BMR Research Newsletter

A twice-yearly newsletter for the exploration industry

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New hydrocarbon plays in the Bass Basin

A significant improvement in deep seismic data resulted from the 1982 BMR contract geophysical survey in Bass Strait (Fig. 2, middle) using a high-energy airgun source and a 3200 m long streamer (96-channel, 48-fold). These data have disclosed the geology of the deeper basin beneath the Eocene coal measures and revealed new hydrocarbon plays related to major early structures, as well as providing a sounder basis for understanding basin formation mechanisms.

The geological history of the Bass Basin described by Robinson (1984: *APEA Journal* 14, 44–9), Brown (1976: *Australasian Institute of Mining & Metallurgy Monograph* 7, 67–82), and Nicholas & others (1981: *BMR Journal of Australian Geology & Geophysics,* 6, 199–212) has been modified to accommodate new results from this survey. Preliminary inspection of data within the Gippsland and Otway Basins indicates that the early basin development for the region can be generalised across Bass Strait.

The Bass, Gippsland, and Otway Basins were initiated by Late Jurassic to Early Cretaceous rifting: movement along major shallow-dipping normal faults gave rise to basement tilt blocks and half-grabens in which alluvial clastics accumulated. These sediments are up to 6 km thick in the depocentres, and thin to a few hundred metres or less over tilt-block edges and near basin margins. They are unconformably overlain by a mainly non-marine clastic sequence from Late Cretaceous to Eocene in age. The Late Cretaceous to Eocene section in the Bass Basin is known as the Eastern View Coal Measures (EVCM, equivalent to the Latrobe Group in the Gippsland Basin), and it has been divided into upper and lower sequences separated by a disconformity of regional extent.

Extensional structures in Bass Basin

The Early Cretaceous fault geometry recognised from the BMR data demands significant horizontal crustal extension, in contrast to the largely vertical movements previously proposed by other authors. The faults are planar, have shallow to moderate dips (generally to SSW), and have rotated during displacement, producing tilts of the basement surface of up to 30° (Fig. 2, bottom; event below 100 m.y. surface; note vertical exaggeration of about 3:1). Fault displacement generally exceed 1 km, and may range up to 10 km. This style of faulting is similar to that described from other extensional terrains, such as the Basin and Range Province, the Aegean Sea, the North Sea, and the Bay of Biscay continental margin. The magnitude of the horizontal extension during the Early Cretaceous in the Bass Basin, calculated from simple models of 'domino' fault geometry, was between 60 and 100 per cent (β = 1.6 to 2.0).

North-northeast-trending dextral transverse faults disrupt the major normal faults (Fig. 2, top). They are not necessarily simple strike-slip faults (the heavily drawn fault near the basin centre is a good example), but have essentially the

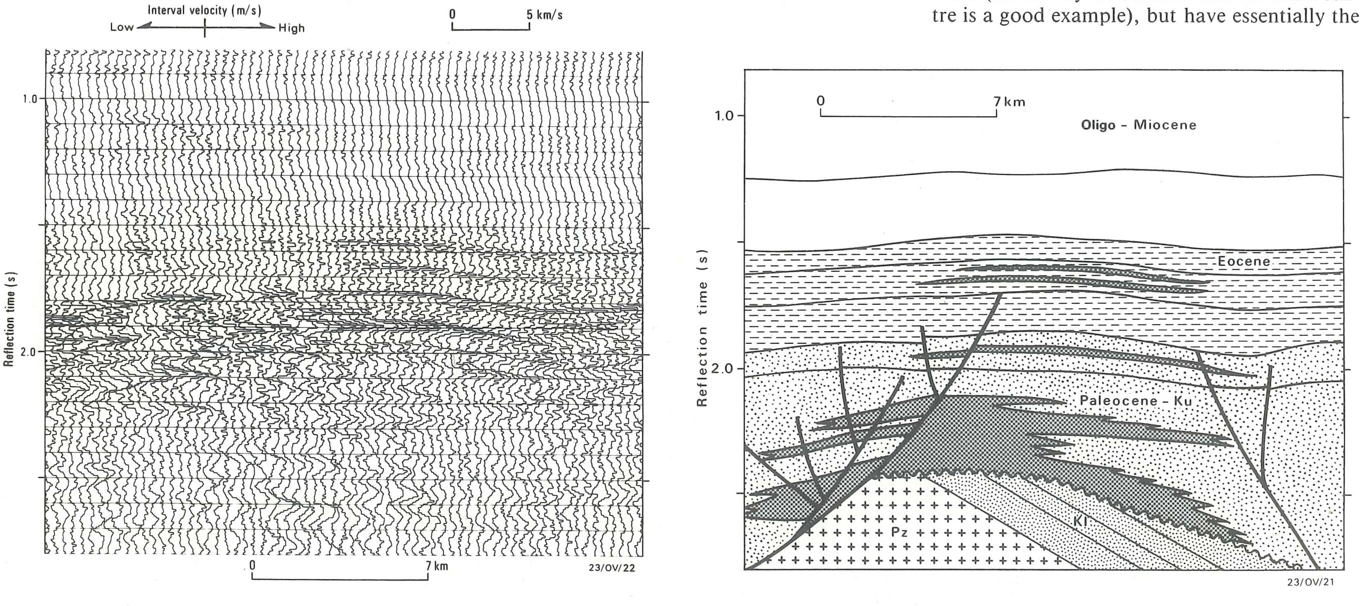


Fig. 1. (*left*) BMR line 11 seismic inversion logs with narrow low-velocity flat spot at 1.55s, 1.64s, and 1.66s twt. The play concept model at right is based on these logs. (*right*) Play concepts based on data near Bass 1. Play types: 1) sand compaction drapes; 2) faulted sand in alternations of sand and clay; 3) folded and faulted sand which terminates against diapiric shale. Units: marine shale — blank; marginal marine to deltaic coal, silt, and clay — open stipple; fluvial and alluvial sand — heavy stipple; alluvial and fluvial silt, clay, and thin coal — medium stipple; basement — crosses.

From the Director

The *BMR Research Newsletter* (of which this is the first issue) is designed to provide for the early dissemination of information and interim results of BMR's research and resource assessment projects that are relevant to the exploration industry. It thus complements both the annual summaries of projects in the Yearbook and the more detailed information that appears in BMR's serial, monograph, and map publications. It will also contain commentaries on advances in research in Australia or overseas which have particular relevance to the understanding of Australian geology and mineral resources.

The *Newsletter* will be published twice each year — normally in April and October. One issue will focus mainly, but not exclusively, on energy-related projects, and the other on minerals-related projects. The emphasis in this issue is on energy projects.

I hope that the *Newsletter* proves to be a useful means of communication from BMR to geoscientistis in the exploration industry, and that it encourages industry comment on, and participation in, BMR research projects. I would welcome any comments or suggestions for improving future issues.

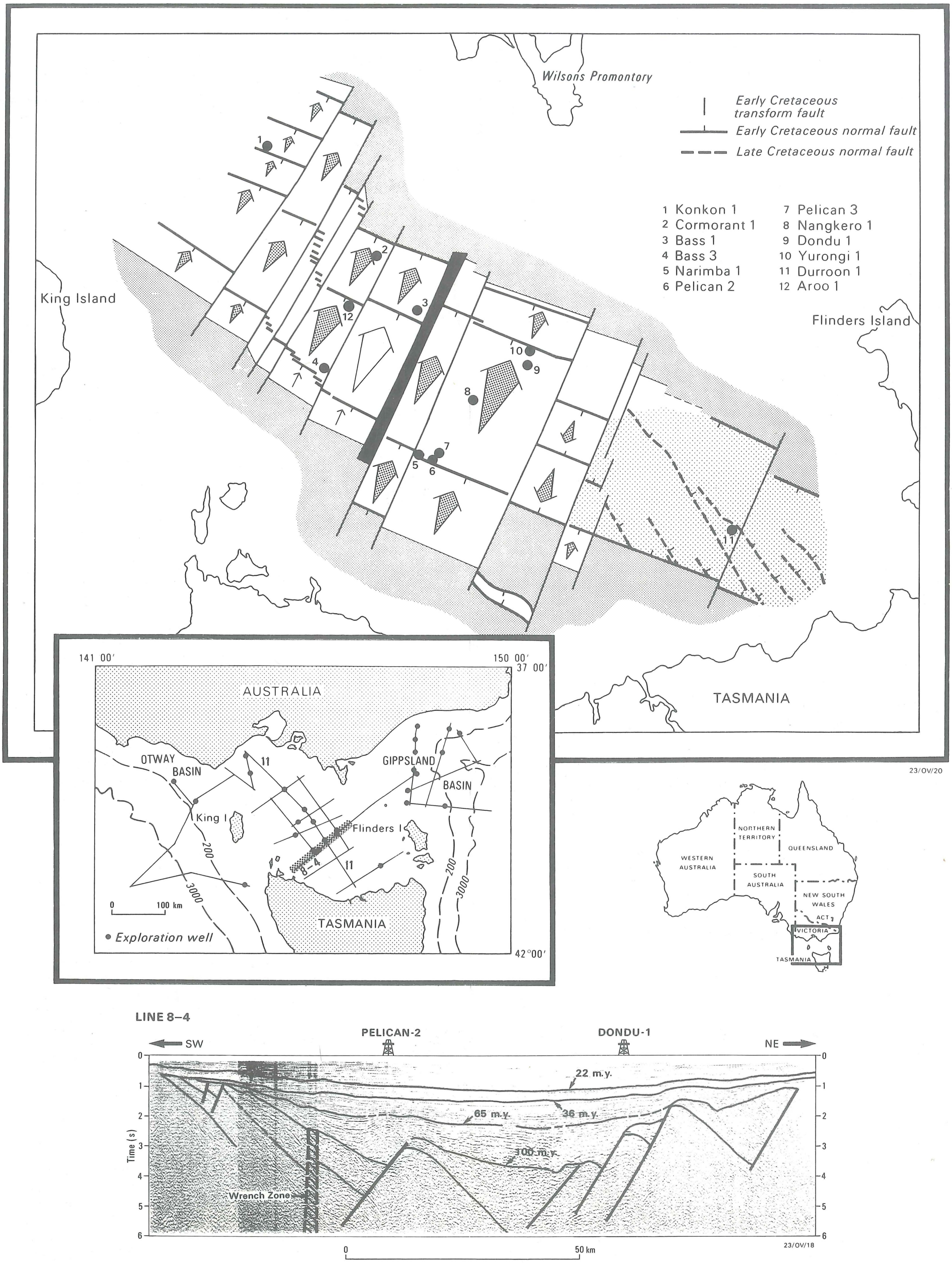


Fig. 2. (*top*) Major Early Cretaceous normal and transform faults and sedimentary wedges (sizes of arrows reflect comparative thicknesses and extents of Early Cretaceous sediment). (*middle*) Regional seismic traverses of BMR 1982 survey. (*bottom*) Interpreted seismic section line 8–4 from BMR 1982 survey, showing major Early Cretaceous faults, tilt blocks, and half-grabens.

same kinematic style and geometry as oceanic transform faults (Bally, 1981: *AAPG Educational Course Note Series,* 19, figs. 21-24); in other words, the transform or wrench faults developed during normal faulting and extension, and were not superimposed later.

The style of the Early Cretaceous structures is different in the southeast corner of the basin, where a near symmetrical Early Cretaceous graben is overprinted by northwest-trending Late Cretaceous tilt blocks (Fig. 2, top). The Late Cretaceous episode of faulting is essentially unrelated to the overall basin development, but is probably related to spreading in the Tasman Sea at that time.

Play concepts

The Early Cretaceous fault and tilt blocks have contributed to the development of hydrocarbon plays. Much of the structure in the more prospective overlying rocks results from differential compaction over and/or rejuvenation of these deep structures. Anticlinal closures over buried tilt block edges have been extensively explored along the basin margin (e.g., Dondu, 1, Bass 3). However, the major hydrocarbon indications have been found closer to the basin depocentre. The Pelican gas field is located in just such a mid-basin structure. Whereas previous interpretations have implied that the Pelican structures correlate with those along the southwest margin of the basin, the new structural model presented here correlates them across transform-like faults with the major tilt block near Aroo 1 and Bass 1, in the centre of the basin. The coincidence of an Early Cretaceous tilt block and a thick Late Cretaceous to Paleocene source section is now regarded as being highly prospective, and play concepts have been developed accordingly.

One example of a number of such new, tilt-block related Paleocene/Late Cretaceous plays is near Bass 1 (Fig. 1, right). The uppermost type of play (1) is due to differential compaction over the basement high or rejuvenation of the early normal fault, and may occur in Eocene, Paleocene, and Late Cretaceous sediments. Closure of such a structure along strike is facilitated by the transverse faults which terminate the high blocks and normal faults. In this particular example, possible direct hydrocarbon indicators (DHIs) are observed on the synthetic sonic log/seismic trace inversion record section (Fig. 1, left). They occur at multiple depths over the structure as both velocity anomalies and 'flat spots'. However, there is a volcanic edifice nearby (intersected in Bass 1), and the velocity anomalies may result from sills or flows.

A deeper play (2) has resulted from the influence of the elevated tilt-block edge on Late Cretaceous sedimentation. Erosion of the basement high block is likely to have given rise to local coarser, possibly reworked sediments that would provide suitable reservoirs.

A play related to possible shale diapirism (3) in the thickest parts of the Late Cretaceous section occurs on the downthrow sides of horst blocks. Cretaceous palaeolatitudes of the region argue against evaporites as the cause of the diapirism, but overpressuring related to shale mobilisation is evident around Pelican 2.

Subsidence and maturation history

The subsidence and thermal maturation history of the plays illustrated in Figure 1 have been synthesised from the seismic stratigraphy, well data from Bass 1, and an anomalous palaeoheatflow predicted by a lithospheric extension model developed in BMR by G. Karner (now at Durham University, UK).

A computer-generated thermal geohistory (Fig. 3) indicates that the entire Paleocene/Cretaceous section falls precisely within the oil window (R_o = 0.6 to 1.3%). This is consistent with observed Eocene to Recent maturation levels in adjacent wells. Oil generation from Late Cretaceous and Paleocene (lower EVCM) source rocks is predicted to have commenced in the Miocene, after structural development of the trap. The presence of DHIs at a depth of 2 km (above the top of the present oil window) implies migration, and is consistent with shows of oil observed at similar levels in Cormorant 1.

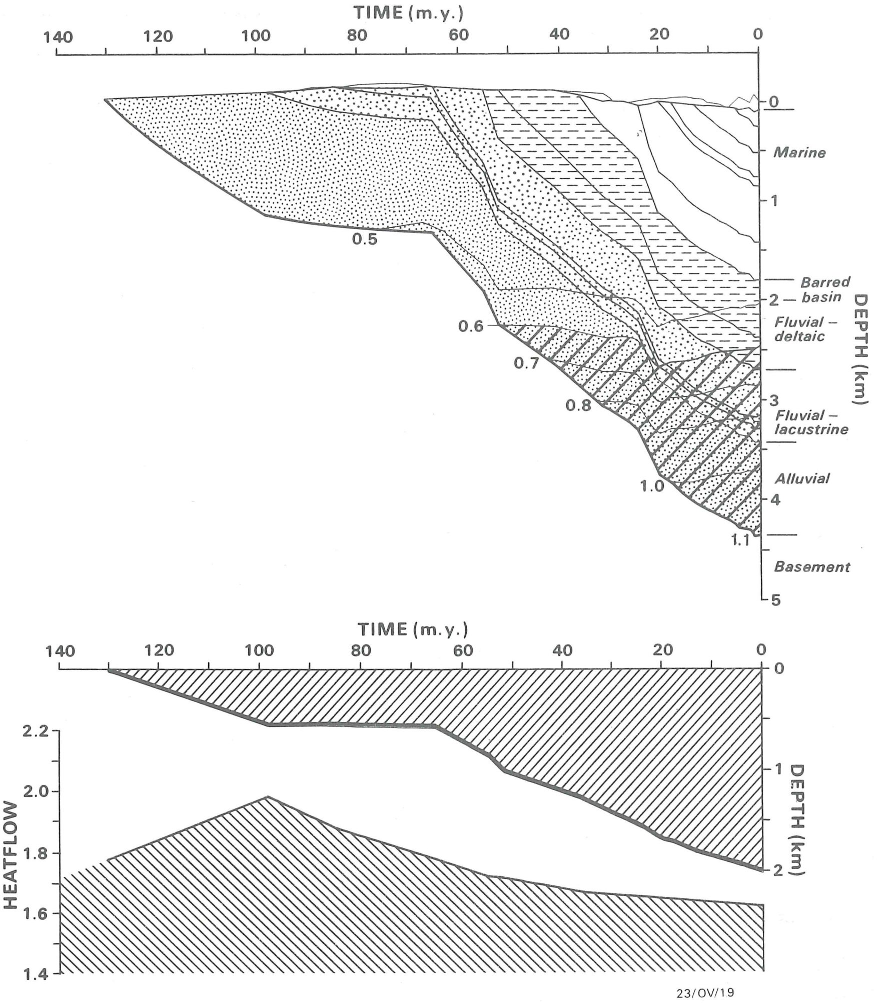


Fig. 3. Computer-generated thermal geohistory based on the interpretation shown in Fig. 1 and data from Bass 1 (units as in Fig. 1); prepared for BMR by I. Deighton (Paltech Pty Ltd, Sydney). (*top*) Burial history and maturation reflectance values 0.5 to 1.1 from current thermal gradient at Bass 1; oil window shaded. (*middle*) Subsidence curve for basement without sediment-loading effects. (*bottom*) Palaeoheatflow in the region of basement tilt-block tops adjusted to Bass 1 from an extension model of the Bass Basin.

Work in progress and release of data

The foregoing represents just the preliminary results from BMR's Bass Basin study. Other work on the new seismic data includes: a complete structural and stratigraphic synthesis of the Bass Basin; Otway and Gippsland Basin correlations; deep-water Otway and Gippsland Basin studies; studies of the regional structural and tectonic framework; and a sedimentological study, including work on diagenetic processes being conducted by Monash University.

The majority of the survey data, including the seismic inversion sections, were released to the public between October 1983 and February 1984. The open-file data include processed record sections, digital field tapes, and digital stack tapes. The total cost of the survey was $3 million.

For further information, contact Mr John Branson (for play concepts), Mr Keith Lockwood or Mr Steve Scherl (for stratigraphy), Dr Mike Etheridge or Mr Peter Stuart-Smith (for structure), and Dr David Falvey (for geohistory).

New gravity standards

In 1967 and 1971 a new normal gravity formula and observed gravity datum were adopted internationally, and with metrication in Australia a new gravity unit became the only legal unit. Transfer to the new standards has been intentionally slow, but more recently there has been an increasing tendency to conform to them in international journals, maps, and data sets. Australia should now complete its transfer to the new standards as soon as possible. It is appreciated that industry abhors changes in control standards, but the present up-grading is necessary, and is sufficient for several decades into the future.

The International Gravity Standardisation Net 1971 (IGSN71) was adopted by the International Association of Geodesy (IAG), so that observed gravity values throughout the world could be as near to absolute values as possible. The IGSN71 correction to the old Potsdam datum is about −14 mGal, but varies throughout the world. IGSN71 establishes both datum and scale for reduction of gravity observations.

The new normal gravity formula based on the Geodetic Reference System 1967 (GRS67) was adopted by the IAG to take account of revised figures for the Earth's size and shape, particularly data from satellite orbits and new gravity determinations. Normal or theoretical gravity values calculated from the new formula differ from values based on the 1930 formula by − 17.2 mGal at the equator and − 3.6 mGal at the poles.

IGSN71 and GRS67 must always be used together for the calculations of gravity anomalies based on the new standards. The magnitude of a 'new' anomaly will then be not more than a few mGal different from the equivalent 'old' anomaly at the same point within Australia. Contour shapes and amplitudes of gravity features will be unaffected by the transfer to the new standards except for the very broadest continental features.

The new unit is the appropriate SI unit of acceleration, the micrometre per second squared (μms^{-2}), where 1 μms^{-2} = $10^{-6}ms^{-2}$ = 0.1 mGal = 1 old American gravity unit (g u) = 1 $\mu N/kg$ (microNewton per kilogram).

Before a transfer to the new standards could be effected it was necessary to increase the accuracy of the Australian National Gravity Base Station Network. This need had been brought about by the widespread use of LaCoste & Romberg gravity meters by exploration companies; this use had up-graded the accuracy of many semidetailed surveys to almost equal that of the network which provides their datum and scale. Control surveys throughout the seventies culminated in accurate remeasurements using groups of LaCoste meters between selected base stations in 1979 and 1980. A publication is now being prepared listing gravity values for all Australian base stations on the old and new datums, giving approximate formulae for transforming gravity values between the datums, and giving the old and new gravity formulae.

Users of the new series of BMR gravity maps at scales of 1:250 000 and 1:1 000 000 will have noted that they are produced to the new standards.

For further information, contact Mr Brian Barlow or Mr Alan Murray at BMR.

An exhaustive study of Permian coals concludes

The significance of coal rank in petroleum exploration has received attention in a 10-volume report of a study on the Permian coals and coal basins of eastern Australia. The report was handed to NERDDC, the sponsor of the study, on 28 February this year.

Coal rank can be correlated directly with palaeotemperatures in the basins, and indirectly with depths of burial, which in turn were controlled by Permian tectonic events and by several Mesozoic and Cainozoic episodes of folding, faulting, and igneous activity. Some of these events were more localised than others, but the rank changes are surprisingly regular and systematic.

The study embraced an area equivalent to the Carboniferous coal basins of Europe, from UK, through western and central Europe, to western USSR. The report, which was completed in exactly four years, contains two major databases. A BMR database (four volumes) covers the stratigraphy and structure of the basins between the coast and the middle of the Great Artesian Basin, and between Cape York and Tasmania. A CSIRO database covers the properties of the coals in the same basins. The databases are summarised in 35 plates and scores of line drawings showing geology, stratigraphy, sedimentology and structure, and the chemical and petrographic properties of the coals.

The basins fall naturally into three groups: small rifts and valleys, large interior intracratonic basins, and marginal basins.

Though the **rifts and valleys** are a lot smaller than the other basins, they are nevertheless important because they contain seams of black coal (some over 30 m thick) that are among the thickest in the world (e.g., Blair Athol and Oaklands Basins).

The **intracratonic basins**, such as the Cooper and Galilee Basins, have histories similar to the North Sea and West Siberia Basins. They formed on an early Palaeozoic orogen, were filled by mainly non-marine sediments and coals — over 3×10^{12} tonnes, but not yet mined — and were then covered by Mesozoic sediments of the Great Artesian Basin.

The **marginal basins**, so called because they formed near the Permian coast of Australia, include the Sydney–Bowen Basin, which contains all the major black coal mines in Australia (except for some in the Triassic Ipswich Basin).

Both the intracratonic and marginal basins contain basal, middle, and upper coal measures, which are separated by lacustrine sediments (intracratonic basins) or marine sediments (marginal basins). In the interior basins, low water-tables and slow deposition favoured the development of finely banded coals with sparse vitrinite and low semifusinite ratios, whereas the higher and more stable water-tables and the faster deposition in the marginal basins favoured the development of coarsely banded coals rich in vitrinite and with high semifusinite ratios.

Total sulphur in the coals reflects depositional environment: high sulphur is generally related to marine influences.

The report may be studied in the Energy Research and Development Division of the Department of Resources & Energy, Canberra City; copies are available at cost from the same source.

For further information contact Dr Larry Harrington at BMR.

Release of new gravity and terrain data sets

An edited version of the Australian National Gravity Database, extensively updated to September 1983, is now available on magnetic tape for sale to other organisations at a price of $300. The data coverage is practically complete onshore, and covers most of the continental shelf except for gaps in the Gulf of Carpentaria, Great Barrier Reef, and Bass Strait. The database contains just over 450 000 point values, which are irregularly spaced but roughly on an 11-km grid for most of the continent. The new data tape supercedes the earlier released tapes which contain gravity data as at 1977.

Prospective purchasers are required to agree to the usual conditions regarding non-transmittal to a third party, limitation to a single project, and acknowledgement of data sources.

Maintenance of this database is an ongoing function of BMR, and further updates will be published from time to time. Contributions to the database are most welcome, and these data can be kept confidential between BMR and the contributor for a specified time. The database is free from gross errors, but has not been fully checked, and any suspected errors should be reported to BMR.

The first file of the new database contains the principal facts of the Australian National Gravity Network (Isogal Network) which defines the datum for gravity surveys in Australia.

The edited database has been used to create new digital terrain and digital gravity models consisting of gridded values at six-minute intervals in both latitude and longitude. These two gridded digital data sets are suitable for computer display and enhancement as images on image analysis hardware and are available for purchase as a pair on one magnetic tape for $300. The new digital terrain and gravity models replace those which have been in use for development and research purposes.

Coloured contour maps produced from these new models are reproduced on the insert. Images of synthetic reflectance representing terrain or gravity illuminated from various azimuths and elevations can be manipulated from these tapes to emphasise various features of the gravity or elevation field seen as three dimensional models. Techniques for manipulation, and examples of images produced by enhancement, have been published in several places (e.g., Moore & Simpson, 1982: *BMR Journal of Australian Geology & Geophysics,* 7(1), 63-7).

Elevation grid values are derived from the elevations of gravity stations, which are not normally sited at points of extreme local elevation, so the digital terrain model has a lower frequency distribution than models derived from most other sources. Gravity grid values are Bouguer anomalies calculated to the new gravity standards for a density of 2.67 $t.m.^{-3}$.

Orders for the Australian National Gravity Database tape or for the combined digital terrain model and digital gravity model tape should be addressed to the Chief, Division of Geophysics, attention A. S. Murray.

The production of updated 1:1 000 000 gravity maps throughout Australia is another ongoing project. BMR has compiled into these maps all data currently held for the area in the database, and the data are thoroughly checked for major errors before release. The new gravity standards are used in the computation of gravity values for these maps, and for the composite 1:250 000 gravity maps which are released at the same time. A further five 1:1 000 000 maps in this series will be released shortly through the AGPS Copy Service.

For further information, contact Mr Alan Murray, Mr Brian Barlow, or Dr Peter Wellman.

Recent BMR publications and data releases

Publications and data that were released during the March quarter are announced in the latest *Quarterly List of Publications of BMR,* which is available from Mrs Margaret Bartlett, Senior Information Officer (telephone 062–499620). The following publications and data were released during the month of April.

Australian Mineral Industry Annual Review 1981

BMR Earth Science Atlas of Australia (maps and commentary)

Phanerozoic palaeogeography (three maps)

1:100 000 geological map and commentary

Carrara Range Region, NT

Kuridala Region, Qld

Record

1984/6: Mineral resources of Australia; by Minerals Branch

Data released through the Copy Service, Australian Government Printer (Production)

Isomagnetic charts of Australia for epoch 1980.0, 1:5 000 000

Horizontal magnetic intensity

Magnetic inclination

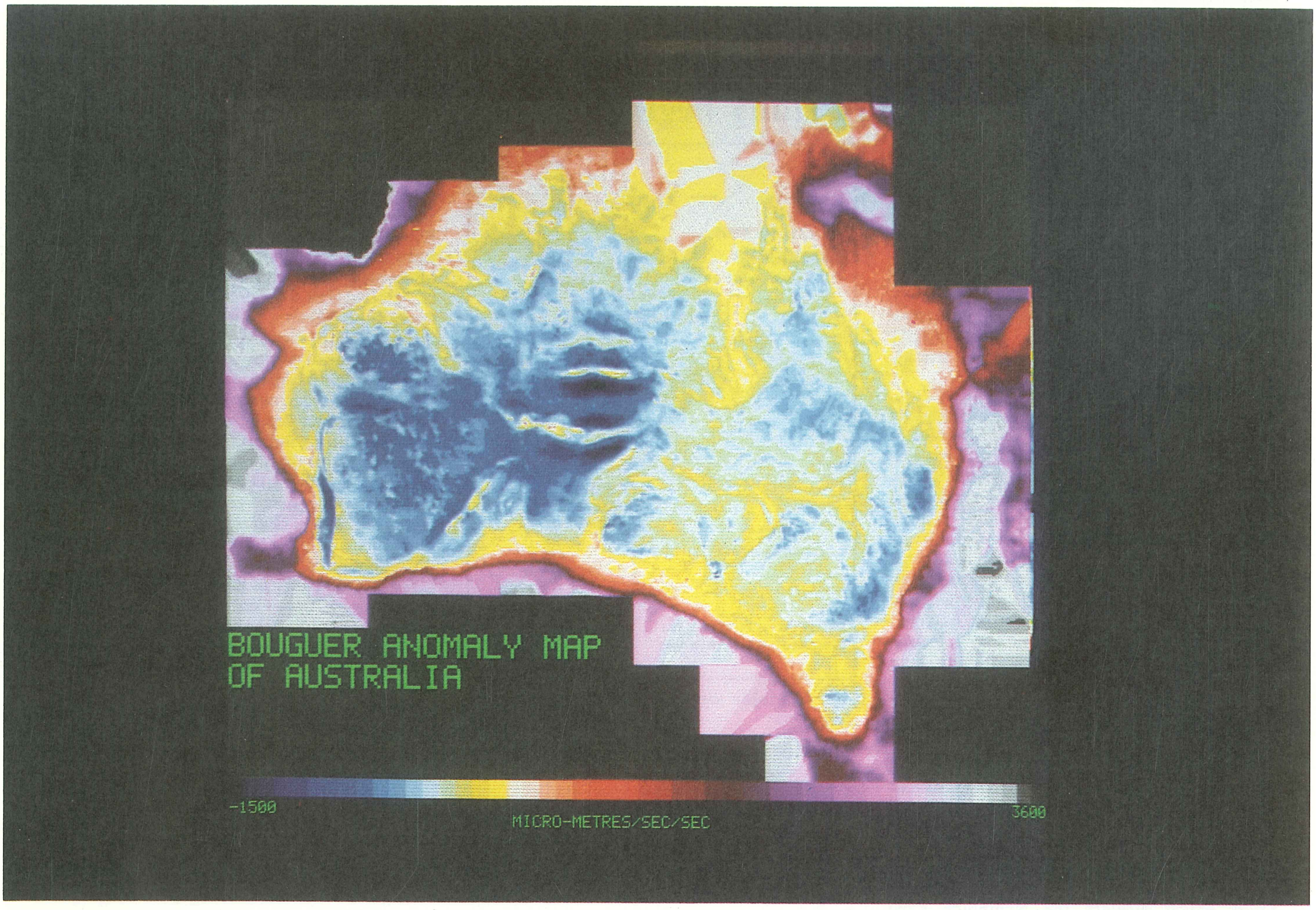
Lachlan Fold Belt 1:000 000 geophysical sheets

Bouguer anomalies

Contours of second vertical derivative of gravity

Publications excluding Records may be purchased from the Publication Sales Counter on the 4th Floor of the BMR Building (telephone enquiries to 062–499519). Mail orders must be prepaid and addressed to Publications Sales at BMR.

Records and data releases are available only from the Copy Service, Government Printer (Production), GPO Box 84, Canberra, ACT 2601 (telephone 062–954560). General enquiries, but *not* orders, about these may be addressed to Mrs Bartlett.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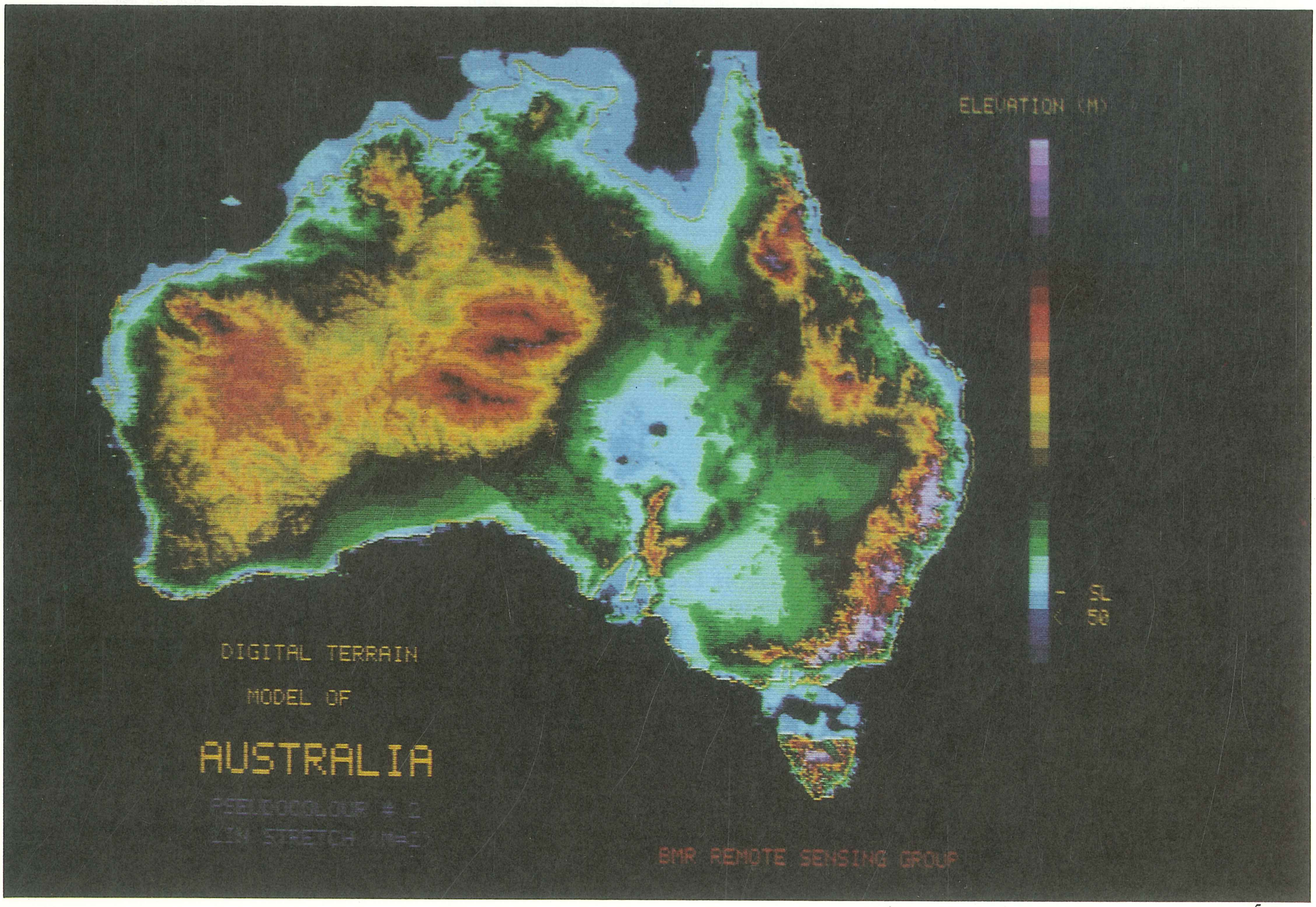
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The Clarence-Moreton Basin a multidisciplinary study begins

The Clarence-Moreton Basin is the subject of multidisciplinary research by the Division of Continental Geology in co-operation with State geological surveys. The aims of the study, which started late last year, are to elucidate the structure, stratigraphy, sedimentology, organic geochemistry, and postdepositional history of the basin. So far, a start has been made on fission-track analysis applied to a study of thermal history (see separate article), on Landsat imagery interpretation, and on sedimentological studies.

Landsat imagery

A large anticlinal feature on the western side of the Logan Sub-basin (Fig. 4) corresponds to the South Moreton Anticline in the north and the Richmond Range structure in the south. Basement lineaments parallel to and continuous with this fold south of the edge of the Clarence-Moreton Basin indicate that it is controlled by basement structures. It has a long history of movement, some of which must be postdepositional because some of the uppermost stratigraphic units are preserved on its crest; however, it predates the Cainozoic volcanics overlying the Clarence-Moreton Basin because lineaments cutting the structure have no expression in these volcanics. It may have controlled the distribution of facies in the Woogaroo Subgroup.

North-northeasterly trending lineaments and tightly folded sediments on the eastern side of the Logan Sub-basin suggest greater structural complexity there than previously thought.

Northwesterly trending lineaments that penetrate both cover and basement at the southern end of the Logan Sub-basin parallel faults which displace the Nymboida Coal Measures.

A large curvilinear feature encompassing the group of large Tertiary igneous intrusions centered on Mount Barney implies that they form a broad dome. Numerous smaller circular features have been identified as individual igneous intrusions and as structural domes.

Sedimentology

Field investigations east of Toowoomba have shown that the Helidon Sandstone (Woogaroo Subgroup) is a sheet of large-scale cross-bedded quartzose sandstone deposited by streams flowing from the west or southwest. At its base, pockets of poorly sorted conglomerate, diamictite, and well-bedded mudstone and fine sandstone probably represent colluvium and alluvium which filled in local hollows. Mudstones in this part of the sequence contain fossil soils, and some are carbonaceous. Samples of these carbonaceous mudstones are being tested for their hydrocarbon source potential. The distribution and nature of porosity in the formation will be investigated.

The Marburg Formation in the Chinchilla and western half of the Ipswich 1:250 000 Sheet areas consists of lithic sandstone and mudstone, probably deposited by streams flowing from the south and southeast. A thick shaly interval, the Ma Ma Creek Member, contains thin kerogenous shale and coal seams whose distribution and hydrocarbon source potential are currently being investigated.

Program for 1984-85

- Deep-crustal seismic survey from the Eromanga Basin across the Surat Basin and across the northern end of the Clarence-Moreton Basin.
- Source-rock richness and maturation studies.
- Palynology of basin sediments.
- Studies of basin palaeoenvironments, palaeogeography, and basin evolution.

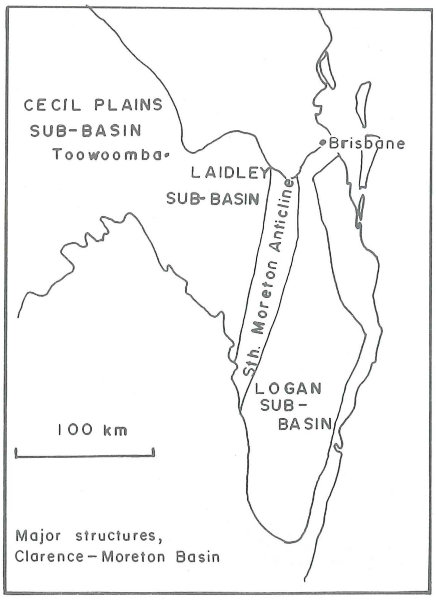

Fig. 4. Major structures, Clarence-Moreton Basin.

- Studies of the distribution and nature of porosity and permeability in basin sediments.
- Continuation of thermal history studies in conjunction with the Department of Geology, University of Melbourne.
- Studies of the nature and distribution of dispersed organic matter in basin sediments in conjunction with the CSIRO Division of Fossil Fuels.

For further information, contact Mr Allan Wells or Mr Phil O'Brien.

BMR to host ISMI meeting

BMR will host a meeting of participants in the International Strategic Minerals Inventory (ISMI) project in Perth (WA) in September 1984, and make arrangements for brief field visits to mines in the Eastern Goldfields and the southwest of Western Australia.

ISMI is a co-operative project of the German Bundesanstalt fur Geowissenschaften und Rohstoffe; Canadian Department of Energy, Mines and Resources; South African Department of Mineral and Energy Affairs; United States Bureau of Mines; United States Geological Survey; British Geological Survey; and BMR.

ISMI aims to compile, exchange, and review non-confidential information on the location, geology, resources, and production of mines and significant major deposits of minerals considered to be of strategic importance, so that each country can make its own mineral policy analysis and decisions. It will also encourage a uniform and consistent approach to estimating mineral resources, and facilitate comparisons between methods of resource estimation and documentation.

The participants in the project have already contributed data on nickel, chromium, manganese, and phosphate deposits, and summary reports on these commodities are to be published as USGS *Professional Papers* during 1984. Work is now in progress on cobalt, graphite, platinum group elements, titanium, tungsten, and vanadium mines and deposits.

For further information, contact Mr Brian Elliott at BMR.

Space-shuttle radar research soon to be launched

BMR is to participate in a shuttle imaging radar (SIR-B) experiment over three sites in Australia — Lake Eyre or Lake Frome (SA), Davenport Downs (Qld), and Rodinga (NT). SIR-B will for the first time have the capability to change the incidence angle of the radar beam, and to record data in digital (rather than optical) form. The experiment, which is due to start in August this year, is being sponsored by NASA, and will be co-ordinated by the Remote Sensing Group of the Division of Continental Geology in conjunction with CSIRO.

Previous investigations have shown that comparison of radar images of the one area using different incidence angles is important for investigating surface geometry and composition. Digital recording will allow researchers to undertake computer analysis of data with minimum signal degradation.

Imagery of the selected target sites will be acquired from an orbital altitude of 225 km using an L-band (23 cm wavelength) synthetic-aperture radar system. Each image swath will have a ground width of about 50 km, and a resolution of 25 m in the azimuth direction.

Lake Eyre or Lake Frome

Research on the imagery of Lake Eyre — designated by NASA as the prime Australian target — will aim to evaluate the capability of radar to assist in the differentiation of salts, clays, and soil-moisture zones. Lake Eyre currently has an extensive cover of water; if this has not evaporated sufficiently by August, the research activities will be switched to Lake Frome. The investigations will involve the use of BMR's Comtal image analysis system to digitally merge Landsat spectral information with data on surface roughness and dielectric constant derived from the radar.

Davenport Downs

Extensive surface sheets of limonitic lag gravel derived from the chemically weathered Winton Formation will be imaged to provide data about the surface roughness and dielectric constant of the secondary iron mineral deposits. This information will be used to determine the applicability of radar, in conjunction with Landsat data, for direct mapping of parameters related to superficial weathering in the Australian environment.

Rodinga

The site that will be imaged in Rodinga is part of a lineament between Broome (WA) and Wollongong (NSW) detected during computer manipulation of a digital terrain model of Australia (Moore & Simpson, 1982: *BMR Journal of Australian Geology & Geophysics,* 7, 63-7); the small scale of the original data precludes the accurate location of this lineament on detailed topographic maps. The imagery will be investigated to determine whether low-angle radar illumination will enhance subtle topographic features sufficiently to allow the lineament to be pinpointed for further study.

If the seventeenth shuttle mission flies successfully in August, radar data of Australian sites should be available for research by investigators in November 1984.

For further information, contact Mr Colin Simpson at BMR.

BMR commences new offshore research program

The Australian Government is embarking on a new program of marine geological and geophysical research which will focus on the petroleum potential of the sedimentary basins of Australia's vast continental margins.

Under this new initiative, BMR's Division of Marine Geosciences & Petroleum Geology will commence a program of offshore surveys which will provide a geoscientific framework designed to promote exploration, provide data for national resource assessment and policy advice to the Australian Government, and make a significant contribution towards global scientific studies of continental margin evolution.

In fiscal 1983–84, an additional Budget allocation of almost $3 million has enabled the first stages of the program to begin. It has provided for the acquisition — by charter — of a dedicated marine geoscience research vessel, purchase of new marine survey equipment and a seismic data processing facility, and an increase in the numbers of scientific staff.

This new program follows on from BMR's highly successful 1982 Bass Strait contract geophysical survey. High-quality deep-penetration regional seismic reflection data from this survey is encouraging renewed local and international interest by petroleum explorers in the Bass Basin, and a resurgence of exploration activity is anticipated. Hydrocarbon-oriented framework studies of the Australian continental margin will be a feature of the new program, although current research will continue on aspects of modern marine processes (e.g., the Great Barrier Reef); deep-sea mineral occurrences; and in the southwest Pacific Tripartite programs.

One reason for the renewed offshore research focus by BMR is the extent to which modern technology now suggests means of exploiting resources beyond the traditional continental shelf. The 'legal continental shelf' which Australia may claim under the provisions of the Law of the Sea is one of the world's largest for the exploration of seabed and subseabed resources. It extends well beyond 200 nautical miles in many places, and contains an area of about 12 000 000 km². The major proportion of

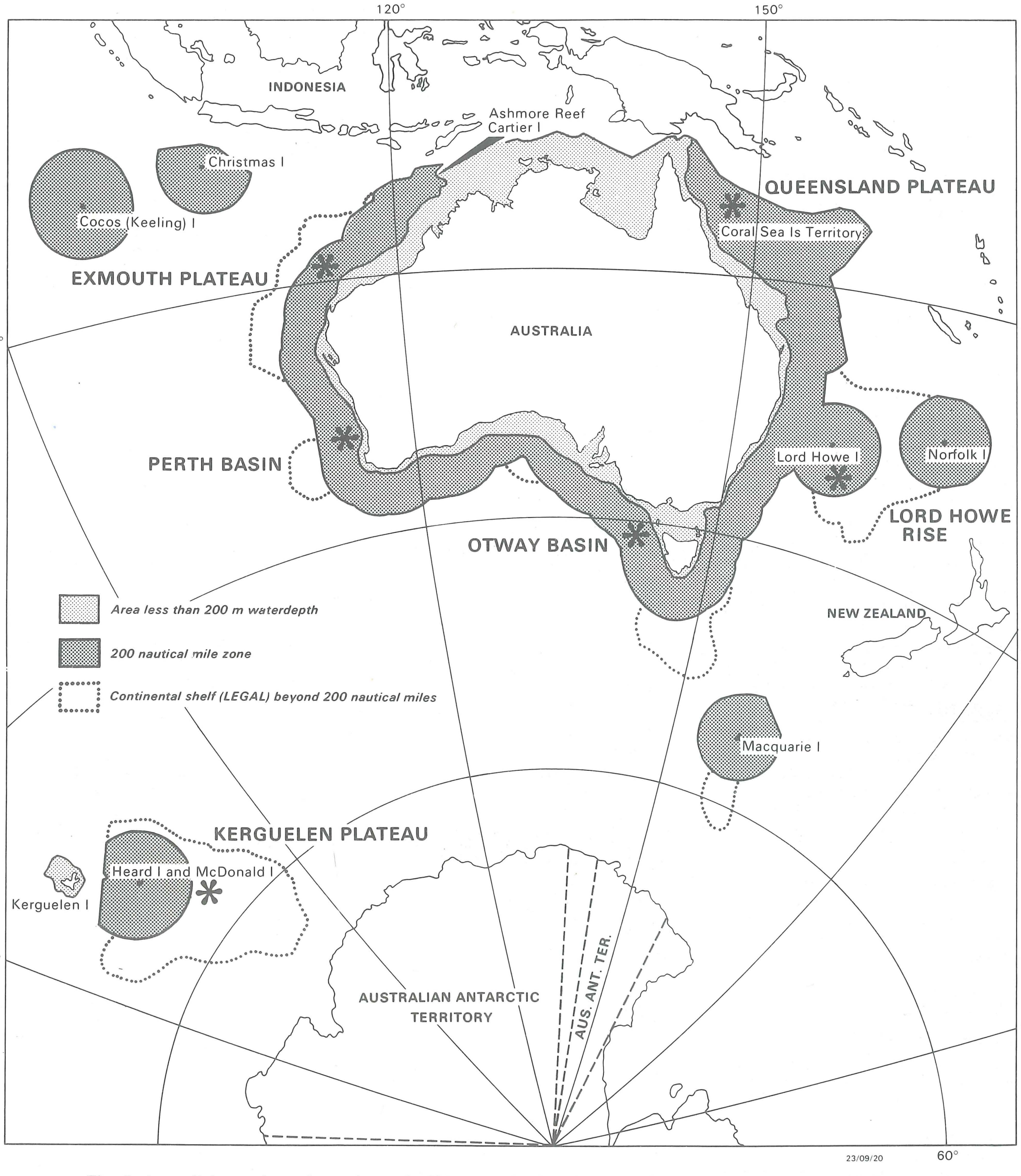

Fig. 5. Australia's continental margins and offshore territories. Asterisks distinguish areas of future BMR surveys.

Australia's undiscovered oil resources is considered to be in offshore basins in this area, and there is a clear need to have publicly available the same kind of regional geoscientific framework data which has provided such a successful stimulus to onshore exploration.

The key to the new offshore research program will be the ice-strengthened, multirole research vessel which will soon be entering a long-term charter to BMR's marine division. It will be fitted out in the next few months for multichannel seismic operations (airgun; 2 400-m, 96-channel cable). Facilities for magnetics, gravity, high-resolution bathymetry, coring for heatflow studies, and dredging will be added soon.

Survey and research operations should be underway in the offshore Otway Basin (Fig. 5) during the latter half of 1984. This area is closely related, geologically and tectonically, to the Gippsland Basin (which is responsible for 92% of Australia's domestic oil production). During 1985, surveys are planned for the Australian sector of the Kerguelen Plateau — a huge area of almost 2 000 000 km² — which has a thick continental-type sedimentary section. Other currently planned surveys in 1985 include the Lord Howe Rise, Queensland Plateau, Western Coral Sea, and Exmouth Plateau. Exploration drilling on the Exmouth Plateau has so far been disappointing, and it is hoped that this project will stimulate new understanding and interest.

A major component of the BMR marine initiative is the new seismic processing research centre, which will be installed and operational in June this year. It will provide BMR with the capacity to process and interpret the many thousands of kilometres of marine seismic data which will be collected each year under the new program.

The commencement of this new program will prove to be a significant step forward for Australia: the understanding and responsible utilisation of Australia's non-living marine resources will be a key element in long-term national development.

For further information, contact Dr David Falvey at BMR.

13th BMR Symposium

5-8 November 1984 Canberra

5-6 November — Workshop on tectonic evolution and metallogenesis of Lower to Middle Proterozoic terrains in northern Australia *(enquiries: Dr Ken Walker (062) 49 9478)*

7 November — Review of BMR program and results (morning only)

7-8 November — Seminar on basin evolution, with special reference to the Bass and Eromanga Basins *(enquiries: Dr G. 'Wilf' Wilford (062) 49 9465)*

A detailed program and registration form will be available by mid-September.

General enquiries can be directed to Mrs Evelyn Young (062) 49 9623.

Four new petroleum-oriented cruises in the southwest Pacific

BMR scientists have participated in four international co-operative research cruises in 1984 in the island-arc basins of the southwest Pacific. These cruises were designed to help assess petroleum potential, and were a logical continuation of three similar cruises in 1982 — the Tripartite-I program — reported on in *BMR 82* and *BMR 83*. Like the earlier cruises, this year's cruises — part of a Tripartite-II program — took place on board the USGS RV *Lee,* and were sponsored by Australia, New Zealand, the United States of America, and CCOP/SOPAC (Suva); Australian participation was financed by the Australian Development Assistance Bureau. Altogether there were 12 Australian shipboard scientists, of whom six came from BMR. In addition to cruises in Tongan, Vanuatuan, and Solomon Islands waters — as in 1982 — the 1984 cruises included work in Papua New Guinea (Fig. 6). All cruises involved the acquisition of multichannel seismic data, and dredging of submarine outcrops.

Tonga Ridge-Lau Ridge (A)

This cruise occupied the month of April. It further investigated potential exploration targets — possible Miocene reefs — identified in the 1982 cruise area, and extended the survey southward, in order to contribute to an assessment of petroleum potential. In addition, seismic profiling and sampling were carried out on the Lau Ridge south of Fiji; the objective is to evaluate the thickness of sediment on its western flank. Micropalaeontologist Dr George Chaproniere was the only BMR participant.

Vanuatu and Eastern Solomons Basin (B)

This month-long cruise in May dredged seismic sequences in four small petroleum-prospective sedimentary basins identified east of Santo and Malekula in the 1982 cruise area. It then moved northward into the little known Torres and Santa Cruz basins, to acquire multichannel seismic data. Sedimentologist Dr Neville Exon represented BMR aboard ship.

Solomon Islands and Bougainville (C)

This cruise, of 18 days duration, took place in June. It dredged some targets in the Central Solomons Basin, and then moved westward into the Shortland Basin and the area north of Bougainville for a program of multichannel seismic profiling and dredging. BMR provided the co-chief scientist — sedimentologist Mr Jim Colwell — and micropalaeontologist Mr Samir Shafik for this cruise.

New Ireland Basin (D)

This 20-day cruise took place in July. Multichannel seismic profiling and dredging were used to define the nature and extent of a possible platform carbonate sequence, 1000-2000 m thick, deeply buried in a thick Cainozoic section which extends north from New Ireland to north of Manus Island (Exon & Tiffin, in press: *American Association of Petroleum Geologists, Studies in Geology Series).* Dr Exon — co-chief scientist — and micropalaeontologist Dr Denis Belford represented BMR.

For further information, contact Dr Exon or any of the other BMR participants.

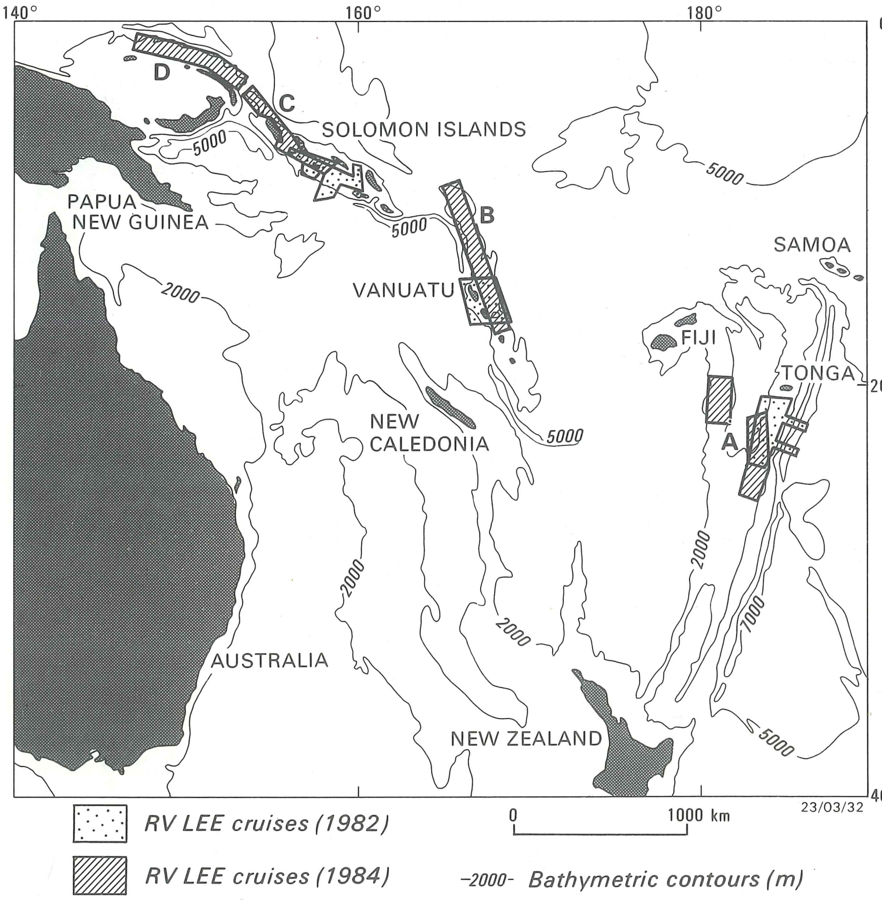

Fig. 6. Locations of 1982 Tripartite-1 and 1984 Tripartite-II (A-D) cruises.

Division of Marine Geosciences & Petroleum Geology provisional forward program summary (to 1985)

Fossil Fuels Program

Framework studies of Australian Offshore areas

(i) Bass Basin
(ii) Otway Basin — shelf and slope
(iii) Kerguelen Plateau
(iv) Lord Howe Rise
(v) Queensland Plateau and western Coral Sea
(vi) Exmouth Plateau
(vii) Perth Basin — shelf and slope
(viii) Southern margin aeromagnetics

Modern marine processes

(i) Central Great Barrier Reef — reef project
(ii) Central Great Barrier Reef — inter-reef project

Marine geophysical systems: research and development

(i) Shipboard acquisition and processing
(ii) Seismic data processing

Minerals Program

Offshore mineral deposits: origin and distribution

(i) Woodlark Basin hydrothermal activity

Overseas Program

Southwest Pacific marine geoscience

(i) Australia/NZ/USA Tripartite Geoscience projects
(ii) Solomon Sea floor and trenches/Tongan trench
(iii) Papua New Guinea — WESTPAC and regional review project

Antarctic marine geoscience

(i) Prydz Bay/George V/Wilkes Land offshore

National Geoscience Databases Program

Marine geoscience database

Fission-track analysis to provide clues to sedimentary basin thermal histories

Fission-track analysis of detrital apatites in sedimentary rocks provides an important new approach to the study of thermal histories of sedimentary basins, and consequently of their hydrocarbon resource potential. This application depends on the observation that annealing of fission tracks in minerals, like the generation and maturation of hydrocarbons is a function of temperature and time. Thus at temperatures between 70 and 125°C fission tracks in apatite will begin to fade, and will be lost if this temperature range is sustained for a time of the order of 10 m.y; tracks will again begin to accumulate once the temperature falls below this range. As this temperature range is remarkably close to that of the maximum generation of liquid hydrocarbons, so fission-track ages in detrital apatites, and an analysis of the distribution of track lengths, can provide a unique record of heating in the oil-generation window.

In line with BMR's philosophy of developing co-operative projects with other organisations, the Division of Continental Geology and the Department of Geology at the University of Melbourne have initiated a collaborative research project of fission-track analysis in several sedimentary basins. This work may have far-reaching implications to the search for hydrocarbons in a number of Australian basins. Two basins, the Late Proterozoic-Palaeozoic Amadeus Basin and the late Palaeozoic-Mesozoic Clarence-Moreton Basin, are being given particular attention. A third, the Proterozoic McArthur Basin, is also being examined to assess the applicability of fission-track analysis in such an old terrain.

Amadeus Basin

The aim of the study in the Amadeus Basin is to examine the thermal and tectonic histories from the apatite fission-track record in the northern central part of the basin. Particular emphasis will be given to the Pacoota Sandstone, which is the major oil exploration target in this area. Results of the fission-track analysis will be compared with patterns obtained from organic maturation indicators already applied to the basin such as reflectance studies and conodont colour alteration.

Outcrop samples from various formations in the basin and marginal basement rocks were collected in October 1983, and these have been supplemented by samples from different levels in exploration wells in the basin, including Alice 1, East Mereenie 2, Orange 1, and Tyler 1.

Good yields of apatite suitable for fission-track analysis have been recovered from the Pertnjara Group and Precambrian basement rocks near the northern basin margin. Satisfactory yields have also been obtained from the Pacoota Sandstone, though large samples had to be used owing to its low heavy-mineral concentration.

As a separate study, outcrop and drillhole material has been collected from around Gosses Bluff to assess the age and thermal effects of this important impact structure. Owing to the different track retention properties of apatite and zircon, it should be possible to reconstruct the distribution of palaeotemperatures around the structure from the fission-track data.

Clarence-Moreton Basin

Samples for fission-track dating were collected over a wide area of the Clarence-Moreton Basin in late 1983 after a pilot study had identified those formations which are likely to consistently yield suitable detrital apatites. The aim of the study is to compare the thermal history of these formations both in outcrop and in subsurface intersections in different areas across the basin. Significant variations in the thermal history across the basin are suggested by a regional increase in intensity of folding from west to east.

The pilot study showed that good apatite yields can be expected from the labile sandstones of the Walloon Coal Measures and, in somewhat lower abundance, from the sandstones of the Marburg Formation. Field-work, therefore, concentrated on these two formations, which were sampled along a number of roughly east-west transects across the basin. Sampling was also designed to determine the extent of thermal effects in the sedimentary pile from Tertiary igneous activity in the basin.

In addition, basement granitic rocks from the basin margin have been collected to provide background information on apatite age patterns in potential sediment source areas. This information will be important in assessing the degree of postdepositional modification of basement-derived apatites, particularly in the Marburg Formation. Many apatites in the labile sandstones of the Walloon Coal Measures were probably derived from contemporaneous volcanic activity.

McArthur Basin

Little work has been done so far on the McArthur Basin, other than to examine the heavy-mineral suites from a range of pilot samples. This has shown that suitable apatites are present in at least some of the formations, although the potential information contained in the fission-track record of these apatites remains a matter for speculation at this stage.

Dr A. J. W. Gleadow, Dr I. R. Duddy, and Mr P. Tingate of the Fission Track Research Group in the Department of Geology, University of Melbourne, kindly contributed this article.

AUSTCO

a computer-based well data system

A computer-based well data system — AUSTCO — has been established as part of the Resource Assessment Division's continuing project to assess Australia's potential petroleum resources. The database contains data from about 3200 petroleum exploration and development wells drilled in Australia from the early 1900s. Each well is located by its position onshore or offshore, latitude and longitude, State or Territory, and basin, sub-basin, or infrabasin. Other information includes name of operator, classification, total depth, date well reached total depth, and type of petroleum discovery. Estimates of the identified resources of each petroleum field are included, but are confidential.

In addition to its data storage and retrieval facilities, the system can produce graphs of discovery rate (Fig. 7a), success rate (Fig. 7b), and field size *vs* number of discoveries (Fig. 7c). It is also designed to provide the data necessary for estimating undiscovered petroleum resources by the method devised by Drs D. J. Forman and A. L. Hinde; documentation of this method is in preparation. A program has been developed to plot exploration statistics such as the number of new-field wildcat wells or kilometres drilled annually together with the annual totals of resources identified in new-field discoveries (Fig. 7d). Another program has been developed to tabulate success rates, well depths, and numbers of wells drilled annually, and annual totals of resources in new-field discoveries. Programs to plot the positions of wells or oil and gas fields and other relevant data onto maps have been available at BMR for some time.

The well data that are printed out or represented graphically may be selected according to any of the data fields, or by latitude and longitude using a program to extract wells that lie within a digitised boundary. The data for the Roma area (Fig. 7a-d) were selected using this last method.

Compilation of the data was assisted by computer processing of magnetic tapes of some Queensland data supplied by the Geological Survey of Queensland and some Australian data supplied by Shell Development (Australia) Pty Ltd. Some of these data were altered to conform to data available at BMR, and additional data have been added as necessary. The data have been rapidly compiled, and are regarded as preliminary pending completion at BMR of PEDIN, a comprehensive computerised well data system which is being compiled with the assistance of a NERDDP grant.

Documentation of the database *(BMR Report* 256 and *BMR Record* 1984/13 by D. J. Forman & others) is currently in preparation; associated programs *(BMR Records* 1984/4 and 1984/5 by A. L. Hinde) are already available.

For further information, contact Dr David Forman.

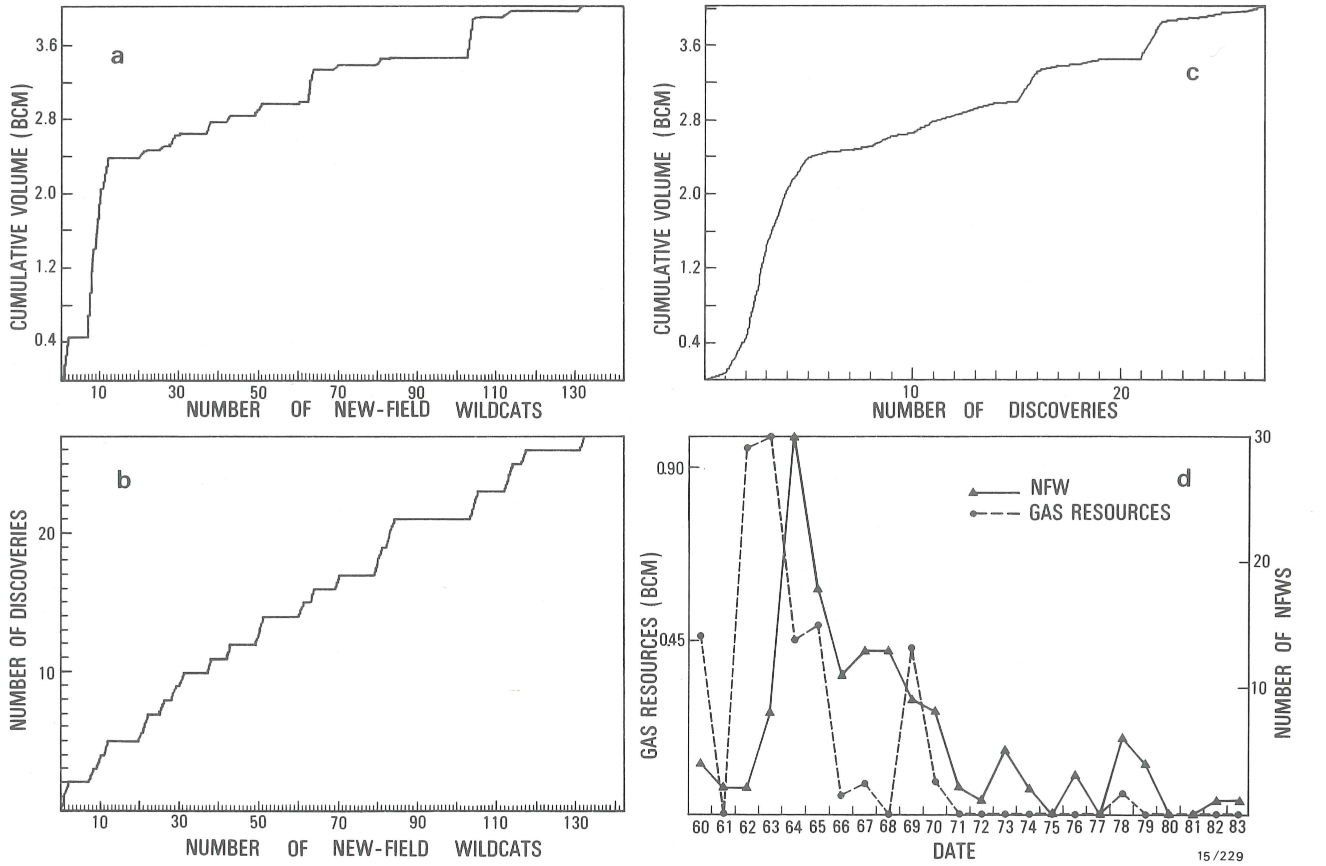

Fig. 7. Computer-generated statistical plots for the Roma area: a) discovery rate of sales gas; b) success rate for gas discoveries; c) decline in gas field sizes; d) annual totals of new-field wildcat wells drilled and gas resources identified.

Lamproite: a new important primary source of diamond

The recent discovery of diamonds in the Kimberley region of Western Australia challenged the view that kimberlite is the only primary source of terrestrial diamond. The occurrence of the Kimberley diamonds in lamproite (potash and magnesia-rich lamprophyres) rather than kimberlite *(sensu stricto)* intrusives is the subject of two papers published recently in the proceedings volume of the Third International Kimberlite Conference held in Clermont-Ferrand, France, in 1982.

One of these papers, by geologists of CRA Exploration Pty Ltd, reviews the discoveries of kimberlitic rocks in Western Australia, and provides the first detailed account of the rich Argyle AK 1 pipe. The other one — by research scientists of the Division of Petrology & Geochemistry in collaboration with the Geological Survey of Western Australia, CRA, and other major mineral exploration companies — describes the geology specifically of the newly discovered West Kimberley diamondiferous pipes, which are intimately associated with leucite lamproite plugs (Fitzroy Lamproite) originally described by R. T. Prider and co-workers forty years ago.

Several important conclusions have emerged from the collaborative studies. Firstly, isotopic dating has shown that the diamondiferous pipes of the Ellendale area and the Fitzroy Lamproite plugs are of a similar age — Early Miocene — thus making them the youngest diamond-bearing pipes known. Secondly, petrologic and geochemical data presented in the papers show that the diamondiferous pipes at Ellendale are olivine-rich lamproites related to the leucite-rich lamproites, and that a petrologic and geochemical continuum exists between the two. The consanguinity of the olivine lamproites and the leucite-rich lamproites is shown by an overlap in the composition of mineral phases, by the major and trace-element chemistry of bulk rocks (including rare-earth elements), and by their similar Nd and Sr isotopic ratios.

Petrologic and geochemical data presented in the CRA paper show that the Argyle AK 1 pipe is also of the lamproite association, though the relationship between the West Kimberley and Argyle lamproites is not yet clear. Although they have many of the distinguishing features of kimberlite, the olivine lamproites of the Kimberley region exhibit a number of important differences: they are closely associated with leucite-rich and abundant magmatic and glassy pyroclastic rocks; they contain groundmass amphibole, and rare garnet and picroilmenite; and they lack primary carbonate (at least in the West Kimberley) and abundant chromite. Lamproites are richer in silica, potash, and titania, and poorer in lime, and they have higher abundances of elements such as F, Ba, Rb, Sr, Zr, and the light rare-earths, than kimberlites.

The Argyle AK 1 pipe is the richest diamondiferous pipe yet found (with a diamond grade of 5 carats per tonne, much higher than that of the Ellendale pipes at 5 carats per 100 tonnes); this is a compelling reason for recognising the lamproite suite as a new primary source of terrestrial diamond. Early recognition of the diamond-bearing potential of lamproites has already figured prominently in the Western Australian diamond discoveries, and will obviously be important in future exploration.

For further information, contact Dr John Ferguson or Dr Lynton Jaques at BMR.

Developing methods for hydrocarbon assessment of Precambrian basins

Evaluating existing techniques currently applied in Phanerozoic basins, and developing new techniques for assessing the hydrocarbon potential of Precambrian basins, are the aims of a new NERDDC-sponsored Division of Continental Geology project. Despite the importance of Precambrian basins for hydrocarbons in some parts of the world (e.g., Siberia and Oman), their potential in Australia has not been adequately assessed. The main emphasis of the project will be to define geochemical criteria for assessing source potential, and to study stratigraphic and sedimentological data for identifying reservoir and cap-rock potential.

The NERDDC funding has enabled the BMR geochemical facilities to be upgraded so that modern petroleum source rock studies can be carried out. Of particular importance is the establishment of maturation criteria for the recognition of the oil window in Proterozoic rocks using both organic petrological and chemical techniques, the richness and variability of potential source horizons, and the response of Proterozoic organic matter to thermal diagenesis. The McArthur Basin is being used as an example, and the geochemical program is being carried out in conjunction with sedimentological studies (see separate McArthur Basin article, on p. 14). A geochemical database of Precambrian rocks is being established as part of this project.

For further information, contact Dr Trevor Powell at BMR.

Future direction of airborne geophysical mapping and interpretation

Recent restructuring of BMR has focused renewed urgency on (1) completing regional airborne coverage of Australia, (2) building up a digital database of the continent, and (3) interpreting the data in terms of discrete metalliferous and hydrocarbon provinces.

BMR's objective is to complete basic regional magnetic and gamma spectrometric survey flying of the continent onshore by 1989, and provide the results in various formats — including magnetic tape and colour maps — by 1990. It is fundamental that the database be in digital format and be suitable for construction of grids with cell sizes appropriate for entire metalliferous and hydrocarbon provinces. Figure 8 indicates the status of BMR's regional airborne magnetic database. The regional gamma spectrometric coverage unfortunately though inevitably will be neither as complete nor as compatible between surveys as the concurrently gathered magnetics.

New proposals recognise the need for magnetic and gamma spectrometric interpretation to shift significantly into strategic research. One such mission-oriented study could investigate the geophysical signatures resulting from the geological processes which lead to the distribution, development, and degradation of relevant source minerals in rocks. This in turn could inspire new methods of data analysis which may be widely applicable in the search for orebodies and petroleum. Though the emphasis would be on province studies, proposals have been made for research that will focus on Australia-wide problems in exploration, including orebody-related geophysical lineaments and magnetic lithostratigraphy (as distinct from magnetostratigraphy).

Magnetic maps of Australia

A feasibility study is currently in progress with the aim to initiate a program to produce colour magnetic anomaly maps of Australia at 1:1, 1:2.5, and 1:5 million scales. The projected completion date is 1990, though intermediate products should be available before then.

The general approach will be that used by the Geological Survey of Canada in producing similar maps relating to Canada. Existing digital aeromagnetic data will be augmented by digitising analogue records from BMR surveys flown in the 1950s and 1960s. Several of these have already been successfully digitised by private companies and the Geological Survey of New South Wales. At this time, it is not proposed to incorporate all private company digital detailed surveys into the BMR database, but this may be considered. In any event, BMR is not necessarily aware of the extent of all of such surveys, particularly for large open-range surveys.

Advice was sought recently from industry on the most desirable order of preference for digitising and reprocessing blocks of old analogue data. While there were wide-ranging variations of opinion, a majority of respondents favoured placing the Yilgarn Block high on the list. This then is likely to be the first area to be reprocessed by BMR. It follows that the southwest corner of the continent would be the first to emerge in the various formats proposed.

A major product of the reprocessing will be an integrated edge-matched digital database of gridded magnetic data suitable for interpretation at 1:250 000 scale. The grid interval will be of the order of 250-500 m.

For further information, contact Dr David Tucker or Mr Tony Luyendyk at BMR.

Long-wavelength magnetic anomalies

Long-wavelength magnetic anomalies over Australia have previously been mapped using measurements made on the POGO and MAGSAT satellites at altitudes of 300 km and above. A compatible 400-km-altitude magnetic map was prepared, from BMR observations at 0 to 3 km altitude, by gridding the observations

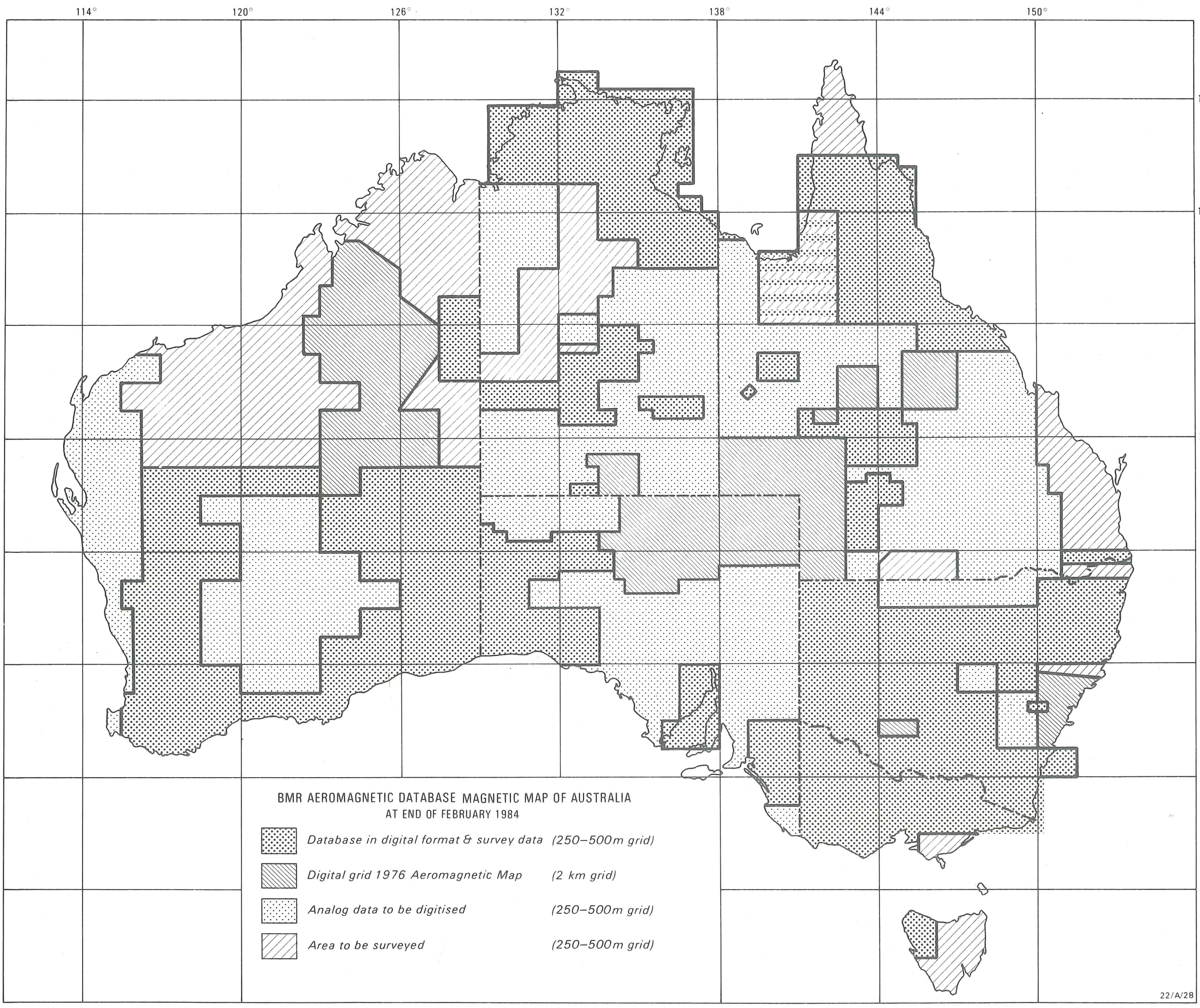

Fig. 8. BMR aeromagnetic database magnetic map of Australia.

and upward-continuing the derived grid. Maps based on near-surface and on satellite observations have the same major features, and there seems to be no information in the satellite observations that is not also present in correctly reduced near-surface observations.

The major features of a 100-km-grid, 1.5-km -altitude map are elongate positive magnetic anomalies. In the eastern half of Australia they overlie wide, roughly symmetrical basement uplifts, and in the western half of Australia they overlie asymmetric obduction structures at crustal block boundaries. These positive anomalies are thought to be caused by rocks of high magnetisation in the upper or lower crust. Their positions coincide with major long-wavelength positive free-air anomalies.

For further information, contact Dr Peter Wellman at BMR.

Lake George: preliminary palynology of deep sediments

Twelve boreholes were drilled by BMR in Lake George during the drying out of the lake in 1982–83, in order to provide a cored sequence of lake basin sediments. Such a sequence should provide a late Cainozoic climatic and environmental history for southeast Australia; additionally it should furnish a model for sedimentation patterns in fault-controlled basins. Two of the boreholes, coreholes 354 and 358 (Fig. 9), have been sampled in a preliminary way for palynology, with the aim of dating sediments near the base of the sequence. Sampling was confined to sediments sufficiently unweathered as to be likely to yield pollen. Samples were taken from the lower of two sedimentary units provisionally identified within the sequence by R. S. Abell *(BMR Record,* in preparation). The lower unit, the Gearys Gap Formation, has a mixed lithology of clay interbedded with sand and silt — possibly of fluviatile/lacustrine origin. It underlies lacustrine clay of the Lake George Formation.

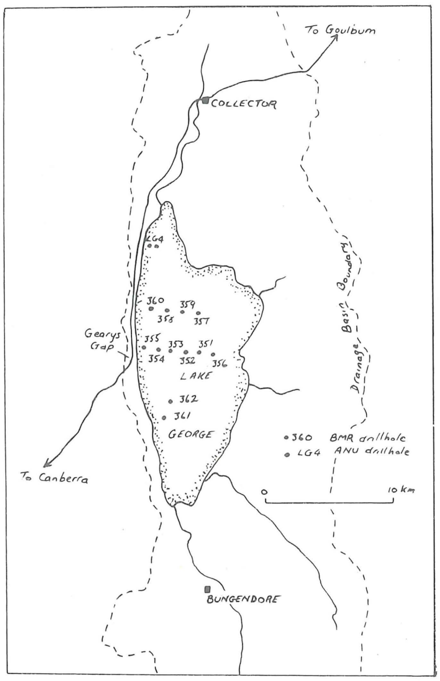

Fig. 9. Locality map of Lake George, showing positions of BMR boreholes.

Preliminary palynological results

From corehole 354, the deepest yet drilled, fifteen samples were taken for palynological examination (Fig. 10). The deepest sample, at 110.25 m, lies just above a highly weathered section of the sequence which extends down into Palaeozoic basement rocks drilled to a total depth of 197 m; weathering throughout this interval was severe enough to make preservation of palynomorphs unlikely.

Eleven samples yielded pollen and spores. Samples from 108 m, 110 m, and 110.25 m yielded assemblages in which pollen of temperate rainforest taxa was well represented. Percentages of major taxa are illustrated in Figure 10. Pollen of *Nothofagus,* the southern beech, is numerically significant, and six pollen species of the genus were identifiable. They include fossil forms corresponding to all three living pollen groups. Pollen of the *Nothofagus brassi* type, now growing in the New Guinea uplands, is most common. Other taxa of the rainforest association include pollen of the podocarps or southern conifers, again in some variety, and of *Symplocus,* a tree of the modern rainforest understory.

Non-rainforest types include the sheoak, *Casuarina,* with frequency figures of 9 and 25 per cent. Myrtaceous pollen (3-6 per cent) includes some of the *Eucalyptus* type, and others closer to rainforest taxa. Ferns are represented by abundant Gleicheniaceae. Minor taxa include *Banksia* and other Proteaceae, Epacridaceae (heaths), Restionaceae (rushes), *Acacia,* and *Stephanocolpites oblatus,* a pollen grain of unknown affinity.

In corehole 358, similar pollen assemblages were recovered from black clays in the interval 90.55-101.10 m. There, rainforest taxa are present, but abundant pollen of reeds and rushes suggests the imprint of a local habitat. High proportions of the alga *Botryococcus* suggest too that open-water conditions were prolonged.

The age of the rainforest-dominated pollen suite, designated Assemblage B in Figure 10, is difficult to determine. Most forms are long-ranging. The difficulties are compounded by the lack of independently dated reference sections in southeastern Australia for the Late Miocene/Pliocene. Data for a critical reference section, that of the offshore Gippsland Basin, where marine sequences allow correlation with global timescales, remain largely unpublished.

Within Assemblage B, a number of pollen species suggest correlation with the *Triporopollenites bellus* Zone of the Gippsland Basin, which extends from the latest Early Miocene into the Late Miocene. A maximum age of late Early Miocene can therefore be established for Assemblage B with reasonable confidence. Younger age limits are more difficult to ascertain. Broad aspects of the assemblage suggest that the younger, Late Miocene part of the *T. bellus* Zone is represented, but this is tentative. One taxon which accords with such an estimate is *Stephanocolpites oblatus;* this is known to occur near the top of a rainforest-dominated interval in the Lachlan River Valley, which is probably Late Miocene — although time control is imprecise.

The presence of rare sedge pollen within Assemblage B would, according to Gippsland Basin comparisons, confirm a Late Miocene age. However, this pollen appears much earlier in the Murray Basin, so its biostratigraphic significance is suspect. The frequences of *Nothofagus* pollen in the assemblage, although significant, are low compared with those from the Early and Middle Miocene, which is another reason for considering the assemblage to be Late Miocene: *Nothofagus,* particularly *N. brassi,* diminishes markedly in abundance near the Miocene/Pliocene boundary in the Gippsland Basin.

From a palaeoenvironmental viewpoint, the presence of *Nothofagus* and other rainforest taxa in Assemblage B suggests that the rainfall exceeded the present 650 mm per year in the Lake George catchment: indeed, the annual rainfall may have been as high as 1500 mm with a uniform distribution throughout the year. Beech forest probably occupied the better drained sites; *Casuarina* perhaps the drier slopes, or the lake margin. Other taxa showing high local representation, such as the fern *Gleichenia* and the Restionaceae (rushes), could have grown on raised bog surfaces.

In corehole 354, Assemblage B is separated from the palyniferous section above by 20 m of sand and silt. The spore and pollen assemblage from 75.25 to 87.75 m, designated Assemblage A, differs dramatically from Assemblage B. None of the rainforest elements remain. In their place are the Compositae (daisies) in frequencies of 45-55 per cent, and grass pollen in frequencies of 8–11 per cent. The only tree pollen common is *Casuarina.*

According to data presently available, assemblages of this composition are not believed to occur in Australia before the Pliocene. The presence of rare *Monotoca* (Epacridaceae) in Assemblage A accords with a Pliocene age. The overall composition of the assemblage favours, on current thinking, a Late Pliocene, even early Pleistocene age. The basis for such age assignments must, however, be treated cautiously. In northern New South Wales, earlier workers have distinguished Pliocene from Pleistocene sediments using proportions of Compositae pollen; on that basis, the Lake George assemblage would be Pleistocene. There are dangers inherent, however, in using pollen frequencies as time markers, and the possibility remains that what is represented in Lake George is an older, Early Pliocene or even latest Miocene, occurrence of this open vegetation type. A significant time break is suggested between Assemblages A and B, but its magnitude is not determinable. There is also a dramatic environmental shift, from an environment moist enough to support rainforest, to one with rainfall sufficient only to support open *Casuarina* forest and grassland.

Future work

The task now, with the examination of more material from closely spaced samples, is to reconcile these tentative dates with those obtained by Singh & others (1981: *Journal of the Geological Society of Australia,* 28, 435–52) from coreholes in the northern end of Lake George. In those holes, magnetic reversal studies identified the Matuyama/Gauss boundary (2.47 m.y.) at a depth of 30 m. Should the tentative Late Pliocene date suggested here for sediments at 75–87 m in BMR corehole 354 be confirmed by further work, then the Pliocene sequence in the lake centre must be much thicker than it is at the northern end of the lake. Should this interval in corehole 354 eventually be proved to be older than Late Pliocene — perhaps by magnetostratigraphic methods — then the site would record the oldest occurrence yet known in Australia of an open vegetation dominated by grass and composites. The difficulties surrounding the palynological dating of the Lake George core emphasise the need for biostratigraphic and magnetostratigraphic studies to be undertaken concurrently in future studies of the sequence at the site. Only such a combination of dating methods will provide time control firm enough to allow Lake George to serve as a reference section for the late Cainozoic history of southeastern Australia.

For further information, contact Dr Liz Truswell at BMR.

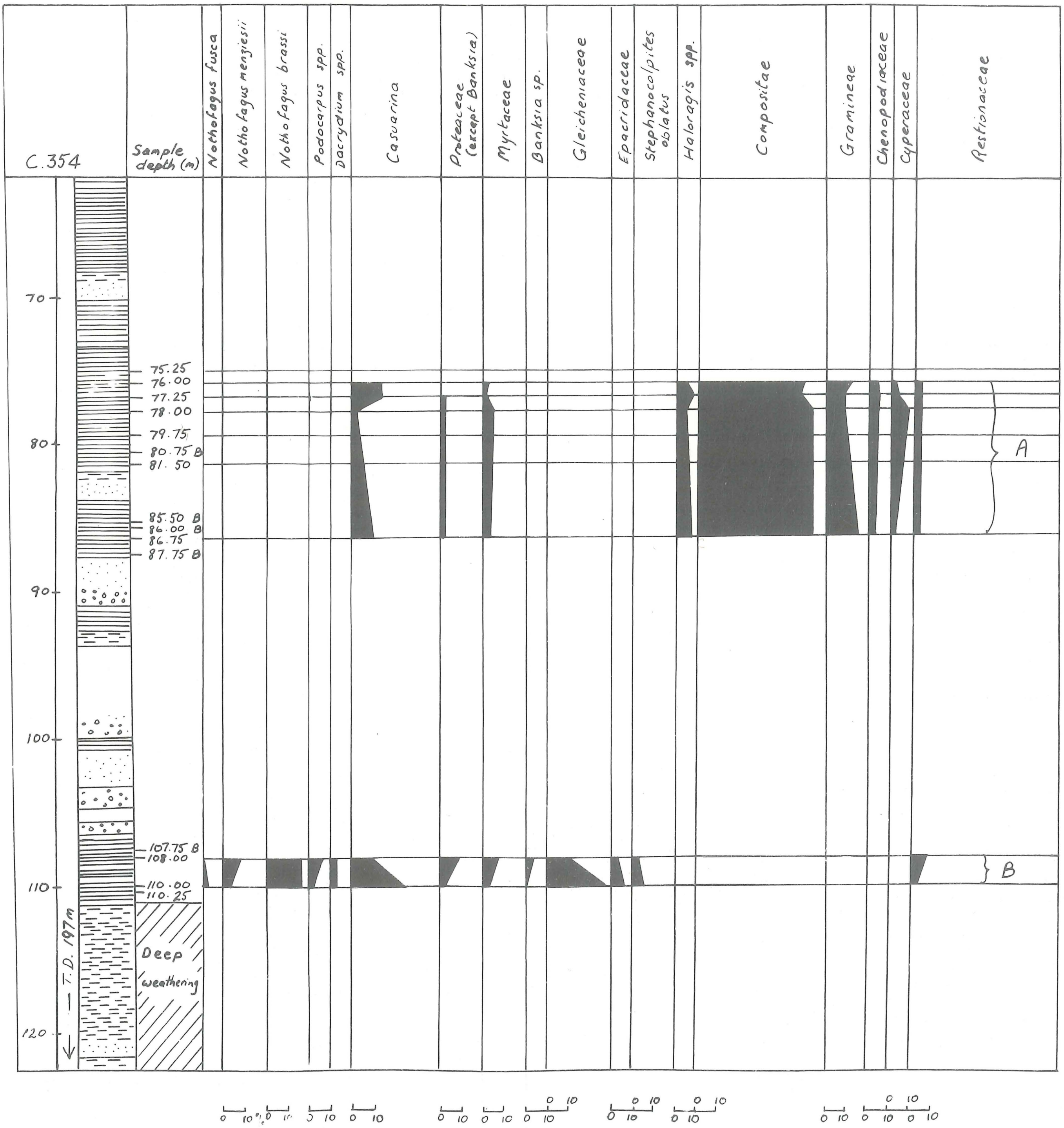

Fig. 10. Pollen diagram showing percentages of major taxa in BMR corehole 354. Barren samples shown by B.

Uranium deposits
handbooks forthcoming

The great surge of interest and activity in exploration for uranium deposits over the last decade has added significantly to our knowledge of uranium geology and the nature of uranium deposits. Much of the information that has been derived from government and industry programs has not been widely available, and in many cases has not had the benefit of systematic gathering, organisation, and publication. Consequently this information could be lost now that uranium exploration and research have declined, and the time, money, and effort spent in gaining it would have to be spent again when activities resume.

In an effort to gather together the most important information on uranium deposits, a series of handbooks is being prepared, each covering a specific type of deposit.

These handbooks are a product of the International Atomic Energy Agency's Working Group on Uranium Geology, which has been active since 1970 gathering and exchanging information and co-ordinating investigations on uranium geology. They are planned for completion and release in time for the 27th International Geological Congress, in Moscow.

The titles of the handbooks and their editors, are:

- 'Sedimentary basins and sandstone-type deposits', *Warren Finch*
- 'Uranium deposits in Proterozoic quartz-pebble conglomerates', *Desmond Pretorius*
- 'Vein-type uranium deposits', *Helmut Fuchs*
- 'Proterozoic unconformity and stratabound uranium deposits', *John Ferguson*
- 'Superficial deposits', *Dennis Toens*

The 'Proterozoic unconformity and stratabound uranium deposits' handbook has recently been completed and submitted for publication. The manuscripts in it relate to the uranium deposits of Zambia; Zaire; northeast China; Olympic Dam, SA; Pine Creek Geosyncline, NT; Turee Creek, WA; Athabasca Basin region and Beaverlodge area, Saskatchewan; Central District of Keewatin, NWT; Labrador; Dripping Spring Quartzite, Arizona; and Rio Preto, Brazil.

For further information, contact Dr John Ferguson at BMR.

RAD's enhanced oil recovery studies

Enhanced oil recovery is the objective of two separate studies in the 1984 program of the Petroleum Branch of the Resource Assessment Division (RAD). One concerns (mechanical) studies of formation damage problems which occur in the environs of a well during drilling and completion operations; in the other, RAD is co-ordinating research on various aspects of enhanced recovery by four Australian universities.

Formation damage research

Clays are a common constituent in many of Australia's domestic reservoirs, and formation damage from clay movement and pore blockage has been known to occur in most of our basins where petroleum is found; the resulting effect often hampers oil recovery. To gain a better understanding of the problems associated with this damage, and possible ways of alleviating it, the BMR Petrophysical Laboratory is conducting formation damage studies using core material from known oil productive formations. Two areas being investigated are the Surat Basin and the central Eromanga Basin in Queensland. Samples from the Pacoota Sandstone reservoir in the Amadeus Basin are being used for control purposes because of the dearth of clays in that formation.

Co-ordination of enhanced recovery research

In January 1983, four Australian universities — the Universities of Sydney, New South Wales, and Melbourne, and the Australian National University — commenced a program of research into enhanced oil recovery, taking into account the special characteristics of Australian oilfields. This research is sponsored by the Commonwealth Government through the NERDDP.

Research at the ANU has initially centred around improving apparatus that university staff developed for measuring interfacial forces. This apparatus has facilitated a unique investigation of oil-water capillary behaviour at microscopic level, studies of which are fundamental to improving oil recovery.

At the University of Melbourne, similar fundamental research has led to the development of equipment to evaluate formation wetting properties and 'fingering' characteristics of reservoir fluids.

At the Universities of Sydney and New South Wales, equipment is being installed for research into miscible-displacement enhanced recovery. Computer programs and simulators have been developed to predict oil recoveries by carbon dioxide displacement. Preliminary work on the use of carbon dioxide displacement in Cooper Basin oilfields is progressing well.

BMR has participated in all this research by providing technical support, by supplying reservoir geology information on various domestic petroleum accumulations, and through the loan of PVT equipment to the University of New South Wales for phase studies in their miscible displacement investigations.

For further information, contact Mr Brian McKay at BMR.

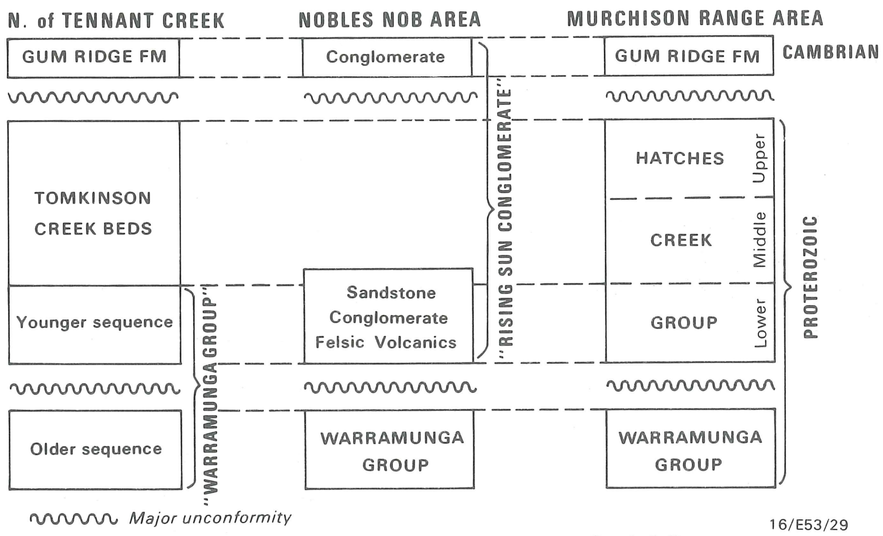

Fig. 11. Stratigraphic correlations, Tennant Creek Inlier.

Conodont colour alteration applied to thermal maturation and mineralisation studies

In recent years several groups of organisms have been used to determine levels of thermal maturation of organic material in sediments. Of these, the conodonts — phosphatic structures of an organism of uncertain zoologic affinity found from the Late Cambrian to the end of the Triassic in a wide variety of marine habitats — are becoming increasingly used in exploration programs. Their value in thermal maturation studies is based on the fact that they change colour as they are heated over the range 50-600°C, and therefore can indicate the temperature that their enclosing sediments reached during burial. They are particularly applicable to pre-Devonian sediments, which were deposited before the advent of land plants and, hence, vitrinite.

Thermal maturation study

In a paper in the latest issue of *APEA Journal,* Dr R. S. Nicoll (Division of Continental Geology) and Mr J. D. Gorter (Pancontinental Petroleum Ltd) document the results of a study of thermal maturation based on conodont colour alteration in the Canning Basin. Their study is based on the examination of subsurface samples from more than 50 petroleum exploration wells and several hundred outcrop samples from along the northern margin of the basin. In their paper they suggest that a major thermal event coincided with the intrusion of the Fitzroy Lamproite on the Lennard Shelf and adjacent Fitzroy Trough during the Miocene. The conodont colour data indicate that the thermal effects are most pronounced in the area (at least 3000 km^2) incorporating the lamproite intrusives, and are attenuated outside that area. No effects of a Miocene thermal event are apparent from the sparse data in the Kidson Sub-basin.

Mineralisation study

In a separate study, Dr Nicoll has been assessing the value of conodont colour alteration in the investigation of mineral deposits in calcareous sedimentary sequences. The examination of conodonts recovered from close proximity to mineralised rock provides clues to the character — including temperature — of the mineralising fluids. Etching of conodonts can give some indication of the extent of penetration of the mineralising fluids in the sediments, even if the fluids were representative of low-temperature conditions. Initial indications are that conodont studies may be of some benefit in the investigation of lead-zinc mineral prospects in the Canning and Bonaparte Basins.

For more information, contact Dr Bob Nicoll at BMR.

New stratigraphic correlations in the Tennant Creek Inlier

Field studies by the Division of Petrology & Geochemistry have shown that the **Warramunga Group,** as previously mapped near Tennant Creek, consists of two Proterozoic sequences separated by a major angular unconformity (Fig. 11). The older sequence is made up mainly of turbiditic greywacke, siltstone, and shale, with interlayered fragmental felsic volcanics, and contains all the Tennant Creek gold-copper ironstone lodes; it was tightly folded and subsequently eroded before the deposition of the younger sequence, which crops out north of Tennant Creek. The younger sequence, formed mostly of cross-bedded feldspathic or lithic sandstone and siltstone, is correlated with the lower part of the **Hatches Creek Group** exposed in the Davenport and Murchison Ranges to the south; it is overlain conformably by the **Tomkinson Creek beds,** a sequence of cross-bedded quartzose sandstone, siltstone, mudstone, carbonates, and minor basalt which is correlated with the middle and upper parts of the **Hatches Creek Group.** No part of the **Hatches Creek Group** and its stratigraphic correlatives appears to be prospective for gold-copper ironstone lodes of the Tennant Creek type.

Field studies have also shown that the **Rising Sun Conglomerate,** which crops out near the Nobles Nob mine, Tennant Creek, is a composite stratigraphic unit. The lower part is unconformable on the **Warramunga Group,** and consists of southerly dipping porphyritic felsic volcanics and conformably overlying volcaniclastic conglomerate and quartzose sandstone; these rocks are correlatives of the **Hatches Creek Group.** The upper part consists of flat-lying conglomerate and minor sandstone; it overlies the lower part unconformably, and is correlated with the Middle Cambrian **Gum Ridge Formation.**

For further information, contact Dr David Blake at BMR.

McArthur Basin

hydrocarbon assessment studies

Indications of hydrocarbon potential have been documented at several stratigraphic levels in the Proterozoic rocks of the McArthur Basin. Assessment of this potential is the aim of detailed sedimentological studies and organic geochemistry that BMR is focusing on two sequences in the basin — the Batten Subgroup and the Roper Group.

Studies in the **Batten Subgroup** have outlined a regressive hypersaline evaporative carbonate complex more than 1000 m thick. This complex grades from a euxinic sublittoral black shale sequence of either marine or lacustrine origin, through intertidal and sabkha environments, into ephemeral hypersaline lakes, all deposited in a fault-controlled half-graben with structural similarities to the Persian Gulf. Preliminary geochemical data reveal a significant proportion

(> 20%) of carbonates with Mg/Ca ratios in excess of normal dolomite; mineral phases have yet to be confirmed by XRD. Significantly high organic carbon values are indicated for shales throughout the sequence, but particularly in the 100-400 m thick Caranbirini Member; these still await measurements of maturation states.

Encouraging results have been obtained from the preliminary geochemical analysis of kerogen-rich shales from one of the three holes that BMR drilled into the 500-5000 m thick **Roper Group** in 1983. Some samples have very high organic carbon values, and Rock-Eval analyses suggest that the rocks are mature, in line with the earlier results of Peat & others (1978: *BMR Journal of Australian Geology & Geophysics,* 3, 1–17); they should make good oil source rocks. The best source rocks encountered during the 1983 drilling are in the Velkerri Formation, about the middle of the Roper Group. The best reservoir rocks occur stratigraphically below, in the Bessie Creek and Abner Sandstones.

For further information, contact Mr Ken Plumb (Batten Subgroup) or Mr Ian Sweet (Roper Group).

Summary of stratigraphy and palaeoenvironments, Nathan, McArthur, and Tawallah Groups, southern McArthur Basin

The information tabulated below is summarised from BMR Bulletin 220 (in preparation): Geology of the southern McArthur Basin, Northern Territory, by M. J. Jackson, M. D. Muir, & K. A. Plumb.

Unit	*Thickness*	*Rock types, structures, evaporite pseudomorphs*	*Palaeoenvironment*
		ROPER GROUP	
		regional unconformity	
NATHAN GROUP			
Dungaminnie Formation	240 +	Sandstone, dolostone, siltstone; channels, slumps	Lacustrine
Balbirini Dolomite	1500	Cyclic dolostone, dolarenite, sandstone, siltstone; ooids; gypsum, anhydrite, halite, ? shortite	Hypersaline lakes and playas
Smythe Sandstone	0 – 65	Dolomitic sandstone, conglomerate	Alluvial fans — braided streams
		regional unconformity	
McARTHUR GROUP			
Batten Subgroup			
Amos Formation	50 – 80	Karstic recrystallised dolostone	Calcrete
Looking Glass Formation	65 +	Silicified dolostone	Regolithic peritidal or lacustrine
Stretton Sandstone	30 – 270	Flaggy quartz sandstone	Continental or intertidal?
Yalco Formation	Up to 250	Nodular cherty dololutite, intraclast dolarenite; polygons, teepees	Emphemeral hypersaline lakes
Lynott Formation	50 – 600	Dolomitic siltstone and sandstone, dolostone, chert, bituminous pyritic shale; slumps; gypsum, anhydrite, halite	Regressive marine or lacustrine complex: euxinic basin to continental sabkha
		local unconformity	
Umbolooga Subgroup			
Reward Dolomite	10 – 350	Dololutite, dolarenite, sandstone; slumps; gypsum needles	Shallow to emergent lakes or lagoons
Barney Creek Formation	0 – 700	Dolomitic bituminous pyritic shale, tuff, breccia; slumps, rare crusts, teepees, pisoids; anhydrite	Hypersaline euxinic lake; occasionally emergent
Teena Dolomite	15 – 70	Dolostone, shale, dolarenite; gypsum needles, halite	Hypersaline lakes or playas
Emmerugga Dolomite	Up to 620	Dolostone, siltstone; halite, gypsum, anhydrite	Hypersaline lagoons or lakes
Myrtle Shale	30 – 100	Red dolomitic siltstone, sandstone; halite, anhydrite	Subaerial to hypersaline lakes
Leila Sandstone	0 – 30	Dolomitic sandstone, dolarenite; ooids	Subtidal sand shoals
Tooganinie Formation	200 – 500	Cyclic dolostone, siltstone, dolarenite; teepees; halite, gypsum	Hypersaline peritidal complex
Tatoola Sandstone	ca. 120	Dolomitic and quartz sandstone; channels; halite, baryte	Peritidal sand shoals
Amelia Dolomite	150 – 180	Dolostone, dolarenite, shale; ooids; ex-gypsiferous marble	Hypersaline lagoon and tidal flats
Mallapunyah Formation	100 – 200	Red-brown dolomitic siltstone, sandstone; anhydrite, halite, baryte	Peritidal to continental sabkha complex
Masterton Sandstone	50 – 650	Quartz sandstone, locally pebbly	Complex of shallow marine, alluvial fan, and aeolian
		regional unconformity	
TAWALLAH GROUP			
Gold Creek Volcanics	5 – 225	Intermediate volcanics and sediments	Subaerial
Wollogorong Formation	50 – 150	Red siltstone, sandstone, and dolostone, and pyritic bituminous siltstone; halite, gypsum, anhydrite	Complex of hypersaline lakes, alluvial plain, and shallow marine
Wununmantyala Sandstone	ca. 500	Red quartz sandstone	Sublittoral marine
Settlement Creek Volcanics	100 – 150	Basic to intermediate volcanics, hematitic shale, glauconitic sandstone, dolostone	Subaerial to shallow marine
Aquarium Formation	150	Glauconitic shale, sandstone, dolostone	Marginal marine
Sly Creek Sandstone	100 – 900	Quartz sandstone, shale, dolarenite, local conglomerate	Offshore to shoreline marine
McDermott Formation	0 – 400	Sandstone, dolostone, siltstone, chert; ooids, glauconite; anhydrite, gypsum, halite	Subtidal to supratidal marine complex
Seigal Volcanics	100 – 600	Amygdaloidal basalt, feldspathic sandstone	Subaerial
Yiyintyi Sandstone	ca. 2500	Quartz sandstone, basal arkose and conglomerate	Fluvial to shallow marine transgression
Westmoreland Conglomerate	20 – 1000	Conglomeratic and quartz sandstone, conglomerate	Alluvial fans and braided streams
		regional unconformity	
		BASEMENT	

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