AUSTRALIA

Report 268

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DEPARTMENT OF RESOURCES & ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

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Australian Geoscience 1984

Annual Report of the Australian Geoscience Council Inc. The Council of Earth Science Societies in Australia

COMPILED AND EDITED BY
JOHN ROBERTS
School of Applied Geology
University of New South Wales

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA 1985

DEPARTMENT OF RESOURCES & ENERGY

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BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

DIRECTOR: R. W. R. RUTLAND

Published for the Bureau of Mineral Resources, Geology & Geophysics and the Australian Geoscience Council by the Australian Government Publishing Service

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ISBN 0 644 04049 1

ISSN 0084-7100

Printed by Graphic Services Pty Ltd, 516-518 Grand Junction Road, Northfield, S.A. 5085

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PRESIDENT'S REPORT

Within the objectives of the Australian Geoscience Council (the Council of earth science societies in Australia) two roles predominate. The first is to *inform* geoscientists of developments and trends in their professional area. This, I believe, the Council has successfully initiated and continues in its Annual Reports, in the Council-sponsored and industry-financed study by Dr Morgan Sant of 'Human Resources in the Geosciences', and most recently in its support of a conference at ANU on soil degradation.

The second role is to *unify* geoscientists in order to enable Governments, industry and the public to obtain a heightened awareness of the contribution made by geoscientists to the growth of our nation's living standards and international stature. This affects the status of geoscientists, and involves lobbying, public relations and education. These aspects of the Council's activities, which began with the Radwaste Management Symposium in 1983, are now gaining momentum and include inviting senior politicians and industry leaders to attend and speak at Council meetings.

The single window

The need for unification of geoscientific organisations is illustrated in Figure 1 which shows the plethora of institutions involved in Australian geopolitics, and Figure 2 (based on a draft prepared by Professor J. F. Lovering) which adds an international dimension. For many years each individual organisation has been attempting to exert an influence on those outside its professional field, and yet the tide of Government in particular continues to run against us.

With this in mind the Australian Geoscience Council was formed with the intention of it becoming the coordinating body to channel communication without political, social or industrial bias between the profession and those outside it. This technique is sometimes referred to as the single window approach.

The potential advantages of a single window approach are readily apparent. Ideally, it permits a high degree of coordination in both negotiation and implementation, leading to faster and, one would hope, more informed decision making. Nonetheless, one must also recognise the difficulties of this approach, especially when it is applied to an established regime. Hence the Council acknowledges that its activities do not preclude individual initiatives by Council members in their traditional manner whenever this is judged to be beneficial.

Research funding

In the current furore over demonstrably inadequate research funding the single window approach to Government would seem to be the most efficient and to have the greatest impact. As stated recently by Dr Lyle A. Douglas, President of the Australian Society of Soil Science: 'Politicians, in particular, have recently emphasised the need for communication to be improved if they are to allocate further funds to our area. This is of course an anathema to scientists who expect needs to be evaluated objectively by informed persons, but the facts are that decisions are now being made in a manner that can be described as highly subjective' (*Soil News*, 62, 1985). To overcome the problems inherent in this style of decision making the Council is combining with other scientific fraternities in a joint approach to the relevant Government authorities to inform them of the realities and consequences of the present situation.

Influencing Government

The question of how best to inform Government involves not only direct lobbying but also public education and personal involvement by all geoscientists. I draw your attention to a paper on this topic by Dr P. T. Warren 'The provision and receipt of advice' (*Open Earth*, 19, 1982-D, p. S46-S48). In summary his nine suggested actions are:

(1) Ensure that in the school curriculum an element of geoscience enters a balanced curriculum involving science and the humanities for all pupils. Only in this way can one hope to create a better basis for mutual understanding between scientists and administrators.

(2) Increase the time spent in degree courses on inculcating techniques of written and oral communication. Far too

GEOPOLITICS IN AUSTRALIA—1984

ORGANISATION	LEARNED SOCIETIES	PROFESSIONAL GROUPS	UNIVERSITIES, CAE's AND ACADEMIES	INDUSTRY	GOVERNMENT	POLITICIANS
NON-POLITICAL	ROYAL SOCIETIES					
	GEOLOGICAL SOCIETY OF AUSTRALIA			AUSTRALIAN MINERAL FOUNDATION		
	ASSOCIATION OF EXPLORATION GEOCHEMISTS			AUSTRALIAN MINERAL INDUSTRIES RESEARCH ASSOCIATION		
	AUSTRALIAN GEO-MECHANICS SOCIETY	AUSTRALIAN SOCIETY OF SOIL SCIENCE	AUSTRALIAN ACADEMY OF SCIENCE		COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION	
	INSTITUTE OF AUSTRALIAN GEOGRAPHERS	AUSTRALIAN MINING AND PETROLEUM LAW ASSOCIATION	CONSORTIUM FOR OCEAN GEOSCIENCES		BUREAU OF MINERAL RESOURCES	
	STATISTICAL SOCIETY OF AUSTRALIA				SOIL CONSERVATION SERVICE OF N.S.W.	
	AUSTRALIAN GEOSCIENCE INFORMATION ASSOCIATION					
	AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS	AUSTRALIAN AND NEW ZEALAND ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (SECTION 3)	AUST. COUNCIL OF CHAIRMEN EARTH SCI. DEP.		AUSTRALIAN RESEARCH GRANTS SCHEME	
					AUSTRALIAN TERTIARY EDUCATION COMMISSION	
		PETROLEUM EXPLORATION SOCIETY OF AUSTRALIA				
		AUSTRALASIAN INSTITUTE OF MINING AND METALLURGY (incl. MICA)	AUSTRALIAN ACAD. OF TECH. SCIENCE		GOVERNMENT GEOLOGISTS' CONFERENCE	
		AUSTRALIAN GEOSCIENCE COUNCIL				
		AUSTRALIAN INSTITUTE OF GEOSCIENTISTS		AUSTRALIAN COAL ASSOCIATION	AUSTRALIAN SCIENCE AND TECHNOLOGY COUNCIL	
				AUSTRALIAN MINING INDUSTRY COUNCIL	AUSTRALIAN MINERALS AND ENERGY COUNCIL	STATE MINISTERS OF MINES AND ENERGY
				AUST. PETROLEUM EXPLORATION ASSOC.		MINISTER FOR SCIENCE AND TECHNOLOGY
POLITICAL						MINISTER FOR RESOURCES AND ENERGY

Members of the Australian Geoscience Council indicated in heavier type

85 125 SADME

Fig. 1. Geopolitics in Australia 1984.

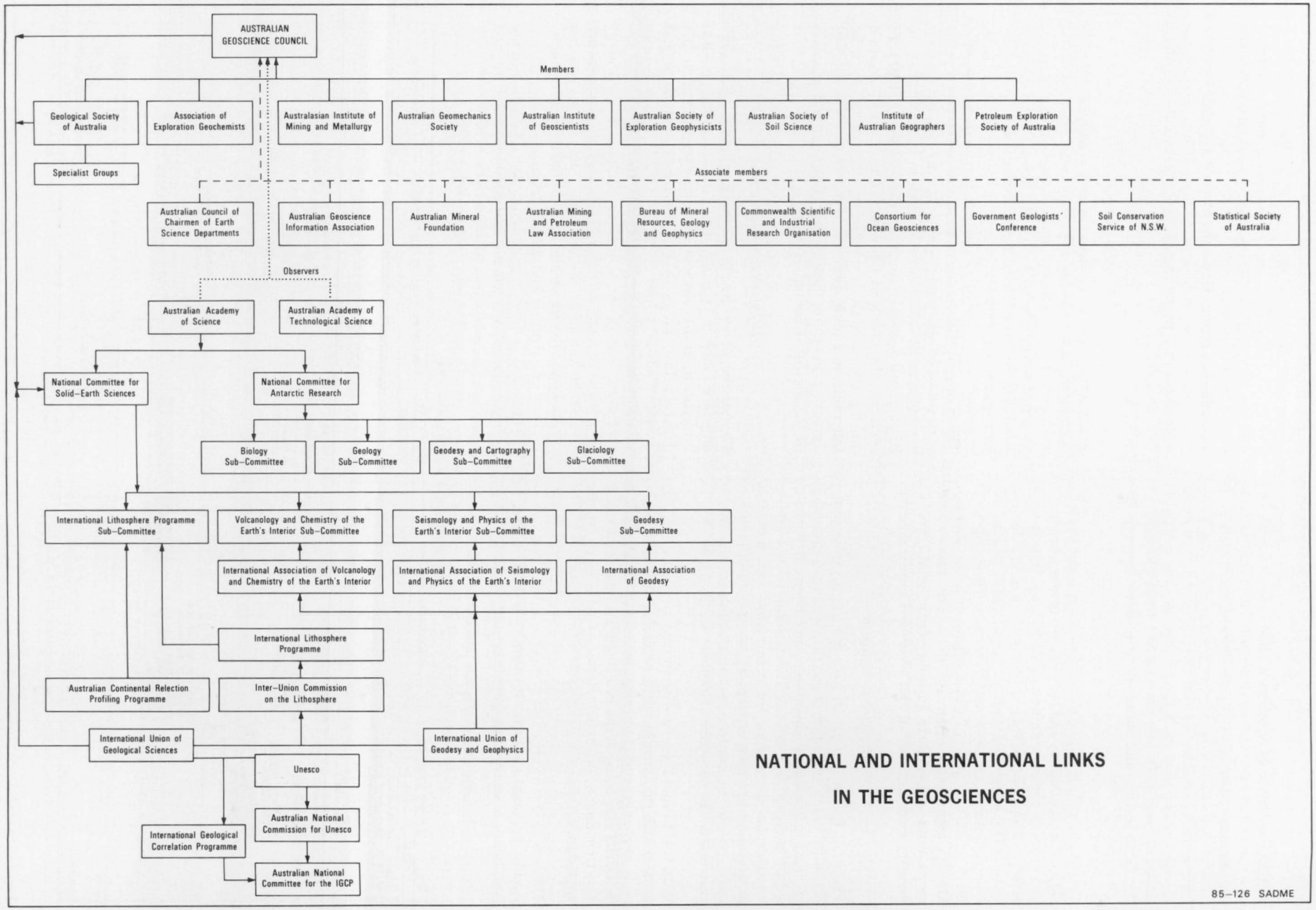

Fig. 2. National and international links in the geosciences.

many geoscientists are unable succinctly to express their advice.

(3) Make geoscientists aware of the needs of those they may advise; and be conscious of time constraints, and the lack of comprehension of scientific principles of even Government Ministers. An advisor must keep faith with the scientific evidence, but any one moment has its own right answer—the best that can be given—and this must recognise not only the science but the political, economic, legal and social realities of the moment.
(4) Enhance the contacts, individually and collectively, with outside bodies and people likely to influence geoscientific activity, or be influenced by it.
(5) Actively encourage more geoscientists to enter Parliament or Local Government.
(6) Stimulate the movement of geoscientists from their professional activities into administration, and conversely reduce the extent to which individuals doing so are ignored, ostracised or considered, in some way, to have 'let the side down'.
(7) Increase the efforts to develop an even stronger collective voice.
(8) Seek to get geoscientists represented on major advisory bodies.
(9) Press the Government to provide the maximum information about its current scientific activities and its channels of advice, and to give the reasons behind rejection of advice when proffered.

With regard to item one, I am attracted to two themes suggested recently by Professor Lovering as a possible basis for a public awareness campaign, either 'Australia: you're standing on it', or 'Australia: you're drifting with it'!

Tertiary education

Item two relates to the standard of tertiary geoscientific education in Australia. A spate of papers over the past six months has drawn on the results of the Council's Human Resources Survey and compared the numbers and quality of tertiary graduates with the forecast needs of their potential employers. The general conclusion has been that too many inadequately trained geoscientists are graduating in Australia.

The 28 separate Earth Science Departments in Australia, of which 27 provide first degree courses in geology, would appear to extend the available staff and research funds to, or beyond, the limit. If the ratio relating the size of the population and the number of geology degree-awarding institutions in the USA is applied to Australia, there should be about seven tertiary institutions in Australia granting geology degrees (Professor B. J. Skinner, Seventh Australian Geological Convention, Sydney 1984). Although the comparison is not completely valid, it indicates that overservicing may be occurring in Australia.

Yet all undergraduates at all institutions should have the opportunity to be exposed to earth science. It will be difficult to resolve this complex situation, but it is recognised by Council as one that deserves immediate attention. Consequently, Council has requested the Australian Tertiary Education Commission to sponsor a review by the Council primarily of Earth Science Departments, with merit seen in the review including tertiary education in physical geography and soil science to complete the geoscience sector. The response of the Commission to this proposal is awaited.

Funding

From the outset, the Council has consistently believed that its general purpose funds should not come from industry sources, but that these sources may be tapped for special projects. Thanks to the generosity of a minority of State Geological Surveys, CSIRO, and most recently BMR in agreeing to publish the Annual Report, the general purpose account is just adequate for current needs, but is inadequate to generate activities reflecting the contribution of the 5000 geoscientists represented by the Council to the nationally important resources industry.

Opportunities in recession

Raising finance for projects from the mineral and petroleum industry, especially exploration companies, has proved almost impossible over the past two years, and this is understandable. But this situation is symptomatic of the fluctuating financial circumstances facing the minerals industry, and the causes and consequences should be recognised.

One cause of the present downturn is that geoscientific exploration has been too successful and the need now is to make past discoveries economic; with an overabundance of potential producers and a depressed world economy, finding markets is difficult.

As a consequence there is a tendency for companies to introduce an austerity program and to reduce or abandon their exploration effort. This may have a short-term beneficial effect on the balance sheet, but it neglects the historical pattern whereby recession is invariably followed by progression at which time resources are needed for development. If these resources have not been discovered prior to the economic upturn (that is, during the recession) it is more than likely that short-sighted companies will miss the peak market opportunities, or find it unduly expensive to acquire resources.

Ways in which to smooth the economic swings and roundabouts need to be discovered, but with respect to personnel a positive attitude is required now. 'Extremely competent, well-paid individuals are the cheapest commodity we have in the mineral and petroleum industry. Recessions are *not* the time to lay off or retrench in hiring programs; but rather an opportunity to reassess exploration and development programs, upgrade the technical competence of personnel, and hire and train recent graduates to assume future positions of responsibility' (adapted from Daniel A. Bush, *PESA Journal*, August 1983, p. 8).

Conclusion

As geoscientists, and as scientifically informed laymen, we have a responsibility to ensure that Government, industry and society are made more fully aware of the role and significance of the geosciences; thus when issues such as research funding arise, a well-informed body of opinion should already exist amongst decision makers. The duty lies with us, both individually and collectively through the Council, to positively represent the Australian geoscientific community to those whose attitudes and policies influence it, thereby encouraging the development of the earth sciences in the best interests of the nation and the geoscientific community.

Colin D. Branch
PRESIDENT

SECRETARY'S REPORT

The Council and the Executive

The Council elected a new six member Executive at the Annual Meeting held in Canberra on 23 May 1984. Executive Meetings were held on 20 July 1984 (Adelaide), 20 September 1984 (Sydney) and 20 February 1985 (Sydney). Meetings of the full Council were held in Canberra on 23 May and 9 November 1984.

Associate Professor John Roberts was appointed Editor for the Council Annual Report.

The Member Societies continued to contribute financial support to assist with the running expenses of the Council. Additional funding and donations were received from the Geological Surveys of New South Wales and the Northern Territory, and the South Australian Department of Mines and Energy.

Employers of Council and Executive Members made a worthy contribution by way of time, travel expenses and support services. This generous support is acknowledged gratefully. Without it the Council could not have functioned.

Membership

The membership list reads as follows:

Members

Association of Exploration Geochemists (AEG)
Australasian Institute of Mining and Metallurgy (AIMM)
Australian Geomechanics Society (AGS)
Australian Institute of Geoscientists (AIG)
Australian Society of Exploration Geophysicists (ASEG)
Australian Society of Soil Science Inc. (ASSS)
Geological Society of Australia Inc. (GSA)
Institute of Australian Geographers (IAG)
Petroleum Exploration Society of Australia (PESA)

Associate Members

Australian Council of Chairman of Earth Science Departments (ACCESD)
Australian Geoscience Information Association (AGIA)
Australian Mineral Foundation Inc. (AMF)
Australian Mining and Petroleum Law Association Ltd (AMPLA)[1]
Bureau of Mineral Resources, Geology and Geophysics (BMR)
CSIRO
Consortium for Ocean Geosciences (COGS)
Government Geologists' Conference (GGC)
Soil Conservation Service of N.S.W.
Statistical Society of Australia

Observers

Australian Academy of Science
Australian Academy of Technological Sciences

Discussions were initiated with the International Association of Hydrogeologists' national committee, the Australian Mineral Industries Research Association and the Australian Science and Technology Council regarding their possible involvement in the Council.

[1] New Member admitted in 1984

Activities

Settlement of account on the completion of the Human Resources Survey by Dr M. Sant, University of New South Wales, was made possible by a generous grant-in-aid from Kennecott Explorations (Australia) Ltd supplemented by a contribution from CRA Exploration Pty Ltd which are acknowledged with gratitude. Dr Sant advised the Council that an update of the data gathered in the Survey would be desirable after a lapse of three to five years. The positive results of the Survey are reported to have prompted scientists in other disciplines to plan for similar assessments. As reported by the President the Survey results have provided the feedstock for several recent papers on geoscience education topics and are clearly proving of value to the geoscience community.

The principal ongoing activity of the Council is production of the Annual Report on geoscience in Australia, now entitled 'Australian Geoscience 1984'. The breadth of this overview means that it has obtained a high degree of acceptance in geoscience circles. Its appearance in improved form has been greatly facilitated by the Bureau of Mineral Resources who has agreed to publish the annual report in their Report series. The Bureau and the responsible Federal Minister are thanked for their generous help to Council. Editorial control and circulation remain however with the Council and its constituent organisations.

The Radioactive Waste Management Symposium held in 1983 and reported on in earlier Annual Reports generated a small profit and the Council as a joint guarantor with the Australian Academy of Science has no indebtedness on that account. Unfortunately efforts to raise funds to publish the papers given at the symposium were unsuccessful and the subject matter has now lost much of its topicality.

In order to fulfil its role of bringing geoscience matters to the public view the Council was a co-sponsor of a successful symposium on 'Soil Degradation: The Future of Our Land?' held in conjunction with the Centre for Continuing Education at ANU in Canberra from 25-27 November 1984. The symposium attracted about 130 registrants from a wide range of interests and disciplines. They were virtually unanimous in their agreement on the nature of the problem, its enormity and the need to act vigorously to halt the degradation process. To prepare for the Council's next major effort in the area of public awareness of geoscience matters, discussions were held regarding a future seminar on baseline geochemical studies and their relationship to environmental impact studies. As a co-sponsor of the Third International Conference on Geoscience Information to be held in Adelaide in June 1986 the Council can report healthy progress in preparations with over 50 papers offered to date, many of them from overseas authors.

At the initiation of the Council a proposal was put to the Chairman of the Commonwealth Tertiary Education Commission for an in-depth review of tertiary geoscience education. The matter is still under consideration. Council indicated to the TEC Chairman that it would expect to have a major role to play in such a review.

Executive discussed at length the public image of geoscience and as a result invited senior public figures from politics, education and industry to attend the November 1984 Council meeting luncheon and address the Council. It is planned to make these invitations a regular feature of Council Meetings.

The Human Resources Survey has obtained a good press but Council are still seeking supplementary ways to continue presentation of an effective public image for geoscience.

Other matters of concern considered and discussed by

Council and Executive during the year included the low level of funding of geoscience research and how to improve it; support for the Australian Academy of Science Calendar of Conferences; plans for special efforts and events to celebrate the bicentennial; the National Ocean Drilling Program; and the Australian Government's declining interest in support for the UNESCO National Commission and the International Geological Correlation Programme.

As a measure of the status of the Council the President was requested in his official capacity to adjudicate the award of the 1984 Royal Society of Victoria Research Medal in geoscience.

David H. Mackenzie
Secretary

TREASURER'S REPORT

The 1984 financial year (calendar year) is described in this report. Once again the general finances were dominated by expenditure on the Annual Report. This constant demand on Council finances will be eased in 1985 by assistance from the Bureau of Mineral Resources in printing the report. Support for other activities of Council, which includes new initiatives in hosting senior executives in Industry, the Public Service, politicians and Ministers of Government at Council Executive meetings, has come from State Geological Surveys and subscriptions from Members. The final cash balance of $3213 should enable Council to enhance its representation of Geoscience interests in Australia during 1985.

The Council's Human Resources Project was brought closer to completion in 1984 with the publication of a two volume report. The manpower survey and publication of the report were funded by donations from industry, government and individuals, but publication costs were especially high and these were only met by a grant-in-aid from Kennecott Explorations (Aust.) Ltd supplemented by a contribution from CRA Exploration Pty Ltd. During the year, Project receipts were $6032 and expenses $11 223. Total receipts to the end of 1984 were $28 162 and total expenditure $27 183, leaving a credit balance of $979.

Auditors for the Council are Price Waterhouse, Chartered Accountants. The Council appreciates their generous services free of charge.

Financial Statement

Receipts		$
Subscriptions		1200
Donations		3000
Bank Interest		122
		4322
Expenses		**$**
Meetings		63
Annual Report 1983		4881
Audit		300
Miscellaneous		43
		5287
Balance brought forward	(31-12-83)	$4178 Cr
Cash balance	(31-12-84)	$3213 Cr

Gordon J. Burch
Treasurer

STATUS OF THE GEOSCIENCES IN AUSTRALIA

The status of the geosciences within Australia has now been reviewed in three reports of the Council and will form the basis for a quadrennial report to be produced by the Australian Academy of Science National Committee for Solid Earth Sciences.

Statements on individual disciplines cover, in a national context, research and exploration activities during 1984, major achievements and problems, and in some cases outline plans for future work. They have been provided by representatives of constituent organisations of the Council. The texts have been edited to achieve a basically uniform style, but the individual spirit of each assessment has been retained.

Those responsible for the compilation of the reviews are acknowledged in Table 1. Council thanks all those who contributed to the reviews.

Table 1. List of review compilers

Topic	Responsibility for preparation	Compiler(s)
Antarctic studies	BMR	R. J. Tingey
Australian mining and petroleum law	AMPLA	M. Crommelin
Coal geoscience	BMR GSA (Coal Geol.)*	M. B. Huleatt, C. Mallett
Enhanced oil recovery	BMR	B. A. McKay
Environmental and engineering geology	GSA (Eng.Geol.)*	A. S. Power, M. J. Knight
Exploration geophysics	ASEG	S. Greaves
Geochemistry	AEG	R. H. Mazzuchelli, J. D. Saxby
Geochronology and isotope geology	GSA (Geochem. Min. Pet.)*	T. Green
Geological mapping	BMR	J. S. Adkins
Geomathematics	SSA	N. I. Fisher
Geomechanics	AGS	J. Small, F. C. Beavis
Geomorphology	IAG	R. W. Young
Geophysical mapping	BMR	J. S. Adkins
Geoscience information	AGIA BMR	L. Gerdes, A. Mond
Groundwater	ANCIAH	W. H. Williamson
History of Earth sciences	GSA (Hist.Earth. Sci.)*	C. Gatehouse

Antarctic studies

Field work in the Australian Antarctic Territory during 1984 was limited to graduate work on the petrology of the Mawson

Industrial and construction minerals	GSA (Eng.Geol.)*	A. S. Power
Marine geoscience	COGS	K. A. W. Crook
Mineralogy and crystallography	GSA (Geochem. Min.Pet.)*	T. Green
Mineral resource classification and estimation	BMR	M. B. Huleatt
Ore deposit geology	GSA (Econ.Geol.)*	G. Derrick
Palaeontology	GSA (AAP)*	B. Runnegar
Petroleum geology	PESA	G. C. Geary, M. L. P. Cadart
Petrology	GSA (Geochem. Min.Pet.)*	T. Green
Remote sensing	BMR	C. J. Simpson, W. J. Perry
Soil science	ASSS	G. J. Burch
Solid Earth geophysics	GSA (Solid Earth Geophys.)*	D. Denham
Stratigraphy and sedimentology	GSA (Sed.)*	P. J. Cook
Structural geology and tectonics	GSA (Tec.Struct. Geol.)*	D. Gray

AEG	Association of Exploration Geochemists
AGIA	Australian Geoscience Information Assoc.
AGS	Australian Geomechanics Assoc.
AMPLA	Australian Mining and Petroleum Law Association
ANCIAH	Australian National Committee of the Int. Assoc. of Hydrogeologists
ASEG	Australian Society of Exploration Geophysicists
ASSS	Australian Society of Soil Science
BMR	Bureau of Mineral Resources, Geology and Geophysics
COGS	Consortium for Ocean Geosciences
GSA	Geological Society of Australia
IAG	Institute of Australian Geographers
PESA	Petroleum Exploration Society of Australia
SSA	Statistical Society of Australia
*	denotes Specialist Group

Charnockite (University of Tasmania) and structural geological studies (University of Melbourne). Both students were based at the Mawson ANARE station. In Australia, research on material collected in Antarctica in earlier years continued at BMR and at a number of universities. Material from Enderby Land continued to produce valuable petrological results, and a similar geological picture emerged from the Vestfold Hills area.

Soviet Antarctic Expedition geologists are currently working in the Prince Charles Mountains, between the Vestfold Hills and Enderby Land, following up earlier BMR discoveries of Cretaceous alkaline intrusive rocks. The Soviet workers have discovered various types of alkaline intrusive rocks including some described as kimberlites. A visiting US scientist will join this group in the 1984-85 season.

A research team, including one Australian scientist, based at Ohio State University, produced evidence from the Transantarctic Mountains that eastern Antarctica was ice free in Pliocene times. Controversy surrounds this concept because other evidence points to continental scale Antarctic glaciation starting in the Late Oligocene—Early Miocene or even the Eocene. Two Australian scientists (BMR and Macquarie University) joined a marine geophysical cruise, organised by the United States Geological Survey, off the eastern sector of the Australian Antarctic Territory and in the Ross Sea. A preliminary report was published in May 1984.

Australian scientific research in Antarctica, particularly that in the Australian Antarctic Territory, is overseen by the Antarctic Research Policy Advisory Committee (ARPAC) and by the Australian Academy of Science's National Committee for Antarctic Research (ANCAR). Logistic support for Antarctic research is provided by the Antarctic Division of the Department of Science. ARPAC has has outlined a wide ranging Antarctic earth science program, and one important component, research in the Bunger Hills-Denman Glacier region not far from the Soviet station at Mirny, appears likely to get under way in 1985-86.

Australian Mining and Petroleum Law

Aboriginal land rights attracted much attention in 1984, with government reports and some legislative activity. However, further legislative developments appear inevitable before the legal regime governing mineral and petroleum operations on Aboriginal land is settled. There was also legislative change regarding petroleum resources, with a new Petroleum Act in the Northern Territory and amendments to the *Petroleum (Submerged Lands) Act* 1967 (Cwlth) and the *Petroleum Act* 1940 (SA). In Western Australia a Committee of Inquiry into aspects of the *Mining Act* 1978 (the Hunt Inquiry) delivered its report to the State Government.

Aboriginal land rights

In December 1983, Mr Justice Toohey reported to the (Commonwealth) Minister for Aboriginal Affairs on the *Aboriginal Land Rights (Northern Territory) Act* 1976 and related matters.[2] The report recommended numerous amendments to the Commonwealth Act operating in the Northern Territory. So far, no amendments have eventuated, although it is known that the entire framework of Aboriginal land rights throughout Australia is under review by the Commonwealth Government.

In the meantime, the Commonwealth Parliament enacted the *Aboriginal and Torres Strait Islander Heritage (Interim Protection) Act* 1984 conferring broad, discretionary powers on the Minister for Aboriginal Affairs to protect areas of significance to Aboriginals and Torres Strait Islanders from injury or desecration. As its name suggests, this Act is intended to operate as a temporary measure, for two years from 25 June 1984.

On 22 March 1984 the *Maralinga Tjarutja Land Rights Act* 1984 (SA) received royal assent. The Act confers ownership of a large tract of land in the far western region of South Australia (comprising some 8% of the area of the State) on a new corporate entity known as Maralinga Tjarutja, made up of traditional Aboriginal owners of the land. This legislation follows the pattern established by the *Pitjantjatjara Land Rights Act* 1981 (SA). Mineral and petroleum explorers and producers require the permission of Maralinga Tjarutja before entry upon the subject land. Provision is made for arbitration in the event that permission is refused or granted on unacceptable terms.

On 17 September 1984 Mr Paul Seaman, QC delivered the report of the Western Australian Aboriginal Land Inquiry to the Western Australian Government. That report recommended that Aboriginal land-owners should have a right of veto in relation to mineral and petroleum operations on their land. However, in releasing the report to the public, the Western Australian Government announced its opposition to such a veto. Since the release of the report the Government has prepared a Bill for introduction into the Western Australian Parliament to make provision for Aboriginal land rights in that State.

Petroleum legislation

On 15 October 1984 the *Petroleum Act* 1984 (NT) came into force, replacing the *Petroleum (Prospecting and Mining) Act* 1954. This is the first entirely new petroleum legislation in

[2] *Seven Years On:* Canberra, AGPS, 1984

Australia since 1967, when both the offshore[3] and the Western Australian[4] statutes were enacted. The main feature of the new legislation is that it establishes a three-state system of titles in place of the more familiar two-stage systems encountered elsewhere in Australia. The first stage, represented by the permit, applies to exploration. The second stage, represented by the retention licence, allows evaluation of a petroleum discovery. The third stage, represented by the production licence, applies to commercial production. The holder of a permit is entitled, upon application, to the grant of a retention licence when he establishes, by drilling operations, the presence of petroleum in his permit area and satisfies the Minister that the petroleum is potentially of a commercial quality and quantity. The holder of a retention licence is entitled, upon application, to the grant of a production licence provided he has complied with the conditions of his retention licence, any directions of the Minister, and the requirements of the Act.

On 25 October 1984, the *Petroleum (Submerged Lands) Amendment Act* 1984 (Cwlth) came into effect. This Act makes many technical amendments to the Commonwealth *Petroleum (Submerged Lands) Act* 1967 governing petroleum operations on the continental shelf, beyond the seaward limits of the territorial sea. In addition, the Act allows the Minister for Resources and Energy and the Designated Authority to control entry to a specified area in Bass Strait encompassing the offshore petroleum fields, for reasons of security. Further, the Act makes highly significant amendments to s. 58 of the *Petroleum (Submerged Lands) Act* 1967, the effect of which is to empower the Joint Authority to direct the holder of a production licence to reduce the rate at which petroleum is being recovered from the licence area, having regard (among other things) to the impact on Commonwealth revenue of the specified rate of production.

The Minister for Resources and Energy has also foreshadowed further amendments to the *Petroleum (Submerged Lands) Act* 1967 (Cwlth) to provide for a system of cash bidding for the award of exploration permits, to introduce a new (third) form of title known as the retention lease between the exploration permit and the production licence, and to revise the provisions of the Act governing the registration of transfers of and dealings with petroleum titles.[5]

The *Petroleum Act Amendment Act* 1984 (SA) makes several notable amendments to the South Australian *Petroleum Act* 1940. The applicant for a petroleum exploration licence is now required to include in his application an outline of the exploratory operations which he proposes to undertake in each year of the term (five years) of the licence. Further, upon renewal of a petroleum exploration permit the Minister has the power to vary the statutory expenditure obligation and to prescribe a work programme in relation to the licence. Finally, the Act now prohibits the grant of a petroleum production licence after discovery if the quality or quantity of discovered petroleum is not sufficient to warrant production.

Hunt Report

The Western Australian Committee of Inquiry into Aspects of the Mining Act issued its report early in 1984, containing recommendations for many amendments to the *Mining Act* 1978 (WA). Perhaps the most controversial of these recommendations is that the veto enjoyed by private landowners in respect of the grant of mining titles over 'land under cultivation' should be abolished. However, no amendments have yet been made to the *Mining Act* 1978 consequent upon this report.

Coal Geoscience

Exploration activity and mine development declined during the year principally because of the oversupply of all types of coal on world markets. The position is not expected to improve until supply and demand are more closely balanced. The need for more efficient mine operations has accelerated the use of geophysical and geological techniques to accurately determine the geological controls of mining conditions.

Black Coal

Australian production of black coal reached record levels again in 1984, with a significant increase in the proportion of steaming coal exported. Stockpiles remained high, and exploration and drilling declined. Total exploration drilling during 1983/4 in NSW fell 48% to 84 230 m—35% of the 1980/1 level, and in Queensland drilling by the Department of Mines fell 44% to 20 240 m—30% of the 1981/2 level of activity.

Brown Coal

The Victorian Government has established the Coal Corporation of Victoria as a commercially oriented body to lead the development of brown coal for uses other than electricity generation. Initially the Corporation is owned by the State Electricity Commission of Victoria but will be independent from the electricity generating part of the Commission.

During 1983-4, 33 Mt of coal was dug from four open-cut mines in the La Trobe Valley. The new Loy Yang open-cut supplied 400 000 t for the first of three new 500 MW electricity generating units. In the 10-year program for analysis of La Trobe Valley coals, 11 200 m of proving drilling was carried out and there was an additional 4 700 m of drilling for regional stratigraphy and groundwater investigations.

Research undertaken by the State Electricity Commission of Victoria at its Yallourn open-cut mine has resulted in the production of a coal quality map based on energy and boiler fouling properties. This type of map will be more widely used in the SECV's other mines, and in conjunction with production plans will enable more accurate prediction of the properties of coal to be mined.

In South Australia the State Government, through the Future Energy Action Committee, is evaluating data on six deposits of brown coal for electricity generation. Major geotechnical and coal evaluation programs have been carried out by Electricity Trust of South Australia and private companies. As in Victoria, private exploration has virtually ceased.

Coal Research

The Australian Coal Association undertook an appraisal of coal-related research carried out in Australia. It concluded that the allocation of funds to programs for geological evaluation and survey, and for coal conversion research, was questionable in terms of the relatively high emphasis these areas currently receive.

The Association believes geological surveys and deposit evaluations, although essential for the maintenance of future

3. *Petroleum (Submerged Lands) Act* 1967 (Cwlth) and ancillary legislation.
4. *Petroleum Act* 1967 (WA).
5. Draft Bills have been circulated to industry for comment.

production levels and for planning of resource utilisation, are the responsibility of State authorities, as part of normal resource inventories. In the priorities established by the Association, no research in the general area of geology was included in the high priority group. Those areas of research regarded as medium priority targets included—(i) prediction of washery yields from geological exploration; (ii) improved borehole logging equipment; (iii) prediction of geotechnical problems ahead of underground mining. A further area of research regarded as having low priority, was the prediction of seam contamination from geological exploration results.

The National Energy Research Development and Demonstration Council continued to provide funding for research into various aspects of the coal industry, allocating almost $4 M in 1984. Most of the funds were channelled through the Australian Coal Industry Research Laboratories, with the remainder spread through companies, universities, government departments and CSIRO. Amongst the programs was a CSIRO project to improve both techniques and equipment for downhole logging of drill holes, with the major objective of determining *in situ* ash content of coal. Other programs to receive funding include the development of a vibrator seismic source, laser-excited fluorescence of coal, and coal characterisation by vitrinite and inertinite fluorescence.

Enhanced oil recovery research

Research directed towards improving the recovery of petroleum from subsurface reservoirs (EOR) was in progress at the Baas Becking Geobiological Laboratory in BMR and at four Australian Universities (Australian National University, and the Universities of Melbourne, New South Wales and Sydney) during 1984.

The research at the Baas Becking Laboratory is aimed at the isolation of micro-organisms which will facilitate improved recovery of petroleum and the investigation of problems associated with individual reservoirs being considered for microbiological enhanced oil recovery programs.

Research at the Australian National University and University of Melbourne is directed towards understanding the effects of capillarity, interfacial effects, wetting properties, contact angles, 'water fingering' and 'bridging'. The ability of certain aqueous solutions to improve displacement efficiency in oil reservoirs is also being investigated.

At the Universities of Sydney and New South Wales the research relates to gas miscible displacement including minimum miscibility pressures, phase studies of gas-liquid systems, CO_2 core flood tests and reservoir fluid analysis (PVT) studies.

BMR is helping to co-ordinate the various EOR research and is providing information (characterisation studies) on Australian petroleum accumulations to help direct the work towards practical applications in Australia.

Environmental and engineering geology

Issues which continued to occupy the attention of the government and the scientific community during 1984 have been water resources management, conservation policy and environmental problems related to the mining industry, in particular uranium mining.

In August and September 1984, the Commonwealth Minister for Resources and Energy tabled papers relating to the Government's new water policy, guidelines for the new Federal Water Resources Assistance Program and the Government's response to the recommendations of the *Water 2000* report. In answer to the recurring theme of the *Water 2000* report concerning the lack of adequate and reliable data on Australia's water resources, a new national water data program is being initiated. The report of the Interim Council for an Institute of Fresh Water Studies concluded that the establishment of an Institute would not be the most effective response to national water research needs. The Interim Council recommended the establishment of an independent advisory body to advise the Government on national water research priorities and also called for a substantial increase in funds for water research.

The Australian Water Research Council has completed a pilot survey of Australian stream sedimentation problems and policies. In early 1984 the Rufus River Groundwater Interception Scheme, adjacent to Lake Victoria, was commissioned. The Scheme is historic as it is the first salinity mitigation scheme undertaken by the River Murray Commission.

At the 1984 ANZAAS Congress, the Environmental Studies Section resolved to seek the support of the Prime Minister and state Premiers for the endorsement of the National Conservation Strategy to enable the implementation process, which will flow from the strategy, to begin formally.

A further contribution to Australia's uranium debate was the report of the inquiry by the Australian Science and Technology Council. The report argues for expansion of uranium mining and Australian participation in other parts of the nuclear fuel cycle, including high-level radioactive waste disposal. The need for further research to define the desirable characteristics of host rocks and to define criteria to be used in selecting suitable disposal sites is noted in the report.

The environmental geological mapping program of the Geological Survey of Western Australia in the Perth Metropolitan area has been completed and the first map (Muchea 1: 50 000) has been published. Mapping has commenced in the Collie coalfield and adjacent areas (1: 50 000) in support of an investigation into the environmental management and future land use of the Collie Basin. Work continues in collaboration with the Forests Department into the investigation of environmental parameters influencing the spread of the fungal disease dieback in the northern jarrah forest.

In New South Wales, the Department of Environment and Planning issued *Sydney's Extractive Industry Regional Environmental Study* which was based on a major investigation carried out by the Geological Survey of New South Wales (GSNSW). The study has been issued for comment prior to the establishment of a regional environmental plan for extractive resources. The GSNSW has continued to assess Environmental Impact Statements especially in relation to the coal industry. Coal waste disposal problems on the South Coast were investigated, and in the Hunter Valley, the relation between geology and salinity was established.

Waste disposal research at the School of Applied Geology, University of New South Wales has focussed on the behaviour of fluoride and biodegradation of cyanide in weathered rocks and clay. The results have been related to the practical disposal of wastes resulting from the production of aluminium. Studies have also been made of the long term geochemical behaviour of coalmine waste piles.

Authority to commence construction of a major tunnel for sewage outfall offshore from Malabar was given by the New South Wales State Government. Engineering geological factors will be considered during construction by the Metropolitan Water Sewerage and Drainage Board. A number of major engineering geology projects were carried out by the Electricity Commission of New South Wales. These included an ash dam at Bayswater; continuation of the Barnard River Scheme construction involving a tunnel, three dams, pumping stations and pipelines; power station foundations; and computer simulation of subsidence around coal mines.

Mapping by the Geological Survey of Victoria (GSV) has continued in the Melton-Sunbury Growth Corridor. A GSV study of the subsidence problems over the Wonthaggi coal mine workings has progressed to a computerised basis, and the State Electricity Commission of Victoria continued regional and site specific studies of groundwater and subsidence in relation to La Trobe Valley open-cut dewatering requirements. The GSV study of coastal processes in the Corner Inlet area has been completed and work is advanced on a similar study of the western Victorian coast-line. The long term study of the salinity of the northern plains has continued, as have pollution studies of urban and industrial wastes in the Melbourne region. Slope stability assessments were carried out in the Otway Ranges and South Gippsland Highland.

Mapping by the Geological Survey of Queensland of industrial and urban development is in progress at Bundaberg and Cairns (1: 100 000). Maps and commentaries for Rockhampton, Gladstone, Townsville and Mackay (1: 100 000) have yet to be issued. Landslide studies were carried out for Brisbane, the Toowoomba Range foothills and Cairns hillslopes. Coastal investigations continued in Hervey Bay, Princess Charlotte Bay and at Cairns. In Moreton Bay, sediment movement was monitored to assess the impact of proposed channel deepening.

Environmental geoscience topics at the Seventh Australian Geological Convention included quarry rehabilitation, water resources management in mining, planning legislation, geological disposal of nuclear fuel wastes, landslide risk assessment and water quality. The Second Australian Workshop on Oil Shale included papers on revegetation experiments at the Rundle (Qld) site and environmental monitoring at the Condor and Julia Creek (Qld) prospects. A Queensland earthquake engineering workshop drew attention to the need for a revision of the Seismic Hazard Map for Queensland.

The land rehabilitation newsletter *Landline* has now become a regular supplement to *Mining Review.*

Exploration geophysics

Exploration for coal and minerals continued at the low levels of the previous two years, resulting in some reduction of staff levels.

Geophysical techniques most commonly employed were ground and airborne magnetics, various electromagnetic (EM) and some gravity methods. SIROTEM utilisation increased in 1984, with year-round use of equipment, but little induced polarisation (IP) surveying was undertaken. Most airborne surveying was for minerals exploration, the search for diamonds accounting for approximately half of the line kilometres flown. There was a slight increase in high resolution airborne magnetometer surveying for petroleum exploration during 1984.

Research continues to be directed towards electromagnetic (EM) and audiomagnetotelluric (AMT) exploration methods for both minerals and petroleum. Field evaluation of the long offset transient EM method indicates that the technique can be used in the delineation of exploration targets. Software for inversion and modelling methods continues to expand in conjunction with field studies. In-seam seismic techniques are being successfully applied by a major coal producer, and research has now been directed to more complex imaging, including topographic imaging by seismic waves in coal seams.

Interpretation of MAGSAT data is entering a stage of collaboration with petrologists to reconcile MAGSAT anomalies with the presence of various intrusive rock types.

Seismic surveys for the petroleum exploration industry increased during 1984. Offshore operations remained at around the 1983 level, but there was increased onshore activity, particularly in Queensland. Maximum utilisation of onshore seismic crews occurred during the third quarter. Seismic data processing centres consequently experienced a similar upsurge of activity, with Australian based centres obtaining the majority of offshore and onshore data for processing. Advances in processing and acquisition technology continue to be introduced.

Geochemistry

Inorganic geochemistry

Gold was again the main target of private sector mineral exploration programs during 1984, and interest and expertise in geochemical prospecting techniques for gold deposits continued to grow. This was reflected by a special session at the 7th Australian Geological Convention organised by the Association of Exploration Geochemists on the topic 'Geochemical Exploration for Gold'. Nine papers were presented to an audience of over 200 people covering fundamental studies of the geochemical dispersion of gold during weathering processes, and the application of geochemical sampling and analysis of soils, vegetation and groundwaters, in the search for gold deposits. Empirical studies involving the direct analysis of trace concentrations of gold in soils, stream sediments and other naturally occurring sample materials, are now widely applied in mineral exploration programs throughout Australia. Concurrently, understanding of the mechanisms and factors controlling the dispersion of gold during weathering is being increased by studies carried out by CSIRO and the University of Queensland. Continuing research involving fluid inclusion and isotope studies have provided more detailed knowledge of the conditions under which gold deposits have formed, contributing to the refinement of genetic models and hence to geochemical search technology. The application of the phenomenon of thermoluminescence in gold exploration has also been advocated.

Geochemical exploration for deposits of base metals, tin, tungsten and molybdenum, continued in many parts of Australia and research aimed at optimising geochemical exploration programs is continuing in many centres. Recent work includes detailed studies of the relationships between mineralogy and trace element chemistry in weathering profiles over base metal mineralisation (University of Western Australia). Studies of Pb istopes in gossans, soils and

vegetation are being pursued by CSIRO in an attempt to detect the presence of concealed base metal mineralisation. In a project with similar objectives, electrogeochemical studies by the University of New South Wales have yielded encouraging results over examples of deeply weathered massive sulphide deposits in NSW. The results of major CSIRO investigations into vapour geochemistry over ore deposits (Hg and He) have recently become available. Although the studies have provided useful case history data, the anticipated benefits of vapour geochemistry in providing surface geochemical indications of buried mineral deposits have in general not eventuated.

In the analytical field, advances have been made in the measurement of minute amounts of Au, As and base metals in naturally occurring waters, leading to the possibility of effective hydrogeochemical exploration for gold deposits. Work continues on the development of the inductively coupled plasma emission spectrograph (ICP) as a means of providing cost-effective, multi-element analyses for geochemical exploration.

Research in advanced data processing techniques for geochemical exploration is being actively pursued at the University of New South Wales. Recently published results show how new techniques of statistical map analysis using multi-element regional stream sediment data from a major survey carried out by the BMR can supplement geological mapping and delineate zones of mineralisation.

Of more general application to mineral exploration is a method for discrimination of original igneous rock types on the basis of the concentrations of stable trace elements present in highly weathered surface materials. Other more fundamental studies of the geochemistry of granitoids and volcanics (Australian National University and La Trobe University) and precious metals (University of Melbourne) are continuing.

Organic geochemistry

The Seventh Australian Geological convention held in August 1984 provided a forum to assess the role of organic geochemistry in the Australian context. In keeping with the theme of Geoscience in the Development of Natural Resources, major symposia were held on the topics of oil and gas (31 papers), coal (22 papers) and oil shale (22 papers). The 1984 Australian Coal Science Conference (incorporating the Australian Workshop on Coal Liquefaction) was a major new initiative of the Australian Institute of Energy.

As a result of a more systematic application to basin and play evaluation, the strengths and weaknesses of organic geochemistry in petroleum exploration are better known. Potential source rocks can be identified, correlations between oils and source sediments can be established and the degree of biodegradation in reservoirs can be determined. Migration, timing of hydrocarbon generation and quantitative estimation of amounts of generated hydrocarbons remain problems in organic geochemical research. Areas investigated geochemically during 1984 include the Gingin and Bootine gas fields in the Perth Basin, and the Officer, Amadeus and Eromanga Basins. Despite many studies, the Gippsland Basin still retains its fascination for organic geochemists.

Cross polarisation carbon-13 nuclear magnetic resonance spectrometry with magic angle spinning is now a viable technique for measuring the aromaticity of coals. Australian and overseas research during 1984 has shown how dipolar dephasing experiments can give additional structural information. Studies on many coals have established that little aromatic crosslinking occurs until the anthracite stage of coal rank is reached.

Basic studies on Australian oil shales continue, often with the blending of geochemical and petrographic data. Investigations at Duaringa have shown that at least two types of oil shale are present in Tertiary sequences. Oil shale occurrences may be overlooked during exploration if drilling fails to reach pre-Tertiary basement. Our understanding of the geochemistry of the Cretaceous Toolebuc oil shale is still limited because of the large area involved and the lack of outcrops. Oil yields have been shown to decrease southwards because of a facies change, and trace element distributions are shedding light on environments of deposition.

Geochronology and Isotope Geology

Geochronological unravelling of the crustal evolution of cratons and craton margins in the Yilgarn and Pilbara, WA, and Enderby Land, Antarctica, has continued by Sm-Nd, U-Pb and Rb-Sr dating. In particular, detailed comparative isotopic study of rocks from the Western Gneiss Region (Yilgarn Block) has included the oldest known sialic rocks in the world together with ion microprobe studies of zircons which represent the oldest known terrestrial matter. The work in the Pilbara has revealed a pattern of continuous geological evolution over a period of 700 Ma. A dolerite occurrence at the Black Range, Pilbara, has provided data on the behaviour of Sr isotopes during contact metamorphism, while detailed Sr isotopic analysis of granite-gneiss terrains in the Pilbara has pointed to a relic paragneiss older than 3600 Ma, and indicated that these felsic rocks may have formed a basement to the greenstones of the eastern Pilbara. At the other end of the time scale K-Ar dates, linked with magneto- and biostratigraphic data from Pliocene marls of Fiji, enabled determination of absolute ages for some important biostratigraphic zone boundaries.

Fission track studies have been linked with determining the thermal history of sedimentary basins, and the concomitant maturing of fossil fuels, through the annealing and disappearance of the tracks as a result of heating during burial. Finally, in the geochronological field, intermediate isotope products in the decay from lead to uranium have been applied to dating fossil bones and speleothems in limestone caves of South Australia.

An isotopic window on the mantle beneath eastern Australia has been provided by Sr and Nd isotopic studies of Tertiary-Recent basaltic and ultrapotassic rocks and their xenoliths. The results show significant regional and depth dependent inhomogeneity, together with extensive metasomatism of the mantle beneath this part of Australia.

Stable isotopes have continued to be usefully applied to aid in the genetic understanding of ore deposits, especially the Archaean gold deposits of WA. Also, sulphur isotope studies of massive lead-rich sulphides within mafic lavas from Currawang East, NSW, has supported an epigenetic origin for the mineralisation, while oxygen and sulphur isotope results for fluid inclusions in the Sundown Tin Prospect, Queensland, suggested that the cassiterite mineralisation resulted from a predominantly magmatic fluid, although meteoric water may have influenced later base metal vein mineralisation. Stable isotope study of the Heemskirk Granite, Tasmania, pointed to a dual magmatic-hydrothermal and meteoric origin for the mineralisation.

PRELIMINARY EDITION

1:100 000
1 Devils Marbles Region (BMR)
2 Edith River Region (BMR)
3 Elkedra Region (BMR)
4 Forsayth (Qld) reprint
5 Georgetown (Qld) reprint
6 Kurundi Region (BMR)
7 Noonamah (BMR)

COLOUR EDITION

1:10 000 GREAT BARRIER REEF
8 Myrmidon, Davies Reefs (BMR)

1:25 000
9 Broken Hill (NSW)
10 Mount Gipps (NSW)
11 Singleton (NSW)
12 Wedderburn (Vic)

1:50 000
13 Eddystone (Tas)
14 Muchea (WA)
15 St. Marys (Tas)

1:100 000
16 Abner Range Region (BMR)
17 Albury (Vic)
18 Ararat (Vic)
19 Beaufort (Vic)
20 Carrara Range Region (BMR)
21 Creswick (Vic)
22 Hydrogeology of the ACT and Environs (BMR)
23 Kuridala Region (BMR)
24 Mary River – Point Stuart (BMR)
25 Mount Oxide Region (BMR)
26 Myally (BMR)
27 Rockhampton (Qld)
28 Rum Jungle Uranium Field (BMR)
29 St. Arnaud (Vic)
30 Strangways Range Region (BMR)

1:250 000
31 Baralaba (Qld) reprint
32 Boulia (Qld) reprint
33 Busselton–Augusta (WA) reprint
34 Cape Melville (Qld) reprint
35 Clermont (Qld) reprint
36 Cloncurry (Qld) 2nd edition
37 Cooktown (Qld) reprint
38 Cootamundra (NSW) reprint
39 Dubbo (NSW) reprint
40 Emerald (Qld) reprint
41 Forbes (NSW) reprint
42 Georgetown Region Mineral Deposits (BMR)
43 Glenormiston (Qld) reprint
44 Julia Creek (Qld) reprint
45 Kurnalpi (WA) reprint
46 Lawn Hill (Qld) 2nd edition
47 Mackunda (Qld) reprint
48 Menzies (WA) reprint
49 Mossman (Qld) reprint
50 Mount Barker–Albany (WA)
51 Mount Coolon (Qld) reprint
52 Mount Whelan (Qld) reprint
53 Pemberton–Irwin Inlet (WA)
54 Rawlinson (WA) reprint
55 Springvale (Qld) reprint
56 Warragul (Vic) reprint

1:500 000
57 Pine Creek Geosyncline 1984 (BMR)

1:1 000 000
58 Gawler Craton (SA)

1:5 000 000
*59 Metamorphic Map of Australia (BMR)

1:10 000 000 EARTH SCIENCE ATLAS
*60 Phanerozoic Palaeogeography (BMR) 3 sheets
*61 Cainozoic Geology and Mineral Deposits (BMR)

*map area not indicated on index

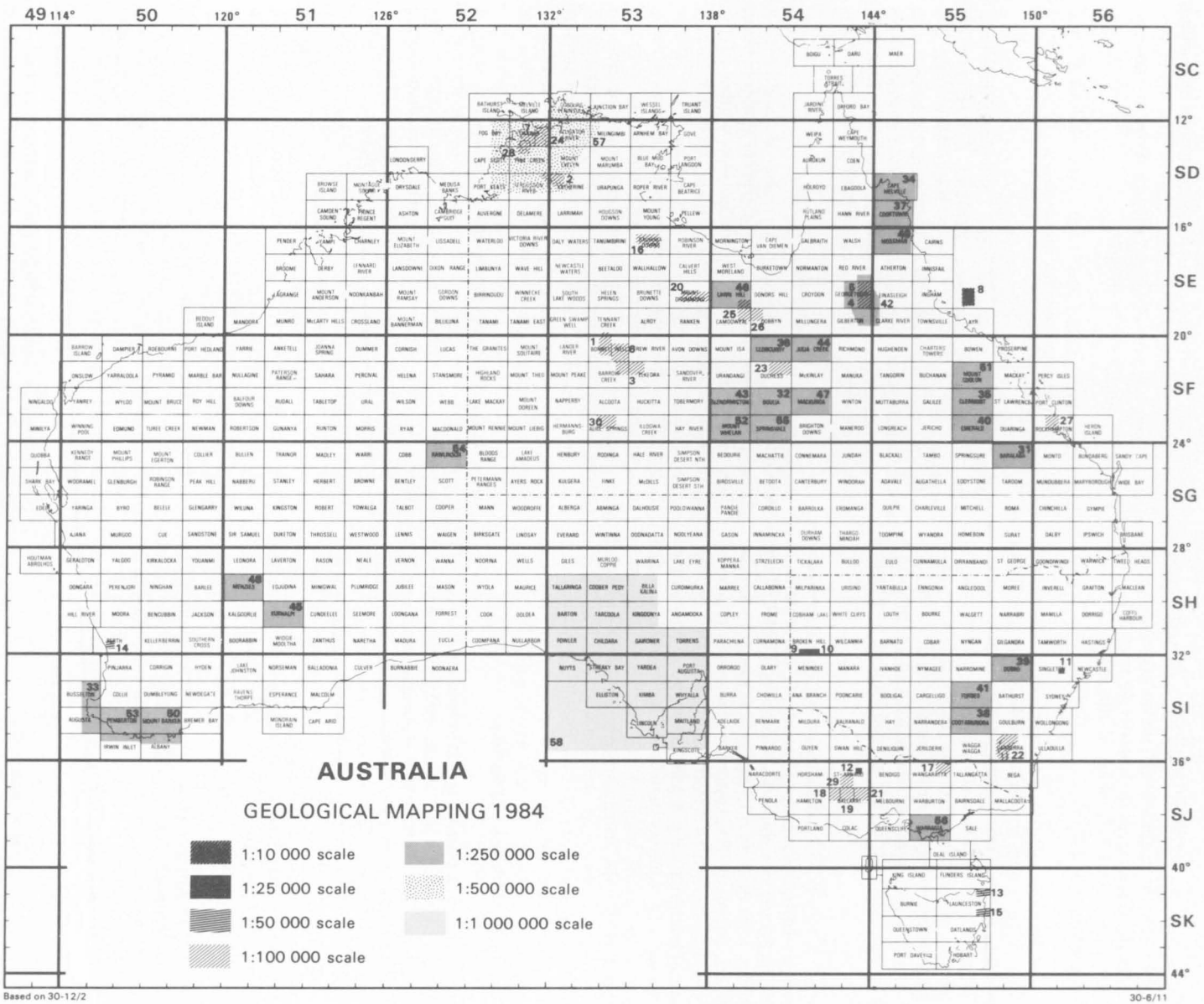

Fig. 3. Geological mapping within Australia, 1984.

Geomathematics

The current status of mathematical, statistical and computing activity in the Geosciences in Australia during 1984 can be conveniently reviewed by looking at the various scientific meetings during this period.

The most active area from a geomathematical viewpoint continues to be remote sensing, as evidenced by the 300 or so delegates to the Third Australasian Remote Sensing Conference. Current problems of particular interest relate to the handling of very large data sets generated by satellite or aircraft scanners, and problems of integrating different sorts of information (geochemical, remotely-sensed and magnetic) for a region to form a proper appreciation of its physical nature.

In an effort to promote collaboration between statisticians and geophysicists, the Statistical Society of Australia and the Australian Society of Exploration Geophysicists (ASEG) ran a one-day joint meeting on Geophysical Signal Processing in August, during the 7th Australian Statistical Conference. The specific aims were to identify common ground between the sort of mathematical problems geophysicists encountered and the sort of techniques statisticians had available, and to provide some initial stimulus for further collaboration between these groups. It remains to be seen how successful this meeting will have been. Applied mathematical aspects of some geophysical problems were the subject of a one-day meeting in June on Inverse Problems in Applied Mathematics, run by the Applied Mathematics Division of the Australian Mathematical Society.

Problems relating to smoothing and interpolation of spatially distributed data continued to engender lively debate at workshops and in the literature. Two one-day workshops run by the CSIRO Division of Mathematics and Statistics, in Melbourne and Sydney, focussed on comparison of various competing methods, with particular reference to geostatistical and contouring problems. Application to contouring faulted surfaces was discussed at the Second Australian Petroleum Geophysics Symposium, held in Melbourne in October under ASEG auspices, as were other problems involving use of seismic data in petroleum exploration.

The Australian Mineral Foundation continued its strong support of geomathematics, with a range of courses on seismic data processing, geostatistics and computing in the mining and petroleum industries. Reports on much of the activity in geomathematics appeared regularly in BANG (the Bulletin of Australian News in Geomathematics).

Geomechanics

During the past year, pure and applied geomechanics research in Australia showed a significant increase, with universities, colleges of advanced education, CSIRO, and major mining companies making contributions. Applied research included continuing studies in numerical modelling and analysis of excavations, pollution dynamics, tailings disposal, stability of coal stock piles with respect to flow slide development, and the mechanics of foundation on coral reefs. Research has been initiated on the engineering characteristics of calcareous sand, and of the arid zone soil, bulldust, in terms of their behaviour as foundation and as construction materials.

New basic research has involved a continuing study of the post-failure behaviour of rock, X-ray techniques for the measurement of strain, and the behaviour of expansive soils. Deformation behaviour of sands under stress is also under investigation. Theoretical studies of foundation dynamics, the dynamic loading of piles, and the flow of fluids in anisotropic media are in progress.

Instrumentation design has been directed towards the development of more reliable, and accurate pressure meters and earth pressure cells.

During 1984, two successful major conferences were held. The Fourth Australia-New Zealand Conference on Geomechanics took place in Perth during May. Some 200 delegates attended and 126 papers were presented. The specialist Fifth International Conference on Expansive Clays was held in Adelaide in May. Over 150 delegates, including 26 from overseas, attended and 64 papers were presented.

Geomorphology

Probably the most noteworthy recent development in Australian geomorphology is the increasing attention being given to arid and tropical Australia. New studies of the distribution of dunes has demonstrated the importance of understanding their origins, for they are known to occupy almost 40% of the continent. Significant progress is being made in unravelling the complex relationships between the distribution of different types of dunes and variations in climate and in the availability of sand. The extension of lacustrine research to the central and northwestern parts of the continent is providing the additional detail needed to reconstruct the Late Quaternary conditions under which the main dune fields were formed, and is giving new insight into long term fluctuations in monsoonal dynamics. Encouraging advances also have been made in studies of the streams of the centre and the north, especially of alluvial sequences in Western Australia, Arnhem Land, and the great anastomosing systems of western Queensland. These studies will not only do much to offset the bias given to the humid southeast in Australian fluvial research, but should make important contributions to fluvial theory because they deal with environments which contrast markedly to those in which this theory has been primarily fashioned. The northern coasts, particularly the reefs, estuaries and chenier plains, continue as a major focus of research. An important aspect of this research is the increasing awarness of the significance of the geometry of the depositional environments in controlling switches from sedimentation to erosion. The practical value of estuarine and fluvial work in the north is nowhere more strikingly illustrated than in the investigation of the long term stability and likely environmental impact of uranium tailings dumps.

Sound progress continues to be made in fluvial and coastal studies in the southern parts of the continent. Marshalling of evidence from diverse sources has provided an overview of the extent of human impact on streams. Observations of the effects of extreme rainfalls, together with new chronological and stratigraphic evidence, is pointing to the need for renewed evaluation of the role of climatic change in fluvial systems. The excellent research on beach morphodynamics that has come from the southeast coast in the last decade is now being increasingly augmented by work from the southwest. Moreover, it has become increasingly clear that there have been major regional differences in Late Quaternary coastal evolution, especially with regard to the relative movement of land and sea.

Research into the survival of ancient landforms in many parts of Australia has attracted considerable attention overseas; as one French reviewer puts it, the contribution of Australian

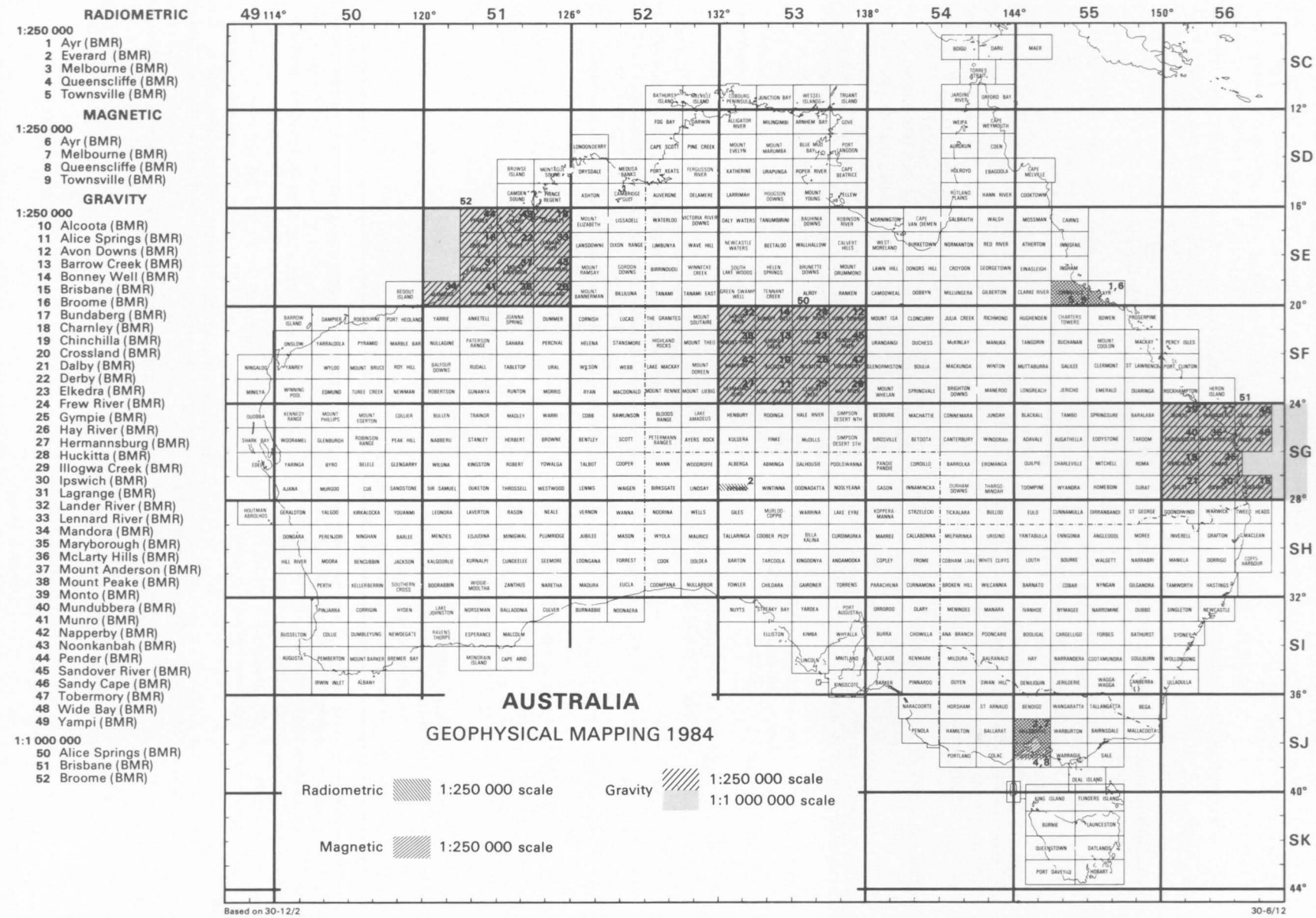

Fig. 4. Geophysical mapping within Australia, 1984.

geomorphologists to the field is fundamental. As our knowledge of Tertiary landscapes, and of the extent and rate of more recent erosion (especially through K–Ar dating) increases, the prospects for evaluating general models of denudation will be enhanced. So too will the prospects for evaluating competing tectonic models.

Geoscience Information

Principal contributions to the published literature on Australian geoscience information, as recorded in the Australian Earth Sciences Information System (AESIS) in 1984, are listed as follows:

(1) 'A survey of major library collections in the geosciences in the State of Victoria, Australia' by Rosalind Walcott in which she concludes that ' . . . in general, Victorian geoscience collections are adequate for the geoscientist's needs'. Her paper is published in the *Proceedings of the Geoscience Information Society*, 14, p. 231-242, (1983) and is based on a study carried out in early 1982.

(2) *Information needs of the exploration geoscientist*, 10 papers and workshop discussions presented at the Australian Geoscience Information Association (AGIA) Seminar, 5-7 December, 1983, and published by the South Australian Branch of AGIA.

(3) 'Supplement 1984' to the *Australian Thesaurus of Earth Sciences and Related Terms*, 2nd ed. (1979), published by the Australian Mineral Foundation.

(4) 'A rock property database for The Lachlan Fold Belt of New South Wales' published as *BMR Report* 244 and produced in microform.

Unpublished literature added to AESIS includes: 'The AUSTCO database system: User manual' by A. L. Hinde and 'Data file AUSTCO: Wells drilled for petroleum in Australia (to January 1984)' by D. J. Forman, A. L. Hinde and J. Totterdell, *BMR Record* 1984/5 and 1984/13 respectively—the latter produced in microform (MF204); and 'Index of hydrogeology reports' by B. Eberhard, *SADME Report* RB 84/058.

The main thrust in geoscience information activity is in the area of automation, and there is increasing recourse to computer-based systems. Through a questionnaire sent out for the 'Directory of Government Geoscience databases in Australia' BMR has recorded information on 255 databases in 37 organisations. Of these, 59 are 'reference' databases providing bibliographic information, and the remainder cover numerical or factual data and are termed 'source' databases. Only 69 are available for direct public use, two with on-line access, and a further 83 are available for use through departmental personnel. The directory is due for publication in early 1985.

One new source database developed in 1984 and available for public access through the I. P. Sharp Associates network is the METPRI metal prices database produced by BMR. The New South Wales Department of Mineral Resources in late 1984 implemented a 6-month pilot program to provide direct access to its reference databases (MINFINDER and COREFINDER) through the CLIRS Information System network. CLIRS is a Computerised Legal Information Retrieval System being created by the Computer Power Company in collaboration with the New South Wales and Victorian Governments. It will be used for better access to mineral and petroleum legislation as well as all other legislation in both States.

Geological surveys and BMR are making additional progress towards computerisation of their reference and source data files. In the Northern Territory, Queensland and South Australia, well established computer-based systems are available for public use through the departments, whilst in Western Australia computer-based systems for some reference data files will be operational for public use in early 1985. The Geological Surveys of Victoria and Tasmania, which already have computer-based internal data files, also intend to make them available for public use.

With the assistance of a grant from NERDDC, BMR is preparing a National Petroleum Exploration Data Index (PEDIN). The PEDIN system includes basic geoscientific information and statistics related to petroleum exploration and development wells, and geophysical surveys carried out in Australia and its territories; references to reports and samples from these operations; the storage location and availability of results; and the objectives, major results and their interpretation. The PEDIN database contains substantial information relating to PSSA (Petroleum Search Subsidy Act) wells, and aeromagnetic, gravity and seismic surveys. All other gravity and magnetic data catalogued by BMR are also included as basic entries. As at December 1984, the database included approximately 900 gravity, 380 magnetic, 20 refraction seismic and 60 reflection seismic surveys, and 500 wells. Data on surveys and wells are being added to the system as they are commenced, completed and released. Much of the data in PEDIN will be accessible to the public during 1985.

For published geoscience literature, awareness of resources in the major Australian libraries is improving appreciably through the Australian Bibliographic Network (ABN) hosted by the National Library of Australia. The libraries of the BMR, Northern Territory and South Australian Departments of Mines and Energy, Victorian Department of Minerals and Energy and the AMF have joined the network. The gradual addition of their specialised holdings to existing records of the National Library, the State libraries, the libraries of the universities and CAE's and other participating institutions, will facilitate access to the geoscience information resources of Australia.

Groundwater

Regional investigations of groundwater resources were carried out in the Namoi, Lachlan and Macquarie valleys, and the Murray Basin in New South Wales; in Victoria, in the Riverine Plains (with particular reference to salinity problems), the Ballarat-Colac area, the Western Port Basin, and, jointly with South Australia, a 40 km border zone; in South Australia, in the Adelaide region, with special reference to the relationship between Tertiary and basement rock aquifers; in Western Australia, in the Perth, Carnarvon and Canning Basins; in the Northern Territory, in four regions, including the eastern margin of the Daly River Basin; in Queensland, in the Don and Dee valleys; and in Tasmania, the East Coast and Midlands areas. The joint Commonwealth/State hydrogeological study of the Murray Basin was continued, and studies made of the Amadeus Basin (NT) and of discharge zones of the Great Artesian Basin.

Urban and other localised groundwater supplies were sought in the Gellibrand area for Geelong; in deep (800 m) aquifers

of the Otway Basin in the Euralie Vale and Warrnambool areas; the flanks of the Grampian Ranges for Hamilton and other centres; near Coober Pedy, where a source of groundwater of 5000 mg/L salinity is being developed to replace one of 19 000 mg/L, with consequent savings in desalination costs; various areas in the Northern Territory for 8 communities and 15 aboriginal institutions; and for construction of the re-routed Stuart Highway (SA) and the Dampier-Perth natural gas pipeline. Water balance and recharge studies were carried out in relation to groundwater supplies for Perth.

The dramatic increase in the demand for groundwater over the past two decades has led to emphasis on management of the resources. As part of its State Water Plan documentation, the NSW Water Resources Commission issued the report *Groundwater in New South Wales*. Victoria launched a Parliamentary Inquiry into Water Resources Management and also conducted studies on such aspects as artificial recharge of the Mitchell River alluvium, and drought relief strategy. Management studies in South Australia included the Mallee, Padthaway, and Keith-Willabooka-Bordertown Irrigation areas and the Eyre region, including the Uley and Polda Basins and protection of their recharge areas. A large part of the upper southeast of the State was proclaimed to safeguard its groundwater resources. In Queensland, studies of conjunctive use of alluvial aquifers and major dams were made in relation to the valleys of the Callide River and Three Moon Creek. Groundwater legislation is presently being recast in Tasmania.

In relation to mining, investigations included the impact of brown coal mining on the groundwater resources of the La Trobe Valley (Vic.); water supply for Rocky Downs mine, from the southern marginal zone of the Great Artesian Basin (SA); the impact of coal mining on groundwater resources in the Collie Basin (WA); and dewatering of the Leigh Creek Upper Series coal (SA).

Salinity and pollution problems attracted much attention. Salinity problems in irrigation areas in Victoria led to investigations in the Kerang and Campaspe areas, that in the latter including the use of airborne electromagnetic surveys to map shallow saline groundwater. In South Australia, investigations were commenced on the Woolpunda Groundwater Interception Scheme to reduce saline inflows to the Murray River between Waikerie and Overland Corner. Unusual aftermaths of the disastrous 1983 South Australian bushfires were (i) at Wangwarry, where salvaged partly burnt logs were kept moist by spraying with groundwater, and studies made to ensure that pollutants from the logs were contained, and (ii) studies of groundwater pollution problems arising from the some 300 pits in which destroyed stock were buried. Studies continued in Western Australia on land and stream salinisation accompanying bauxite mining, woodchipping, irrigation and land clearing. Salinity and pollution investigations were carried out in the Perth Area, and, in relation to industrial and solid and liquid waste disposal sites, in the Swan Coastal Plain and in Sydney. At Kwinana (WA), a 1200 m deep waste injection well was constructed for disposal of herbicide residues, include dioxin.

Groundwater topics featured prominently in the 7th Australian Geological Convention, held in Sydney. Three symposia on groundwater attracted 22 papers, and other relevant papers were presented in Engineering Geology sessions.

History of Earth Sciences (Summary of developments since 1975)

Australian Earth Scientists have long shown an interest in the history of the profession, but only in the past two years has this led to moves to form a local association. The Earth Sciences History Group was formed as a Specialist Group of the Geological Society of Australia in August 1984 with a membership of 60 geologists.

Australia has been involved with the 'International Commission on the History of the Geological Sciences' (INHIGEO) since its inception in 1967. Associate Professor T. G. Vallance (University of Sydney) is a current INHIGEO Vice President. Several Australian geologists are also members of the North American based History of Earth Sciences Society', founded in 1982.

Investigations since 1975 of 19th Century geology in Australia include the development of geology in general and specifically on palaeontology, mineralogy and early government involvement. Papers have appeared on French and German influences on Australian geology, and contributions have been made on the history of the petroleum industry in both South Australia and Australia as a whole. Important historical compilations have begun to appear on specific geological provinces, for example the Eromanga Basin, Adelaide Geosyncline and Canning Basin, as well as on specialist topics.

Within institutions, the South Australian Department of Mines and Energy published a history of all Australian Geological Surveys (1976) and two historical works during its centenary year in 1982. Mining company histories which have appeared over the past decade include those of Western Mining Corporation (until 1953) and the Broken Hill Pty Co. Ltd.

Biographical studies have traditionally involved the preparation of obituaries, a field which has expanded recently due to the compilation of the *Australian Dictionary of Biography*. Sketches of most eminent 19th Century geologists in Australia have been published in the Dictionary and the early 20th Century compilation is underway. Book-length biographical studies have been published on the Rev. W. B. Clarke, Sir T. W. Edgeworth David and Sir Douglas Mawson.

Some workers are developing reference files on geologists in Australia, and others have been collecting rare books, maps and photographs relating to the science. The files of Sir T. W. Edgeworth David (University of Sydney) and Sir Douglas Mawson (University of Adelaide) have recently been sorted and are easily available for examination. The Basser Library, at the Australian Academy of Sciences in Canberra, has a growing amount of archival material on Australian geology.

The Australian Institute of Petroleum is planning to erect a monument in the Coorong region of South Australia to commemorate Australia's first oil well. Geologists in Victoria are planning a biennial special lecture series to honour Alfred Selwyn, first Director of the Geological Survey of Victoria. They have also instituted the D. E. Thomas Medal, to be awarded annually to the best Victorian geology honours thesis emphasising field work.

Research on Earth sciences history in Australia is in its infancy. Given the major contribution of past and present Australian geologists and the historical basis of geology as a science, continuing investigations into the historical aspects of the Earth sciences are necessary.

Industrial and Construction Materials

Although the immediate market for industrial minerals remains clouded, production estimates for most mineral sands products show increased tonnages of 10-15% for 1984 in comparison to the 1983 output. Increased production also occurred for barite (50%), gypsum (40%), magnesite (90%), talc (23%) and salt (4%). Production falls occurred for diatomite, dolomite (10%), feldspar (50%), limestone (10%) and glass sand (35%) during 1984. The patchy nature of production trends is indicated by increases in production of limestone at Riverton (Qld), attapulgite (WA) and perlite in the Numinbah Valley (Qld). Export sales of Queensland marble have continued and have now reached 5 000 t. In general, export markets were depressed with only mineral sands products and talc showing increased tonnages for 1984.

Despite significant developments in specific commodities, the continuing difficult economic conditions have again limited exploration for most industrial minerals. CRA has reported that it is investigating graphite (SA), magnesite (Tas.) and mineral sands (Vic.) prospects. Calibex Nominees is exploring for potash east of Shark Bay (WA) and a Poseidon-PPG Industries Inc. joint venture is exploring for potash in the Adavale Basin (Qld). Australian Diamonds NL have identified a smaller area within their lease for intensive diamond exploration at Coanjura (NT). A Freeport of Australia–Gem Exploration and Minerals joint venture is considering a 300 t/day plant at their Limestone Creek (WA) prospect. Denison Holdings in joint venture with Adelaide Brighton Cement Holdings Ltd and Poseidon Ltd is studying the feasibility of tapping known soda brine reserves in the Denison Trough (Qld). Reconnaissance exploration increased for silica and interest in bentonite and wollastonite continued in Queensland, and in South Australia there was significant interest in gypsum, silica, palygorskite, celestite, chlorite, wollastonite and andalusite.

A new gypsum producer, Southern Asiatic Engerprises, commenced production at Lake Cowan (WA). In South Australia tenure was obtained over ten gypsum deposits on Eyre Peninsula, in Riverland and in the mid-north of the state. A feasibility study of the large Streaky Bay (SA) deposit is well advanced.

Queensland Alumina Ltd has opened a new market for magnesite. Trials using magnesite from Myrtle Springs (SA) have been carried out and the new market could require 50 000 t/yr.

Westralian Sands are carrying out feasibility studies on a major investment in a large synthetic rutile (beneficiated ilmenite) plant. Overseas companies have expressed interest in participating in the development of high technology processes at the Allied Eneabba monazite plant for the purpose of recovering rare earth oxides. Pacific Mining Ltd has signed a 'Heads of Agreement' with Japanese interests to develop a silica sands deposit at Shellbourne Bay (Qld). Large glass sand deposits have been proved at Mount Compass (SA).

Comalco has released plans for a 100 000 t/yr kaolin plant at Weipa (Qld). Two companies are carrying out parallel studies on the feasibility of producing synthetic mullite and fluorine by-products from silexite at Torrington (NSW).

In Queensland and New South Wales the upturn for construction materials evident in the final quarter of 1983 continued throughout 1984. In New South Wales, the increase in road works has been accompanied by a significant shift towards concrete pavements. This has placed increased demand on first quality stone. A significant development in the Brisbane area has been the use of quartzite (metachert), previously considered unsuitable because of potential alkali reactivity and excessive clay, for high strength concrete aggregate.

The State Geological Surveys continue to be active in providing assistance to government bodies and industry. Western Australian projects included limestone assessment (State Forest 65), road base (Carnarvon, Newman-Port Hedland, Derby), borrow materials and site geology (Harding Dam, Pilbara), breakwater materials (Jurian, Fremantle, Point Piquet) and a resources information base and map (Perth). In Victoria, a reconnaissance survey of basalt for aggregate on the Werribee Plains is in progress. In the Melbourne region, a review of reserves of hard rock, sands and clay is being completed, and a computerised data base for extractive industry licence data is being prepared. Mineral and construction resources were assessed in the Shires of Tallaroop, Upper Murray and Tallangatta and for the Land Conservation Council study areas of East Gippsland, and Melbourne District No. 1. In Queensland, construction materials surveys were completed in the Dalby-Millmerran-Chinchilla, the North and Central Burnett, Gladstone and Townsville areas. Surveys in the Cairns and Goondiwindi districts are continuing. In South Australia, granite, calcrete and gneiss/dolerite were investigated for potential road resource sites on Eyre Peninsula, and quartzite quarries were mapped at Gladstone. Reviews were made of gypsum deposits, the vermiculite potential of phlogopite-bearing rocks, magnesite, flint and celestite.

The Parliament House Construction Authority is presently preparing contractural documents to procure dimension stone cladding for the new Parliament House, Canberra. The largest contract for 25 000 m^3 of Carmina Grey Granite, for exterior cladding, has commenced at Eugowra (NSW). Other dimension stone types proposed for internal walls, paving and columns are: Black Imperial Granite (Adelaide), Mundaring Granite (Perth), AM Brown Granite and EHC Grey Granite (NSW), Blue-Grey Basalt (Tumut, NSW) and a variety of marbles from NSW, Greece and Italy. The Geological Survey of Western Australia has published a booklet on the building and facing stones of Perth and Fremantle, and the Mineral Resources Branch of the Geological Survey of South Australia has a major commitment in 1985 to the documentation of South Australia's building and facing stone resources for publication in 1986.

Work by the the CSIRO Division of Building Research on the suitability of weathered microgranite for use in concrete for the Burdekin Falls (Qld) dam has been extended to study the behaviour of the moderately and slightly weathered rocks, and the influence of crusher fines on the properties of the concrete. An evaluation is also being made of the suitability of Western Australian aggregates for use in bridges in the Pilbara area.

Marine Geoscience

1984 marks the acquisition by Australia of its first research ship dedicated to marine geoscience. The ship, *Rig Seismic*, was chartered by the BMR using funds from its 1984 budget allocation. Current funding provides for six months' sea time per year.

The ship has a modified trawler hull 72.5 m long and 1560 t dead weight. It is ice strengthened and has a cruising range

of approximately 75 days. In addition to ample laboratory space and accommodation for up to 38 persons, its equipment includes a major seismic system with 2400 and 1200 m streamer cables each with up to 96 data channels, 3 airguns, 4 compressors, computer acquisition and display systems, a multi channel seismic system, sonobuoy capability, 2 proton precession magnetometers, 3.5 and 12 kHz echo sounders, 2 geological winches each with 10 km of wire rope and a satellite-sonar Doppler navigation system. *Rig Seismic* had its shakedown cruise in November. Its first scientific cruise is scheduled for early 1985.

The CSIRO oceanographic research ship, *Franklin*, of 55 m length and 1200 t displacement was under construction and scheduled to come into service in January 1985. Some geoscience research will be conducted by this vessel.

The Ocean Sciences Institute of the University of Sydney (Director: Gordon Packham) completed its first full year of operations with a budget of $400 000 (including $127 000 from MST grants).

The Marine Sciences and Technologies Grants Scheme provided $628 570 in 1983-84 for Australian continental shelf and margin studies, this amount being 16.7% of the total MST grants. Three-quarters of the money went to projects on the Great Barrier Reef.

The second cruise under the Australian-Japan Scientific Cooperation Agreement took place in the northern Tonga Ridge and Lau Basin in November. Australian scientists participated in a USGS cruise in Antarctica, and a PNG Geological Survey cruise in the western Woodlark Basin.

Australia has continued to support CCOP/SOPAC, which is now an independent intergovernmental body representing SW Pacific Island countries. Final cruise reports for the Tripartite I cruises to Tonga, Fiji, Vanuatu and the Solomon Islands were published as a CCOP/SOPAC Technical Report. A dozen Australians, including two Co-chiefs, participated in the four petroleum-oriented RV *SP Lee* Tripartite II cruises in Tonga, Fiji, the Solomon Islands and Papua New Guinea in 1984. The National Coordinating Committee for Marine Geoscience Programs planned participation by Australians in 1985 Tripartite II cruises.

The Consortium for Ocean Geosciences of the Australian universities (COGS) arranged for Australian observers to attend the January and September 1984 meetings of the Ocean Drilling Program Planning Committee. In October, the Australian Government received an invitation from the European Science Foundation (representing Italy, Switzerland, the Netherlands, Norway and Sweden) inviting Australia to join ESF as a consortium member of the Ocean Drilling Program. This invitation was under consideration at the end of the year.

Mineralogy and crystallography

Emphasis in mineralogical research in 1984 continued to be placed on mineral assemblages associated with soils, weathering profiles, laterites and gossans—all surface or near-surface features covering much of the Australian continent, and hosting, or pointing to, many of our valuable ore deposits.

Geochemical, x-ray and electron microscopic studies of the progressive mineralogical changes in the weathering profiles of granites and basalts (from different parent rocks or from different climatic zones) have given remarkably detailed documentation of these processes, and their controlling factors. In addition, combined microbeam, x-ray and light studies of the mobility of an important chemical marker group, the rare earth elements, provided documentation of the mineral phases capable of fixing these elements during stages in the weathering process. A detailed study of gold mobilisation during weathering has been made in the field, and experimentally.

Investigations of the chemistry and mineralogy of laterites, with emphasis on exploration potential has continued. A large geochemical database has been built up. Experiments on Al solubility in CO_2^- saturated waters demonstrated a mechanism for forming allophane-like substances making up some hardpans.

Studies of platinum-group minerals in WA nickel deposits has linked sperrylite with Cu-rich massive sulphide ore and sudburyite with stringer sulphide and hydrothermal vein deposits. Application of computer techniques to all aspects of crystallographic studies, and to a mineral database, enables efficient identification and documentation of new or rare species. A new mineral, jeppeite, has been found in the WA lamproites, and research is continuing into these rocks, together with studies on their 'heavy mineral' indicators.

The composition of the mineral pumpellyite is providing an indicator of hydrothermal processes in the Hamersley Basin. A new model for the origin of BIF-hosted iron ores has been developed and a book published, entitled *Banded iron-formation: facts and problems*. A practical mineralogical result was the identification of fine-grained pyrite-graphitic intergrowths as the cause of fires in the Pilbara iron mines.

Experimental mineral studies have centred on biotite phase equilibria and on the composition of rare-earth enriched Ti-minerals such as sphene, chevkinite and davidite. Studies of the deformational characteristics and defect chemistry of important minerals (e.g. quartz, 'ice') and the structure and properties of mineral boundaries in rocks have utilised the transmission electron microscope, and controlled experimental and chemical conditions.

New mineralogical techniques developed during 1984 include the application of the Raman microprobe to the study of fluid inclusions in minerals, and solid state nuclear magnetic resonance to intercalated clay minerals and organic matter. The development of the powerful PIXE microprobe technique, capable of analysing elements present in trace amounts in mineral grains has continued.

Mineral Resource Classification and Estimation

During the year BMR published a revised version of the system it uses for the general classification of mineral resources and the Standing Committee on Coalfield Geology of New South Wales ratified the fifth edition of their *Code for Calculating Coal Resources and Reserves.*

The BMR system of resource classification is a refined version of the system adopted in 1975 for use in the presentation of regional and national assessments of petroleum and mineral resources. It is based on the McKelvey system as adopted by the US Bureau of Mines and US Geological Survey in the early 1970s. BMR has made some minor changes to the definitions of terms it used previously and has decided to avoid completely the use of the term 'reserves' because of the various different meanings given to that term in the many different resource classification systems currently in use. The

revision incorporates guidelines to facilitate consistent interpretation and application of the definitions and illustrates the relationship between the BMR system and some of the other resource classification systems in common use.

The fifth edition of the *Code for Calculating Coal Resources and Reserves* introduces a distinction between 'resources' and 'reserves' into coal resource assessment in New South Wales. Resources refer to all of the *in situ* coal which may have the potential for use; various categories indicate the level of geological confidence of the assessment. Reserves apply to those resources that are planned to be exploited, the tonnage that will be recovered, and the tonnage that will be marketable.

In 1984 the Australian Minerals and Energy Council requested the State and Commonwealth Government Geologists to formulate a national code for coal resource assessment. A committee established by the Government Geologists' Conference has prepared a draft code which has been circulated to relevant bodies throughout Australia for comment on its suitability.

Ore Deposit Geology

Gold exploration continued to be the dominant activity in economic geology during 1984. In the Eastern Goldfields of Western Australia the Paddington, Porphyry and Harbour Lights prospects moved towards production, and there was continued exploration throughout the state. As well as numerous small discoveries, high-grade deposits were located at Powell's Find, together with a potentially significant deposit at Mount Pleasant, northwest of Kalgoorlie. At Boddington, south of Perth, the Worsley bauxite partners are preparing for probable gold production from concentrations in bauxite and laterite overlying pyrite-bearing metasediments, felsic volcanics and basic rocks in a greenstone belt.

The Late Palaeozoic Kidston breccia pipe in north Queensland became an operating mine, and will rank as Australia's largest gold mine, producing 84 000 kg of gold annually from reserves of 44 Mt at 18 g/t. Feasibility studies continued at Red Dome, near Mungana, and increased reserves were found at Starra, near Selwyn, where the gold-bearing ironstones may be of metasomatic hydrothermal rather than sedimentary origin. Gold-bearing Proterozoic clastic sediments were explored in the Westmoreland region of northwestern Queensland, and reserves at the Mount Leyshon breccia pipe near Charters Towers are now put at 7 Mt at 2 g/t Au.

Discovery of potentially economic gold mineralisation at Temora, NSW, stimulated gold exploration throughout the Siluro-Devonian arc-trough complexes. The Temora (Gidginbung) mineralisation is hosted by altered andesites extensively replaced by chalcedonic silica. The deposit can be worked by open cut methods and contains probable oxide zone ore reserves of 5.6 Mt, with 2.5 g/t Au, and 7 g/t Ag. Interest continued in the potential of the Woods Point–Walhalla dyke swarm in Victoria, and gold production was accelerated at the newly developed Stawell mine.

A zone of relatively high-grade and large tonnage gold-bearing ore (100 Mt, 4 g/t Au) was defined at Olympic Dam, SA; gold exploration and possible development continued in the Pine Creek area of the Northern Territory; and deep fault/vein gold deposits were under investigation at Beaconsfield, Tasmania.

Base metal discoveries of world significance were announced from Hellyer in Tasmania and Mount Isa in Queensland. At Hellyer, near Que River, a +12 Mt volcanogenic massive sulphide deposit was located at a depth of 125 m following a program of advanced EM and geochemistry. Grades of 21% combined lead-zinc, 180 g/t Ag and 2.5 g/t Au have been encountered. At Mount Isa, extensions of the Hilton Pb–Zn ore zone, 300 m thick and extending for 3.5 km along strike at depths from 300 to 1000 m, have doubled existing reserves.

Opportunities for diamond exploration continued to expand as evidence accumulated for the presence of old stable crust (?2400 Ma) in the Tennant Creek, Georgetown and possibly Mount Isa Inliers. Diamonds were located in black soil areas near Brunette Downs—Coanjula Creek, using aeromagnetic techniques to define possible kimberlites, some of which may be represented by Clusters of up to 40 magnetic anomalies.

Exploration was also directed at platinum group elements and rare earths, and non-metallics, including large soda ash resources in the Denison Trough, Queensland. Tin-tungsten exploration remained depressed. Significant resources of heavy mineral sands (possibly 1818 Mt of sand averaging 5.9% heavy minerals) were located in the King Sound estuary near Derby, Western Australia.

Research at the CSIRO Division of Mineralogy and Geochemistry focused on the solution, transport and redeposition of gold in the lateritic environment, and BMR, in collaboration with universities, surveys and CSIRO, commenced studies on the origin and distribution of various mineral deposit types in space and time.

Important examples of ore discovery case histories were amongst numerous research papers on ore deposits presented at the 7th Australian Geological Convention in Sydney.

Palaeontology

Getting fossils out of rocks has always been a problem in palaeontology, so a new technique developed by H. T. Zapasnik & P. A. Johnston of the Australian National University promises to be of great importance. Their method (*Science* 224, p. 1382) is to dissolve the carbonate or phosphate skeletons in acid, to fill the cavities with plastic, and to extract the plastic replicas of the fossils by dissolving the matrix in hydrofluoric acid. Although this method may be used to extract large fossils from clastic and pyroclastic sediments, it is particularly useful for obtaining microfossils from indurated non-carbonate rocks. The plastic replicas faithfully reproduce fine structures such as the microstructure of echinoderm plates and are therefore suitable for study by scanning electron microscopy. Some obvious applications of the technique are the extraction of complex skeletons (e.g. whole echindoderms), the extraction of microfossils from tectonised rocks, and the extraction of small and rare elements from well-studied localities.

Zapasnik & Johnston's technique may be particularly applicable to a problem addressed in a theoretical way by P. J. Cook & J. H. Shergold of the Bureau of Mineral Resources (*Nature* 308, p. 231). Cook & Shergold have suggested that the sudden appearance of many different kinds of organisms with mineral skeletons at the beginning of the Cambrian may be related to a major period of phosphogenesis which occurred at that time. In their model, oceanic overturn at the end of the Proterozoic resulted in abnormally high concentrations of phosphate in the surface waters. Much of the phosphate was withdrawn by newly-evolved organisms that formed phosphate skeletons and

deposited in shallow-water sediments in the tropical and subtropical parts of the Cambrian Earth. As the concentration of phosphate in oceanic waters dropped, animals with phosphate skeletons were gradually replaced by those using calcium carbonates as skeletal materials. A secondary effect of the high concentration of phosphate in the Early Cambrian oceans may have been a significant increase in the abundance of phytoplankton and hence increased amounts of oxygen in the atmosphere and hydrosphere.

The fossil biota of the Early Cambrian is poorly understood, partly because many of the fossils are very small and of uncertain affinities. It may therefore be possible to test Cook & Shergold's hypothesis with the help of Zapasnik & Johnston's technique; there are already studies in progress which are attempting to document the information available from phosphatic microfossils from Early Cambrian strata in southern and central Australia. An important biostratigraphic framework for this work has been provided by the recent publication of D. I. Gravestock's monograph on early Cambrian Archaeocyatha from South Australia (*Memoirs of the Association of Australasian Palaeontologists* 2).

These examples demonstrate the necessary interplay of new methods, ideas and classical taxonomic palaeontology in the development of palaeontology in Australia. During 1984, a large amount of new information from Australia was published in *Alcheringa* and other international journals. Some highlights include M. Wade's description of an ichthyosaur from the Australian Cretaceous (*Lethaia* 17, p. 99), G. Playford & F. Martin's work on superbly preserved acritarchs from the Canning Basin (*Alcheringa* 8, p. 187), M. Wade & R. A. Thulborn's analysis of the now-famous dinosaur trackways of western Queensland (*Memoirs of the Queensland Museum* 21, p. 413) and M. O. Woodburne & J. A. Case's descriptions of Miocene potorine marsupials (*Journal of Paleontology* 58, p. 1062, 1074). A complete report of palaeontological activities in Australia appears in the annual newsletter of the Association of Australasian Palaeontologists (*Nomen Nudum* 13).

Petrology

The abstracts of the Seventh Australian Geological Convention, 1984, provide a resumé of current research in this area.

High-pressure experimental studies on island arc andesites and silicic volcanic rocks allowed closer modelling of the petrogenesis of these rock types, especially when linked with the new geochemical and petrological data obtained from Indonesia, New Guinea, Solomon Islands and neighbouring ocean-floor regions. Results obtained for the partitioning of rare earth elements between pyroxene, amphibole and silicate liquid as a function of compositional and physical parameters contributed to geochemical modelling of petrological processes. Field and geochemical studies have been carried out on major silicic volcanic provinces in Victoria and NSW, and on basaltic rocks from Kenya, Victoria and Antarctica. Work on a world database for the chemistry of volcanic rocks has continued.

Attention has been given to the petrology of layered mafic suites in WA and the Sydney Basin, with emphasis on the mechanism of differentiation and on economic mineralisation. Links between the production of basalt magmas from the mantle, sulphur saturation, sulphide immiscibility and the genesis of hydrothermal ore deposits has been investigated through the study of platinum group element distributions in a variety of basic volcanic and intrusive rocks. This provides a model for assessing the potential platinum mineralisation in layered intrusions.

Petrological studies on granites have focused on the geochemistry and microstructure of Archaean to Mesozoic granitoids from Australia and western USA, with special attention to pyroxene and sphene-bearing types, and to magma mixing and mingling. The role of fluids in the late-stage evolution of granitic magmas, and the development of Sn–W ore bodies was a further development of the granite work.

The solubility of volatiles in magma at high pressure has been studied experimentally by application of FTIRS (Fourier Transform Infrared Spectroscopy), enabling interpretation of the potential role of volatile components in the mantle source regions for basalts and diamond-bearing kimberlitic rocks. The petrology of the mantle and crust beneath eastern Australia has been documented through the detailed study of granulitic xenoliths from basalts in this region. Application of geothermobarometry has enabled a geotherm to be determined, and linked with available geophysical and experimental data to produce a petrological model for the lower crust/upper mantle boundary beneath eastern Australia.

Theoretical, experimental, mineralogical and field studies of granulites from Antarctica and Australia have delineated their conditions of formation and their relationships to nearby mobile zones. Development and application of mineral geothermometers and geobarometers, and consideration of the nature of melting reactions and metasomatism has been a central part of the studies of high-grade metamorphic rocks.

Petroleum Geology

The Australian petroleum industry achieved a record drilling year in 1984 with 246 exploration and appraisal wells (204 onshore and 43 offshore) being completed by year's end. This eclipsed the previous record of 230 wells set in 1982 and resulted in 42 oil, 48 gas and 5 oil and gas finds onshore as well as 7 oil and 4 oil and gas finds offshore for a total of 106 discoveries.

Offshore, most activity was again centred in the Gippsland, Carnarvon, Browse and Bonaparte Basins. Some of Australia's other relatively unexplored offshore basins also received attention with interesting wells being drilled in the Arafura, Carpentaria, Perth, Canning, Bass and Otway Basins.

In the Gippsland Basin, Shell made an oil and gas discovery early in the year with Manta-1. Esso followed with oil discoveries in Tuna-4 and Wirrah-3. South Pepper-4 and Lenita-1 both found oil and gas in the Carnarvon Basin close to Barrow Island, while appraisal drilling on the Harriet Field was also successful. The Talisman-1 oil discovery in the northern part of the Carnarvon Basin was perhaps the year's highlight although BHP made another potentially major oil and gas discovery in the Browse Basin with Challis-1. However, these successes were tempered by disappointment at Jabiru where three stepout wells were dry, a dry hole on the highly regarded Eclipse structure also in the Browse Basin, and disappointing test results from the promising Turtle-1 well in the Bonaparte Basin.

The continued success of drilling in the Cooper and Eromanga Basins dominated onshore activity. The success rate in these basins averaged 73% in 1984 compared to a

combined success rate in all other onshore basins of only 14%. Exploration in the Cooper and Eromanga Basins was encouraged by the completion of the liquids pipeline linking Moomba and Port Bonython in South Australia and the Jackson oil field with the Moonie to Brisbane pipeline in Queensland. Most excitement was generated by significant oil discoveries at Tintaburra-1, Bodalla South-1, Pepita-1, Big Lake-36, Gidgealpa-17 and Wancoocha-2.

Several small gas discoveries were made in the Surat and Bowen Basins, with only one small oil discovery in Bellbird-1 in the Surat Basin. Drilling in the Canning Basin was very disappointing with only Pictor-1 a discovery, testing gas with a small quantity of oil. Interest in rank wildcat areas such as the onshore Bonaparte, Drummond, Clarence-Moreton and Murray Basins was also revived with drilling taking place in some of these basins during 1984.

Selected sedimentary basins where significant activities took place during 1984 warrant a more detailed review of exploration.

Browse and Bonaparte Basins

Renewed interest in the offshore Browse and Bonaparte Basins was kindled in 1983 following BHP Petroleum's Jabiru-1A oil discovery. Analysts predicted that the field could contain oil reserves of up to 500 M barrels, but stepout wells, Jabiru-2, 3 and 4, drilled in 1984 were disappointing. Estimated recoverable reserves are now put at between 35 to 40 M barrels. Pollard-1 and Eclipse-1 also drilled by BHP were dry, but 20 km south of Jabiru a potentially large oil discovery in Lower Jurassic sandstones was made at Challis-1.

In the neighbouring Bonaparte Basin to the east, Western Mining's Turtle-1 well encountered oil in the Permo-Carboniferous Kulshill Formation but only small, non-commercial quantities were recovered from drillstem tests.

Carnarvon Basin

Appraisal wells were drilled on two of the five small oil finds discovered previously in the shallow water around Barrow Island. Only the third of three stepout wells from the South Pepper-1 discovery was productive, the others being dry. Appraisal of the Harriet-1 discovery was more successful and the first commercial oil production from offshore Western Australia is expected to flow from this field early in 1986. A new oil and gas discovery was made in Lenita-1 close to the Harriet field, but most interest was focused on the Talisman-1 oil discovery in the northern part of the Carnarvon Basin or Dampier Sub-Basin. Talisman-1 tested three separate zones covering a gross pay of over 35 m achieving a cumulative flow of 11 300 barrels of oil per day. It is thought that these excellent reservoir sands are of Early Cretaceous (Neocomian) or Late Jurassic (Tithonian) age. Recoverable oil reserves have been put at between 40 and 100 M barrels. Talisman-1 represents a major breakthrough in oil exploration in the Dampier Sub-Basin and potential for further oil discoveries must be rated as high.

Canning Basin

The Canning Basin was again the focus of considerable exploration activity with the drilling of 31 exploration wells. However Pictor-1 was the only success producing 62 260 m^3 (2.2 M cubic feet) per day of gas with 24 barrels of oil from the Nita Formation. The result is most encouraging for the southern Canning Basin where in the past oil shows encountered in the Nita Formation have not flowed to the surface because of poor reservoir quality.

Cooper and Eromanga Basins

Discoveries during the year considerably increased the geographic extent and stratigraphic range of known hydrocarbon occurrences in this region. Tintaburra-1 and Bodalla South-1 were important oil discoveries located significantly to the east of previous finds, upgrading the potential of a significantly larger area of the Eromanga Basin to yield oil. First, Tintaburra-1, then Bodalla South-1 broke the onshore record for the largest cumulative oil flow from production testing. However the record was broken yet again late in the year when Wancoocha-2, located 45 km south of Moomba, flowed oil in excess of 8700 barrels per day. Oil was tested from the Namur, Birkhead, Hutton and Patchawarra Formations. Not only was this the first oil discovery in this part of the basin, but it was the best oil flow from the Patchawarra Formation yet achieved anywhere in the Cooper Basin.

Gippsland Basin

The Gippsland Basin continues to be Australia's main commercial oil producer, accounting for about 90% of total Australian oil production of 420 000 barrels per day. Exploration continued in the region with eleven exploration and appraisal wells being drilled in 1984. Emphasis has now shifted from locating reservoirs at the top of the Latrobe Group to finding deeper intra-Latrobe Group sandstone reservoirs. Significant discoveries in Manta-1, Tuna-4 and Wirrah-3 during the year have confirmed the prospectivity of these deeper reservoirs and provided encouragement for further exploration.

Remote Sensing

A review of Remote Sensing in the geoscience activities first appeared in the 1983 Australian Geoscience Review. The closing paragraph of that review pointed out that the future of satellite remote sensing in Australia was dependent on the Federal Government's providing funds to upgrade the Australian Landsat Station (ALS) to receive X-band transmission. All future earth resources satellites will utilise X-band frequencies. Landsat-4, the first operational satellite using X-band transmission and carrying the Thematic Mapper (TM), was launched in July 1982 but failed after 7 months operation. Landsat 5 was launched in March 1984 as a replacement. The TM data from those satellites have been shown to be of considerable potential to geoscience; unfortunately, owing to the lack of an onboard recording capability on the spacecraft, and of adequate ground reception facilities, no satellite TM data have been recorded over Australia to date.

In March 1984 responsibility for the ALS was transferred from the Department of Science and Technology to the Division of National Mapping within the Department of Resources and Energy. Continued pressure was directed at the Federal Government, particularly by INDUSAT and CSIRO, to upgrade the ALS facility. Emphasis was directed at the need for the Government to formulate a National Remote Sensing Policy. This is seen as a necessary pre-requisite to providing a suitable framework within which upgrading of the ALS, and other future space-related activities of benefit to the nation, can be maintained.

Both the Landsat 4 and currently operating Landsat 5 carry the conventional multispectral scanners (MSS) and the ALS has continued to receive that data. There has been continuing demand by the geoscience community for Landsat products, and the disciplines of geology (primarily mineral exploration)

and geography combined accounted for 52% of product sales from the ALS during 1983/84.

BMR remote sensing research into the regolith and weathered materials was expanded beyond Landsat to include evaluation of data from the NOAA Advanced Very High Resolution (AVHRR) satellite scanner, and the Nimbus Coastal Zone Colour Scanner (CZCS). Though designed for ocean water scanning the CZCS is proving of considerable value for differentiating and mapping onshore surficial materials especially on a small scale (one CZCS scene covers an area equivalent to about 70 Landsat scenes).

During 1984 there was increased interest in aircraft scanner research and applications, particularly for mineral exploration. CSIRO's Division of Mineral Physics continued their airborne research into spectral responses of rocks and minerals and development of sensing systems. CSIRO also announced the establishment of the CSIRO Research Aircraft Facility which makes their F27 Fokker Friendship aircraft available as a remote sensing instrument platform for universities and research groups throughout Australia. Hunting Geology and Geophysics Ltd flew mineral exploration oriented surveys in Australia with their British-based eleven-channel Daedalus AADS 1268 multispectral scanner. The National Safety Council of Australia (Victorian Division) made its aircraft and two eleven-channel Daedalus (DS1260 and DS1268 TM) multispectral scanners available for contract survey operations during the non bush fire season. Carr Boyd Minerals Ltd launched their new Perth-based remote sensing survey company (Geoscan Pty Ltd) operating their Carr Boyd/CSIRO designed and developed fifteen-channel multispectral scanner. During 1984 Geoscan flew some 10 000 km^2 of test data in preparation for commencement of commercial operations early in 1985.

In response to a worldwide call in 1983 for scientific involvement in the space shuttle radar project (SIR-B), 44 international proposals, including three from Australia, were accepted by NASA. The Australian proposals were from CSIRO/BMR, University of New South Wales, and the Defence Research Centre. Only twice before had radar systems been flown in space; on Seasat in 1978 and SIR-A on the shuttle in 1981. The third mission SIR-B was the first space radar system to have digital recording capability, and was conducted during the shuttle mission from 5-13 October 1984. Owing to technical difficulties less than half of the planned radar imaging was acquired. Both the joint CSIRO/BMR, and the University of New South Wales proposals involve geological investigations of space radar capabilities, and will commence with receipt of the SIR-B data during 1985.

The Third Australasian Remote Sensing Conference, Landsat 84, was held at the Gold Coast, Queensland 21-25 May 1984 and attracted 430 participants; 10% represented geoscience interests.

In 1984 the Australian Mineral Foundation attempted to introduce a new course on advanced remote sensing. The course, to be conducted by two of the leading researchers in geological remote sensing in the USA was undersubscribed and has been re-scheduled for November 1985.

Soil Science

In 1984 renewed and perhaps long overdue attention has been focused on conserving Australia's soil resources. Considerable impetus in promoting soil conservation occurred with the initiation of the National Soil Conservation Program (NSCP) by the Labor Government after it took office in March 1983. Since January 1984, several soil conservationists from various State Departments have been seconded to the Commonwealth Department of Primary Industry in Canberra to develop the NSCP Program.

Initially $1 M was made available to State and Commonwealth authorities, including academic institutions, for new initiatives in soil conservation, including research. Then, in the 1984 budget, this allocation was increased to $4 M, $3.3 M of which was dispersed directly to State agencies to support conservation works, and a further $0.58 M to academic institutions and CSIRO. Consequently, most of the funds are going to specific State conservation or reclamation works. It is to be hoped that these initiatives will continue to redress the past and present degradation of Australia's soil resource.

The growing commitment to conservation was evidenced by the widespread and well represented attendance at a conference sponsored by the Australian National University on the topic of 'Soil Degradation: The Future of Our Land?' The outstanding achievement of this conference was the degree of consensus reached between delegates from extremely diverse backgrounds, which included primary production, State land agencies, Commonwealth organisations, academic institutions and a number of conservationist organisations. The proceedings of the conference and recommendations for actions needed to combat land degradation are to be published through the University Centre for Continuing Education.

Soil salinisation is a major degradation problem and is now receiving considerable attention from soil scientists throughout Australia. A major study of salinity in Victoria was commissioned by the Victorian Parliamentary Joint Select Committee on Salinity. The findings are set out in a series of public documents culminating in the Third Report to Parliament, October 1984, entitled *Salt of the Earth: Final Report on the Causes, Effects and Control of Land and River Salinity in Victoria.*

Dryland soil salinisation occurs as a result of excessive clearing of native vegetation bringing changes in landscape hydrology. Salt is mobilised in percolating groundwaters and concentrated in soils at locations where water tables rise close to the surface. Similarly, in irrigation areas soils may be salated out by rising saline ground waters or by the addition of salts in poor quality irrigation waters.

A new approach for detecting incipient salinisation has been developed using remote sensing equipment operated from light aircraft. The spectral characteristics of salt affected soils are being investigated using multi-spectral scanning techniques. Commercial application of this method in WA is planned in the near future. Another method of detecting high salt concentrations in soils and substrata as deep as 15 m is electro-magnetic induction. This technique has been used to survey areas at risk from salinisation and is now sufficiently proven to allow its adoption as a commercial survey technique.

A feature of soils research in Australia is the growing cooperation and coordination between the agricultural industry, academic institutions and State and Commonwealth authorities. Concerted efforts are being made to research new tillage and crop production techniques in almost every State. In eastern Australia, the focus is particularly on the vast areas of clay and duplex soils where intensification of cropping of both irrigated and rainfed areas has sparked renewed

interest in their management. In WA the emphasis is on the sandier soils. In all cases the fragility of the soils to traditional farming techniques is becoming increasingly apparent, as degradation by erosion, structural breakdown, loss of organic matter, salinity, accumulation of herbicide residues, increasing acidity and water-logging is documented. Detailed understanding of the processes involved is leading to new systems of management, designed to give high productivity while maintaining the soil resource.

Soil science is involved in operations at the Ranger Uranium development in the Northern Territory. Tailings produced from the uranium mill contain radionuclides and metals which if sufficiently concentrated, could be toxic to biota if dispersed in regional drainage waters. The Office of the Supervising Scientist for the Alligator Rivers Region is investigating storage of the tailings to avoid release into Magela Creek. Storage is needed for several thousand years to render the radionuclides safe, but such storage is unlikely to avoid a possible accidental failure of the tailings dam. Therefore, there must be some prediction of the fate of the tailings in the Magela Creek system. Because it is difficult to directly and accurately monitor deposition on floodplains and in billabongs, scientists have adopted a stratigraphic approach to the problem. Late Holocene rates of deposition are being estimated using ^{14}C, ^{137}Cs and ^{210}Pb. Environments at times of deposition are being reconstructed using pollen and sedimentary facies analysis, and the diagenetic fate of metals is being investigated pedologically in the field and experimentally in the laboratory. The past history of the floodplains is then used to predict future deposition rates and sites of pollutants.

Solid-earth geophysics

Earthquake seismology

Over 70 permanent seismographs operated on the Australian continent during 1984 under the auspices of the Australian National University (Research School of Earth Sciences), BMR, Department of Works WA, Phillip Institute of Technology, Geological Survey of Queensland, Riverview College, and the Universities of Adelaide, Queensland and Tasmania. The level of seismicity during 1984 in Australia was comparatively low, but in the Dalton-Gunning region near Canberra there was an upsurge of earthquake activity during the second half of the year, the largest earthquake in this series causing strong ground motion with an acceleration as high as 0.3 g. In Queensland, an earthquake near Murgon in October 1984 was sufficiently large to be felt over about 50 000 km^2, but no damage was reported.

Research on earthquake focal mechanisms, deep structure of the Earth, seismic anisotropy, and stress in the lithosphere was carried out at ANU (RSES) and BMR.

In the 1984 Budget the Government announced the establishment of a centre at BMR to monitor underground nuclear explosions and to provide Australia with an independent capacity to detect and identify nuclear explosions. It also approved the establishment of an International Data Centre to receive information from seismic stations in Australia and elsewhere in the world to locate earthquakes and explosions on a global basis.

Explosion seismology

Most research on explosion seismology in Australia is carried at BMR. A four year field program to determine the structural framework and depositional history of the Eromanga Basin and underlying Cooper, Galillee and Adavale Basins was completed in 1984. This program included long-range refraction shooting and deep (~20 s) CDP reflection shooting. The field work incorporated one of the longest continuous deep CDP traverses ever recorded. It extended for 1200 km from western Queensland to near the coast at a latitude of 27°30'S.

Refraction studies were carried out in the New England Fold Belt (NSW) and the Yilgarn Block (WA), and there was continued analysis of deep reflections from elsewhere on the Australian continent.

Geomagnetism

Permanent geomagnetic observatories operated at BMR (Canberra), Charters Towers (Qld), Gnangara (WA), Toolangi (Vic.), Macquarie Island and Mawson (Antarctica), and steps were taken to commission a new observatory at Learmonth (WA).Isogonal charts of the Earth's magnetic field for the epoch 1980.0 were produced in 1984 and all the data for the 1985.0 charts have now been collected.

At BMR, research is being carried out on the properties of the Earth's magnetic field and its generation, and at Flinders and the Australian National Universities and the University of Tasmania research is underway on ways to use the Earth's magnetic field to determine deep conductivity structure.

Palaeomagnetism

Palaeomagnetic research is carried out at ANU (RSES), BMR, CSIRO Division of Mineral Physics and Flinders University. The two main palaeomagnetic laboratories are in Canberra and Sydney. The groups involved with this work are undertaking many problems but considerable effort has been put into studies of Proterozoic basins, Proterozoic dykes in Antarctica, the Lachlan and New England Fold Belts, the Sydney Basin, Tertiary polar wander curves, weathered profiles, and Tertiary geodynamics of the Australian region.

Physical properties of the Earth's interior

Most research on the physical properties of the Earth's interior, such as the rheology of the lithosphere, internal dynamics, petrophysics, and geophysical fluid dynamics are undertaken at the ANU's Research School of Earth Sciences. Extensive use is made of specially constructed apparatuses to measure the physical and chemical properties of rocks at high temperatures and pressures. Theoretical studies on thermodynamic problems of the Earth are carried out at the University of Queensland.

Stratigraphy and Sedimentology

The area of marine geoscience has shown a dramatic growth in the past year. Perhaps the most important element in this growth has been the acquisition by BMR of the *Rig Seismic*, undoubtedly one of the finest geoscience research vessels in the world. A major investigation of the Australian continental margin and other areas will be undertaken by BMR's Division of Marine Geoscience, with the first major cruise of 1985 being to the Kerguelen Plateau. Marine research by various universities and other organisations continued during the year in the South Pacific region under the aegis of the Tripartite Agreement.

Nearshore work was undertaken by universities, the Geological Survey of South Australia and the BMR-CSIRO Baas Becking Laboratory in the South Australian gulfs. On the Great Barrier Reef, areas of study included the

sedimentology of reefs affected by crown-of-thorns starfish, the effects of European settlement on rates of erosion, and the sea-level history of the reef. The equipping of the *James Kirby* with a side scan sonar and 3.5 KHz profiling gear was an important step in a continuing marine program in north Queensland waters by James Cook University. Reef and nearshore studies continued at AIMS with a highlight being the acquisition of long cores through corals; these are providing an opportunity to extend climatic records for the region back many hundreds of years through analysis of the coral banding patterns. Modern sediment studies continued in Victoria with the geological survey carrying out studies in Lake Wellington, Corner Inlet and along the western Victorian coast, and the University of Melbourne on Recent sediments in Bass Strait. Research at Shark Bay, Lake Mcleod and other coastal environments in Western Australia is providing new insights into the workings of coastal and evaporitic systems. The Geological Survey of Queensland is endeavouring to develop conceptual geological models of coastal and shallow marine sedimentation by sedimentary, seismic, lithostratigraphic and chronostratigraphic investigations in nearshore waters. This work is contributing towards basic research and is also relevant to coastal management, coastal engineering problems, and to the development of marine resource inventories.

Onshore, recent oil discoveries in the Eromanga Basin have been responsible for an upsurge of activity, with research programs being undertaken by the Geological Surveys of Queensland and South Australia, BMR, and Monash and James Cook Universities. An IGCP project has focused attention on the Cretaceous of Australia, and several universities are pursuing active research programs, particularly in the southern half of the continent. A palaeogeographic project by BMR's Division of Continental Geology in conjunction with industry (through AMIRA) is providing a major new compilation of the Phanerozoic history of Australia. Other joint BMR and State survey projects are concerned with the McArthur, Amadeus, Clarence-Moreton and Lake Eyre Basins. The commissioning of major new facilities in organic geochemistry by BMR will provide an important new dimension to these studies. State geological surveys are also undertaking projects in a number of sedimentary basins including the Carnarvon, Canning, Bonaparte and Collie Basins in Western Australia; the Officer Basin, the Adelaide Geosyncline and the Stuart Shelf in South Australia; the Otway Basin (SA and Vic.), the Gippsland Basin in Victoria; and the Surat, Cooper, Adavale, Hodgkinson, Bundock and Clarke River Basins and the Broken River Embayment in Queensland. A considerable amount of effort continues to be expended by the State Geological surveys in the Tasman Fold Belt. Major studies of the fold belt were continued by a number of universities, notably Monash, through work on volcanogenic sediments and on the palaeogeography of the Lachlan Fold Belt, James Cook University through its work in the Mount Windsor area, and Macquarie University and ANU through the development of broad tectonic models for the fold belt. Detailed work on the New England Fold Belt is continuing at the Universities of New South Wales, Newcastle, New England and Sydney.

Studies of coal basins were also undertaken by a number of universities and geological surveys. The Bowen Basin continued to receive significant attention, and work continued in the Taroom, Callide and Sydney Basins. The new fission track technique developed by the University of Melbourne for unravelling the thermal history of a basin has been applied to these and other basins. Late Cainozoic basins continued to attract attention, and a study of Lake George showed that the lake system extended back into the Miocene.

The drilling phase of the ANU SLEADS Project on Salt Lakes Evaporites and Aeolian Deposits was successfully concluded during the year. Studies of the regolith are underway in several areas including detailed investigations of silcrete, ferricretes and calcretes jointly by SAMDE and the CSIRO Division of Soils. The Geological Survey of Queensland is undertaking broadscale regolith studies in various parts of the State. Queensland Institute of Technology is also involved in silcrete research. BMR (Continental Geology) is compiling a 1:2 500 000 regolith map of the continent using a range of techniques including remote sensing.

The sedimentological community continued to lobby for Australian involvement in the Ocean Drilling Project. Detailed planning is continued for the 1986 International Sedimentological Congress which Australia will be hosting in Canberra.

Structural Geology and Tectonics

Much of the research being undertaken in structural geology and tectonics within Australia was highlighted at an international conference on 'Multiple Deformation and Foliation Development' held at Bermagui, NSW, in February, 1983. All abstracts for this conference are listed in *Newsletter No. 9 of the Specialist Group in Tectonics and Structural Geology.*

Major structural and tectonic research is being undertaken by the universities, CSIRO, BMR and State geological surveys. Tectonics and regional geology includes work in Timor and Papua-New Guinea, on the Precambrian in the Harts Range, NT, Antarctica and the Pilbara, WA. Granite evolution in the Pilbara and Arunta Complexes is also being studied. Continuing research on the Tasman orogen by numerous workers is leading to a better understanding of its evolution, and the production of a tectonic map for the 1988 Bicentenary Year. Work in the Arunta Complex and associated Ngalia and Amadeus Basins has provided more insight into the development of intra-cratonic orogens.

Another important area of active research involves general aspects of the deformation environment of ore bodies and problems of fluid-rock interaction. Specific projects relate to copper mineralisation at Mount Isa; gold mineralisation at Wattle Gully, Victoria; Pine Creek, NT; and within the Yilgarn block, WA; uranium mineralisation in the Northern Territory, and mineralisation in the Cloncurry region, Qld.

Theoretical aspects of structural geology being investigated are computer-generated strain models for general rock deformation, the theory of rock fracture and associated instabilities, and dilatancy effects on the obliquity of *en echelon* fractures. Development of computer applications is also an important area of interest.

Experimental deformation of quartz sulphides, ice and rock analogues is providing information about rock/mineral rheology, crystal plasticity, deformation mechanisms, and the microstructure of naturally deformed rocks, minerals and metals. This work gives a framework to help understand the regional aspects of deformation, in particular the physiochemico conditions and mechanisms operative during crustal deformation. Experimental rock deformation is also

being undertaken to examine flow through stressed porous media in an attempt to resolve problems of fluid migration during deformation and metamorphism.

More detailed information about research at individual institutions is provided in *Newsletter No. 9 of the Specialist Group in Tectonics and Structural Geology.*

STATUS OF GEOLOGICAL SURVEYS, AMF, BMR, AND CSIRO

Information contained in this section of the report summarises the main geoscientific activities carried out in major Government organisations, and one non-profit servicing organisation, during 1984. It is not intended to replace reports issued by each of the institutions. Council gratefully acknowledges the information supplied by each organisation.

Australian Mineral Foundation

The Australian Mineral Foundation has been affected in 1984 by the continued downturn in the mineral industry as distinct from the petroleum industry. Financial operations have been curtailed because of decreased attendances at courses and cancellation or postponement of courses. The continued depressed nature of the Australian dollar has also affected income because a number of the 1984 courses were contracted, some 12 months earlier, in US dollars. Nevertheless, a number of valuable and worthwhile courses were presented, including renewed activity in SE Asia in Indonesia. An additional overseas program on Coal Geology was presented in New Zealand. It is anticipated that problems associated with the mineral industry will continue during the next 12 months.

AMF's Information Services Manager, Mr D. A. Tellis, received recognition for his contribution to the development of information science in this country when he received the prestigious Robert D. Williamson Award in November. This award, which commemorates the life of Robert D. Williamson, is presented annually, the first presentation having been made in 1981.

During this period there has been a great increase in open file reports released by geological surveys in Australia for input to the AESIS general file. The AESIS Retrospective Input Program (open-file and unpublished reports back to 1965) was completed by December 1984. The AESIS public file as at December 1984 had approximately 34 700 references. Of these, some 3750 have been added through the Retrospective Input Program.

A significant development during the period was the decision by AMF Council to establish a technical book shop. The first agency to be secured was the American Association of Petroleum Geologists. Negotiations are in hand with the Institution of Mining and Metallurgy, Economic Geology Publishing Company, Geological Association of Canada, Geological Society of America, Oxford University Press, and other professional organisations overseas. It is anticipated that this development will provide a valuable service to the Australian mineral and petroleum industry.

Despite the difficulties within the mineral industry, a new course entitled Middle Management for the Mineral Industry is to get underway in March 1985. The course will be run in conjunction with the Australian Administrative Staff College at Mount Eliza and will extend over 4 weeks, the last of which includes a program for spouses.

Two original councillors, Sir Henry Somerset and Sir Alwyn Barker who retired in 1983, were this year appointed Life Members of AMF Council. The founder of the Mineral Foundation, Professor Eric A. Rudd, who succeeded Sir Henry Somerset as Chairman, is due to retire early in February 1985 and his position as Chairman will be filled by Sir Russel Madigan, with Mr Norton Jackson as Deputy Chairman and Chairman of Executive Committee

Bureau of Mineral Resources, Geology & Geophysics

BMR undertakes geoscience research into the geological framework of Australia and its territories, petroleum and minerals resource assessment, and is the primary national source of geoscience data.

The highlight of 1984 was the arrival in Australia of BMR's new research vessel, *Rig Seismic*, chartered for BMR to undertake a major new research program on Australia's continental margins. *Rig Seismic* is a 1500 t advanced research vessel with modern facilities to support research staff and activities. Following its arrival in late 1984, equipment installation and trials took place to allow the vessel to undertake multi-channel seismic, gravity and magnetic surveys and to take rock and sediment samples from the deep sea floor. Initial cruises in early 1985 will be undertaken over the Lord Howe Rise and the Heard/Kerguelen Plateau.

Processing of seismic data from the marine surveys will be undertaken on a new DECVAX 11/780 data processing computer installed in BMR's new computer centre in late 1984. The centre will also process land seismic data obtained under the collaborative Australian Continental Reflection Profiling Program (ACORP).

In 1984, earlier seismic reflection traverses in the Eromanga Basin were extended eastward across parts of the Adavale Basin, Nebine Ridge, Surat Basin and Clarence-Moreton Basin to complete the longest continuous line (1200 km) anywhere in the world over which deep seismic reflections to 20 s have been recorded.

In the 1984/85 Budget the Commonwealth Government announced that Australia would establish a Nuclear Monitoring Centre (NMC) which will play an integral part in the verification of any Comprehensive Test Ban Treaty (CTBT). An international data centre (IDC) will integrate the NMC into a global monitoring capacity. The NMC is to be established and operated by BMR in Canberra and will entail the upgrading of BMR's earthquake detection facilities so that they can reliably detect quite small ($\geqslant$ 10 kt) underground nuclear explosions within the hemisphere centred on Australia.

In major continuing programs, over 187 000 km of airborne geophysical surveys were flown; basin studies continued in the Amadeus, McArthur, Clarence-Moreton, Murray and Lake Eyre Basins; and metallogenic provinces studied were in the Pine Creek, Davenport, Arunta and Georgetown regions. Of particular interest was the discovery of possible petroleum source-rocks in Middle Proterozoic levels of the McArthur Basin with important implications for other Proterozoic rocks as possible exploration targets.

The Australian Minerals and Energy Council (AMEC) decided early in 1984 that BMR should have responsibility, in conjunction with the appropriate State, industry, and professional organisations, for coordinating government geoscience data activities and developing suitable standards, and BMR is now developing the organisational structure for this area. An initial project to compile a directory of all government geoscience databases is nearing completion.

The *BMR Research Newsletter* was initiated this year to provide the exploration industry with early information twice yearly on BMR's research and resource assessment projects, and report relevant developments overseas. The newsletter complements the annual summaries of projects in BMR's Yearbook and the more detailed information that appears in BMR's serial, monograph, and map publications. In addition, the BMR Symposium and the Petroleum & Minerals Review Conference held each year provide valuable opportunities for contact with industry in the research and resource assessment fields respectively. In 1984, highly successful workshops on the Proterozoic and Bass Strait region were held in conjunction with the BMR Symposium.

Internationally, BMR carries out a number of activities in southeast Asia, China and the southwest Pacific, mostly under aid provisions. Major activities during 1984 included the continuation of geological and geophysical mapping and training in Kalimantan in the Indonesia-Australia Geological Mapping Project (IAGMP); participation in a marine geoscience cruise to the Solomon Sea area under the Japan-Australia Science and Technology Agreement; participation in a further set of petroleum-oriented cruises in the southwest Pacific as part of a Tripartite research program carried out by the USA, Australia and New Zealand in collaboration with CCOP/SOPAC; and the strengthening of links with the Chinese Ministry of Geology and Mineral Resources with the development of cooperative projects in the fields of regional geophysics, hydrogeology, natural gas and diamond/kimberlites.

BMR's staff at the end of 1984 was 532 including 220 research and other scientists and 188 technical and cartographic staff. BMR's Budget for 1984/85 was $31.1 M.

Commonwealth Scientific and Industrial Research Organisation

Division of Energy Chemistry

The Division of Energy Chemistry is based at the Lucas Heights Research Laboratories and has 90 staff including approximately 50 professional scientists (mostly chemists) and engineers. Its terms of reference are to 'carry out chemical, engineering and materials research directed towards the exploitation of Australia's energy resources, by developing new or improved processes for the production and utilisation of fossil fuels, substitute liquid fuels and renewable energy sources, including their environmental impact'. Major emphasis is therefore placed on process research but earth science related projects comprise about 10% of the research program and include applications of neutron activation analysis (NAA) in geology and geochemistry and trace element studies on oil shale and coal.

Neutron activation analysis can determine a wide range of elements in a variety of samples, ranging in concentration for sub-parts per million to several per cent. In collaborative studies with universities, rare earth concentrations have been determined in dacites and andesites from the Cudgegong-Mudgee region with the aim of evaluating the geological changes which have occurred with time. A simple rapid field method for concentrating gold from river water has been developed which, combined with NAA determination of gold, can be used for hydrogeochemical prospecting for gold.

The distribution of trace elements in coals and oil shales and their fate during processing and combustion is also being investigated. In the oil shale studies, the concentrations of trace elements are first determined by NAA and spark source mass spectrometry. A combination of X-ray diffraction, inter-element correlation techniques, selective leaching procedures and electron microprobe analyses are then used to establish specific mineralogical residences of the important trace elements.

Multi-element characterisation of coal seams and related geological strata is being investigated in coal seam correlation studies. For example, samples of the Archerfield Sandstone from different locations in the Hunter Valley have shown that it can be identified by above average concentrations of tantalum, niobium, zirconium and hafnium.

Division of Environmental Mechanics

The CSIRO Division of Environmental Mechanics investigates the exchange and transport of energy and of natural and introduced substances in the environment. The work is concerned especially with plants, soils, and the lower layers of the atmosphere.

Recent activities in the hydrological area of the Division's work include the discovery of the scattering analogue to multi-dimensional, unsaturated water flows in soils and an analysis of mixed saturated-unsaturated flows. The former work allows the powerful mathematical techniques of scattering theory to be applied to problems in a soil-water context. This work has significant practical consequences. For example, the scattering analogue has shown that for flows with gravity dominant and capillarity weak, the customary engineering device of neglecting capillarity gives a wholly incorrect picture of the wetted region.

The work on mixed saturated-unsaturated flows involves an approximate method of solution, in which a model of the saturated flow within a 'saturated bulb' is matched with the quasilinear flow in the unsaturated surrounding cavity. Already this work has provided a much-needed analysis of the borehole permeameter in unsaturated soil, a geophysical technique which has been in use for some 30 years without benefit of a rational analysis of its hydraulics.

The application of soil physics theory to porous materials in the environment is also an important component of the Division's research. Over the past year work has concentrated on flow in heterogeneous porous materials. The work has involved a three-pronged attack on the problem: (i) the development of predictive schemes for describing flows in 'deterministically' variable media; (ii) the characterisation of the heterogeneity of water flow properties of surface soils in the field, and (iii) rapid measurement of soil hydraulic properties at scales relevant for field application. Research on rainfall infiltration has been expanded to consider the effects of soil management practices on runoff and erosion.

Division of Geomechanics

The Division of Geomechanics conducts basic and applied research on the geology, physics and mechanics of geological systems in order to achieve precision in the prediction and control of the performance of these systems during

geoengineering operations. These operations include mining, underground construction, subsurface isolation of waste and marine geoengineering. Divisional Sections engaged in geological research are the Surface Mining and the Geoengineering Materials Section.

Sedimentological models to predict the distribution of lithologies within the Bowen Basin coal measures have been developed and applied at a number of mine sites. A previously unsuspected pattern of thrust faults has been identified in the Blackwater district and compared with other areas of the basin. Preparation of an illustrated manual of coal measure lithologies is underway. Factors controlling the strength of clay rich rocks are being studied. The characterisation of surficial deposits which form a significant proportion of the mined sequence is proceeding. This utilises remote sensing techniques to achieve regional assessment.

Projects on the stability of steady frictional sliding and the influence of OH on the deformation of quartz are in progress. In the first project, experimental work to date will establish the influence of changes of normal stress upon the shear stress response at constant sliding velocity. The relation of normal stress to shear stress is being modelled numerically.

Work is in progress on the characterisation of load-bearing properties of Australian offshore calcareous sands. Synthetic sands with extremes of composition and texture have been generated by isolating components from natural calcareous sands and by manufacturing grains with specific properties. These will be analysed to establish the significance of grain shape, composition and size.

The Division of Geomechanics has 36 professional and 43 technical support staff.

Division of Mineral Physics

The CSIRO Division of Mineral Physics research objectives are to apply fundamental principles of physics, engineering, mathematics and geology to the identification and solution of problems in the minerals and energy industries. The current research covers geophysical exploration methods and instrumentation together with analysis, control and instrumentation in the mining, beneficiation, processing and utilisation of mineral and energy resources.

Research in remote sensing has expanded on a number of fronts. Studies of the spectral properties of the Australian terrain together with the development of improved sensing techniques are leading to the discrimination and identification of mineralogical species in surface rocks and in the regolith. Wide-band spectroradiometric sensors are being developed with AMIRA support to define specific spectral bands for enhancement and interpretation to aid mineralogical mapping. Magnetic, gravity, radiometric and other types of data are being integrated with spectral measurement as a new technique for minerals exploration. Rugged, portable electronic devices for recording of geoscientific information in the field have also been developed.

Electromagnetic, electrical and rock magnetic research have also received AMIRA support to develop geophysical exploration techniques. REDOX chemical remanent magnetisation has been measured in field transect studies in Tasmania and NSW and parallel laboratory studies with controlled experiments are being used to assess the potential of the technique for exploration purposes. With industry support, mathematic modelling of the geoelectrical structure of ore bodies has complemented analogue modelling based on field measurements to enable the geometry of the ore bodies and the conductivity of the ore body and its environment to be determined.

Second-order exploration techniques—deposit delineation, grade assessment and mine development—have been boosted with the commercial application of various bore core logging procedures. *In situ* techniques have proved invaluable as quantitative tools for measurements of the grade of iron ore and stratigraphic mapping in coal-bearing basins. Pre-mine development structural work has been phased out with a conscious shift of research emphasis away from underground mapping to remote sensing and surface measurements of fracture patterns.

Nuclear and other techniques of analysis applicable to the coal and metalliferous mineral industries are being developed through the commercial stage particularly for on-stream analysis. SIROASH, a method for measuring the ash content of coal, has been incorporated in COALSCAN. In 1984, the IR 100 Award was made to Mineral Control Instrumentation (MCI) and CSIRO for the design and construction of COALSCAN.

Process control theory is being developed for industry to make use of on line analysis instrumentation. Theoretical modelling and analysis of natural gas pipeline networks is being developed for use by the Australian gas industry, and acoustic emission techniques are being applied to determine defects in industrial structures.

HIAF (Heavy Ion Analytical Facility) is a 3 MV accelerator which has been extended to include beam lines facilitating the techniques of Particle Induced X-ray Emission (PIXE), Rutherford Back Scattering (RBS), Nuclear Reaction Analysis (NRA) and the PIXE microprobe. An accelerator based mass spectrometer is currently under development to facilitate dating methods using the cosmogenic radionuclides ^{14}C, ^{10}Be and, potentially ^{36}Cl. This research represents state-of-the-art methodology for studying the genesis and evolution of the weathered profile, the age and migration characteristics of groundwater, and absorption coefficients for understanding the mobility of radionuclides.

HIAF is expected to impact on analytical techniques for studying advanced materials in particular, and surface properties in general using non-destructive procedures on small mineral samples, for example, in the search for tracer minerals as path-finders to minerals of economic significance.

Division of Mineralogy and Geochemistry

During 1984 the CSIRO Executive published their decisions on the future objectives of the Division. These decisions were based on recommendations from the external review of the Division of Mineralogy, conducted during the previous year. The Division will apply the disciplines of mineralogy, petrology, geochemistry and geobiology to developing concepts and techniques for mineral exploration and exploitation, and will be renamed the CSIRO Division of Mineralogy and Geochemistry.

Two major AMIRA Projects were completed in 1984, one dealing with mercury pathfinder techniques in precious metal exploration and the other with hydrogeochemical exploration for uranium. Results of another AMIRA project were incorporated into a commercial service, SIROTOPE, through which exploration companies can obtain assessments of their prospects based on lead isotope characteristics. A major report, on the use of helium in waters and soil gases as an

indicator of hydrocarbon and uranium deposits, has been completed and published by NERDDC. WAMPRI projects on helium in waters associated with uranium mineralisation, and on platinum group element mineralogy at Kambalda have been completed, and a new WAMPRI project on dunite-associated nickel mineralisation at Agnew will be commenced in 1985.

In collaboration with BMR and AMIRA, the Baas Becking Geobiological Laboratory program was expanded into two new projects covering sediment-hosted base metal mineralisation and the generation of hydrocarbons in relatively ancient sequences, both incorporating analogue studies of modern environments. Hamelin Pool, Shark Bay (WA) is a unique modern environment dominated by cyanobacteria which form stromatolites. The interdisciplinary research is focused on controls on the production and preservation of organic matter, and on the transport and fixation of metals and includes hydrogeochemistry, the microbial ecology of cyanobacteria, sulphate reducing and mathanogenic bacteria, organic geochemistry and sedimentology. An electronic monitoring system has been developed and deployed to continuously monitor groundwaters, tides and weather; this information is made available in Canberra via satellite and telex.

Core research continued on the genesis and characteristics of ore deposits and on exploration in weathered environments. Multidisciplinary studies of ore deposits and their environments, directed towards new or improved exploration concepts and techniques, concentrated particularly on Que River-Hellyer, Kidston, Sundown, Currawang, Cobar, Telfer, Kambalda, Greenbushes, the Agnew-Yakabindie area, the Hamersley province, and the Lennard Shelf. Multielement pathfinder techniques for deeply weathered and lateritised terrains, hydrogeochemical methods, and isotopic approaches to exploration were tested at a number of localities throughout the continent.

Mineralogical studies relating to benefication problems emphasised platinoids in nickel sulphide ores, precious metals in volcanogenic base metal sulphides, effects of weathering of ilmenite on processing, and heat treatment of sapphires. Red mud wastes from alumina refining were studied with a view to improving caustic recovery.

Significant developments also occurred during the year in the development of instrumentation for laboratory and field use. Image processing facilities were installed on the powerful CAMEBAX electron microprobe. Advances were made in applying ICP and XRF methods to geochemical analysis. In collaboration with CSIRO Division of Mineral Physics, an accelerator-based particle microprobe employing PIXE to analyse ultra-low level trace elements in individual mineral grains was constructed and tested. Two prototype field-portable geochemical instruments were developed further, an AAS-based mercury analyser (SIROMAN) and a digital voltammeter for analysis of trace metals in groundwaters. The latter instrument can be used in both the field and laboratory for the determination of heavy metals, and will have wide applications in mineral exploration, mineral processing and environmental control. It is to be made in Western Australia by CSIRO joint venture company, CHEMTRONICS.

Divisional staff continued to serve on various national and international professional bodies, and played a major role in organising the Seventh Australian Geological Convention held in Sydney on the theme 'Geoscience in the Development of Natural Resources'.

Division of Soils

The research of the CSIRO Division of Soils covers the full spectrum of soil science: soil biology, soil chemistry, soil physics, mineralogy and pedology. The following is a summary of current research falling within the sphere of geoscience.

Two soil survey/land classification projects—one on Eyre Peninsula, SA, and one in wet coastal areas of north Queensland—are progressing towards completion. Related to the Eyre Peninsula studies are others investigating the origins of calcretes, aeolian calcareous materials, and hardpans in soils.

Several projects using micromorphological techniques are aimed at understanding the processes responsible for the formation of duplex (texture-contrast) soils, which cover large areas of Australia. An expanded study of clay soils, particularly the agriculturally important and diverse soils of southern Queensland and northern NSW, is being carried out to determine their differing properties. This information will be used to formulate appropriate management strategies. Continued investigations of the earth soils of northern Queensland have shown how they were formed and have quantified important differences in the hydrological environments of the several types of earth soils. A project assessing the effects of mulches on soil temperature and moisture regimes is also continuing.

Stable isotopes (^{18}O, ^{2}H) are being used to determine the amounts of water moving into aquifers in the drier parts of Australia. For example, in the Murray Mallee of SA recharge rates are around 1 mm per year. The information derived is of considerable importance in assessing the long-term effects of the clearing of native vegetation.

Investigations continue into the clay minerals of Australian soils, of the conditions of formation of the various iron compounds in soils and of the interactions between mineral particles and organic molecules. Studies of boron toxicity in barley crops in southern Australia have continued, with emphasis on determining the geographical extent of the problem and of aiding in programs for breeding tolerant strains of barley.

Investigations of sand movement along the Adelaide coastline of St Vincents Gulf were concluded. Studies of the engineering properties of the deeper strata of soils in metropolitan Adelaide show that the stability of buildings depends much more on fluctuating moisture levels in the lower strata than was first thought.

Division of Water and Land Resources

A research project at the CSIRO Division of Water and Land Resources in Canberra is examining water storage reservoir sediments with a view to gaining a better understanding of soil erosion.

Reservoirs provide long-term records of erosion in their catchments since they trap most of the sediment produced by erosion upstream. The volume of sediments gives a crude estimate of the amount of soil eroded since the dam was built. Stratigraphic studies are used to determine a sequence of depositional events, and the provenance of the sediments is determined by mineralogy, geochemistry and pollen content. Pollen are also used to date the sediment and to record vegetation changes caused by variations in climate or land

use. Geochemical studies provide information on the introduction and effects of fertilisers.

Reservoirs so far examined in this study have been Burrinjuck in the sub-humid environment near Yass, and Umberumberka in the arid zone near Broken Hill.

Burrinjuck has a catchment of some 13 000 km^2, drained by the Murrumbidgee, Yass and Goodradigbee Rivers. The chronology of the sediments has been established by matching charcoal layers with the bushfire history of the catchment, measurement of ^{137}Cs, matching the thickest and densest layers with the biggest recorded floods and by the location of seasonal grass pollen peaks. Cores show that the rate of sedimentation has been considerably slower since 1950, perhaps as a result of improved land management in the catchment, but possibly because of greater vegetation cover due to increased rainfall. Initial pollen analyses of the sediments show pines and grasses increasing at the expense of eucalypts since the mid-1930s, reflecting clearance of native forests and woodlands for softwood plantations and pastures.

Umberumberka Reservoir, with a catchment of about 420 km^2, was completed in 1915. Some 6 Mm^3 of sediment have accumulated in the reservoir, implying an average soil loss of 12 mm across the catchment. Two-thirds of the sediment accumulated in the first 27 years, which indicates how the rate of sedimentation has decreased since 1942. The rate of erosion before European settlement can be assessed from the volume of sediment deposited by Umberumberka Creek in alluvial fans on Mundi Mundi Plain. The erosion rate since 1915 is twice that of the period 6500-3000 years ago, but 85 times the rate between 3000 years ago and the arrival of Europeans.

As the work extends to a wider range of reservoirs it will provide a fuller knowledge of the rate and amounts of soil erosion across the continent since European settlement. By identifying the effects of changes in climate, vegetation and land use it should be possible to identify regions most vulnerable to erosion and to suggest policies for minimising its effects.

Geological Survey of New South Wales

During 1984 the Geological Survey of New South Wales was reorganised into regional groups in order to more effectively achieve the aim of encouraging developing of the State's mineral resources. Within the Department of Mineral Resources, geological activities now arise from three branches, covering respectively regional geology and mineral resource assessment, coal geology, and geoscience information services. The staffing of each is as follows:

	Geoscientists	*Support*	*Total*
Geological Survey Branch	60	42	102
Coal Geology Branch	16	9	25
Information & Extension Services	10	27	37
	86	78	164

In the Geological Survey Branch, regional geological studies were concentrated in the New England area, five geologists being stationed at the Armidale office. Compilation and field checking of geology for the Manilla 1:250 000 sheet was nearing completion, and had commenced for the Grafton 1:250 000 sheet. Field assessment of mineral deposits on the Dorrigo and Coffs Harbour 1:250 000 sheet areas was completed. A synthesis of geological and geophysical data covering the New South Wales part of the Clarence-Moreton Basin was prepared in connection with petroleum prospectivity assessments of the State's sedimentary basins.

Geological mapping at Cobar and Broken Hill has resulted in greater understanding of the relationships between stratigraphy, structure and mineral deposits, and provides a sound basis for mineral exploration. Results of these programs have been presented in publications and at conferences, including the Australian Geological Convention. During 1984 the first of the 1:25 000 sheets for the Broken Hill area were published (Mount Gipps, and Broken Hill sheets). Field mapping was completed on the Purnamoota sheet, and notes were prepared on the mineral deposits of the southwestern part of the Broken Hill Block. An accompanying map at 1:50 000 scale was being compiled. For the Cobar area, mapping was completed on five 1:100 000 sheets and these with notes, are in various stages of production.

Detailed mapping has also been undertaken in the upper Hunter Valley area, in connection with studies of groundwater salinity, and the Muswellbrook and Singleton 1:25 000 sheets have now been published. Cooperative studies with the Geological Survey of Victoria have been undertaken in the mapping of the Numbla and Bendock 1:100 000 sheets in southeastern NSW.

Regional geophysical studies have benefited from data acquisition and processing by contractors. Contracts completed include magnetic maps of Wollongong, Newcastle and Singleton 1:250 000 sheets; gravity coverage for Cobar, Nyngan, Forbes and Narromine sheets; and processing of radiometric data for the Dorrigo-Coffs Harbour sheet. Staff geophysicists continued interpretation and field checking of New England data and the Walgett and Forbes/Narromine portions of the Lachlan Fold Belt.

Geophysical exploration techniques have been developed in projects supported by NERDDC and AMIRA, and directed towards use of geophysical methods in exploratory boreholes, for coal and for base metals. A continuous down-hole IP logging system has been developed and demonstrated to provide superior data to that obtainable from commercial units. Seismic surveying was undertaken at Tibooburra to assist in siting of a stratigraphic borehole for assessment of petroleum potential in the area.

The DIPIX image processing system at the Lands Department was utilised for enhancement of airborne magnetic data to improve its interpretation potential. Investigations were also commenced into applications of computergraphics to geological cartography, and into computerisation of various source data systems (mineral deposits and field data).

Mineral resource investigations in 1984 included studies of base metal mineralisation at Parkes, Cobar and around Tamworth; sapphire occurrences in New England; opal at Lightning Ridge; and extractive resources of the central coastal area, including sand at Botany Bay and Kurnell, and clay/shale at Menai. As encouragement to petroleum prospecting in NSW summary data packages were commenced for each of the sedimentary basins, and a seminar was presented for petroleum company representatives. Departmental geologists supervised the drilling of a stratigraphic hole in the Clarence-Moreton Basin at Pillar Valley.

Another seminar detailed the potential for development in NSW sunrise minerals. In addition, advice was provided for use in land planning and resource management, for environmental matters, and for the administration of exploration titles and applications.

The Coal Geology Branch activities for 1984 included programs of exploration drilling at Narrabri and at Rylestone in conjunction with the Electricity Commission. A reassessment of coal resources and reserves of NSW has been commenced in conjunction with the Joint Coal Board.

The new Coal Resources/Reserves Code was ratified by the Standing Committee on Coalfield Geology of NSW in June 1984. The Code introduces the concept of *resources* being potentially usable coal *in-situ* and *reserves* that part of the coal planned to be mined. A slight modification to the Code has been agreed to by Queensland as a possible basis for a national code.

Maps at 1:25 000 scale showing the location of all coal boreholes drilled in the State (some 30 000) are being proposed and will be available for public usage. A publication *Profile of the Coal Industry in NSW* was issued, giving details of all existing and proposed coal mines.

Geological activities of the Information and Extension Services Branch include management of the Geological and Mining Museum, the Core Library, geoscience information services, and editing for publication of geological papers, reports and maps. Highlights of the year's activities include redevelopment of the Mining Museum and presentation of several topical displays, completion of a new core library building at Londonderry, and implementation of computer-based searching facilities for geoscience reference information from unpublished reports held by this Department. Major publications issued include a bulletin on the Department's studies in the Great Australian Basin, and a Mineral Resource volume on bentonite.

Northern Territory Geological Survey

Regional mapping and associated projects continue to be the main activities of the Northern Territory Geological Survey. A major change of emphasis has been the provision of Geological Resource Studies and contributions to plans of management of both National Parks and Conservation areas in the Northern Territory.

Field activities during 1984, were concentrated in the southern region, where helicopter surveys and a stratigraphic drilling program were undertaken to assist the collation of data for mapping projects. The drilling program was designed to give a better understanding of the western margin of the Georgina Basin, and to determine the relationship between the overlying sediments and basement. Limited field work also took place in the northern part of the Territory. Six 1:100 000 map sheets in the Musgrave Ranges area were flown for colour airphotography as a fore-runner to a major mapping project.

An airborne magnetic and radiometric geophysical survey was conducted across six 1:100 000 map sheets in the top end of the Northern Territory. The survey was made along 40 000 line km with flightline spacings of 500 m, tieline spacings of 5 km, and a maximum terrain clearance of 250 m. Contour maps will be released in mid-1985.

Metalliferous studies of potential uranium and gold deposits continued in the vicinity of the Northern Territory/ Queensland border. Field work included regional traverses, sedimentological studies, logging and inspection of bore hole samples and inspections of mine sites.

A 1:50 000 scale geological map and Explanatory Notes of the Keep River National Park were prepared for use in the overall plan of management and operation of the Park. The assessment of the Katherine Gorge National Park is also well under way, and a display and accompanying map have been prepared and arranged at the camping site for tourists visiting the area. The aim of these activities is to provide an accurate geological assessment of the areas incorporated within the parks for both tourism and conservation purposes.

A computer data base (Geosystem) incorporating all company and mineral exploration reports is now 85% complete and will become fully operational during 1985. A complementary database (COREX) to list exploration drill holes and core storage is also being prepared. The discovery of hydrocarbons in NT offshore waters has greatly increased demands for information. Technical Information and Library staff have cooperated in develping new procedures to meet these requests.

Pamphlets on gold, uranium, bauxite, manganese, petroleum and certain geological features of central Australia were produced for the public.

Geological Survey of Queensland

The Geological Survey is the largest of five Divisions of the Department of Mines, with one-third of the total Departmental establishment. Organisationally, a third Branch was established within the Geological Survey during 1984. This Branch, the Regional Investigations Branch, incorporating Regional Mapping, Palaeontology, and Marine and Coastal Investigations Sections, was created mainly in response to the administrative needs arising out of the new Regional Geological Mapping Program (RGMP). The other two Branches, Metalliferous and Geological Services, and Fossil Fuels, continued largely in their traditional roles, but with the expectation of increased future input into the RGMP.

Undoubtedly, the most significant development in the Geological Survey division in 1983-84 was the planning and implementation of the major program of regional geological mapping (RGMP). Resources available within the Geological Survey were redeployed and representations made to Treasury for a special allocation so that the program could commence in north Queensland in 1984, with two parties based respectively at Dimbulah and Greenvale. Specialist support for the RGMP in biostratigraphy and sedimentology was provided by the Palaeontology and Petroleum Resources Sections respectively.

A cooperative effort to produce a revised 1:500 000 geological map of the Bowen Basin commenced early in 1984 with field investigations in the Cracow-Banana area. Input to this project will come primarily from the Petroleum Resources and Coal Exploration Sections. Mapping of the Cairns 1:100 000 Sheet area with coincident studies of landslide hazards and extractive materials resources were undertaken by the Urban and Environmental Geology Section. Surveys of extractive materials in other areas such as the Burnett district and the Goondiwindi area were also carried out.

An important event which required substantial efforts by many staff, but most particularly the Economic Geology Section, was the hosting by the Geological Survey of an Australian Mineral Foundation-sponsored symposium on 'Queensland Exploration Potential' in October. Papers

covered a variety of topics, with reviews of coal, petroleum and oil shale resources, overviews of regional geology, mineral resources and mineral exploration, and specific papers on gold, tin/tungsten, base metals, limestone, various non-metallic and industrial minerals, regolith and environmental matters. An open forum during one afternoon session saw active audience participation.

In other on-going projects within the Geological Survey, deep core drilling in the Eromanga Basin continued to provide basic stratigraphic data to assist the burgeoning efforts of the petroleum exploration industry. Engineering geological input and geophysical expertise continued to be provided for such major projects as the Wivenhoe and Burdekin Falls damsites.

Geological Survey of South Australia

Geological maps published during the year were the 1:250 000 Abminga and Dalhousie sheets and a 1:500 000 map of the Gawler Craton summarising the geochronology. Regional geological mapping continues in the eastern Eucla Basin, Gawler Craton, southwest Eromanga Basin and near Adelaide. Other activities include coring of Quaternary coastal sediments, U–Pb dating of zircon, study of mafic dykes, preparation of jubilee atlas maps of the State, contributions toward a tectonic map of the Tasman Fold Belt, further discoveries of fossil eucalypt material and production of a comprehensive well completion report for Wilgena-1 stratigraphic well.

Active study of Late Palaeozoic, Mesozoic and Cainozoic palynology continued, with widespread application to hydrocarbon exploration and regional mapping. Important biostratigraphic data were contributed to the joint South Australia/Victorian Otway Basin Study. A volume in honour of Dr N. H. Ludbrook, containing 24 significant papers in stratigraphy, palaeontology and malacology, has been assembled for publication in 1985. Study has begun of a small fauna of conodonts from the Warburton Infrabasin.

Mineral exploration involving metallic and non metallic minerals, gemstones and building stones has continued in many areas of the State with emphasis on gold, lead-zinc, gypsum, magnesite and road aggregate. Work increased on building stones for a special Jubilee 150 publication in 1986. Monitoring of the opal and jade industries continued, and a short film on opal was completed by the South Australian Film Corporation with Departmental support.

In the Handbook series, *Geology and the Adelaide Environment* was published.

Regional assessments of groundwater resources have continued concentrating on Metropolitan Adelaide, the Murray Mallee and Keith-Bordertown areas (the last two now proclaimed Regions under the Water Resources Act) and the Southeast. In the latter area over 300 sites that were used to bury stock destroyed during the 1983 bushfires have been located and quality monitoring networks established. Drilling for groundwater supplies to allow sealing of the final portion of the Stuart Highway was completed.

An assessment of geotechnical and groundwater aspects of six coal deposits was made to assist in selection of the deposit to be developed for future energy requirements.

Geological Survey of Tasmania

Geological maps published during 1984 included the 1:50 000 Eddystone and St Marys sheets and a 1:25 000 sheet of the Mount Dundas—Mount Ramsay area. The Middlesex 1 mile to 1 inch geological sheet and the State mineral occurrence maps were reprinted. Field work has been completed on the Pedder and Valentines Peak maps and these are currently being compiled and drafted.

Regional mapping is continuing on the Lyell, Macquarie Harbour and Corinna sheets on the west coast and St Helens, Ben Lomond and Snow Hill on the east coast, has been virtually completed on the Interlaken sheet of central Tasmania and has been commenced on the Trowutta sheet on the far northwest of the State.

Explanatory notes were printed for the Maria Island, Oatlands and Sorell map sheets, whilst the texts are virtually complete for the Strahan and Kingborough sheets. The text for a major bulletin on the Zeehan-Pieman area of the west coast is also close to completion.

A major groundwater assessment of the resources of the lower midlands has continued, and in the Port Sorell district of north-central Tasmania a major survey has been commenced to assess the long term sustainable groundwater yield. In engineering geology, investigations continue into unstable slopes in urban or semi urban areas, and a major foundation study has been made of the proposed Craigbourne dam in southern Tasmania.

Assessments of coal, tin-tungsten and silver-lead-zinc deposits have continued. Evaluation of company reports on mineral exploration projects within the State has continued and all available reports placed on open file. A new system making more land available for mineral exploration became operative in mid-year and several tenders from companies seeking title to relinquished ground have been dealt with. Drilling has continued on targets of interest on the west coast, a gold resources study has been initiated and compilation of a metallogenic map of the State is well advanced.

Geochemical activity has been transferred to the west coast, and quite promising results have been obtained from a new technique of geochemical prospecting involving analysis of the organic component of A horizon samples.

Work has continued on collection of data, based on a 1 km spacing, for a systematic gravity map of the State. Areas surveyed this year include the Copping, Smithton and Gladstone districts. All gravity data for the State have been reviewed during the year and terrain corrections applied where necessary. As a result of this work, significant alterations will be made to the gravity map of the State.

At the end of the year the staff of the Survey comprised 25 geologists, 2 geophysicists, 5 technicians, 7 draftsmen, 2 editorial officers, 1 surveyor and 6 field assistants. Three vacant geological positions were in the process of being filled.

Geological Survey of Victoria

The Victorian Geological Survey is rearranging its mapping programs to accelerate the preparation of an improved geological mapping coverage for Victoria's areas of greatest mineral potential. Emphasis during 1984 has centred on the Palaeozoic rocks of East Gippsland and the Cambrian rocks of the Mount Stavely-Ararat region; the gold-bearing sequence of the Bendigo district; and the La Trobe Valley brown coal province.

Mapping in East Gippsland has shown that the rock types, complex geological structure and depositional

environment—similar to those associated with the Wilga and Currawong prospects near Benambra—are more widespread than had been recognised in previous reconnaissance mapping. *Geological Survey Report* 72 describes the geology of the area surrounding the promising copper-silver-zinc mineralisation near Benambra which is being intensively prospected by Western Mining Corporation.

Detailed geological mapping between Heathcote and Seymour led to a re-evaluation of the geological structure and indicated possible extensions to the Bailieston and Graytown goldfields.

The highlight of the Survey's geophysical investigations was a joint project with the BMR which completed the aeromagnetic and radiometric coverage of Central Eastern Victoria. Data were collected in the areas covered by 1:250 000 Melbourne, Queenscliff, Warragul and Sale map sheets. Of particular interest was a test aeromagnetic survey over part of the Bass Strait oilfields which showed strong correlation between magnetic anomalies and some known volcanic structures.

The major review of the oil and gas potential of the Otway Basin was completed as a joint project between the Geological Survey, the Department's Oil and Gas Division, the Department of Mines and Energy, South Australia, the Mines Department, Tasmania and BMR. Preparation of a publication is well advanced.

The Victorian Department of Minerals and Energy is the principal authority for investigation of the State's groundwater resources. Greatest emphasis was placed on investigation of the groundwater resources of the eastern margin of the Otway Basin, where deep Tertiary aquifers supply water to most of the towns in the southeast of the State and have recently been developed to augment supplies to Geelong. Investigations to the east of Warrnambool have demonstrated considerable potential for further development of deep aquifers. At Portland, groundwater is being used to heat the town's swimming pool and civic buildings with a saving of more than $80 000 per year in energy costs. Investigation of deep aquifers of the Gippsland Basin continued in 1984.

Investigations of groundwater aspects of the salinity problem have resulted in a clearer understanding of the underlying causes of salinity, a serious problem for the Riverine Plains irrigation areas. This work will enable prediction of the rate of growth of the area affected by salinity and will indicate those salinised areas where dewatering bores can effectively lower the water table and so control the spread of salinity and allow reclamation of some salt-affected land. Groundwater Section staff participated in the current Parliamentary Salinity Inquiry which is examining all aspects of the salinity problem in Victoria.

The Geological Survey is Victoria's central advisory authority on the evaluation of landslip hazards and the risk of subsidence over formerly mined areas. Slope stability zonation maps were produced as an aid to planning for three shires in Gippsland.

The Geological Survey is associated with the Ports and Harbours Division of the Ministry of Transport in beach restoration in Port Phillip Bay. Nearly $1 M has been spent in the past eighteen months to restore seven bayside beaches through the addition of over 130 000 cubic metres of sand. An understanding of regional coastal processes is being gained by beach monitoring in selected areas of the State's coastline.

A review of the objectives and strategies of the Geological Survey undertaken during the year resulted in the redefinition of the Survey's functions to give greater emphasis to geological mapping, mineral resource investigations and information services. To complement these functions, a revised organisational structure has been submitted by the Department to the Public Service Board for approval.

Geological Survey of Western Australia

With first-pass systematic 1:250 000 scale geological mapping in Western Australia essentially completed, the thrust of GSWA research in 1984 was directed towards syntheses of geological histories of selected structural units or provinces and appraisal of the economic potential of mineral commodities.

In the Proterozoic Ashburton Fold Belt, additional mapping and investigation of the sedimentology of shelf and deep water sediments were undertaken to establish the sedimentary history. This was supplemented by geochemical investigations in the vicinity of the Mount Clement gold prospect.

Field mapping of the Sylvania Dome, a granitic body covering 6000 km^2 between the Pilbara and Yilgarn Blocks, was completed during the year. The principal aim of the project is to determine the relationship of the dome to the major crustal blocks and to the adjoining Hamersley Basin. Geochronological determinations are proceeding.

Problems in correlating Bangemall, Manganese and Yeneena Group rocks prompted remapping of the Balfour Downs sheet area which had been first mapped in isolation in 1960. Although a better understanding of the stratigraphy is emerging, further correlative problems have arisen and field work will be extended southwards to revise the stratigraphy of the eastern Bangemall Basin.

In the Murchison Province, a study that began with an attempt to establish the metallogeny has been extended to study the geological evolution. Field work was completed in 1984 and geochemical and geochronological investigations are continuing.

Near Kalgoorlie, the Widgiemooltha and Boorabbin sheets are being remapped, after some 20 years, to incorporate the results of surface and subsurface mineral exploration and to develop a new stratigraphic and structural model for the region. Concurrently, detailed surface mapping of the 'Golden Mile' and immediate environs was conducted with the eventual aim of reinterpreting gold mineralisation controls within a regional structural framework. Aeromagnetic contour maps of the region were purchased from a commercial contractor (Aerodata Pty Ltd) late in the year to supplement these projects.

In a State-wide assessment, selected areas in the Western Gneiss Terrain, Eastern Goldfields Province, Pilbara Block and Halls Creek Mobile Zone were examined for potential platinum group metals occurrences. The Western Gneiss Terrain contains significant remnants of layered mafic intrusions, some of which have a potential to bear platinum group elements and other mineralisation.

A study of the paragenesis of sulphide minerals at all known lead/zinc prospects in the Kimberley Region was conducted

in conjunction with an investigation, funded by WAMPRI of the carbonate rocks of the region.

A computer-based EDP index and retrieval system was successfully established in December. The system provides comprehensive information retrieval options for company mineral exploration data on open-file microfilm and an outline information system (7 data areas) for restricted material.

EXPENDITURE ON GEOSCIENCE RESEARCH IN AUSTRALIA

This survey is based on information collected from funding bodies, CSIRO, and BMR only. The expenditure by these organisations is estimated to represent more than 75% of total expenditure on public geoscience research in Australia.

For the purposes of the survey, the term 'geoscience' is defined as comprising the disciplines of, and sub-disciplines within, geology, geophysics, and geochemistry, and includes soil science and relevant areas of geography and oceanography.

Information for the survey was obtained from the following organisations:

Australian Mineral Industries Research Association (AMIRA);
Australian Research Grants Scheme (ARGS);
Bureau of Mineral Resources, Geology & Geophysics (BMR);
Commonwealth Scientific & Industrial Research Organisation (CSIRO);
Earth Resources Foundation (ERF);
National Energy Research, Development & Demonstration Program (NERDDP);
Queen's Fellowship and Marine Research Allocations Advisory Committee (QFMRAAC)—formerly Australian Marine Sciences and Technologies Advisory Committee—Funding Advisory Panel (AMSTAC-FAP); and
Western Australian Mining and Petroleum Research Institute (WAMPRI).

Expenditure for 1983-84 (and comparable figures for 1982-83 and 1981-82) is shown in Table 2. Expenditure by funding bodies increased by more than $1 M from 1982-83 to 1983-84, following a similar increase from 1981-82 to 1982-83. All funding bodies reported an increase in expenditure.

Total expenditure in 1983-84 was up 11% on the 1982-83 figure. This is a lower percentage increase than was recorded for 1981-82 to 1982-83, mainly due to smaller increases in the capital spending by BMR and CSIRO, the two major contributors to total expenditure (in fact, BMR spent less on capital works in 1983-84 than for 1982-83, mainly owing to the late delivery of major items of equipment and payment in the subsequent financial year. For both BMR and CSIRO, salaries represented the largest increase in expenditure.

If it is assumed that total expenditure on geoscience research by tertiary education institutions, State Geological Surveys, and other research organisations increased by a similar amount (11%), the data suggest that total spending on geoscience research in Australia in 1983-84 was around $90 M, almost twice the amount spent on public geoscience research in Australia just two years ago (1981-82).

Table 2. Comparative expenditures for 1981-82, 1982-83, and 1983-84 by funding bodies, BMR, and CSIRO on geoscience research

Funding body organisation	Expenditure, $M		
	1981-82	1982-83	1983-84
ARGS	1.22	1.47	1.58
QFMRAAC	1.07	0.77	1.17
NERDDP	1.00	1.34	1.68
ERF	0.04	0.52	0.55
AMIRA	1.91	1.95	1.99
WAMPRI	0.21	0.46	0.63
Sub-total (funding bodies)	5.45	6.51	7.60
CSIRO[1]—Salaries	17.33	19.36	23.6
—Operations	7.62	10.59	10.8
—Capital	1.48	7.03	7.8
Sub-total (CSIRO)	26.43	36.98	42.2
BMR[2]—Salaries	11.31	13.16	14.25
—Operations	6.71	6.39	6.50
—Capital	0.63	1.46	0.98
Sub-total (BMR)	18.65	21.01	21.73
TOTAL	50.53	64.50	71.53

[1] 1983-84 figures include geoscience research by Divisions of Soils ($8.41 M), Water & Land Resources ($1.93 M), Oceanography ($11.79 M), Geomechanics ($3.28 M), Environmental Mechanics ($0.83 M), Groundwater Research ($3.58 M), Fossil Fuels ($0.66 M), Mineral Chemistry ($1.19 M), Mineralogy ($5.53 M), and Mineral Physics ($4.98 M).

[2] Includes resource assessment and geoscience database.

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NOTEWORTHY MINERAL AND HYDROCARBON DISCOVERIES 1984

Hydrocarbon discoveries during 1984 are listed in Table 3. Metallic mineral discoveries for 1984 are shown in Table 4 which also includes two discoveries from late 1983 that were not included in the corresponding table in the 1983 Annual Report. Table 5 lists coal discoveries for 1983-1984 (the 1982 Annual Report listed coal discoveries for 1977-1982).

The data were prepared and compiled by officers of the Resource Assessment Division of the Bureau of Mineral Resources, Geology and Geophysics.

Table 3. Noteworthy hydrocarbon discoveries — 1984 (a)

Basin	State	Field name	Company (Operator)	Type discovery
Bonaparte	NT	Challis	BHP	o/g
Bowen-Surat	Qld	Blackbutt	Sydney Oil	g
Bowen-Surat	Qld	Carbean	Hartogen	g
Bowen-Surat	Qld	Roswin	Bridge Oil	g
Carnarvon	WA	Talisman	Marathon	o
Carnarvon	WA	Lenita	Aust. Occ.	o/g
Cooper-Eromanga	Qld	Ballera	Delhi	o/g
Cooper-Eromanga	Qld	Baryulah	Delhi	g
Cooper-Eromanga	Qld	Bodalla South	Lasmo	o
Cooper-Eromanga	Qld	Jackson South*	Delhi	o
Cooper-Eromanga	Qld	Yanda	Delhi	o/g
Cooper-Eromanga	SA	Biala	Delhi	o
Cooper-Eromanga	SA	Big Lake*	Delhi	o
Cooper-Eromanga	SA	Bookabourdie	Delhi	o/g(c)
Cooper-Eromanga	SA	Gidgealpa*	Delhi	o/g
Cooper-Eromanga	SA	Leleptian	Delhi	g
Cooper-Eromanga	SA	Limestone Creek	Delhi	o
Cooper-Eromanga	SA	Moolion	Delhi	g
Cooper-Eromanga	SA	Moomba*	Delhi	g
Cooper-Eromanga	SA	Wancoocha	Delhi	o/g
Gippsland	Vic.	Manta	Shell	o/g
Gippsland	Vic.	Tuna*	Esso/BHP	o/g

(a) Gas discoveries with flow rate > 100 Mm^3/d
Oil discoveries with flow rate > 20 m^3/d
* New pool discovery
(c) Condensate

Table 4. Noteworthy metallic mineral discoveries 1983-1984

Year	Name	Companies	Location	Type of deposit	Grade
1983	Abra	Peko-Wallsend Ltd/Amoco Australia Ltd	Jillawara Bore, central Western Australia	Stratabound Pb deposit in Proterozoic sediments	200 Mt 2% Pb & 20 g/t Ag
1983	—	CRA Exploration	Murray Basin, Vic.	Mineral sand accumulations	Low grade
1984	Makai Prospect	Hill Minerals NL	Davyhurst, WA	Hydrothermal Au lode	n.a.
1984	—	Mareeba Mining Ltd Leighton Resources Pty Ltd Chase Minerals	Palmer River, north Queensland	Alluvial gold deposit	1.1 Mm^3 grading 0.5-0.6 g/m^3
1984	TC8	Norseman Gold Mines NL Preussag Australia Pty Ltd	Near Tennant Creek, NT	Hydrothermal Au in tight fold	35 000 t grading 67 g/t
1984	Boddington	Reynolds Australia Alumina Ltd Shell Australia Ltd BHP Minerals Co. Ltd Kobe Aluminium Associates of Japan		Supergene Au enrichment in laterite and clays	Low grade

n.a. = not available

Table 5. Noteworthy coal discoveries 1983-1984

Year	Name	Companies	Location	Coal Type	Resources
1983	Vasse Shelf	Bond Corp./Mallina Holdings	South Perth Basin	Black Sub-bituminous	n.a.
1984	Hill River	CRA Ltd	North Perth Basin	Black Sub-bituminous	n.a.

n.a. = not available

Resource Assessment Division
Bureau of Mineral Resources, Geology & Geophysics

AUSTRALIA'S PALAEONTOLOGICAL HERITAGE

By providing reliable national and international ages for sedimentary rock sequences, palaeontology has played a vital and central role in the geological exploration of Australia. Partly for this reason—but also because of the quality of the people attracted to the profession—palaeontology has a long and illustrious history in Australia. It is one of the disciplines that has helped establish Australia's international reputation in science, and at the same time has contributed significantly to the economic and cultural development of the nation.

The foundations of Australian palaeontology were monographic studies of fossil invertebrates, fossil plants and ice-age marsupials. Because most of the onshore marine fossiliferous sequences are of Palaeozoic age, strong schools of invertebrate palaeontology developed in the older universities (Adelaide, Melbourne, Queensland and Sydney), and it was this development that directly or indirectly provided the palaeontologists required for state and national regional mapping programs in the middle decades of the century.

The subsequent growth and diversification of palaeontology in Australia was due to several different factors. The great post-war expansion of the coal and petroleum industries required the specialist skills of a large number of micro-palaeontologists (especially palynologists) who are now able to provide precise information about the ages, environments of deposition, and thermal histories of the sequences drilled. In a similar manner, many invertebrate palaeontologists and palaeobotanists have become increasingly involved in palaeo-environmental studies that relate to the evolution of sedimentary basins, to the formation of biogenic materials (oils, coal, carbonates and phosphorites), and to the tectonic history of the continent and the Indo-Pacific region. In parallel with an increasing public interest in the Australian flora and fauna, vertebrate palaeontologists and palaeo-botanists have developed a deeper understanding of the origin and history of the vegetation and marsupial fauna of Australia, and there have been a number of discoveries of older fossils of considerable cultural importance. The palaeontologists employed by State and regional museums have played a particularly important role in bringing the palaeontological heritage of the nation to the attention of the general public.

Another new frontier has been a move to the Precambrian. Like other earth scientists, palaeontologists have become increasingly aware of the importance and difference of this vast period of Earth history. Stimulated by pioneering work at the University of Adelaide on the Late Precambrian Ediacarian animals and in Western Australia on modern stromatolites, a new generation of palaeontologists has attempted the difficult task of attempting to understand the Precambrian history of the biosphere and its impact on the atmosphere, hydrosphere and lithosphere. As a result of recent studies, Australia now has some of the best-documented and best-preserved examples of Precambrian life, and the knowledge so gained is being applied to more practical problems such as the search for hydrocarbons in Proterozoic rocks.

Finally, palaeontology has itself undergone a revolution in both approaches and techniques. There are now much closer links with modern biology (ecology, biogeography, physiology, biochemistry and developmental biology) and a far greater appreciation of the biological information contained in fossils. Thus Australian palaeontology is contributing information and ideas that are helping to understand how evolution occurs, how ecosystems such as the Great Barrier Reef develop and evolve, and how the geographic distributions of animal and plant species change through time.

Most palaeontologists in Australia are employed by museums, government departments (geological surveys), universities and other tertiary institutions, and the petroleum industry. The proportion of industry-employed palaeontologists has increased significantly in the last two decades, reflecting the importance of the discipline to the search for oil and gas. Communication between these different groups and different fields is provided by the Association of Australasian Palaeontologists, a specialist group of the Geological Society of Australia formed about ten years ago. The Association organises scientific meetings, publishes a first-class international journal (*Alcheringa*) and a series of monographs (*Memoirs of the Association of Australasian Palaeontologists*), and also provides a roundup of the professional activities of all Australian palaeontologists in a sizeable annual newsletter (*Nomen Nudum*). Judged on this basis alone, palaeontology in Australia is a remarkable success.

But what of the future? Despite the progress that has been made in the last 150 years, the extinct biota of Australia is inadequately known. So one important task for the future is the continuation of the collection, study and interpretation of Australian fossils. The justification for such work is both cultural (in the broadest sense of the word) and pragmatic; it will change the way we and our children view the history of the continent and it will enable palaeontology to be used for other theoretical and practical purposes. Although it has become fashionable to view taxonomy with disfavour, this demanding procedure is the essential prerequisite for all other useful work.

On the other hand, it is clear that palaeontologists will be increasingly involved in interdisciplinary studies with other scientists. Traditionally, palaeontologists have worked closely with other geologists in mapping, correlating and dating sedimentary rock sequences, but there is already great scope for team work in fields such as oil genesis and migration, the chemical history of the hydrosphere, and molecular biology and evolution. In Australia there is a need for greater knowledge of the effects of global changes in climate, sea level and sea water chemistry, and for a better regional time scale that is well-calibrated by isotopic dates. As palaeontology becomes closer to biology it should be possible to extract more environmental information from fossils and for palaeontologists to continue to contribute to the development of evolutionary theory. Lastly, through our museums, schools and popular press, palaeontology will continue to play an important role in the cultural development of the nation.

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PETROLEUM GENERATION: LABORATORY SIMULATION OVER SIX YEARS

Organic geochemists have been attempting to understand the genesis and characteristics of petroleum, coal and oil shale in order to assist in both exploration for and utilisation of these resources. In particular, they have endeavoured to duplicate in the laboratory reactions of organic matter trapped within sedimentary rocks.

One of the most important chemical reactions taking place within sedimentary basins is the formation of oil. Most scientists believe that petroleum is formed by pyrolysis reactions as the remains of living organic matter buried in rocks are gradually exposed to successively higher temperatures; the geothermal gradient in sedimentary basins increases with depth at about 3 °C/100 m. Previous experiments to simulate this process have been attempted over a period of days, weeks or months, but the resulting liquid and gaseous products have not resembled crude oil and natural gas. The oils contain olefins and the gases contain carbon monoxide, neither of which occur naturally.

Consequently, scientists at the CSIRO Division of Fossil Fuels (North Ryde, N.S.W.) moved to the virtual limit for a laboratory experiment, by increasing the heating time to years and duplicating burial in a sedimentary basin by regularly increasing the temperature (Fig. 5). In experiments completed in 1984, two types of source rock were heated in sealed tubes for six years, beginning at 100 °C and increasing the temperature 1 °C each week. One tube from each series was opened at the end of each year, and all the gaseous, liquid and solid products in the tubes analysed. To illustrate widely differing source rocks, torbanite from Glen Davis and brown coal from Loy Yang were chosen as starting materials. Torbanite is an oil shale produced when the remains of algae are concentrated in a rock, whereas coals are formed from lignin and other minor components of land plants.

The results (Table 6) show that, for the first time, the experiments have achieved a good simulation of generation in a subsiding basin with a constant geothermal gradient. Olefins and carbon monoxide are not significant products from either source material, indicating a better simulation than previous laboratory experiments. Torbanite, after four years heating, gave an oil (Fig. 6), equivalent to 40% of its

Table 6. Products from slow pyrolysis of torbanite and brown coal under simulated geological conditions

Sample	Time (years)	Maximum temp. (°C)	Oil (%)	Gas (%)	Solid (%)
Torbanite	1	150	1	0	99
	2	200	1	1	98
	3	250	1	1	98
	4	300	41	4	55
	5	350	3	43	54
	6	400	0	51	49
Brown coal	1	150	3	2	95
	2	200	2	10	88
	3	250	1	20	79
	4	300	1	33	66
	5	350	0	45	55
	6	400	0	42	58

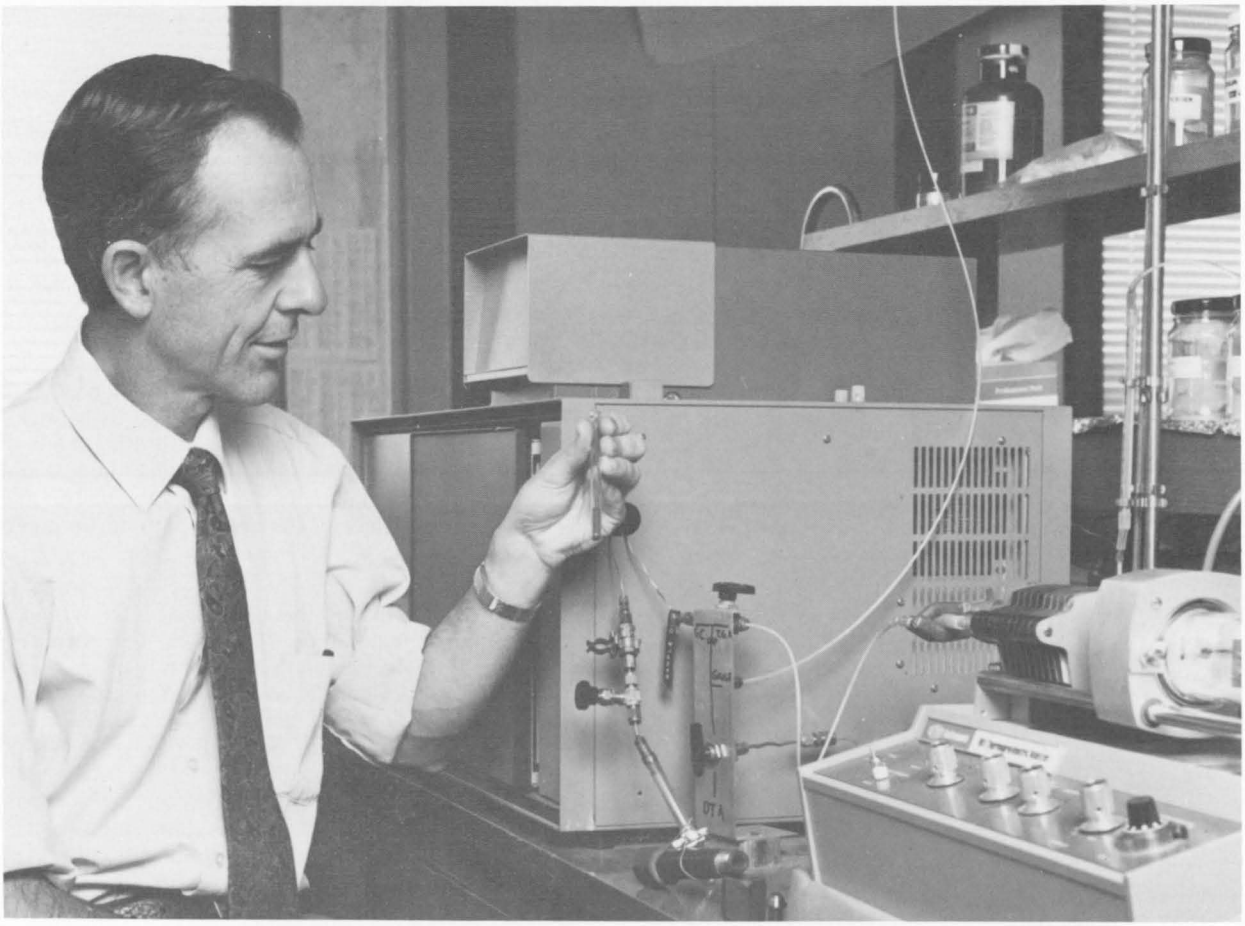

Fig. 5. Dr John Saxby examines the contents of a tube containing an oil source rock after slow pyrolysis for several years. Gaseous, liquid and solid products are separated and analysed by chemical and microscopic techniques.

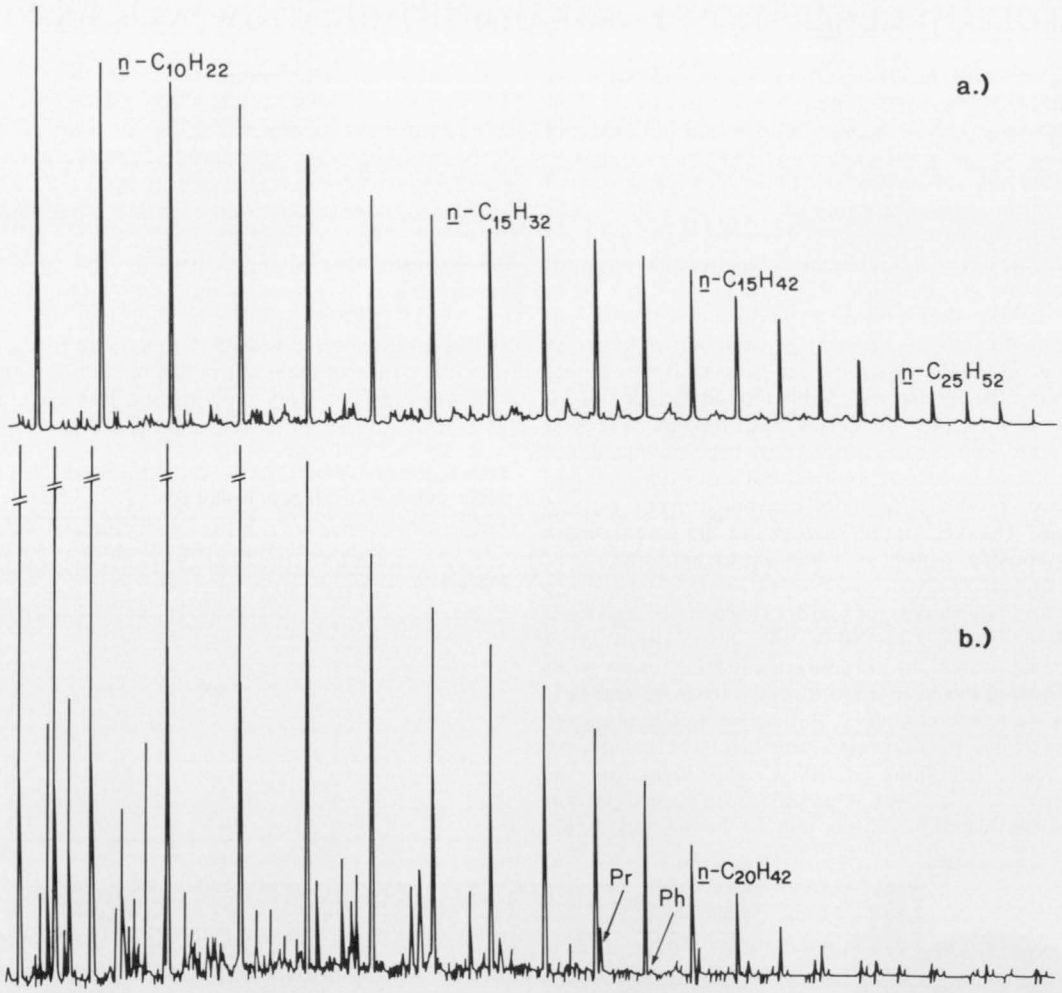

Fig. 6. Gas chromatograms of oil formed after four years during programmed heating from 100 °C to 300 °C. Oil is a major product from torbanite (a), while only a trace of oil is generated from brown coal (b). Normal alkanes dominate in both these chromatograms. Unsaturated compounds are absent, as in natural crude oils.

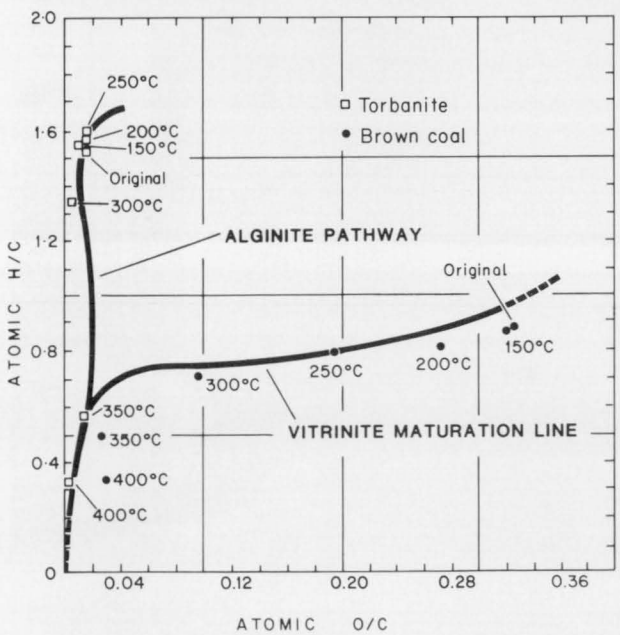

Fig. 7. Atomic H/C and O/C ratios for solid products from simulated laboratory maturation of torbanite and brown coal over several years. Temperatures beside each point are maximum values. Torbanite closely follows the 'alginite pathway'; brown coal points lie close to the well-established vitrinite maturation line.

original weight, typical of many paraffinic crude oils from Australian and overseas basins. Further heating resulted in cracking of the oil to gas, a reaction that also has a geological counterpart.

During the six years of heating, the brown coal 'matured' through a sub-bituminous coal, to bituminous coal and finally to anthracite (Fig. 7). Carbon dioxide is the main volatile product during the early stages of heating. Only a trace of oil is formed (Fig. 6), since lignin lacks long-chain aliphatic lipids. Methane-rich gas and condensate are generated when the rate of C-C bond rupture becomes significant.

The experiments clearly show that the hydrocarbons released during geological maturation depend on the chemical structure of the source material. Torbanite is an excellent source rock for oil; coals are generally gas-prone. In moving from the usual laboratory time-scale of hours to one of years, the fundamental chemistry of pryolysis changes and the dominant products are recognisable as petroleum and natural gas. Evidently, this slow 'molecule-by-molecule' mechanism remains unchanged, when even longer time intervals are available in the natural geological environment.

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GEOSCIENCE IN AUSTRALIAN TEACHING INSTITUTIONS

Introduction

Undergraduate courses to bachelor level or its equivalent, in what may be broadly termed geoscience, are offered by 27 Australian tertiary institutions. Sixteen are universities and the remainder institutes of technology, colleges of advanced education, or schools of mines. Some provide a wide range of courses, extending beyond those normally regarded as strictly geological, others direct their training to areas of close specialisation, in particular mining geology.

This is the first attempt to incorporate information on tertiary geological teaching programs in the annual report. In some respects, it is premature, as the available data are incomplete and not altogether reliable. They have been collated mainly from two recent surveys; one conducted by the Australian Council of Chairmen of Earth Science Departments (ACCESD) and the other by the Australian Institute of Mining and Metallurgy (AIMM). ACCESD was established in 1983, principally as the result of the initiative of Professor John Lovering, and meets annually in conjunction with the Geological Society of Australia. It is currently chaired by Dr John Glover, Department of Geology, University of Western Australia. The survey mentioned was intended to document the human and physical resources of Australian tertiary geoscience departments and was organised by Professor Bruce Hobbs and collated by J. F. Lovering and J. L. Semmens (*ACCESD Publ.* No. 1, 1984). It provides important information not available from other sources, but in some areas further amplification is necessary before the data are usable in any significant sense. Figures on student numbers, for example, are difficult to interpret because they have been expressed in a variety of terms by different institutions. In this account the details of student enrolments provided by the 1984 survey conducted by AIMM have been accepted. Despite the necessity for clarifying matters of detail, the ACCESD and AIMM reports set out general patterns of current resources and enable certain broad conclusions to be drawn. Tables 7-12 are intended to summarise the available data, which are briefly discussed in the paragraphs that follow. Little interpretation is attempted for the reasons outlined earlier, but it is hoped that a more complete and critical review of Australian tertiary geoscience teaching may be possible in the 1985 report.

Student enrolments

Tables 7 and 8 show the most recent available enrolment figures for universities and other tertiary institutions,

Table 7. 1984 enrolments in university Earth science departments (AIMM survey, 1984)

	Undergraduates				Graduates 1983		Postgraduates 1984			
							M.Sc		Ph.D.	
	1st yr	2nd yr	3rd yr	Hons + M.Sc. Prelim.	Pass	Hons	P/T	F/T	P/T	F/T
Adelaide	116	39	63	21	39	18	7	5	4	25
ANU (Geol. Dept)	76	28	20	5	8	4	2	4	2	8
ANU (RSES)	No undergraduates						1		19	
Flinders	176	26	18	9	15	13		29		
James Cook	61	26	24	11	15	5	4 + 14[1]		18	
Latrobe	84	18	20	10	20	9	3		4	
Macquarie	139	197	113	11	n.a.	n.a.	19[2]	3[2]	6[2]	10[2]
Monash	69	39	37	23	22	19	4	3	2	20
New England	141	23	13	17	9	10	1	14	3	6
NSW	73	25	29	18	2	1	61[3]		18[3]	
Newcastle	107	27	25	5	11	2	1		3	
Queensland	31[4]	34[4]	16	11	25	5		24		
Sydney	90	40	35	22	20	17	14		12	
Tasmania	44	20	35	22	2	7	6	2	3	10
UWA	119	32	34	14	30	12	7	2	13	21
Wollongong	109	11	8	—	6	—	32		11	

1. Course work master's candidates. 2. 1983 figures. 3. Includes Broken Hill campus. 4. Excludes non-geology majors.

Table 8. 1984 enrolments in Earth science departments at colleges of advanced education, institutes of technology and schools of mines (AIMM survey, 1984).

	Undergraduates				Graduates 1983		Post-graduates 1984 includes Grad. Dipl. M. Sc. doctoral
	1st yr	2nd yr	3rd yr	4th yr	Pass	Hons or equiv.	
Ballarat CAE	85	12	12		5	—	—
Bendigo CAE	15[1]	63[1]	55[1]	—		—	—
Canberra CAE	23	66	18	—	9	—	—
Darling Downs CAE	12	13	15	—	2	—	—
NSWIT	26	22	35	30	3	6	12
Queensland IT	26	20	28	—	15	—	3
Royal Melbourne IT	43	37	35	—	11	3	17
South Australian CAE	16[1]	7[1]	8[1]	2[1]	—	—	—
South Australian IT	17	11	7	2	7	1	6
West Australian IT	200[2]	40	34	11	26	12	20
West Australian SM	8	5	3	—	3	2	—

[1] 1983 figures from ACCESD Survey, 1984
[2] Includes students not majoring in earth sciences.

respectively. Most refer to 1984, but those for Bendigo and the South Australian CAE relate to 1983, as do the post-graduate figures for Macquarie. Totals are not directly comparable, as some departments have included all students enrolled in earth science units, whereas others have counted only those proceeding to a geology major.

The most significant figures, in relation to the training of professional geologists, are those in the columns headed 'Honours and Master's Preliminary' and 'Graduates, 1983'. Even here some duplication is implicit, as many 1983 pass graduates undoubtedly continued into honours in 1984. There is also an increasing trend, although no firm data are available, for more able CAE and institute pass graduates to proceed to honours at those universities whose regulations are sufficiently flexible to allow such transfers.

Staffing profiles

Staffing structures are shown in Tables 9 and 10, except for those at ANU Research School of Earth Sciences, which has no undergraduate teaching function. The tables emphasise patterns of established staffing, but research and teaching personnel engaged on a non-recurrent basis are included in the column headed 'Others'. Similarly, the numbers of technical and administrative staff relate only to established positions. Most institutions, especially universities, employ additional technical staff on a casual or contract basis from external funding.

Table 9 shows clearly the preponderence of senior staff in the universities and suggests that only ANU (Geol. Dept), Monash and Wollongong, have an acceptable spread across all academic levels from tutor to professor. Skewing towards the upper career ranges probably reflects two factors: easier promotional criteria in the sixties, and the virtual moratorium on recruitment that has existed since the mid-seventies. Unless early retirement is made more attractive, a crisis in staffing structures seems inevitable within 5-10 years in almost all universities.

Table 9. 1983 staffing levels, university Earth science departments (ACCESD survey, 1984).

	Academic							Non-academic	
	Professor	Assoc. professor/reader	Senior lecturer	Lecturer	Senior tutor	Tutor	Other[1]	Technical	Administrative/clerical
Adelaide	3	4	6	1	1	1	2	14	3.1
ANU (Geol. Dept.)	1	4	—	3	1	—	7	11	2
Flinders	2	1	4	1	—	—	—	c.8	3
James Cook	1	2	4	2	1	1	3	6	2
Latrobe	1	—	3	2	—	—	1	4	1
Macquarie	4	9	16	5	3	3	21	20	9
Melbourne	1	3	6	2	—	1	5	13	3
Monash	1	1	4	4	3	—	5	8	2.7
NSW	2	5	7	3	1	1	1	9	4
New England	1	3	5	2	—	2	3.5	7	1.5
Newcastle	1	4	2	1	—	—	0.7	5	1.2
Queensland	3	4	6	3	—	—	6	17	3.5
Sydney	1	7	9	1	1	—	4	15	4
Tasmania	1	4	3	2	—	—	4	8	3
UWA	1	4	1	2	2	—	4	8	3
Wollongong	1	1	1	2	1	1	—	6	?

[1] Includes research and teaching positions supported by external or non-recurrent internal funds.

Table 10. 1983 staffing levels in departments of geoscience at colleges of advanced education, institutes of technology and schools of mines (ACCESD survey, 1984).

	Academic							Non-academic	
	Professor	Principal lecturer/head	Senior lecturer	Lecturer	Senior tutor	Tutor	Other	Technical	Administrative/clerical
Ballarat CAE		1	1	2.5				0.6	
Bendigo CAE		1		3				1 + [3]	
Canberra CAE		1	3	2			c.0.5[1]	4	
Darling Downs CAE		1	1	2.5				2	
NSWIT		1	3	2	2		c.0.5[1]	6	1
Queensland IT		1	1	5			c.2[2]	4	
Royal Melbourne IT		1	2	6		1		4	1
South Australian CAE			1	3				2[3]	
South Australian IT	1		1	3		1		1	
West Australian IT		1	3	6			c.3[1]	3	
West Australian SM				no information					

[1] Part-time teaching funds. [2] Part-time positions. [3] Access to shared technical assistance.

Sharp divergences in technical support are also obvious from university to university and between the universities and the other tertiary institutions. The CAEs and institutes of technology, on the face of it, are less well-serviced, although sharing of facilities between departments appears to be more general in the non-university sector. Differences may thus be less acute than the figures suggest.

Within the universities, the average ratio of established technical to academic staff is 0.8:1.0. Melbourne, ANU (Geol. Dept), Flinders and Queensland are substantially better off than this and James Cook, Macquarie, New South Wales and New England significantly worse.

Staff expertise

Tables 11 and 12 attempt to indicate the range of specialist academic staff expertise available at each of the teaching institutions. It is not pretended that the picture presented is other than generalised, as most tertiary staff are able to teach at a sophisticated level outside their field of special interest. When such areas of subsidiary competence have been indicated on the ACCESD questionnaire they are shown by means of a (+) sign on Tables 11 and 12.

Despite these allowances, there is no doubt that Tables 11 and 12 give the impression of 26 essentially conservative departments, all offering, on different scales, the same range of course options. There is little evidence of notable course initiatives since the nineteen-sixties. Only Queensland and N.S.W., for example, have specialist petroleum geologists—a remarkable commentary on the response of tertiary educational bodies to the expansion of hydrocarbon exploration and production in Australia during the past 30 years. It is sometimes contended that petroleum geology derives its principles from the classic areas of the science and that specialist appointments in the field are an unnecessary luxury. The same argument, of course, applies to economic geology (in the traditional Australian sense of ore genesis), yet all but two universities have at least one 'economic

Table 11. Specialist interests of staff in university Earth science departments (ACCESD survey, 1984). Figures indicate number of staff whose primary interest is in the field designated.

	Adelaide	ANU (Geol. dept.)	Flinders	James Cook	Latrobe	Macquarie	Melbourne	Monash	New England	NSW	Newcastle	Queensland	Sydney	Tasmania	UWA	Wollongong
Coal Geology							+			+	1 +				+	1
Economic geology	2	1		2	1	6	2	1	1	3	1	2	2	1	1	
Engineering geology										2 +	+		1			
Geochemistry		1 +	1		1		2 +	1 +	1	1 +	+			1	1	
Geomorphology		1				10	1			+		1				
Geophysics	3	+	3			4	1		2	3		2	3	2	1	+
Hydrogeology			1							+					+	
Mathematical geology						+	+			1	+					+
Mineralogy	2	1		1			2			1	1	1		1	1	+
Igneous-metamorphic petrology	2	1	1	3	1	6	+	2	4	3	2	2	2	2	1	2 +
Palaeontology	2	1		1	1	4	2	1	1	1 +	1	3	5	1	2	1
Petroleum geology										1		1				
Regional geology Stratigraphy	1	2 +		+		3	1	+	+	1		+		1	+	+
Sedimentology-Marine geology	1	1 +	1	2	1	1 +	1	2 +	2	2	+	2 +	3	1	3	2
Structural geology	1	+	1	1	1	2	1	2	1	1 +	1	2	2		1	1
Unspecified							2									
Other							1									1

(+)—denotes that other staff have a secondary competence in the area.

Table 12. Specialist interests of staff in earth science departments at colleges of advanced education, institutes of technology and schools of mines (ACCESD survey, 1984). Figures indicate numbers of staff whose primary interest is in the field designated.

	Ballarat CAE	Bendigo CAE	Canberra CAE	Darling Downs CAE	NSWIT	Queensland IT	Royal Melbourne IT	South Australian CAE	South Australian IT	West Australian IT	West Australian SM
Coal geology				+		+				1	
Economic geology		+	1	1 +	+	2	1	+	1		
Engineering geology	1		1				2		1		
Geochemistry			+	1		1		+		1	
Geomorphology		1	1 +								
Geophysics	+	+				1			1	3	
Hydrogeology			1			+				+	
Mathematical geology							1				
Mineralogy	+		1	1		1 +			1		
Igneous-metamorphic petrology	1	1	1	+	2	1	1	1		1	
Palaeontology	0.5	1		1		+	1	+	1	1 +	
Petroleum geology											
Regional geology Stratigraphy		+		+		+		+	1	+	
Sedimentology-Marine geology		+	+	+		1	1	1		1	
Structural geology	1	1	+	+	1	+	1	1	+	1	
Unspecified											
Other			+		1			+		1	

(+)—denotes that other staff have a secondary competence in the area.

No information available

geologist' and six have two or more. Other developing fields in earth science, such as remote sensing, computer applications and numerical analysis have also been neglected by all but a few geological departments, although some of these fields have been embraced by sciences peripheral to geology.

It would be unfair to impute this lack of innovation entirely, or even largely, to deficient energy or imagination. Tertiary institutions are now in their tenth year of stagnation, and in some retrogression, as a result of government funding stringencies. Little staff mobility has existed and few options have been available. They are now entering a period of increased flexibility as senior staff, first appointed in the growth period of the 1950s, reach retirement age. The next five years will therefore set staffing patterns that will survive into the next century. It is, therefore, essential that the decisions taken are based on the advice and deliberations of the widest possible range of informed geological opinion.

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WOMEN AND CHILDREN FIRST?
GEOSCIENCE CAREERS AND FAMILY LIFE

The two previous Annual Reports contained short descriptions of results from the Geoscience Council's Human Resources survey dealing with the employment and careers of geoscientists. In this report, attention is shifted to some aspects of the lives of geoscientists, particularly their family lives.

As reported earlier, the vast majority of geoscientists are men—over 95%. Most of them are married; the proportion exceeds 80% and this will increase as younger geoscientists lift their marriage rates to those of older colleagues (see Table 13). Most geoscientists have also been highly mobile. About 34% were born overseas and were educated or began their careers there, and the majority of Australian-born geoscientists have made or will make at least an interstate move during their careers and many have worked, or will work, overseas.

What are the implications of mobility for family life? How are wives and children affected? Are there problems for housing and education? These and similar questions were partially addressed in the questionnaire which formed the basis of the Human Resources survey. While the answers are not wholly conclusive, they do suggest that career patterns sometimes conflict with family life. It should immediately be added, however, that there is no evidence that geoscientists as a whole, or the more mobile among them, have any significantly lesser propensity to marry and have children, or any higher tendency to divorce than the population as a whole. Any apparent discrepancies from the national average are largely due to their age structure which is biassed towards the younger groups.

Table 13. Age distribution and marital status of geoscientists at 1 March 1983

Age	Percentage of responses	Percentage married
under 25 years	4.8	26.7
25 - 29	11.8	57.0
30 - 34	22.5	81.6
35 - 39	18.9	88.1
40 - 44	15.5	90.8
45 - 49	8.3	94.3
50 - 54	9.3	89.9
55 - 59	5.4	91.3
60 and over	3.3	92.9
	Number of responses 870	

The majority of geoscientists obtain their first degree by their 23rd birthday, and over 90% do so before the age of 26. Until this time, most have lacked the financial resources and independence and, perhaps, the wish to take on marital and family commitments. Less than a quarter marry before or in the year of graduation and many of these were mature students who had already had a period of employment before taking their degree courses. Immediately after graduation, the marriage-rate climbed quite steeply (Fig. 8) and within 5 years, about 60% were married. The following 5 years saw the proportion rise more slowly, to reach almost 80%. Child-raising, however, came much more slowly and even 10 years after graduation, only 50% had one or more children, a pattern of deferred family formation that is not uncommon among professional groups where spouses also tend to have their own careers.

Fig. 8. The accumulation of family responsibilities. This graph shows the proportion of geoscientists who are (a) married, and (b) have at least one child during the ten years following graduation.

Indeed, geoscientists' wives tend to be quite well qualified themselves (Table 14), with over 60% having diplomas or degrees (including over 15% who have post-graduate qualifications). Such attainments have important implications for family incomes, since the wife's earning capability is likely to be substantial as long as she has the opportunity to work. Apart from being influenced by child rearing, such opportunities depend also on the husband's mobility and the location in which the family lives. Conversely, a wife's career may influence the potential mobility of her geoscientist husband.

The level of wives' qualifications is reflected in their occupations (Table 15). About two-thirds of them have jobs which require tertiary qualifications. Over a quarter are teachers, almost 14% are in various medical occupations and nursing, and another 15% in scientific, technical or computing jobs. Now, while it might seem that many of these occupations, together with most of those not requiring tertiary qualifications, are relatively transferrable from one location to another, there are several reasons why this mobility is likely to be impaired. Apart from current oversupply in some of these occupations, there is a strong likelihood, for example, that changing locations would lead to losing seniority. Indeed, about 35% of wives who were working had definitely had their career affected by their husband's mobility (Table 17). A further 30% of those who were not working had also been affected.

Table 14. Highest levels of education attained by geoscientists' spouses

Level of Education	Percentage of responses
School certificate or equivalent	19.4
Higher School Certificate	18.1
Diploma	23.6
Bachelors degree	23.0
Higher degree/postgraduate diploma	15.9
Total responses	680

Table 15. Occupations of geoscientists' spouses

Occupation	Percentage of responses
Engineers, scientists, doctors	9.6
Nursing and other medical	13.3
Teachers: tertiary	2.1
Teachers: primary and secondary	25.0
Artists, writers, etc.	2.1
Librarians	4.8
Social workers	2.1
Technicians	4.0
Computing, systems analysts	1.9
Other professions and management	2.8
Clerks, receptionists	21.3
Retail and wholesale workers	2.1
Other services	3.4
Not classified	0.9
'Housewives'	3.9
Total number of responses 671	

Table 16. Employment histories of geoscientists' spouses

	Number of responses
Never worked	12
Worked until marriage	124
Worked until first child	220
Worked throughout marriage:	
has children	94
no children	56
Returned to work after child-rearing	172
No answer/not applicable	192

Some interesting variations, not all of which are obvious, are apparent among the major occupation groups mentioned in the last paragraph. Wives with professional and scientific careers tended to work throughout their marriages, to have fewer children and to be only moderately affected by their husband's mobility. In comparison, those with teaching careers (which require little, if any, lesser qualifications) tended to return to work after child-rearing, but were much more affected by their husband's mobility, particularly where it involved interstate or international movement. Wives in clerical occupations formed a third clearly defined category. They showed a much greater tendency to give up work upon marriage or the birth of the first child, but for those who remained in the work force, there were, according to their husbands, few problems arising from mobility. These differences are not absolute, because 'mobility' was not the same for everyone: for example, being 'mobile' might have meant, at one extreme, several international moves or, at the other extreme, one move between different parts of a city. However, further analysis shows, for all categories, that difficulties faced by wives in their careers are increased by frequency of movement and type of move. International and interstate moves cause more problems than intrastate ones.

The types of effects on wives' careers are listed in Table 17. Of those affected, one-third became employed as the result of a change in the geoscientist's career and a further 28% of wives had to change their jobs. Others suffered by interruptions to their education, losing seniority, having to devote more time to their children, or simply because mobility lessened their career stability. A few geoscientists reported that their wives' careers benefitted from moving, usually because they had moved to metropolitan areas where there were more opportunities to work in their occupations.

Clearly, in the opinion of geoscientists, mobility has more detrimental impacts on their wives than on their children. While substantial numbers stated that their children suffered, more claimed that they had benefitted (Table 18). Without further evidence it is difficult to explain this dichotomy, but it might be suggested that movement into larger metropolitan areas seemed to have educational advantages, whereas interstate moves disrupted education. In contrast, international moves tended to be looked on more favourably, as broadening children's experiences and outlook.

Housing is a third area in which mobility has a marked impact (Table 19). Excluding those who have only moved once, or not at all, since 1970, about two-thirds of those who replied to the question said that their mobility had produced a definite effect on their housing. Some actually benefitted as

Table 17. Effects of mobility on spouses' careers

Effect	Number of responses
No answer/not applicable	238
Don't know	25
No effect: — not working	224
— working	182
Definite effect: — not working	103
— working	101
of which	**Number of times mentioned**
—interfered with spouse's education	15
—extra care needed for children	10
—spouse had to change job/career	56
—spouse's new occupation was less stable	20
—spouse lost seniority in career	27
—spouse became unemployed	66
—unspecified detrimental effects	15
—mobility was beneficial to spouse's career	13

Table 18. Effects of mobility on children

Effect	Number of responses
No answer/not applicable	340
Don't know	48
No effect	278
Definite effect	204
of which	**Number of times mentioned**
Detrimental effects	
—separation from family	11
—loss of friends	14
—'psychologically unsettling'	35
—educational disadvantage	49
Beneficial effects	
—better opportunities	37
—more understanding of people	58
—educational advantage	40
No simple answer (advantages and disadvantages)	15

Table 19. Effects of mobility on housing

Effect	Number of responses
No answer	236
No effect	409
Definite effect	225
of which	**Number of times mentioned**
—lost money	28
—lower housing standards	28
—higher costs of housing	33
—difficult to borrow due to mobility	29
—difficult to invest due to uncertainty	20
—dislikes lack of permanent dwelling	32
—*higher* living standards	20
—*made* money by moving	34

one might expect when movement is from higher to lower priced housing markets, but most suffered what they claimed to be significant economic problems, ranging to higher prices and lower standards, to difficulties in borrowing due to their locational instability.

While it would be wrong to infer from those results that geoscientists are unique in the problems of accommodating family life with careers, there is no doubt that, for a substantial number, the problems are quite severe. Indeed, even when they did not identify specific difficulties many stated strongly that the intellectual and professional challenges of their jobs (which they stress are the main attractions of a geoscience career) had to be set against insecurity, instability and disturbances to family life. Whether anything can, or should, be done about these difficulties is another matter and lies beyond the scope of this paper.

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(E)GAD!
EXPANDING GEOSCIENTIFIC ACRONYM DICTIONARY

(with thanks to Ian McLeod and David Branagan who in *The Australian Geologist, Newsletters* 8, 1975, and 10, 1976, published the first 130 acronyms which started this dictionary.

AAAS	American Association for the Advancement of Science
AAEC	Australian Atomic Energy Commission
AAGS	Association of African Geological Surveys
AAP	Association of Australasian Palaeontologists
AAPG	American Association of Petroleum Geologists
AAS	Australian Academy of Science
AATS	Australian Academy of Technological Sciences
ABN	Australian Bibliographic Network (National Library)
ABS	Australian Bureau of Statistics
ACA	Australian Coal Association
ACAR	Advisory Committee on Antarctic Research (Australian)
ACCESD	Australian Council of Chairmen of Earth Science Departments
ACIRL	Australian Coal Industry Research Laboratories
ACMRR	Advisory Committee on Marine Resources Research
ACORP	Australian Continental Reflection Profiling Program
ACS	Australian Computer Society
ADAB	Australian Development Assistance Bureau
ADDA	Australian Database Development Association
ADDA	Australian Diamond Drilling Association
AEG	Association of Exploration Geochemists
AEG	Association of Engineering Geologists
AESE	Association of Earth Science Editors
AESIS	Australian Earth Sciences Information System
AGC	Australian Geoscience Council
AGC	Australian Geological Convention (of GSA)
AGGSNAR	Aerial, Geological and Geophysical Survey of Northern Australia Reports
AGI	American Geological Institute
AGIA	Australian Geoscience Information Association
AGID	Association of Geoscientists for International Development
AGPS	Australian Government Publishing Service
AGS	Australian Geomechanics Society
AGU	American Geophysical Union
AIE	Australian Institute of Energy
AIG	Australian Institute of Geoscientists
AIM	Australian Institute of Metals
AIM	Australian Institute of Manufacturers
AIMM	Australasian Institute of Mining and Metallurgy, The (formerly AusIMM)
AIMS	Australian Institute of Marine Science (Townsville, Q.)
AIP	Australian Institute of Petroleum
AIPEA	Association Internationale pour l'Etude des Argiles
AIRDIB	Australian Industrial Research and Development Incentives Board
ALS	Australian Landsat Station
AMDEL	Australian Mineral Development Laboratories, The (Adelaide)
AMEC	Australian Minerals and Energy Council
AMEC	Association of Mining and Exploration Companies (Western Australia)
AMF	Australian Mineral Foundation (Adelaide)
AMIC	Australian Mining Industry Council
AMIRA	Australian Mineral Industries Research Association
AMMA	Australian Mines and Metals Association
AMPLA	Australian Mining and Petroleum Law Association
AMSTAC	Australian Marine Sciences and Technologies Advisory Committee

ANA	Australian Nuclear Association
ANARE	Australian National Antarctic Research Expeditions
ANCAR	Australian National Committee on Antarctic Research
ANCC	Australian National Coordinating Committee (for Marine Geoscience Programs)
ANU	Australian National University
ANZAAS	Australian & New Zealand Association for the Advancement of Science
AODP	Advanced Ocean Drilling Program
AOGG	Australian Organic Geochemists Group
APEA	Australian Petroleum Exploration Association
API	American Petroleum Institute
ARDB	Australian Resources Development Bank
ARGS	Australian Research Grants Scheme
ARPAC	Antarctic Research Policy Advisory Committee (Dept Science)
ASCE	American Society of Civil Engineers
ASCOPE	Asean Council on Petroleum
ASEAN	Association of South East Asian Nations
ASEAN/COIME	Association of South East Asian Nations/Committee on Industry, Minerals & Energy
ASEG	Australian Society of Exploration Geophysicists
ASG	Australasian Sedimentologists Group (of GSA)
ASGA	Association des Services Geologiques Africains
ASSS	Australian Society of Soil Science
ASTEC	Australian Science and Technology Council
AWRC	Australian Water Resources Council
AUSINET	Australian Information Network (ACI Computer Services)
AUSSAT	Australia's National Satellite System
BANG	Bulletin of Australian News in Geomathematics
BMR	Bureau of Mineral Resources, Geology and Geophysics
BRGM	Bureau de Recherches Geologiques et Minieres (France)
CAE	College of Advanced Education (e.g. Canberra CAE)
CCOP/EA	(ESCAP) Coordinating Committee for Offshore Prospecting in East Asian Waters
CCOP/SOPAC	(ESCAP)Coordinating Committee for Offshore Prospecting in the South Pacific
CCRS	Canadian Centre for Remote Sensing (Ottawa)
CCT	Computer Compatible Tape
CEGM	Centre d'Etudes Geologiques et Minieres, (France)
CGMM	Centre for Geostatistics and Mathematical Morphology
CGMW	Commission for the Geological Map of the World
CGS	Canadian Geoscience Council
CIFEG	Centre Internationale pour la Formation et les Exchanges Geologiques
CIG	Comite Internationale de Geophysique
CIOS	Conseil Internationale pour l'Organisation scientifique
CIUS	Conseil Internationale des Union Scientifiques
CMG	(IUGS) Commission on Marine Geology
CMMI	Council of Mining and Metallurgical Institutes
CNC/SCOR	Canadian National Committee, SCOR
CNRS	Centre National de la Recherche Scientifique (France)
CODATA	(ICSU) Committee on Data for Science and Technology
COGEODATA	(IUGS) Commission on Storage, Automatic Processing & Retrieval of Geological Data
COGS	Consortium for Ocean Geosciences (of Australian Universities)
COSOD	Conference on Scientific Ocean Drilling
CONSPAR	Committee on Space Research (ICSU)
COSTED	Committee on Science and Technology in Develping Countries
COWAR	Committee on Water Research
CPCEMR	Circum Pacific Council for Energy and Mineral Resources
CRATER	(Committee on) Computers and Related Technologies in Earth Resources (of ACS)
CRES	Centre for Resource and Environmental Studies (of ANU)
CRREL	Cold Regions Research and Engineering Laboratory
CSAGI	Comite Special de l'Année Geophysique Internationale
CSIR	Council for Scientific and Industrial Research (South Africa)
CSIRO	Commonwealth Scientific & Industrial Research Organisation
CSPG	Canadian Society of Petroleum Geologists
DSDP	Deep Sea Drilling Project
DSTO	Defence Science and Technology Organisation
DTCD	(UN) Department of Technical Cooperation for Development
DVDP	Dry Valley Drilling Project (Antarctica)
EAEG	European Association of Exploration Geophysicists
EASE	European Association of Science Editors
ECOR	Engineering Committee on Oceans Resources
EDITERRA	European Association of Earth Science Editors
ERF	Earth Resources Foundation

ERS	Earth Resources Satellite (Japan)
ERTS	Earth Resources Technology Satellite(s)
ESA	European Space Agency
ESCAP	(UN) Economic and Social Commission for Asia and the Pacific
ESEMG	Earth Sciences Education Methods Group
ESRISAT	Earth Science and Related Information-Selected Annotated Titles (of AMF)
FAGS	Federation of Astronomical and Geophysical Services
FIRB	Foreign Investment Review Board
GAA	Gemmological Association of Australia
GAGM	Gemmological Association of Great Britain
GARP	Global Atmospheric Research Project
GARS	Geological Applications of Remote Sensing (UNESCO and IUGS)
GEBCO	General Bathymetric Chart of the Oceans
GEOARCHIVE	British Earth Science Index
GEOREF	American Geological Institute Bibliography and Index of Geology
GEOSEA	Geology Mineral and Energy Resources of Southeast Asia
GGC	Government Geologists' Conference
GGU	Geological Survey of Greenland
GIA	Gemmological Institute of America
GIPME	Global Investigation of Pollution in Marine Environment
GIS	Geoscience Information Society
GMS	Geostationary Meteorological Satellite
GSA	Geological Society of America
GSA	Geological Society of Australia
GSC	Geological Survey of Canada
HCMM	Heat Capacity Mapping Mission
HDDT	High Density Digital Tape
HIAF	Heavy Ion Analytical Facility (CSIRO Mineral Physics)
HIG	Hawaiian Institute of Geophysics
IAB	ICSU Abstracting Board
IABO	International Association of Biological Oceanography
IACOMS	International Advisory Committee on Marine Sciences
IAEA	International Atomic Energy Agency
IAEE	International Association for Earthquake Engineering
IAEG	International Association for Engineering Geology
IAG	Institute of Australian Geographers
IAG	International Association of Geodesy
IAGA	International Association of Geomagnetism and Aeronomy
IAGC	International Association on Geochemistry and Cosmochemistry
IAGOD	International Association on the Genesis of Ore Deposits
IAGP	International Antarctic Glaciological Program
IAH	International Association of Hydrogeologists
IAHR	International Association for Hydraulic Research
IAHS	International Association of Hydrological Sciences
IAMAP	International Association of Meteorology and Atmospheric Physics
IAMG	International Association of Mathematical Geology
IAPSO	International Association of Physical Sciences of the Ocean
IAS	International Association of Sedimentologists
IASH	International Association of Scientific Hydrology
IASPEI	International Association of Seismology and Physics of the Earth's Interior
IAU	International Astronomical Union
IAVCEI	International Association of Volcanology and Chemistry of the Earth's Interior
IAWPR	International Association on Water Pollution Research
ICA	International Cartographic Association
ICES	International Council for the Exploration of the Sea
ICG	Inter-Union Commission on Geodynamics
ICID	International Commission on Irrigation and Drainage
ICL	Inter-Union Commission on the Lithosphere
ICOHTEC	International Coopn. in History of Technology Committee
ICOLD	International Commission on Large Dams
ICS	International Commission on Stratigraphy
ICSOBA	International Committee for the Study of Bauxites, Alumina & Aluminium
ICSU	International Council of Scientific Unions
IDRC	International Development Research Centre (Canada)
IEAust	Institute of Engineers Australia
IEEE	Institute of Electrical and Electronics Engineers
IFP	Institut Francais des Petroles (also Instantaneous Floating Point)
IFS	International Foundation for Science
IGBA	Igneous Data Base (of IGCP Project 163)

IGC	International Geological Congress
IGCP	International Geological Correlation Program
IGOSS	Integrated Global Ocean Station System
IGS	Institute of Geological Sciences (U.K.)
IGU	International Geographical Union
IGY	International Geophysical Year
IHB	International Hydrographic Bureau
IHD	International Hydrological Decade
IHP	International Hydrological Programme (UNESCO)
ILP	(ICSU/IUGS/IUGG) International Lithosphere Program
IMA	International Mineralogical Association
IMM	Institution of Mining & Metallurgy (U.K.)
INHIGEO	International Commission on the History of Geological Sciences (IUGS)
INQUA	International Union for Quaternary Research
IOC	Intergovernmental Oceanographic Commission (Unesco)
IP	Institute of Petroleum (U.K. & Australia)
IPMS	International Polar Motion Service
IPOD	International Project for Ocean Drilling
ISRIC	International Soil Reference and Information Centre (Holland)
ISSMFE	International Society for Soil Mechanics & Foundation Engineering
ISSS	International Society of Soil Science
IUCN	International Union for the Conservation of Nature and Natural Resources
IUCSTP	Inter-Union Commission on Solar Terrestrial Physics
IUCr	International Union of Crystallography
IUGG	International Union of Geodesy and Geophysics
IUGS	International Union of Geological Sciences
IUTAM	International Union of Theoretical and Applied Mechanics
JOIDES	Joint Oceanographic Institutions for Deep Earth Sampling
JPL	Jet Propulsion Laboratory (U.S.A.)
LEPOR	Long-term and Expanded Programme of Oceanic Exploration and Research
LITSAC	Lithosphere Transect Studies of the Australian Continent
LLR	Lunar Laser Ranging
LREE	Light Rare Earth Elements
MAB	Man and the Biosphere (UNESCO)
MAMBO	Mediterranean Association for Marine Biology and Oceanography
MERLCO	Mineral (Exploration) Research Liaison Committee (BMR/CSIRO)
MIDAS	Multimode International Data Acquisition Service
MMA	Mine Managers' Association (of Broken Hill)
MSS	Multispectral Scanner
NAGT	National Association of Geology Teachers (U.S.A.)
NASA	National Aeronautics and Space Administration, U.S.A.
NATO	North Atlantic Treaty Organisation
NCAR	National Committee for Antarctic Research (of AAS)
NCCMP	National Coordinating Committee for Marine Geoscience Programs
NCSES	National Committee for Solid Earth Sciences (of AAS)
NERC	Natural Environment Research Council, The (U.K.)
NERDDC	National Energy Research, Development and Demonstration Council
NERDDP	National Energy Research, Development and Demonstration Program
NHA	National Hydrocarbon Association
NNR	National Nature Reserve
NOAA	National Oceanographic and Atmospheric Administration (U.S.A.)
NSCA	National Safety Council of Australia
OCSEAP	Outer Continental Shelf Environmental Assessment Program (of NOAA)
OECD	Organisation for Economic Cooperation and Development
PEDIN	Petroleum Exploration Data Index, National (BMR)
PEPS	Programme d'Evaluation Preliminaire SPOT
PESA	Petroleum Exploration Society of Australia (former Professional Division of APEA
PIOSA	Pan Indian Ocean Science Association
POGO	Polar Orbiting Geophysical Observatory
PSA	Pacific Science Association
QFMRAAC	Queen's Fellowship and Marine Research Allocations Advisory Committee
RANRL	Royal Australian Navy Research Laboratory (Sydney, NSW)
RMRDC	(ESCAP) Regional Mineral Resources Development Centre
ROSTSEA	Regional Office for Science and Technology for Southeast Asia (of UNESCO)
RSES	Research School of Earth Sciences (of ANU)
SCAR	(ICSU) Scientific Committee on Antarctic Research
SCOPE	Scientific Committee on Problems of the Environment
SCOR	(ICSU) Scientific Committee on Oceanographic Research
SCS	Soil Conservation Service (of NSW)

SEAGS	Southeast Asian Geotechnical Society
SEAPEX	Southeast Asia Petroleum Exploration Society
SEARING	Southeast Asia Regional Network of Geoscience
SEATAR	Studies on East Asia Tectonics and Resources
SEATRAD	Southeast Asia Tin Research and Development Centre
SEG	Society of Exploration Geophysicists (U.S.A.)
SEG	Society of Economic Geologists
SEPM	Society of Economic Palaeontologists & Mineralogists (a Division of AAPG)
SES	(Section of) Statistics in the Earth Sciences (of SSA)
SG(s)	Specialist Group(s) within the Geological Society of Australia
SGEG	Specialist Group in Economic Geology (of GSA)
SGESH	Specialist Group in Earth Sciences History (of GSA)
SGGMP	Specialist Group in Geochemistry, Mineralogy & Petrology (of GSA)
SGS	Specialist Group in Sedimentology (of GSA)
SGSEG	Specialist Group in Solid Earth Geophysics (of GSA)
SGTSG	Specialist Group in Tectonics & Structural Geology (of GSA)
SGU	Geological Survey of Sweden
SHRIMP	High-resolution ion microprobe mass spectrometer
SIPRE	Snow, Ice and Permafrost Research Establishment (US Army. Since about 1960, CRREL)
SLEADS	Salt Lakes, Evaporites and Aeolian Deposits program (ANU)
SLR	Satellite Laser Ranging
SMEDG	Sydney Mineral Exploration Discussion Group
SOPAC	South Pacific
SPE	Society of Petroleum Engineers
SPEI	Seismology & Physics of the Earth's Interior (of Nat. Comm. Solid Earth Sci.)
SPOT	Systeme Probertoire d'Observation de la Terre (France)
SPRI	Scott Polar Research Institute (U.K.)
SPWLA	Society of Petroleum Well Log Analysts
SSA	Statistical Society of Australia
SSSI	Site of Special Scientific Interest
TIMS	Thermal Infrared Multispectral Scanner (U.S.)
TM	Thematic Mapper
UAI	Union of International Associations
UAR	United Arab Republic
UMC	Upper Mantle Committee
UN	United Nations
UNCLOS	United Nations Conference on the Law of the Sea
UNCSTD	United Nations Conference on Science and Technology for Development
UNDP	United Nations Development Programme
UNDTCD	United Nations Department of Technical Cooperation for Development
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNIDO	United Nations Industrial Development Organisation
UNRFNRE	United Nations Revolving Fund for Natural Resource Exploration
USGS	United States Geological Survey
VCEI	Volcanology and Chemistry of the Earth's Interior (of NCSES)
VIMS	Victorian Institute of Marine Science
VLBI	Very Long Baseline Interferometry
WAMPRI	Western Australian Mining & Petroleum Research Institute
WEDC	Water & Waste Engineering for Developing Countries (Loughborough Univ. of Technology, U.K.)
WESTPAC	Program Group for the Western Pacific (of Internat. Oceanographic Commission)
WHOI	Woods Hole Oceanographic Institution
WMS	World Magnetic Survey
WPC	World Petroleum Congress
WPC	World Power Congress

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APPENDIX: DATA ON MEMBER SOCIETIES, 1984

Society and membership	*Objectives*	*Meetings, activities, committees*	*Publications*	*Awards*	*Association with other organisations*	*Other information*
ASSOCIATION OF EXPLORATION GEOCHEMISTS (AEG). P.O. Box 523, Rexdale, Ontario, M9W 5L4, Canada. P.O. Box 80, Belmont, WA 6104. Membership in Australia: Voting 110 Affiliate 6 Student 78 Worldwide Membership over 700, in 60 nations.	To represent the professional interests of persons specialising in exploration geochemistry: to advance mineral exploration applications of geochemistry: to disseminate Geochemical information and ideas among professional geochemists.	—Regional Meeting Reno, Nevada, March, 1984. —Joint session at 7th Geological Convention on 'Geochemical Exploration for Gold Mineralisation', Sydney, August, 1984. —11th International Geochemical Exploration Symposium, Toronto, April 1985. —Regional Meetings for 1986 in Vancouver and Johannesburg. —Regular Council Meetings. COMMITTEES: Admissions; Bibliography; Case Histories; Geochemical Analysis; Membership; Publications; Research and Education; Student Prize; Symposium.	—*Journal of Geochemical Exploration*, Elsevier (6 issues/year). —Quarterly Newsletter (to members only). —*Geochemical Exploration* 1980, Elsevier 698 pp. —*Precious Metals in the Northern Cordillera 1981*, AEG, 214 pp. —*Exploration Geochemistry Bibliography* 1982, AEG, 388 pp.	—Honorary Membership. —Annual Student Prize.	—Australian Geoscience Council. —Canadian Geoscience Council. —International Union of Geological Sciences. —United States National Committee for Geochemistry.	AEG was founded in 1970 in Toronto as an international organisation. Australia has the third largest membership after the United States and Canada. The office bearers consist of a five-person Executive and 12 ordinary Councillors, all of whom are normally resident in North America, together with four regional Councillors representing Australia, Europe, and Southern Africa and Brazil.
AUSTRALASIAN INSTITUTE OF MINING AND METALLURGY (Aus. IMM). Clunies Ross House, 191 Royal Parade, Parkville, Vic 3052 Honorary Members 19 Members 1805 Associated Members 2750 Company Members 145 Affiliate 305 Junior 1070 Student 794 Total 6888	The objectives and purposes of the Institute are to promote and advance the science and profession of engineering with special reference to mining, including geology and metallurgy in all its branches. The Institute is both a professional body and a learned society. It serves the interests of geologists (including geophysicists), metallurgists and mining engineers as well as persons in other disciplines of science and engineering associated with the mineral industry. The Institute provides affiliate membership for persons working in responsible positions in the mineral industry and who are qualified in other professional fields.	—Annual Meeting. —Annual Conference. —Specialist Symposia and Conferences. COMMITTEES: Membership; Publications; Education; Accreditation.	—*Bulletin* (8 per year). —*AIMM Bulletin and Proceedings* —Annual Conference Volume. —Symposium Volumes. —Monograph Series (Geology of Australia and Papua New Guinea, Field Geologists Manual, Mining and Metallurgical Practices in Australia). Victorian Brown Coal.	—The Institute Medal. —Honorary Membership. —President's Award. —Student Essay Prize.	—Australian Geoscience Council. —Australian Geomechanics Society (Joint technical unit with the Institution of Engineers, Australia). —Council of Mining and Metallurgy Institutions.	The Institute has 36 branches in capital cities and major mining centres in Australia, New Zealand, Papua New Guinea and Fiji.

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AUSTRALIAN GEOMECHANICS SOCIETY (AGS) C/o Mr Roy Bushnell Committee Secretary, The Institution of Engineers, Australia. 11 National Circuit, Barton, ACT, 2600 Financial Membership 498	To promote and advance the science and practice of geomechanics by implementing the learned society functions of the Institution of Engineers, Australia (IE Aust) and the Australasian Institute of Mining and Metallurgy (Aus IMM) in the field of geomechanics.	—Australia-NZ Conference on Geomechanics held every four years. —Each of the State groups meets approximately nine times per year for technical sessions. —Usually each of the State groups holds a major technical seminar each year. —National Committee meets twice yearly (usually Canberra, Sydney or Melbourne).	—*Australian Geomechanics News* is published twice yearly for AGS by IE Aust. —*Australian Geomechanics Computing Newsletter*; twice yearly.	*The Australian Geomechanics Award: The John Jaeger Memorial Medal.* Awarded on the recommendation of the judging panel to an individual, considered to have made a significant contribution to Australian geomechanics over recent years. Awarded every four years to coincide with each Australian-NZ Conference.	—AGS is sponsored by IE Aust and Aus. IMM. Each member of the society shall, upon payment of annual subscriptions, become affiliated with the international Society of Soil Mechanics and Foundation Engineering, the International Society of Rock Mechanics, and the International Association of Engineering Geologists. —Australian Geoscience Council.	The objectives of AGS are carried out by organising technical conferences, symposia and meetings; by promoting research and development and improved practice; by cooperating with appropriate bodies outside the sponsoring societies both within Australia and overseas; and by means of a publication.
AUSTRALIAN INSITUTE OF GEOSCIENTISTS (AIG) C/o Geological Society of Australia 10 Martin Place, Sydney, NSW 2000. Membership 600	To advance the status of Geoscientists in Australia and to act as a professional institute of geoscientists.	Council meets monthly. Branch meetings as required; Seminars; Annual General Meeting.	No formal publication. Special publication of Seminars as soon as possible after the meeting.	No awards.	—Australian Geoscience Council. —Australian Society of Exploration Geophysicists. —Geological Society of Australia. —Petroleum Exploration Society of Australia.	Founded in Oct. 1981 following the report of a GSA committee which recommended that geoscientists required a professional body to represent them. This was supported by PESA and ASEG.
AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS (ASEG) C/o Science Centre, 35-43 Clarence Street, Sydney, NSW 2000. Membership: Active and Associate 862 Student 118 Honorary 6 Corporate 44 1030	To promote: —the science of geophysics especially as applied to exploration; —fellowship and cooperation: —good standing of the geophysical profession; —close cooperation and understanding between all earth sciences. To assist in: —the design and teaching of geophysics courses; —formation of local branches.	—Biennial Conference Sydney 9th-12th September, 1985. —State Branch Meetings, 4 to 12 times per year. —Annual General Meeting, April each year. —Executive Committee, monthly. —Workshops/seminars/ conferences (as advertised).	—*Exploration Geophysics The Bulletin of the Australian Society of Exploration Geophysicists*, four issues per year. —Newsletter (monthly) —*The Geophysics of the Elura Orebody.*	Honorary Membership	—Society of Exploration Geophysicists. —Australian Geoscience Council.	

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AUSTRALIAN SOCIETY OF SOIL SCIENCE INC. (ASS). C/o Department of Soil Science, School of Agriculture, University of Melbourne, Parkville, Vic. 3052.	To advance soil science. To provide a link between soil scientists and members of kindred bodies within Australia and other countries.	—Approximately monthly meetings in each of seven geographical Branches. —Annual Conferences between three Branches. —National Soils Conference (4 yearly) —Regular Federal Council Meetings.	—No formal society journal, although ASSS has a representative on the Advisory Committee of *Aust. J. Soil Res.* —Occasional publications have been produced on nine specific topics including soil classification, glossary of soil science terms, and hydrogeology. —*Soils News* (quarterly) includes summaries of talks and newsletter material.	*J. A. Prescott Medal of Soil Science*, awarded annually to a person who has made an outstanding contribution to soil science. *ASSSI Publication Medal* awarded annually to a person under 35 years of age whose publications are judged on scientific merit, relevance to soil science, and effectiveness in communication.	—International Society of Soil Science. —Australian Geoscience Council.	ASSS was formed in 1956 as a federation of Branches, and most meetings are organised at the Branch level. The next National Soils conference is being organised for 1988 in Canberra.
GEOLOGICAL SOCIETY OF AUSTRALIA INC. (GSA). The Business Manager, Geological Society of Australia, Room 1001 Challis House, 10 Martin Place, Sydney, NSW 2000. Membership: Ordinary 2752 Associate 290 Student 204 Honorary 15 Retired 6 Company 33 3300	To advance the geological sciences in Australia.	—Australian Geological Convention held approximately every 18 months since 1975, hosted by Divisions on a national roster. —National and regional thematic symposia sponsored by the Society and run by Divisions, Branches or Specialist Groups at frequent intervals, as opportunity exists. —Division and Branch monthly meetings. STANDING COMMITTEES: Stratigraphic Nomenclature; Geological Monuments; Education	—*Australian Journal of Earth Sciences* published quarterly. —Special Publications usually major thematic publications (latest release, No. 11, 1983). —*Australian Geologist*, a newsletter published five times each year. —*Alcheringa*, an Australasian journal of palaeontology. —Specialist Groups produce publications and newsletters from time to time, for example, Newsletter in Structural Geology and Tectonics, Coal Geology, etc. —Thematic maps—e.g., Geotectonic Map of Australia and New Guinea 1971. Excursion Guides. Abstract Series.	—*W. R. Browne Medal* awarded by each Executive to a person distinguished in the geological sciences through research, education or administration. —*F. H. Stillwell Award*, awarded annually for the best paper in Aust. J. Earth Sci. —Some Divisions offer prizes such as: for the high school geology student with the best Matriculation mark. —Honorary Membership.	—Australian Geoscience Council. —Australian Academy of Science National Committee for Solid Earth Sciences. —International Union of Geological Sciences. —Fostered the foundation of the Australian Institute of Geoscientists. —Joint meetings with Aus. IMM are commonly held at Division level. —Active scientific liaison is maintained between Australian earth scientists and overseas working groups, in part through collaboration with the International Geological Correlation Program.	—Founded in 1951. GSA has a code of ethics which members must endorse. —GSA is composed of six State Divisions, one Territories Division, two Branches, and nine Specialist Groups; and representatives of these bodies constitute the Council. —The Executive moves from one Division to another on a national roster, and consists of eight members, under the chairmanship of the President, who are elected by Council. —Executive term, and the interval between Council Meetings, is about 18 months. —GSA welcomes overseas members. —Sale of publications is through the Business Manager.

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INSTITUTE OF AUSTRALIAN GEOGRAPHERS (IAG). C/o Dr. C. Adrian, A.I.U.S., G.P.O. Box 809, Canberra, A.C.T. 2601	The promotion of the study and discussion of geography in Australia, especially by the holding of meetings at which the results of research may be presented and discussed. The advancement of geography in Australia, and the representation and advancement of Australian geography internationally. Cooperation with other organisations with kindred purposes.	IAG Meeting every 12 months. —Meetings of study groups.	—*Australian Geographical Studies* published twice yearly. —*IAG Newsletter*, two issues per year.	*IAG Honours Award*, for a paper based on honours research at an Australian tertiary institution.	Australian Geoscience Council.	IAG was founded in 1958. Membership is by one of the following: —honours or higher degree in geography; membership of a Geography department or section in a tertiary institution; —contribution to geographical research; —engaged in work (recognised by IAG Council) as a professional geographer; —by invitation.
PETROLEUM EXPLORATION SOCIETY OF AUSTRALIA (PESA). C/o J. Walters Limited, Secretary/Treasurer, G.P.O. Box N1120, Perth, WA 6001 Membership: in Australia 1439 Overseas 40 1479	To promote professional and technical aspects of the petroleum industry throughout Australia by providing a medium for the gathering of individuals interested in oil and gas exploration and the petroleum industry; to present views and discuss technical and professional matters relating to the petroleum industry on a national basis; to foster and provide continuing education for the benefit of its members; to nurture the spirit of research.	—Monthly luncheon meetings held in each State branch in Sydney, Melbourne, Adelaide, Perth, and Brisbane. —Annual General Meeting March 1985. —1984 Australian Distinguished Lecturer; August 1984 Melbourne, Perth, Adelaide, Brisbane and Sydney. —Symposia.	—*PESA Journal* (biannually), first issue August 1982. —Course Notes—Distinguished Lecturer from Overseas (annually).	—The Constitution makes provision for the awarding of distinguished membership. The last award was made to D. McDonald in April, 1981. —An award is made by PESA for the best presented paper at the annual Australian Petroleum Exploration Association Conference.	—American Association of Petroleum Geologists. —Australian Petroleum Exploration Association. —Australian Mineral Foundation. —Australian Geoscience Council. —Geological Society of Australia, Inc. —Australian Institute of Geoscientists. —Earth Resources Foundation.	PESA started out as the Australian Petroleum Exploration Professional Division in 1968, but became independent of APEA and adopted its new title in 1974. PESA was incorporated on 3 March 1983.

R83/1246 (10) Cat No. 85 0519 1