	1551	58791.37	1751.52	60542.89
	Total metres drilled	-	58791.37 (metres)				
	Total metres cored	-	1751.52				
	Total metres drilled & cored	-	60542.89				
	Total no. of holes	-	1551				
	Total no. of cores cut	-	763				
	Average core recovery	-	84.37%				

20(1)

NO. OF CORES	AVERAGE CORE RECOVERY %	TIME SPENT .HRS OPERATING			AVERAGE PENETRATION RATE METRES		AVERAGE DEPTH OF HOLE METRES	TRAVELLING TIME (HOURS)
		DRILLING	CORING	TOTAL	HR DRILLING	CORING		
48	70	180	136	316	2.28	0.87	29.49	10
143	90	15.5	120	135.5	5.08	3.14	76.00	2.5
114	96	39.0	14.5	184	1.12	2.02	67.43	-
47		12.5	43.5	56	3.56	1.49	36.33	16.5
10	52.00	5.0	11.5	16.5	6.90	2.43		15.0
80	95.00	212.00	170.00	382	2.69	1.11	30.49	147.00
43	100.00	48.5	43.5	92	1.74	.39	10.18	22.5
		137.5	-	137.5	51.36		38.80	19.0
		24.00	-	24.00	15.75		27.00	10.0
11	84.00	-	10.00	10.00	-	2.39		
-	-	1283.00	-	1283.00	38.92	-	38.98	450.00
267	88.00	96.50	320.50	417	1.49	1.98	156.10	-
763	84.37	2053.50	1000.00	3053.50	28.62	1.75	39.03	692.50

APPENDIX

RECORDS AND PUBLICATIONSPetroleum Assessment SectionRecords (issued)

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