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Special Australian issue of *Precambrian Research*

BMR announces the imminent publication, by Elsevier, Amsterdam, of a special two-volume issue of *Precambrian Research*, on the Early to Middle Proterozoic of Australia (running to nearly 600 pages), compiled and edited by BMR staff. The individual papers are listed on page 9 of this *Newsletter*. A limited number of copies of the two-volume set, normally priced at f.450, i.e. approx. $270, will be available for purchase from BMR Publications Sales (see p. 8) at a special price of $125 per set, postage included.

Rig Seismic investigates Tasmanian margin

BMR research cruise 78, a geophysical and geological sampling investigation of petroleum frontier areas on the Tasmanian continental shelf and slope, was recently completed by scientists of the Division of Marine Geosciences & Petroleum Geology aboard RV *Rig Seismic*.

The 24-day cruise, in March–April 1988, was aimed at studying the structure, stratigraphy, evolution, and petroleum potential of offshore west and southeast Tasmania. The work off western Tasmania was designed to build on the results of earlier research cruises in the region involving BMR — RV *Rig Seismic* research cruises 48 (1985) and 67 (1987), and two cooperative cruises with the Bundesanstalt für Geowissenschaften und Rohstoffe of West Germany in 1985 using RV *Sonne*. Geophysical data acquisition by *Rig Seismic* off southeast Tasmania was part of a joint research project with Conga Oil Pty Ltd to investigate the petroleum prospects of this very poorly explored area. Oil seepages are known on Bruny Island, and it is believed that Palaeozoic sediments may be the source rocks. Widespread intrusion of the sedimentary section by massive dolerite sills of Jurassic age presents a formidable challenge to seismic processing and interpretation.

The survey (Fig. 1) completed 1750 km of multichannel seismic, magnetic, and gravity profiling off the west coast of Tasmania and 265 km of such work around Bruny Island off southeast Tasmania. In addition, sonobuoys were successfully deployed at eight sites — mainly located in deep water off the west coast to help establish the structure of extended or transitional continental crust near the continent/ocean boundary.

Thermogenic hydrocarbons

The geophysical monitor records from the west Tasmanian margin reveal that continental basement and assumed Early Cretaceous sedimentary rocks are present at shallow depth beneath the outermost shelf and the lower continental slope above the abyssal plain, but elsewhere there are thick Late Cretaceous and Early Tertiary sediments (3 seconds or more thick in places). The sampling program consisted of 12 dredge stations,

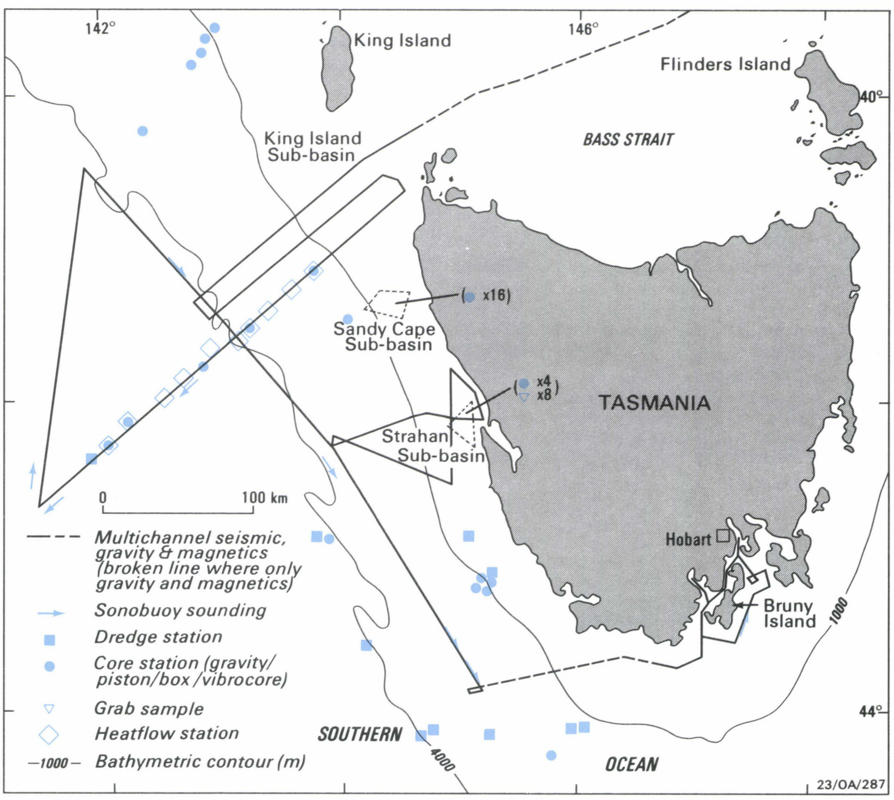

Fig. 1. Geophysical lines surveyed and seafloor sampling stations occupied during the 1988 RV *Rig Seismic* research cruise 78.

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Bureau of Mineral Resources, Geology and Geophysics, Canberra

Department of Primary Industries and Energy

37 core (piston/gravity/box/vibracore) stations, 9 grab stations, and 10 heatflow stations. Gas analyses of samples from the Sandy Cape Sub-basin provide the first strong indication that thermogenic hydrocarbons are being generated at depth in this area.

A preliminary post-cruise report has been prepared, and will shortly be published as a BMR Record. Processing of the seismic, navigational, and potential-field data is expected to be completed during 1989.

For futher information, contact Dr Neville Exon, Dr Chao-Shing Lee, or Mr Peter Hill at BMR (Division of Marine Geosciences & Petroleum Geology).

Cambrian palaeogeographic maps published *(Palaeogeographic Atlas of Australia)*

Palaeogeographic maps of Australia for six Cambrian time slices (see *BMR Research Newsletter 6,* 12; *7,* 15) are included in a recently released folio of maps at 1: 10 000 000 scale, which also includes data and structure maps, summary stratigraphic columns, and explanatory notes. The Cambrian set is the first part of the *Palaeogeographic Atlas of Australia* to be issued; the Atlas will eventually cover the whole of Phanerozoic time, involving a total of 70 time slices. The sets will be published a period at a time, and their release announced in the *BMR Research Newsletter.*

The maps are the result of a major project jointly funded by BMR and the Australian Mineral Industries Research Association (AMIRA), representing thirteen sponsoring companies, and carried out from 1984–87.

The maps show hydrocarbon and mineral occurrences, which can thus be correlated with palaeoenvironments.

Further information can be obtained from Dr P.J. Cook at BMR (Division of Continental Geology).

New Southwest Pacific geological map

A new geological map of the southwest Pacific region at 1:10 000 000 scale, with explanatory notes, is now on general sale through the Australian Mineral Foundation bookshop in Adelaide (AMF Bookshop, 63 Conyngham St, Glenside, SA 5065; tel. (08)379044; fax (08)794634; telex AA87437).

The area covered is the Southwest Quadrant of the Circum-Pacific Map Project (*BMR Research Newsletter*, **3**, 14), and extends from Indonesia in the west to beyond Samoa in the east and from north of the equator to Antarctica.

The map is part of an integrated series of maps of the Pacific basin showing the relationship of geology, tectonism, and geophysics to known energy and mineral resources; eventually there will be eight series of thematic maps at 1:10 000 000 scale, and selected compilations of the entire basin at 1:17 000 000 scale. The region covers more than 100 million km^2, or half the Earth's surface.

The map shows onshore geological units and data on offshore sediment type, ODP sites, stratigraphic columns for selected ODP drillholes, and age and lithology of selected bedrock specimens. The onshore units correspond with the major stratotectonic units of the region, and symbols appended in the map reference indicate the tectonic setting of each unit.

Since 1980, BMR has been coordinating the compilation of maps of the Southwest Quadrant.

For further information, contact Mr David Palfreyman at BMR (Geoscience Planning & Information Branch).

Block and possible terrane boundaries in the Mount Isa Inlier

The Mount Isa Inlier can be regarded as consisting of several large Proterozoic blocks delineated by major north-trending strike-slip faults or fault zones. These include, from west to east, the Mount Isa Fault zone; the Quilalar Fault zone; a fault zone, here termed the Wonga Belt Fault, within the Wonga Belt; and the Pilgrim Fault zone (Fig. 2). The last named appears to have the largest displacement and may represent a boundary between two distinct terranes.

The **Pilgrim Fault** forms the western boundary of the Early Palaeozoic Burke River Structural Belt in the south and corresponds to the Coolullah Fault on the west side of the Boomarra Horst in the north. Probable splays from the main fault include the southwesterly trending Mount Remarkable and Fountain Range Faults, both of which in places have dextral displacements of more than 20 km. Differences in structure, stratigraphy (Fig. 3), and plutonism on either side of the Pilgrim Fault zone indicate that the Proterozoic rocks to the west are not directly related to those to the east, and may have originated hundreds of kilometres away from them.

The most obvious structural difference is in structural grain. West of the Pilgrim Fault the overall grain is markedly longitudinal: folds are typically tight and upright, with subvertical axial planar foliations trending close to north–south, and granite plutons show a pronounced north–south elongation. In contrast, to the east of the Pilgrim Fault the trends of folds and foliations range from north–south to east–west, there are several large recumbent folds with east–west trending axes, and granite plutons are not markedly elongated in any one direction.

Some of the stratigraphic differences are:

- felsic Leichhardt Volcanics (1850-1875 Ma) and unconformably overlying Magna Lynn Metabasalt, extensively exposed to the west, are not present east of the Pilgrim Fault zone;
- in the west, the felsic volcanics which make up the Argylla Formation (1780 Ma), conformably overlying the Magna Lynn Metabasalt, are overlain concordantly by Ballara Quartzite, whereas in the east felsic volcanics similar in age and chemistry to those to the west, but associated with abundant clastic sediments, are separated from Mitakoodi Quartzite, a probable correlative of the Ballara Quartzite, by the basaltic Marraba Volcanics;
- the Ballara Quartzite in the west passes up into a unit of pelitic and calc-silicate rocks — the Corella Formation; the Mitakoodi Quartzite in the east passes up into a unit characterised by cherty rocks — the Overhang Jaspilite (both the Magna Lynn /Argylla/ Ballara/Corella sequence west of the Pilgrim Fault and the comparable Argylla/Marraba/Mitakoodi/Overhang sequence to the east are each several kilometres thick and appear to be essentially conformable);
- no units similar in lithology to the Answer Slate and Marimo Slate, which overlie the Overhang Jaspilite, are known west of the Pilgrim Fault; and black slate, a common rock type east of the fault, is rare to the west. Other distinctive units that crop out only east of the fault are the Soldiers Cap Group, the Knapdale Quartzite/Coocerina Formation/Lady Clayre Dolomite sequence near the Dugald River Zn–Pb prospect, and the Au-bearing Quamby Conglomerate. On the other hand, no undoubted equivalents of the Mount Isa and McNamara Groups, which comprise the youngest Proterozoic stratigraphic units (including the Urquhart Shale, host for the Cu–Zu–Pb–Ag deposits at Mount Isa) in the western part of the Mount Isa Inlier, are known east of the Pilgrim Fault.

The Pilgrim Fault also separates voluminous deformed and recrystallised granites to the west, which predate the Isan Orogeny (1550–1620 Ma), from widespread undeformed younger granites, emplaced at about 1500 Ma, to the east.

Not only Proterozoic rocks are displaced by the Pilgrim Fault. Cambrian strata in the south show vertical displacements of 100 m or more and local steep to overturned dips along the fault zone, and probable Mesozoic movements have been reported in the north, indicating that the zone was also active during the Phanerozoic.

Differences across the **Wonga Belt Fault** and **Quilalar Fault** to the west are less dramatic and mainly stratigraphic. For example, on the west side of the Wonga Belt near Mary Kathleen, a thick sequence of Argylla Formation, Ballara Quartzite, and Corella Formation is exposed, whereas on the east side basement Kurbayia Migmatite, deformed during the Barramundi Orogeny (~1900 Ma), is overlain unconformably by a band only a few tens of metres thick of Ballara Quartzite, above which comes Corella Formation. Here the Argylla Formation, the underlying Magna Lynn Metabasalt, and the Leichhardt Volcanics, and much of the overlying Ballara Quartzite, totalling several kilometres in thickness, are missing on the east side of the Wonga Belt Fault. This fault is generally masked by, and may be older than, intrusions of Wonga Granite emplaced at around 1740 Ma.

The Quilalar Fault zone is taken to continue north as the western boundary of the Ewen Block and south as the Gorge Creek and Dajarra Faults. On the west side near Lake Julius a shallow-water facies of Quilalar Formation (a correlative of the Ballara Quartzite) lies conformably on a thick sequence (many km) of Haslingden Group rocks, whereas on the east side a deeper-water facies of Quilalar Formation is unconformable on Leichhardt Volcanics and comagmatic granite; i.e., the Haslingden Group is missing on the east side of the fault in this area. Nowhere east of the fault is the Haslingden Group as much as 1000 m thick. The Leichhardt Volcanics, Magna Lynn Metabasalt, and Argylla Formation do not extend west of the fault zone, and the lower part of the Haslingden Group and conformably underlying Bottletree Formation are absent to the east. The differences in stratigraphy across the Quilalar Fault may be attributed partly, but certainly not entirely, to the close correspondence of the fault with the eastern margin of the Leichhardt River Fault Trough (*BMR Research Newsletter* **4**, 1)

Near Mount Isa the **Mount Isa Fault zone** comprises a series of closely spaced north–south trending faults. These are thought to continue southwards as the Mount Annable and Wonomo Faults and to join up northwards with the Mount Gordon Fault zone. As such, the Mount Isa Fault zone marks the eastern limit of the 1670 Ma old Sybella Batholith and the western limit of the highly prospective Mount Isa Group.

Because they form major block boundaries that persist for the full length of the Mount Isa Inlier, and beyond in the subsurface, the fault zones are presumed to extend down through the crust to the mantle, and thus be able to accommodate large-scale crustal movements. The Quilalar, Mount Isa, and Wonga Belt Fault zones were probably active during deposition of the Haslingden Group and Quilalar Formation, but the Pilgrim Fault may not have existed until after the Isan Orogeny. Major movements took place along the fault zones, except that of the Wonga Belt, during the

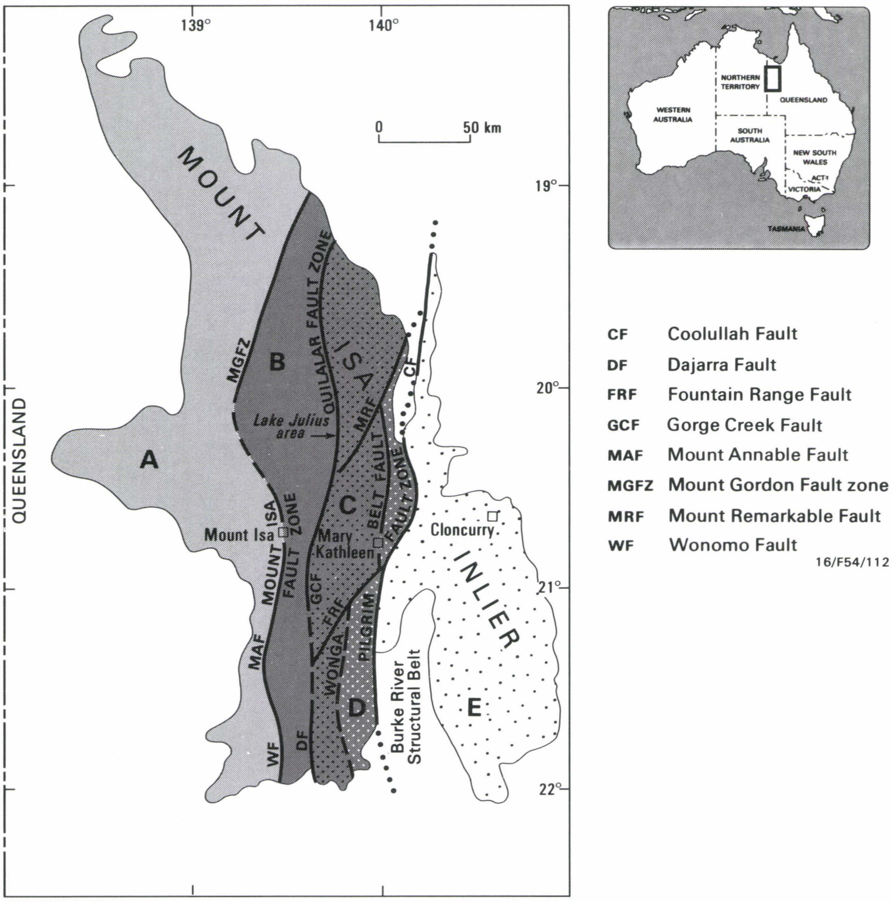


Fig. 2 Fault blocks, Mount Isa Inlier. The key letters refer to Figure 3.

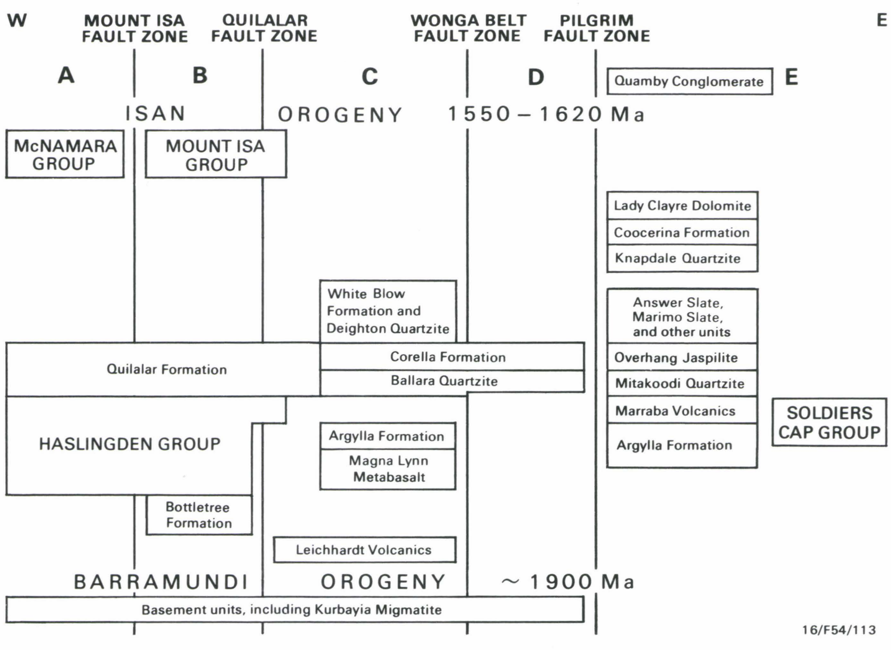


Fig. 3. E–W distribution of major stratigraphic units in the Mount Isa Inlier. The key letters denote the various fault blocks shown in Fig. 2.

later Proterozoic and in the Phanerozoic, post-dating the upper crustal thrusting and extensional events recently documented in the Mount Isa Inlier (e.g., *BMR Research Newsletter* **2,** 11; **8,** 2–4).

For further information, contact Dr David Blake or Dr Alastair Stewart at BMR (Division of Petrology & Geochemistry).

Towards an Australian time scale

BMR palaeontologists, in conjunction with colleagues in State Geological Surveys and university departments, have for the past year been compiling a set of biostratigraphic charts for the Phanerozoic of Australia. The charts originated in response to the need for a firm chronological base to support the AMIRA (Australian Mineral Industries Research Association)-sponsored *Palaeogeographic Atlas of Australia.* Production and publication of the charts is part of the second phase of the palaeogeographic maps project, the APIRA (Australian Petroleum Industry Research Association)-sponsored *Phanerozoic History of Australia.*

Early in the palaeogeographic maps project it became clear that there was a need for high-resolution time scales in the production of the lithostratigraphic charts on which the maps are based. Palaeontological data tend to be scattered through a wide literature and through unpublished reports; zonal concepts have been constantly changing as new data become available, and there has been little attempt to relate the available data to the relatively few radiometric dates where these are available.

The charts in preparation bring together scattered data and demonstrate the relationships between zones based on different groups of fossils, and the relationship of these zones both to standard international time scales, and, where possible, to numerical time scales. Their aim is not to produce a separate 'Australian time scale' designed to compete with internationally accepted scales such as the Harland scale, or the North American 'DNAG' scale, but rather to produce a set of calibrated biostratigraphic charts for use in the Australian region. They will test the applicability of current international scales in the Australian context and will in some cases be able to make substantial contributions to the calibration of international scales — this will be possible where we have in Australia biostratigraphic units associated with igneous or volcanic suites that can be radiometrically dated.

Each of the charts will be accompanied by a set of explanatory notes. Preliminary reports of progress were presented at the Ninth Australian Geological Convention in Brisbane in February 1988. Some of the highlights of presentations given there are reported below.

For the **Cambrian,** biochronological scales have developed from the work of earlier palaeontologists such as R. Etheridge Jr., F.W. Whitehouse, and A.A. Opik. The present chart has been compiled from all available data. For the Early Cambrian, the scheme shown is provisional; selected taxa of ichnofossils from central Australia and archaeocyathans from South Australia are shown in relation to a series of informal faunal assemblages originally proposed in 1956. The Middle Cambrian is zoned by trilobites assigned to five local stages, deriving from the Ord and Georgina Basins. For the Late Cambrian, trilobite sequences from the Georgina Basin form the basis of nineteen assemblage zones. Conodont assemblages become stratigraphically useful during the Late Cambrian, and serve to define the beginning of the Ordovician.

For the **Ordovician,** the only comprehensive Australian stage and zonal scheme is that based on the Victorian graptolite succession developed in deep-water facies of the continental margin. This is probably the most detailed and well established Ordovician biostratigraphic scheme on a global basis. The Cambrian/Ordovician boundary, however, lies below the lowest records of planktonic graptolites. Separate latest Cambrian–Early Ordovician local stages, the Datsonian and Warrendian, have been established in the platform sequences of the Georgina Basin, with conodont zones of mainly North American aspect. When the Cambrian/Ordovician boundary is ratified internationally, it is likely to be located within the Datsonian succession. The Ordovician/Silurian boundary is recognised in an apparently continuous succession near Darraweit Guim, north of Melbourne.

For both the **Silurian** and **Devonian,** major international decisions, defining the Period boundaries and many of the Series and Stage boundaries, have had an immediate effect on correlation of Australian sequences. In the Silurian to Early Devonian, there have been advances in the use of conodonts, with the setting up of a zonation for most of the Early Silurian. In the later Devonian, the standard ammonoid zones are now better correlated with conodonts, as are brachiopod zones. An analysis of recent radiometric work shows the base of the Silurian can be confidently set at 434 Ma. The Silurian/Devonian boundary lies at approximately 408 Ma, but Australian data would suggest 410 Ma may be closer. Australian data also support the suggestion that the boundary with the Carboniferous lies at about 354 Ma.

For the **Carboniferous,** three areas — western Europe, USSR, and North America — provide standard stratigraphic scales. Of these, the scale from western Europe is most appropriate for Australia, where the cosmopolitan shelly faunas of the Early Carboniferous (i.e Dinantian) are replaced by endemic, poorly diversified Gondwana faunas in the Late Carboniferous. Some radiometric (K/Ar) age data from the Hunter Valley have been used to provide age estimates for Stage boundaries. The Paterson Toscanite, with an average age of 308 Ma, would fall within the Westphalian C. The Visean/Namurian boundary lies at about 325 Ma, the base of the Brigantian Stage at 331 Ma, and the Tournaisian/Visean boundary at about 342 Ma.

For the **Permian,** an integrated correlation chart for Australia has been prepared using invertebrate faunas and microfloras. Following recent discussions of the Subcommission on Permian Stratigraphy at the Carboniferous Congress in Beijing in 1987, a twofold subdivision of the System is favoured. For the Lower Permian, division into Asselian, Sakmarian, Artinskian, and Kungurian is recognised; for the Upper Permian, a fivefold division is used: Ufimian, Kazanian, Midian, Dzhulfian, and Changhsingian.

For the **Mesozoic,** preliminary compilations of fossil zones are available for the Triassic, Jurassic, and Cretaceous. The available **Cainozoic** chart shows interrelationships between zones based on foraminifera (both assemblage zones and first and last appearance datums), calcareous nannofossils, palynology (spores and pollen and dinoflagellates), molluscs, and land mammals. Considerable problems remain with the calibration of Australian local stages, and stratotypes of Bairnsdalean, Cheltenhamian, and Mitchellian may overlap. There is a need for firmer establishment of relationships of southern margin foraminiferal events with international scales, and a need too to establish ways of dating sequences in inland basins. Opportunities for relating biozones to radiometrically dated volcanics exist in the eastern highlands, where palynological assemblages are being recovered from sediments interbedded with basalts.

For more information, contact Dr Elizabeth Truswell at BMR (Division of Continental Geology). Further information on the APIRA project may be obtained from Mr J. Cucuzzo, Australian Petroleum Industry Research Association, 11th Floor, 63 Exhibition Street, Melbourne 3000.

Epithermal gold, and foreland faulting and magmatism, Kalimantan, Indonesia

Gold mineralisation, although widespread in Kalimantan, is particularly abundant in an east-trending belt up to 100 km wide that conforms to an uplifted and strongly faulted foreland basement high between latitudes 0° and 1°N, and west of longitude 116°E (Fig. 4). The gold deposits are thought to have formed as a result of hydrothermal activity associated with a Late Oligocene to Miocene igneous event (mainly small, high-level intrusives) coeval with the uplift of the basement high. Although the gold is hosted by a wide variety of rock types (*BMR Research Newsletter* 8, 4–6), its distribution is largely controlled by a complex system of faults. East of longitude 116°E the foreland belt remains poorly mapped, but swings northeasterly.

Regional geology: continent–continent collision

The foreland belt is the southern part of a Late Cretaceous to Eocene orogen that formed as the result of southward subduction followed by collision between two continental terranes. The northern terrane is the southern extension of southeast China and Indo-China, and represents an attenuated and block-faulted passive margin; it is mostly covered by the South China Sea and Cainozoic sediments. The southern terrane is exposed in places in Kalimantan as basement comprising Palaeozoic to Jurassic deformed sedimentary, volcanic, and plutonic rocks, and their metamorphosed equivalents. Cretaceous to Early Eocene ophiolite, unstable shelf sediments and turbidites were intensely folded and fractured, low-grade-metamorphosed, thrust southward and possibly also northward, and incorporated in melange zones during convergence of the continental terranes. At the same time granitoids were emplaced in the southern terrane (hanging plate) at various crustal levels; one phase was accompanied by intermediate volcanism, and acidic volcanics including ignimbrite were erupted in the Middle Eocene (too small to show in Fig. 4) and locally overlie the orogenic sediments and ophiolite.

A remarkably synchronous Late Eocene unconformity that has been traced for hundreds of kilometres along the southern flank of the orogen, truncates the deformed sediments and ophiolite. The unconformity is overlain by terrestrial to shallow and open-marine Late Eocene to Oligocene foreland sediments with several volcanic intercalations. However, convergence continued, and in the foreland belt gave rise to foldings and thrusting, and locally to an unconformity between the Late Eocene and Oligocene sediments.

Foreland basement high

In the Late Oligocene to Miocene, basement underlying the foreland was uplifted along an easterly trend and intruded by numerous plugs, stocks, dykes, and sills. The elongate basement high conforms to a Bouguer anomaly high, and uplift is thought to have been due to isostatic rebound of tectonically thickened crust after the collision. The shallow intrusives have a granodioritic composition, grading into granite and diorite; remnants of volcanic cones are preserved in places.

The uplift of the foreland high was accompanied by **three different types of faulting.** (1) At several places the basement, where it is exposed in windows, is separated from overlying unstable shelf sediments, turbidite, ophiolite, or melange composed of these associations, by gently dipping detachment faults. The basement rocks are amphibolite-facies metagranite, gneiss, schist, and metagabbro that show evidence of strong ductile deformation such as gently dipping mylonite. In contrast, the overlying rocks have been deformed in a brittle way, as shown by slickensiding and dense fracturing. Both cover and particularly basement are riddled with quartz veins, and rivers transecting the detachment faults are choked with milky quartz. In places chloritic breccia derived from the cover rocks also occurs. Apparently the cover rocks and basement were only juxtaposed after the basement had been emplaced at a high crustal level. (2) A second type of fault system is clearly expressed in the topography as fault-line valleys and long linear ridges. The faults are normal and steeply dipping and have tilted the foreland sediments to dips between 30–80°. It is not certain if these faults are planar or listric, or if they merge with the detachment faults. (3) The faults of the third category are steep to vertical and cut into the basement. They include thick zones of brecciation and shearing; horizontal slickensides indicate a component of strike-slip movement, but lateral displacements greater than 1–2 km have not been documented.

Between the Late Oligocene–Miocene magmatic event and a phase of basaltic volcanism in the Pliocene–Pleistocene a conjugate fracture system was formed, usually at high angles to the mostly east-trending older structures. Displacement along these fractures is slight.

Alteration

Hydrothermal alteration is common where the rocks have been cut by all three types of faults, and especially also where these faults intersect the (earlier) thrust faults, and the melange and shear zones that formed during one of the compressive phases. So far two types of hydrothermal alteration have been recognised: silicification, and oxidation/argillisation. **Silicification** appears to be mostly associated with the detachment faults and steep faults that cut basement, and affects a wide range of rock types, including the basement, Cretaceous granitoids, Cretaceous to Early Eocene turbidites, etc, and the sediments and volcanics of the foreland sequence. The degree of silicification ranges from scattered quartz veining to almost complete replacement. The silicified rocks may contain epidote-clinozoisite and chlorite, but pyrite is everywhere present. **Oxidation/argillisation** is widespread in rocks of the foreland sedimentary and volcanic sequence where displaced by normal faults. The altered rocks are off-white to light orange-brown; pyrite is oxidised to limonite forming networks of black to brown crusts. Sandstone is commonly friable and ferruginous, and the other lithologies are more or less altered to clay. Remarkably, the subvolcanic intrusives are only sporadically silicified, oxidised, or argillised, although commonly slightly propylitised.

Gold

The gold occurs in quartz veins and stockworks in the silicified zones, but is also disseminated, some being associated with pyrite. In the oxidised/argillised rocks the gold is disseminated in clayey zones, but in friable sandstone it may form irregular coarse grains filling pores. Quartz veining is minor in zones of oxidation/argillisation, but

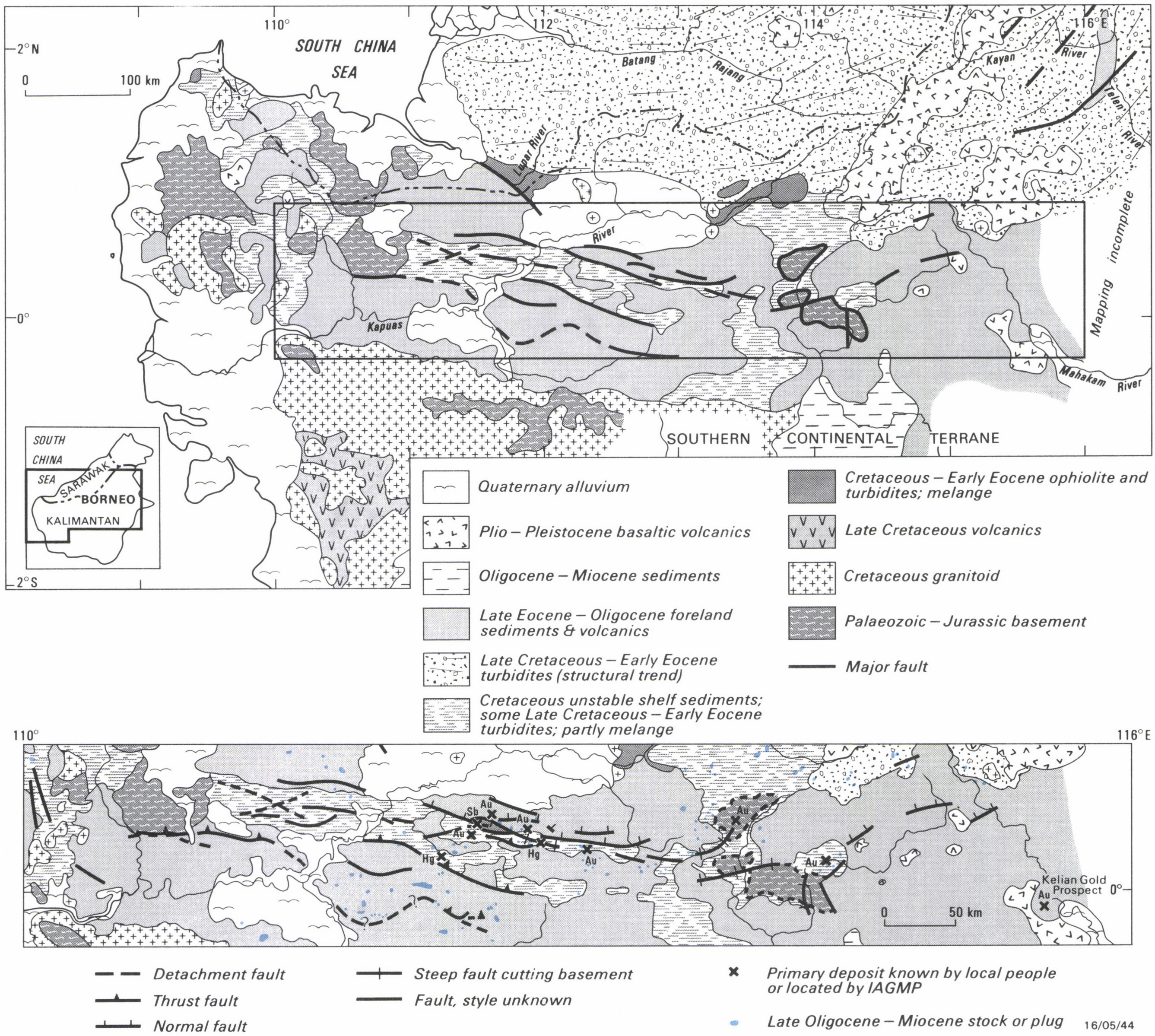


Fig. 4. Geology of central Kalimantan and part of Sarawak. Sarawak geology compiled from *Geological Map of Sarawak* (Geological Survey of Malaysia, 1982).

gold is associated with pyrite and its oxidation products. The coarse gold in the sandstone is probably the product of supergene reworking and agglomeration of microscopic gold liberated from gold-bearing pyrite during oxidation.

The most common accessory ore minerals are cinnabar and stibnite. Both have been mined in small-scale operations. Base metals are notably rare or absent. So far gold has only been recovered from alluvial placers by the local people, but a vigorous exploration program for primary deposits by various mineral companies since 1982 has led to the discovery of several prospects.

Although there is no apparent direct link between the Late Oligocene to Miocene shallow intrusives and the mineralisation and alteration, their close spatial and temporal association suggests that the gold deposits are epithermal. The wide occurrence of cinnabar and stibnite, the low values of base metals, and the diagnostic types of alteration and ore textures support such an origin.

The shallow intrusive bodies probably supplied the heat source to initiate and sustain convection and circulation of meteoric waters. The three types of fault systems provided pathways for the upward movement of the fluids into structurally and chemically favourable horizons. Because of the structural complexity, deposition took place in a wide range of rock types. The alteration also occurred when the hydrothermal fluids ascended but was not necessarily contemporaneous with the gold mineralisation. (Published with the permission of the Director, GRDC).

The Indonesia–Australia Geological Mapping Project (IAGMP), a joint project of the Indonesian Geological Research & Development Centre (GRDC) and the BMR (under the auspices of the Australian International Development Assistance Bureau), carried out the first systematic geological and gravity mapping at 1:250 000 scale of the northern part of west and central Kalimantan between 1982 and 1986. This article covers some of the preliminary results, but for a better understanding of the controls and history of gold mineralisation and alteration much more detailed field work and research are required. Some results of the mapping are available in published form or as open-file reports at GRDC, Jalan Diponegoro 57, Bandung, Indonesia; they may be discussed with Dr Rab Sukamto or Mr Sam Supriatna at GRDC, phone (022) 73205, and Mr Peter Pieters (BMR) in Bandung at Jalan Cilaki 49, phone (022) 72103.

Release of 'GDA', BMR's new whole-rock geochemical data analysis system

GDA is a comprehensive IBM PC-based whole-rock geochemical data analysis system. It is written in Fortran 77 and uses the Media Cybernetics HALO package for plotting routines. This system was designed to accept data from the BMR ORACLE database, but any correctly formatted ASCII data files can be used as input, or the data may be entered into files directly from the keyboard.

The GDA system includes programs for producing a variety of plots (XY, triangular, histograms, and spidergrams) and calculating statistical functions (e.g., mean, standard-deviation, regression lines, correlation coefficients, and cluster analysis). Specialised petrological packages are also available and include CIPW norms and petrogenetic modelling (batch melting, Rayleigh fractionation, least-squares mixing, etc.). There are also facilities for producing hard-copy plots, tables of geochemical data, and for editing and merging datafiles.

It is expected that the Fortran source code will soon be available for purchase for $750, but prospective users will also need to have Microsoft FORTRAN and Media Cybernetics HALO. The price reflects the fact that no software support will be available from BMR.

For further information, contact Dr John Sheraton at BMR (Division of Petrology & Geochemistry).

Thermogenic gases in sea-floor sediments, offshore Otway and Gippsland Basins

In April–May 1988 BMR's RV *Rig Seismic* was engaged in a 21-day geochemical and sedimentological research project in the Otway Basin (17 days) and Gippsland Basin (4 days), in offshore Victoria and South Australia. Light hydrocarbon (C_1–C_5) gases (Table 1) were measured in near-surface sediments at 342 sites on the continental shelf and upper slope, mostly along pre-existing seismic lines. Thermogenic hydrocarbons, identified from the molecular compositions of the gas mixtures (for a description of the methods and interpretation involved in the technique see *BMR Research Newsletter*, 7, 1), were found at 32 sites in the Otway Basin and 10 sites in the Gippsland Basin (Figs. 5, 6, 7). The detailed data are available in *BMR Record* 1988/32.

Otway Basin

— Thermogenic gases were found in sediments at seven sites on the Crayfish Platform, seven sites on the Mussel Platform, and 18 sites in the Voluta Trough.

— Wet gas contents ((C_2–C_4)/(C_1–C_4) × 100), which provide an indication of both the source type and the maturity of the hydrocarbons, are highest on the basin margins, i.e. the Crayfish and Mussel Platforms. Wet-gas contents are consistently lower in the Voluta Trough, where the sediments are thicker and where the vitrinite reflectance values show that the oil window (R_o = 0.7–1.3) normally occurs within the Late Cretaceous strata. Early Cretaceous strata occur within the thermal gas regime (R_o>1.3) for most of the Voluta Trough.

— Total C_1–C_4 gas concentrations are higher in the Voluta Trough than on the basin margins, probably because of more intense near-surface faulting in the trough.

— The geochemical data, when integrated with thermal maturation modelling and well data, suggest that the principal liquid-hydrocarbon source rocks are at the base of the Early Cretaceous Otway Group (i.e., basal Pretty Hill Sandstone). The Late Cretaceous Sherbrook Group appears to be gas-prone.

Gippsland Basin

In the limited sampling program in the Gippsland Basin, ten anomalous locations were found, nine of which were on BMR seismic line 40/1 (Fig. 7). The following observations can be made:

— No anomalies were found in the southern part of the Southern Platform, where the Latrobe Group is thin to absent.

— Most anomalies are in the Central Deep.

— The wet gas contents are extremely variable, the average ranging from 2–39% (compatible with the heterogeneous nature of hydrocarbon accumulations in the Gippsland Basin).

— The average total-gas concentration in the Central Deep (in water deeper than 250 m) is 13.1 microlitres/litre of wet sediment, with an average wet-gas content of 12.5%. These data contrast with the platform data, where the average total-gas concentration is 3.7 microlitres/litre with an average wet gas content of 5.2%. The higher total-gas concentrations and higher wet-gas contents in the Central Deep may be consistent with the greater number of hydrocarbon discoveries there.

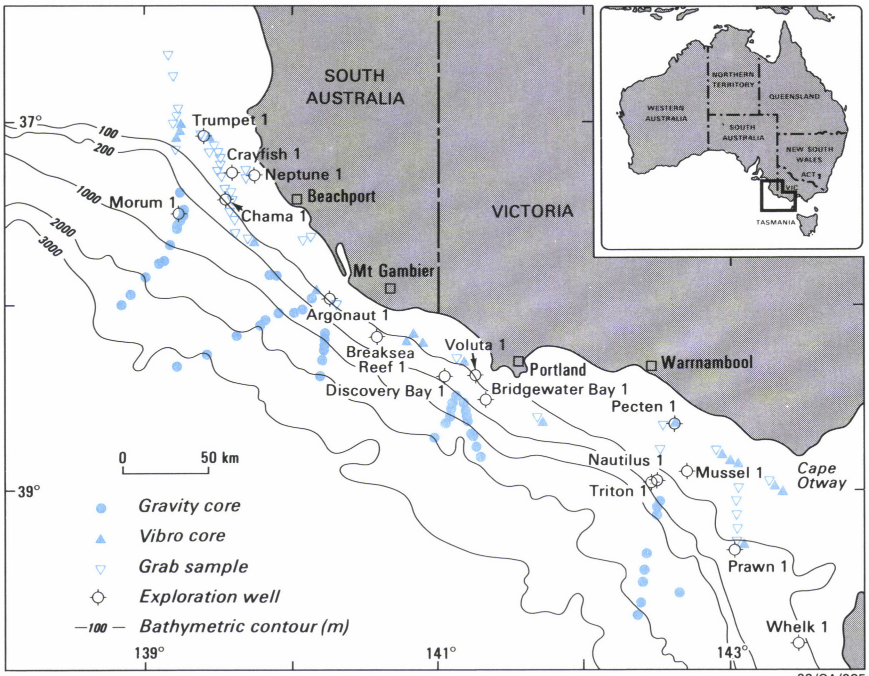


Fig. 5. Geochemical sample locations, offshore Otway Basin.

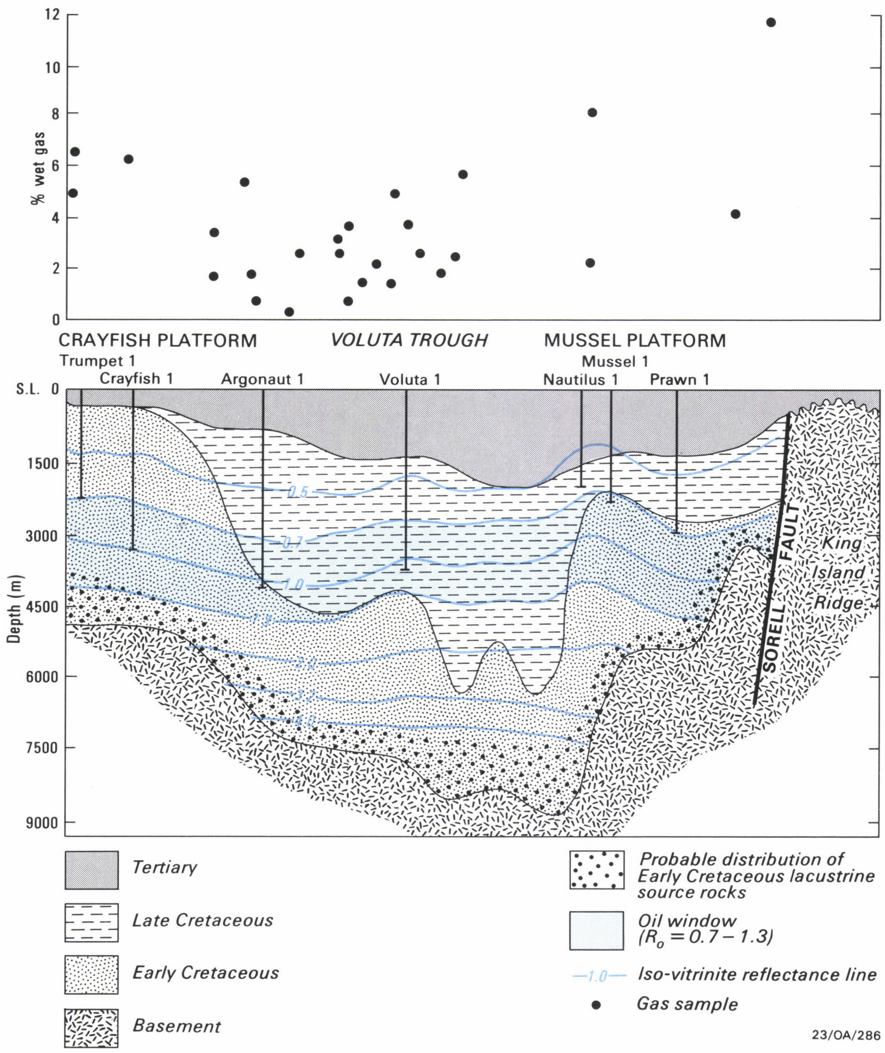


Fig. 6. NW–SE cross-section of offshore Otway Basin showing percent wet gas in relation to maturity for hydrocarbon generation (iso-vitrinite reflectance lines). Oil window is R_o 0.7–1.3, gas window R_o > 1.3.

Implications for future geochemical work in the Otway and Gippsland Basins

The following generalisations can be made about these surface-sediment geochemical prospecting techniques and their applicability in the Otway and Gippsland Basins:

- Total-gas concentrations appear to be partly controlled by the intensity of faulting and its proximity to the seafloor.
- A thick Tertiary section does not appear to preclude the detection of thermogenic hydrocarbons in near-surface sediments.
- The wet-gas data from the Otway Basin suggest that this technique may be useful in evaluating the type and relative maturity of source rocks.

For more information contact Dr David Heggie and Dr Geoffrey O'Brien at BMR (Division of Marine Geosciences & Petroleum Geology).

Table 1. Criteria used in the recognition of thermogenic gases

Component (see key below)	*Percentage abundance*
$C_1/(C_2+C_3)$	<50
$C_2/C_{2:1}$	>1
$C_3/C_{3:1}$	>3
$i\text{-}C_4/n\text{-}C_4$	<1.0
$i\text{-}C_5/n\text{-}C_5$	<4.0

C_1 — methane; C_2 — ethane; $C_{2:1}$ — ethylene; C_3 — propane; $C_{3:1}$ — propylene; $i\text{-}C_4$ — isobutane; $n\text{-}C_4$ — normal butane; $i\text{-}C_5$ — isopentane; $n\text{-}C_5$ — normal pentane.

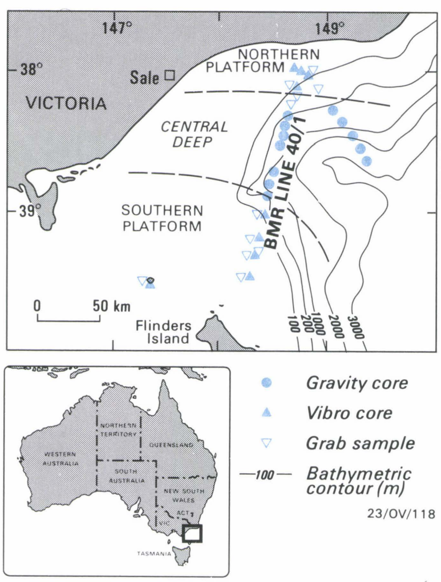


Fig. 7. Geochemical sample locations, offshore Gippsland Basin.

Palaeogeography, Sea Level, & Climate

Implications for resource exploration

1988 BMR Research Symposium, 8–10 November, Canberra

Understanding palaeogeography is essential to understanding sedimentary basin architecture. This symposium will bring together leading Australian and overseas speakers to present the latest ideas from industry, government, and universities. A major emphasis will be the application of these concepts to resource exploration.

The 1988 BMR Research Symposium will be held, as in previous years, at the Australian Academy of Science building, Acton, Canberra. A registration fee of $295 covers morning and afternoon teas, lunches, the symposium dinner, an Extended Abstracts volume, and other conference material. Registrations will be limited to 200, and will close on 31 October. Enquiries should be directed to: Palaeogeography, Sea Level, & Climate Symposium (Attention: Mr C. Modrak), Bureau of Mineral Resources, GPO Box 378, Canberra, ACT 2601. Phone (062) 499623, Telex: AA62109, fax (062) 488178.

The program is as follows:

DAY 1: TUESDAY 8 NOVEMBER

8.30 Registration and Morning Tea
10.00 Official Opening

INTRODUCTION

10.30 Palaeogeography, sea level and climate — keys to petroleum exploration — *A Green* (Exxon, Houston)

10.50 Palaeogeographic maps — applications and tools for resolving problems and defining research priorities — *P J Cook* (BMR)

SEA LEVEL CHANGE — MAGNITUDE AND CAUSES

11.40 Unconformities — the keys to understanding global sea level change — *B Haq* (National Science Foundation, Washington)

12.30 **Lunch**

1.30 Resolution and correlation in determining sea level change — *B McGowran* (University of Adelaide)

2.10 Mechanisms of sea level change throughout the Phanerozoic — *W Pittman* (Lamont–Doherty Geophysical Observatory)

2.50 Glacial controls on sea level — *J Chappell* (Australian National University)

3.30 **Tea**

4.00 Influence of lithospheric stress on relative sea level — *K Lambeck & H W S McQueen* (Australian National University)

4.40 Panel discussion

7.00 for 7.30 **Symposium Dinner**

DAY 2: WEDNESDAY 9 NOVEMBER

SEA LEVEL, CLIMATE AND TECTONICS — PRINCIPAL FACTORS IN FACIES DETERMINATION

8.30 Sea level, subsidence, sediment inputs, and slope — interacting factors in modelling basin formation — *W Pittman* (Lamont–Doherty Geophysical Observatory), *P J Davies & D Johnson* (BMR)

9.10 Seismic facies distribution in the Great Australian Bight — *H Stagg & B Willcox* (BMR)

9.40 Cretaceous and Cainozoic subsidence and plate motion along the west Tasmanian margin — *C-S Lee, N Exon, B Willcox, & J Branson* (BMR)

10.10 **Tea**

10.40 Sea level cycles in the Neogene of the Gippsland Basin — *I Sluiter* (Monash University), *G Holdgate* (Monash University), & *P J Davies* (BMR)

11.20 Late Mesozoic and Early Cainozoic history of the Kerguelen Plateau — facies development, palaeogeography, and palaeo-oceanography: *M F Coffin, K Kelts, J Y Royer, J B Colwell, & Ocean Drilling Program Legs 119 and 120 scientists*

11.50 Sea level, climatic, and tectonic implications of Mesozoic and Cainozoic sedimentary cycles on the Exmouth Plateau — *U von Rad* (Bundesanstalt fur Geowissenschaften & Rohstoffe), *B U Haq* (National Science Foundation, Washington), *N F Exon* (BMR), & *P Williamson* (BMR)

12.20 **Lunch**

1.30 Subject related to facies distribution — *B Haq* (National Science Foundation, Washington).

2.10 Sea level control on development of stratigraphic sequences — examples from the Proterozoic: *K Eriksson* (Virginia Polytechnic)

2.50 Late Cambrian shale–carbonate cycles, Amadeus Basin — high frequency ?Milankovitch sea level oscillations in an intracratonic setting — *J Kennard & J Lindsay* (BMR)

3.20 **Tea**

3.50 Late Cambrian–Early Ordovician event stratigraphy, and development of a Larapintine Seaway, central Australia — *R Nicoll, J Shergold, J Laurie* (BMR), *J Gorter* (consultant), & *M Owen* (BMR)

4.20 The Middle Cambrian phosphogenetic system in Australia and its implications — *J Shergold, P J Cook, & P Southgate* (BMR)

4.50 Controls on Jurassic non-marine sedimentation in eastern Australia — evidence from the Clarence–Moreton Basin — *P E O'Brien & A T Wells* (BMR)

DAY 3: THURSDAY 10 NOVEMBER

PALAEOGEOGRAPHY AND PETROLEUM EXPLORATION

8.30 (to be announced) — *T Loutit* (Exxon, Houston), *A Green* (Exxon, Houston), & *A Reeckman* (Esso Australia)

9.10 Climatic and sea level controls on the distribution of Mesozoic source rocks — *L Frakes* (University of Adelaide)

9.40 Palaeoenvironmental and geological controls on the quality of the Toolebuc Formation oil shale — *S Ozimic* (BMR)

10.10 **Tea**

10.40 Depositional controls on source rock quality and distribution and crude oil composition — *T G Powell* (BMR)

11.20 Palaeogeographic evolution of the northwest shelf region, Australia — *M Bradshaw, A Yeates, R M Beynon, A T Brakel, R P Langford, J M Totterdell, & M Yeung* (BMR)

12.00 Facies analysis of Late Permian and Triassic sediments of the north Perth Basin and its relationship to hydrocarbon generation — *J Marshall, C-S Lee, D Ramsay, & D Choi* (BMR)

12.30 **Lunch**

1.30 Palaeogeography and the generation of play concepts in Australia — *M Bradshaw, A N Yeates, R M Beynon, A T Brakel, R P Langford, J M Totterdell, & M Yeung* (BMR)

2.20 Late Palaeozoic glacial facies in Australia and their petroleum potential — *A T Brakel, P E O'Brien, & J Totterdell* (BMR)

2.50 Sea level, tectonics, and climate: determinants of reservoirs and source rocks off northeast Australia — *P J Davies, P A Symonds, D A Fearey, & C Pigram* (BMR)

3.30 Panel discussion and closing remarks

4.15 Buses leave for airport.

BMR publications, maps and data releases, and how to obtain them

BMR Publications and maps are listed in *Publications of the Bureau of Mineral Resources, Geology & Geophysics (Part I: Publications other than maps; Part II: Maps)*, which is available free of charge from: **BMR Publications Sales, GPO Box 378, Canberra, ACT 2601 (phone 062–499519).** A *Quarterly List of Publications* showing current releases of all publications and other data is also available free of charge from BMR Publication Sales, together with detailed information on prices and postage costs. **All publications can be bought at the Publication Sales counter, BMR building, cnr Constitution Avenue and Anzac Parade, Parkes, ACT. Further information on the availability of preliminary data may be obtained from the Information Section, phone 062–499620.** Please note that orders for publications must be accompanied by payment in advance. Cheques, postal orders, etc., should be made payable to: Collector of Public Moneys (BMR). Payment from overseas should be made by bank draft or international money order in Australian currency.

The full results of most surveys and other research projects are published in two monograph series: *Bulletins* and *Reports*. Another major publication outlet for BMR's research results is the quarterly *BMR Journal of Australian Geology & Geophysics*.

The large-format looseleaf *BMR Earth Science Atlas of Australia* by now contains 16 maps of Australia, mainly at 1:10 000 000 scale, on various earth-science themes. In similar format, the first volume (Cambrian) of a major new publication series, the *Palaeogeographic Atlas of Australia*, is now available.

The *BMR Yearbook*, covering the 12 months to 30 June, summarises the progress of all projects and lists all papers (incl. external) and monographs published in the period covered. The *Australian Mineral Industry Annual Review* covers (currently) 64 mineral commodities, from 'Abrasives' to 'Zirconium', under the headings: production, consumption, treatment, trade, prices, new developments, exploration, resources, and world review. Preliminary summaries and preprints of the major chapters are available each year in advance of publication. The *Australian Mineral Industry Quarterly* contains mineral statistics and prices, an annual table of mineral resources, summaries of the papers given at the annual Petroleum & Minerals Review Conference, and occasional review articles by commodity specialists. A new series of *Resource Reports* has recently been established; covered so far: uranium, Antarctic coal, gold in Western Australia, gold in Queensland. *Australian Petroleum Accumulations Reports*, another recently established series, so far cover the Amadeus, Bass, Adavale, and Gippsland basins.

Preliminary results, results of limited interest, and some other manuscripts are published in the *Record* series. Records are produced in limited numbers, and are not for sale; photocopies can be bought through the BMR Copy Service. Those available for reference at Open File Centres are listed in the *Quarterly List of Publications*.

BMR has published a large number of 1:250 000 scale geological maps, with 'Explanatory Notes' booklets, covering quadrangles mainly in northern Australia. More detailed, 1:100 000 scale, geological maps and accompanying commentary booklets are also available for certain areas. Many smaller-scale geological maps covering various regions have also been published, often in conjunction with geological Bulletins. BMR also publishes stream-sediment geochemistry, radiometric, gravity (new series), total-magnetic-field (TMF), and TMF pixel maps at various scales. The results of most regional geophysical and marine surveys are made available as preliminary maps and sections. **A brochure illustrating the extent of coverage of Australia by surveys by BMR and the State mines departments can be obtained from: Information Section, Bureau of Mineral Resources, GPO Box 378, Canberra, ACT 2601, phone (062) 499620.**

Please note that subscriptions for the *Australian Mineral Industry Annual Review*, the *Australian Mineral Industry Quarterly*, and the *BMR Journal of Australian Geology & Geophysics* are handled by the Australian Government Publishing Service. Cheques should be made payable to AGPS. Payments from overseas should be by bank draft in Australian currency. Enquiries re subscriptions should be directed to: Assistant Director, Sales & Distribution, AGPS — (062) 954411. Subscription orders should be addressed to: Mail Order Sales, Australian Government Publishing Service (AGPS), GPO Box 84, Canberra ACT 2601.

BMR Copy Service

Photoscale geological compilation sheets and other recent survey results are released as dyelines and transparencies through the BMR Copy Service (formerly the Australian Government Printer Copy Service). Some other documents, including Records and preprints of the major chapters of the *Australian Mineral Industry Annual Review*, are also released through the Copy Service. Lists of Copy Service releases are available from Information Section, BMR — address above. **Orders should be sent to Copy Service, Bureau of Mineral Resources, GPO Box 378, Canberra, ACT 2601 or phone (062) 451374, fax (062) 472728.**

Recent publications and data releases

Over the period 1 March–1 September 1988 BMR released the following publications and data:

Publications

Bulletins

226 — Geology of the Proterozoic Davenport Province, central Australia

Reports

255 — A review of airborne gamma-ray spectrometric data-processing techniques

283 — Rig Seismic research cruise 13: northeast Gippsland Basin and southern New South Wales margin — initial report

BMR Journal of Australian Geology & Geophysics (Vol. **10,** No. 4)

Resource Reports

4 — Gold deposits of Queensland: BMR data file (MINDEP)

Australian Mineral Industry Annual Review for 1987 preprint chapters: Aluminium, Black coal, Gold, Iron ore, Lead, Nickel, Titanium, Uranium

Australian Mineral Industry Quarterly (Vol. **40,** Nos. 1, 2, 3)

Petroleum Newsletter (No. **100**)

Palaeogeographic Atlas of Australia (Vol. **1,** Cambrian)

Geological Map Commentaries (1:100 000 scale)
Ranford Hill, NT; Stow Region, NT

Geoscience maps

1:100 000, geological: Stow Region (NT), Cloncurry (Qld)

1:1 000 000, geological: McArthur Basin (NT)

1:1 000 000, total-magnetic-intensity, pixels: Esperance (WA), Townsville (Qld), Melbourne (Vic.)

1:1 000 000, magnetic domains: Adelaide (SA), Hamilton (Vic.)

1:1 000 000, regolith terrain & accompanying databases: Kalgoorlie (WA)

1:1 000 000, Landsat mosaic: Murray Basin (NSW, Vic., SA)

1:1 000 000, shallow groundwater salinity: Murray Basin

Records released on open file

1987/56 (Groundwater **6**) — National groundwater database inventory: 5-year forward program (Vol. **1**)

1987/57 (Groundwater **7**) — National groundwater database inventory: 5-year forward program (Vol. **2**)

1987/58 (Groundwater **9**) — Palynological analysis, BMR Manilla No. 1 borehole, Murray Basin

1987/61 (Groundwater **11**) — Sedimentary petrology of BMR drillcores and shallow vibrocores from playas in the southern Amadeus Basin, NT

1987/63 — Omega time mark generator

1988/1 — Stratigraphic drilling in the Georgina Basin, Burke River Structural Belt, August 1986–January 1987

1988/2 — Petroleum exploration and development in Australia: activity and results, 1987

1988/3 — Regolith terrain data, Kalgoorlie 1:1 000 000 Sheet SH-51, WA

1988/4 — SEAPUP: A computer program for estimating future production of crude oil from undiscovered resources

1988/5 — Extended abstracts, Petroleum & Minerals Review Conference 1988

1988/6 — Rig Seismic Research Cruises 4 & 5, northeast Australia and Queensland Plateau; explanatory notes to accompany release of non-seismic data.

1988/7 (Groundwater 12) — Murray Basin 88: abstracts, Geology, Groundwater, & Salinity Management Conference, Canberra

1988/9 — Hydrothermal transport of platinum and gold in the unconformity-related uranium deposits: a preliminary thermodynamic investigation

1988/11 — Australian crude oil production from new discoveries to the year 2000: Petroleum & Minerals Review Conference 1988; speaker's notes and slides

1988/13 — *Rig Seismic* research cruises 10 & 11: Structure, stratigraphy, and tectonic development of the Great Australian Bight region — preliminary report

1988/15 — Report on a feasibility study for a joint Sino–Australian comprehensive geological and geophysical study of the eastern Junggar region, Xinjiang, China

1988/16 — Geological results of *Rig Seismic* Cruise 11, Great Australian Bight Basin, 1986

1988/17 — Nickel . . . into the nineties: Petroleum & Minerals Review Conference 1988; speaker's notes and figures

1988/18 — Deep structure of the Gippsland and Bass basins: research cruise proposal

1988/19 — RV *Rig Seismic* Research Cruise 3, offshore Otway Basin: explanatory notes to accompany release of non-seismic data

1988/20 — Australia: mineral resource developments 1985–87

1988/21 — International Workshop & Symposium, Canberra, 1988: Seismic Probing of Continents & their Margins, Abstracts

1988/22 — Tumut Trough excursion guide, for International Workshop & Symposium on Seismic Probing of Continents & their Margins, Canberra 1988

1988/23 — International Workshop & Symposium, Canberra, 1988: Seismic Probing of Continents & their Margins. Program and information

1988/24 (Groundwater 14) — Murray Basin Hydrogeological Project; Progress Report 18, for half-year ending 30 September 1987

1988/25 — A review, overview, and preview of industrial minerals in Australia

1988/26 — Mineral sands: will Australia retain its importance?

1988/27 — Surface geology and structure of the Tumut seismic traverse, Lachlan Fold Belt, NSW

1988/29 — Tin: through turmoil towards tranquility. Petroleum & Minerals Review Conference, 16–17 March 1988

1988/30 — Preliminary post-cruise report, *Rig Seismic* Research Cruises 7 & 8: sedimentary basin framework of the northern and western Exmouth Plateau

1988/31 — Preliminary post-cruise report, *Rig Seismic* Research Cruises 7 & 8: deep seismic structure of the Exmouth Plateau

1988/32 — Preliminary post-cruise report: hydrocarbon gas geochemistry in sediments of the offshore Otway and Gippsland basins

1988/33 — Late Palaeozoic and early Mesozoic rocks in the northeastern part of the central Eromanga Basin

1988/34 — Research cruise proposal: organic carbon cycling and Quaternary phosphorite formation, east Australian continental margin

Release of data

Airborne geophysical maps

1:250 000 — 114 maps, showing either magnetic properties, magnetic contours or profiles, radiometric contours or profiles, or flight-line systems (all States)

1:100 000 and 1:50 000 — Several maps (NT & WA) showing either radiometric data or flight-line systems

Digital data

Digital-point-located airborne magnetic data from five 1:250 000 Sheet areas

Marine geophysical data

Continental Margins Program: Folio 1, Bass Basin

Kerguelen Plateau (BMR Marine Survey 47), NE Australia (50, 51), Northern Australia Heatflow (53), Exmouth Plateau (55, 56), Southern Margin (65, 66), North Perth Basin (57).

Issue of *Precambrian Research* on the Early to Middle Proterozoic of Australia

This special issue of *Precambrian Research* (Elsevier, Amsterdam), compiled and edited by Dr Mike Etheridge and Dr Lesley Wyborn of BMR, grew out of a conference entitled 'Tectonics & Geochemistry of Early to Middle Proterozoic Fold Belts', held at Darwin in August 1986, jointly sponsored by BMR, the Northern Territory Geological Survey, and IGCP projects 215 and 217. It contains review articles on most of the Australian Proterozoic provinces, as well as specialised papers on geochemistry, geophysics, geochronology, and structural geology, based on individual provinces and regional studies.

Publication is scheduled for mid October. The final listing of papers is as follows:

Review papers

— Geochronology of Early to Middle Proterozoic fold belts in northern Australia: a review. *R.W. Page (BMR)*

— Age of the Barramundi Orogeny in northern Australia by means of ion-microprobe and conventional U-Pb zircon studies. *R.W. Page (BMR) & I.S. Williams (Australian National University, Canberra)*

— Petrology and geochemistry of a major Australian 1840–1880 felsic volcano-plutonic suite and a model for intracontinental felsic magma generation. *L.A.I. Wyborn (BMR)*

— Australian Precambrian polar wander: a review. *M. Idnurm & J.W. Giddings (BMR)*

— Development of the Australian Proterozoic crust as inferred from gravity and magnetic anomalies. *P. Wellman (BMR)*

— A review of crust/upper mantle structure in the Precambrian areas of Australia and implications for Precambrian crustal evolution. *B.J. Drummond (BMR)*

Albany–Fraser Belt

— A structural and metamorphic traverse across the Albany Mobile Belt, Western Australia. *J. Beeson, C. Delor, & L. Harris (University of Western Australia)*

Antarctica

— Structural constraints on the Proterozoic reworking of Archaean crust in the Rayner Complex, MacRobertson and Kemp Land Coast, east Antarctica. *G.L. Clarke (University of Melbourne)*

Arunta Inlier

— South Arunta Block: the internal zones of a Proterozoic overthrust in central Australia. *C. Teyssier (University of Minnesota), C. Amri (Monash University), & B.E. Hobbs (CSIRO)*

— Isobaric cooling of Proterozoic high-temperature metamorphites from the northern Arunta Block, central Australia: implications for tectonic evolution. *R.G. Warren & A.J. Stewart (BMR)*

— 'Caterpillar tectonics' in the Harts Range area: a kinship between two sequential Proterozoic extension–collision orogenic belts within the eastern Arunta Inlier of central Australia. *P.R. James & P. Ding (Adelaide University)*

— Rate of Arunta Inlier evolution at the eastern margin of the Entia Dome, central Australia. *J.A. Cooper, G.E. Mortimer, & P.R. James (Adelaide University)*

— The petrology and geochemistry of granitic gneisses from the east Arunta Inlier, Central Australia: implications for Proterozoic crustal development. *J.D. Foden, I.S. Buick, & G.E. Mortimer (Adelaide University)*

— Geochemistry of metatholeiites from the Harts Range, central Australia: implications for mantle source heterogeneity in a Proterozoic mobile belt. *W. Sivell (Adelaide University)*

— Metamorphism and crustal considerations in the Harts Range and neighbouring regions, Arunta Inlier, central Australia. *R.L. Oliver, R.W. Lawrence, B.D. Goscombe, P. Ding, W.J. Sivell, & D.B. Bowyer (Adelaide University)*

Broken Hill Block

— The Willyama Supergroup in the Broken Hill and Euriowie Blocks, New South Wales. *B.P.J. Stevens, R.G. Barnes, R.E. Brown, W.J. Stroud, & I.L. Willis (Geological Survey of NSW)*

Davenport Province

— The Proterozoic Davenport Province, central Australia: regional geology and geochronology. *D.H. Blake & R.W. Page (BMR)*

Gawler Craton

— Refined Proterozoic evolution of the Gawler Craton, South Australia, through U–Pb zircon geochronology. *C.M. Fanning (Amdel, Adelaide), R.B. Flint, A.J. Parker (South Australia Department of Mines & Energy, Adelaide), K.R. Ludwig (USGS, Denver) & A.J. Blissett (South Australia Department of Mines & Energy)*

— The geochemical evolution of Proterozoic granitoids near Port Lincoln in the Gawler orogenic domain of South Australia. *G.E. Mortimer, J.A. Cooper & R.L. Oliver (Adelaide University)*

— Petrogenesis of the Proterozoic Gawler Range Volcanics, South Australia. *C.W. Giles (Geocom, Adelaide)*

Gascoyne Province

— The nature of Proterozoic reworking of early Archaean gneisses, Mukalo area, Southern Gascoyne Province, Western Australia. *J.R. Muhling (University of Western Australia)*

Georgetown Inlier

— Proterozoic stratigraphy and tectonic history of the Georgetown Inlier, northeastern Queensland. *I.W. Withnall, J.J. Draper (Geological Survey of Queensland), J.H.C. Bain, D.E. Mackenzie, & B.S. Oversby (BMR)*

Halls Creek Orogenic Domain

— Geochronology of rapid 1.85–1.86 Ga tectonic transition: Halls Creek orogen, northern Australia. *R.W. Page (BMR) & S.L. Hancock (Western Mining Corporation Ltd, Darwin)*

— Geochemistry of the Early Proterozoic granitoids in the Halls Creek Orogenic Subprovince, Northern Australia. *M. Ogasawara (Geological Survey of Japan, Tsubuka)*

Mount Isa Inlier

— The Maronan Supergroup — an inferred early volcano-sedimentary rift sequence in the Mount Isa Inlier, and its implications for ensialic rifting in the Middle Proterozoic of northwest Queensland. *T.J. Beardsmore, S.P. Newberry, & W.P. Laing (James Cook University of North Queensland)*

— Petrology, geochronology and isotope geochemistry of the post-1820 Ma granites of the Mount Isa Inlier: mechanisms for the generation of Proterozoic anorogenic granites. *L.A.I. Wyborn, R.W. Page (BMR) & M.T. McCulloch (ANU).*

Pine Creek Inlier and Litchfield Province

— Tectonic evolution of the Pine Creek Inlier, Northern Territory. *R.S. Needham, P.G. Stuart-Smith, & R.W. Page (BMR)*

— The stratigraphy, metamorphism and tectonics of the Early Proterozoic Litchfield Province and western Pine Creek Geosyncline, Northern Territory. *B.A. Pietsch & C.J. Edgoose (Northern Territory Geological Survey)*

New Davenport Province Bulletin

GEOLOGY OF THE PROTEROZOIC DAVENPORT PROVINCE, CENTRAL AUSTRALIA, by D.H. Blake, A.J. Stewart, I.P. Sweet, & I.G. Hone, 1988. *Bureau of Mineral Resources, Australia, Bulletin* **226,** 70 pp, 5 tables, 87 figs., 1 microfiche appendix, 1 plate (1:250 000 scale geological map, coloured) Price: $25.95, plus $1.20 sales tax where applicable. Available from Publication Sales, BMR, GPO Box 378, Canberra, ACT 2601.

This recently released Bulletin, and accompanying 1:250 000 geological map, describe the geology of the tungsten–gold province that forms the southern part of the Proterozoic Tennant Creek Inlier. They are based on a survey by BMR and the Northern Territory Geological Survey in 1981–1983, and synthesise information contained in four published 1:100 000 maps and map commentaries *(Hatches Creek Region, Kurundi Region, Devils Marbles Region, and Elkedra Region).*

The oldest rocks exposed in the Davenport province are turbiditic metasediments and subordinate chert and felsic volcanics of the Warramunga Group, dated at about 1870 Ma, in the north. This group was folded, intruded by granite, and eroded, before being overlain, probably at around 1810–1820 Ma, by the Hatches Creek Group, which is correlated with some of the Tomkinson Creek beds forming the northern part of the Tennant Creek Inlier and with Division 3 of the Arunta Inlier. The Hatches Creek Group, a folded sedimentary and bimodal volcanic sequence at least 10 km thick, crops out extensively. The sedimentary rocks are mainly shallow-marine and fluvial clastics, but include minor carbonates, some of which are stromatolitic. Subaerial volcanism and hypabyssal igneous intrusion accompanied the sedimentation in an extensional ensialic tectonic setting. Subsequent deformation involved two episodes of upright concentric folding and low-grade regional metamorphism, and was followed by granite intrusion at about 1660 Ma.

Since the mid Proterozoic the Davenport province has been a tectonically stable part of the North Australian craton. Around its margins it is overlapped by flat-lying Palaeozoic marine sediments of the Georgina and Wiso Basins, but the central part may have been land throughout the Phanerozoic.

Mineralisation is largely restricted to wolframite and scheelite-bearing quartz veins (recorded production about 4500 t tungsten concentrates) probably related to granite intrusions, and auriferous quartz veins (recorded production about 15 kg Au) which may have formed during regional deformation. Small amounts of copper, silver–lead, bismuth, and uranium have also been mined.

For further information contact the authors at BMR: Dr David Blake, Dr Alastair Stewart (Division of Petrology & Geochemistry), Mr Ian Sweet (Division of Continental Geology), or Mr Ian Hone (Division of Geophysics).

Release of BMR's whole-rock geochemical database — 'PETCHEM'

BMR's Division of Petrology & Geochemistry has nearly completed the compilation of all whole-rock data acquired by the Division and its predecessors since 1970. Some 10 000 rock analyses from this database will be released in November 1988. Each analysis is accurately located by ANG grid reference and/or latitude and longitude in decimal degrees. For each rock there are full major elements as well as up to 30 trace elements in both regional and specialised databases. The regional databases are (number of analyses in brackets): Mount Isa Inlier (1800), Pine Creek Geosyncline (1400), Turee Creek area (220), Arunta Block (440), Tennant Creek Block (1400), Georgetown Inlier (600), Stuart Shelf (200), Lawn Hill area (90), Kimberley region (100), Granites–Tanami area (50), Davenport Geosyncline (170), Pilbara Block (1100), Lachlan Geosyncline (900), NE Queensland (420), Antarctica (1200), and Papua New Guinea (300). Specialised databases include Kimberlites (450) and Alkaline Rocks (300).

Because of the large size of the database (30 megabytes) the initial release will be on magnetic tape only, in either ORACLE format or as an ASCII file. To begin with, only the entire database will be available; however, it is intended that within 12 months subsets will become available on either a regional or specialty basis. The subsets will be available in either ORACLE or as an ASCII file on either magnetic tape or diskette. Prices for these data releases will be announced at the time of release.

For further information, contact Dr Lesley Wyborn at BMR (Division of Petrology & Geochemistry).

Estimation of oil discovery and production in Australia from undiscovered accumulations (onshore)

SEAPUP (Simulated Exploration And Production of Undiscovered Petroleum) is a computer program designed and employed at BMR to assess Australia's undiscovered petroleum resources and to estimate discovery and production of crude oil from 1987 to 2000. During each iteration, the program simulates drilling a range of petroleum traps and estimates the size of discoveries, the year of their discovery, their economic viability, lead times from discovery to production, and annual production.

The program has been run for all of Australia and for the onshore and offshore regions separately.

The first step in the estimation for onshore Australia was to categorise the petroleum traps that could occur in each prospective sedimentary basin into a number of super-plays, each of which consists of a single trap type within an independent petroleum system. The next step was to compile all relevant historical data, particularly for the new-field wildcat wells drilled and the oil and gas accumulations identified in each play, for input to the computer. Preliminary processing, sorting, plotting, and statistical analysis of these data were then carried out in preparation for examination by groups of colleagues.

Fig. 8. Cumulative probability distribution showing the assessment of undiscovered crude oil resources as at May 1986 in onshore Australia.

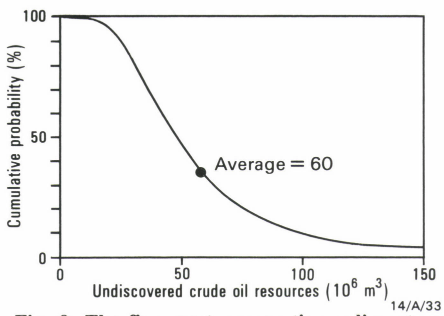
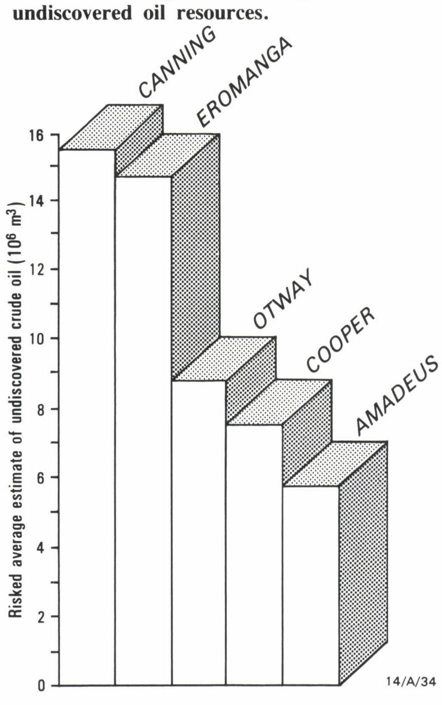


Fig. 9. The five most prospective sedimentary basins in onshore Australia, ranked in order of the risked average assessed magnitude of their undiscovered oil resources.



Output from the SEAPUP program

Simulated drilling of all traps in the onshore petroleum traps model represents the discovery of all undiscovered crude oil accumulations and provides a probabilistic assessment of undiscovered onshore oil resources (Fig. 8) and an estimate of the risked average undiscovered crude oil resources in each basin (Fig. 9).

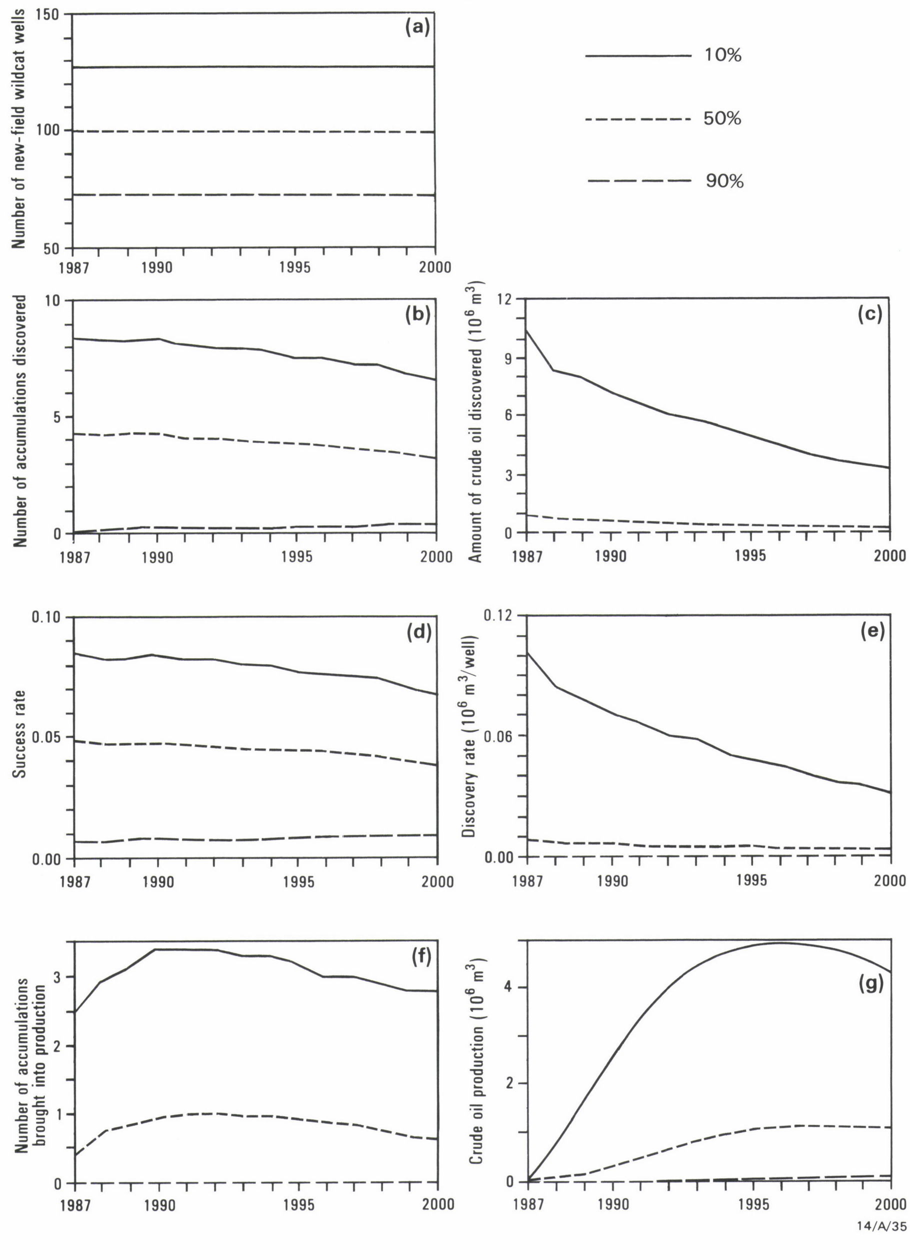
Figure 10 shows how drilling, hypothetically, a range of 50 to 150 petroleum traps each year from 1987 to 2000, under a range of assumptions regarding efficiency of exploration, economic accumulation sizes, lead times, and production rates, provides estimates (at the 10, 50, and 90% probability levels) of the number of wells drilled, number of discoveries made, success and discovery rates, number of accumulations brought into production, and crude oil production rates for each year. Corresponding estimates can also be obtained for the whole period from 1987 to 2000. In addition, the program estimates how much of the oil will be economic and how much will occur in fields that may be brought into production during 1987 to 2000.

The identical range of information may be obtained for any play or for any sedimentary basin.

Fig. 10. Annual estimates for onshore Australia at 10, 50, and 90% cumulative probability: (a) Number of new-field wildcat wells drilled (using alternative drilling model); (b) Number of accumulations discovered; (c) Amount of crude oil discovered; (d) Success rate (number of oil accumulations discovered per new-field wildcat well drilled); (e) Discovery rate (amount of crude oil discovered per well drilled); (f) Number of accumulations brought into production; and (g) Crude oil production.

Limitations

The main deficiency in the estimates is that for many basins we do not have enough information on which to base a reliable assessment. We cannot assess oil that we cannot conceive. For instance, it is possible that oil occurs in well-known play types in as yet unknown sedimentary sequences or in unknown play types in known sequences. Even in well-known plays in well-known sedimentary sequences, our perception of the number and size of the undiscovered fields will improve with the quality and density of the seismic surveys undertaken and as a result of revisions to the reserves of the identified fields. Thus, the range of values given in the estimates may be conservative.



Checking the estimates and the model

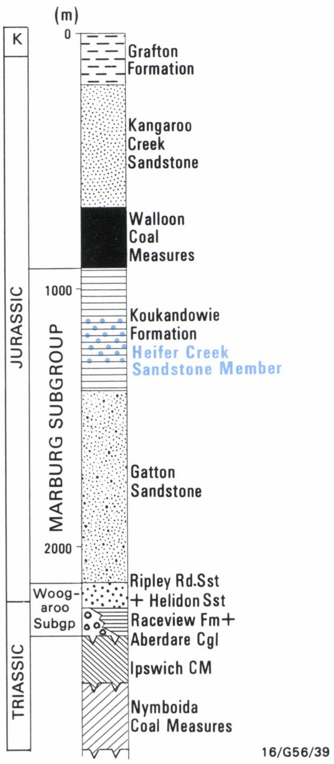
A seemingly obvious way of checking the model is to run the program using data appropriate to some time in the past, such as, e.g., 1976, to see if it predicts subsequent events reasonably precisely. However, SEAPUP contains both the experience of the events that occurred from 1976 to 1986 and subjective expert opinion, and it cannot be reliably converted into a model appropriate to 1976. The only diagnostic testing that can be carried out is best performed by comparing these estimates with the actual future outcome.

Each estimate is given as a cumulative probability distribution against which the outcome can be easily compared. However, there are no commonly accepted standards by which differences between individual estimates given as ranges of values and their outcomes may be judged, especially when dealing with highly skewed distributions. It seems better that the acceptability of an estimate be left to the judgement of the scientists familiar with the region and with the underlying reasons for the trends.

For more information contact Dr David Forman at BMR (Resource Assessment Division).

New potential reservoir identified in Clarence–Moreton Basin

An article in the previous issue of the *BMR Research Newsletter* (*8*, 7) drew attention to the enhanced petroleum source-rock potential of the Clarence–Moreton Basin in northeastern New South Wales, as a result of a recent 4-year BMR–State Geological Survey study. The study has developed a revised stratigraphic framework for the basin and has now identified a widespread unit that has considerable potential as a petroleum reservoir.



The Clarence–Moreton Basin contains Mesozoic sediments in part equivalent to oil-producing sequences in the Surat and Eromanga Basin.

A major problem confronting the search for hydrocarbons in the basin has been the difficulty of predicting the distribution of potential reservoir sandstones. The Ripley Road Sandstone and its equivalent, the Helidon Sandstone (Fig. 11), consist of quartzose sandstone and have long been regarded as the most promising potential reservoirs. The Gatton Sandstone and Koukandowie Formation generally consist of lithic sandstone and have been considered to have less potential. Although some porous intervals were encountered by drilling in the Koukandowie Formation, the intervals were thought to be discontinuous. Sandstones in the Walloon Coal Measures are very rich in volcanic rock fragments and thus have little reservoir potential, though coal and shale make this formation an excellent potential petroleum source. Sediments above the Walloon Coal Measures crop out too extensively to be good targets.

Field work has now traced the relatively quartz-rich Heifer Creek Sandstone Member of the Koukandowie Formation from the area where it was originally identified in the northern part of the basin in Queensland, to the western and southern basin margins in New South Wales. Once the unit's stratigraphic position was established in outcrop it was recognised in petroleum wells across most of the southern part of the basin.

Modal analyses of sandstone from the Heifer Creek Sandstone Member average 50% quartz compared to 33% quartz in other sandstones of the Koukandowie Formation. The member can thus be readily identified in outcrop, and in well sections it shows lower gamma log readings than other sandstones in the formation.

Fig. 11. Revised stratigraphy of the Clarence–Moreton Basin showing the position of the Heifer Creek Sandstone Member in the Koukandowie Formation.

BMR and the Geological Survey of New South Wales drilled two fully cored shallow stratigraphic holes (BMR Warwick Nos. 6 and 7) on the western basin margin in New South Wales to provide palynological samples and sedimentological information on the Koukandowie Formation and the upper part of the Gatton Sandstone, and to test the porosity and permeability of the Heifer Creek Sandstone Member.

BMR Warwick 6 spudded close to the top of the Koukandowie Formation and reached the top of the Heifer Creek Sandstone Member at 160 m; it was stopped before reaching the base of the member, at 199 m. The member consisted of multistorey, fluvial-channel sandstone bodies with a few very thin siltstone and fine sandstone interbeds. The channel sandstones are mostly coarse to very coarse-grained and cross-bedded. Good, visible porosity is common, particularly between 175 m and 182 m. Four core samples from the Heifer Creek and one from the overlying part of the Koukandowie Formation were analysed for porosity and horizontal permeability. The Heifer Creek samples had porosities between 15.4% and 19.0% and permeabilities from 2.04 mD to 227 mD.

The Heifer Creek Sandstone Member appears to have been deposited in sheet-like bodies by low-sinuosity, bed-load-dominated rivers. Preliminary results suggest that it should be considered a potential petroleum reservoir. The Koukandowie Formation overlying the member in BMR Warwick 6 contains a large proportion of mudstone that might act as both source and seal for hydrocarbon accumulations. Furthermore, the Heifer Creek is in a better stratigraphic position to receive hydrocarbons generated by the best source rocks in the basin, the Walloon Coal Measures, than are the deeper potential reservoirs such as the Ripley Road Sandstone.

For further information contact Dr Phil O'Brien or Mr Allan Wells at BMR (Division of Continental Geology).

Is CO_2 involved in the migration of hydrocarbons from type-III kerogen?

Oxygen-rich, type-III kerogen, such as that associated with coal and dispersed coaly particles, releases CO_2 and water during decomposition, as crude oil is generated from source rocks. Evidence indicates that CO_2 and crude oil form in similar temperature zones and would coexist in the matrix. Under the prevailing temperatures (typically 100–150°C) and pressures, the released CO_2 (critical temperature 31°C) is a supercritical fluid (i.e. a liquid). Recent experiments by the Petroleum Geochemistry Group at Curtin University of Technology, Perth, in a BMR Research Fellowship designated project, have shown that crude oil is soluble in supercritical CO_2.

Certain components of the oil, such as fluorene ($C_{13}H_{10}$) and biphenyl ($C_6H_5C_6H_5$) and its methyl derivatives, are especially soluble. These compounds have been found to be more abundant in some Australian crude oils that coexist, in reservoirs, with high concentrations of CO_2, and the work suggests that supercritical fluid CO_2 may be involved in migration.

The amount of CO_2 generated is a function of the total-organic-carbon (TOC) content of the rock, coals generally yielding up to 130 kg/t; thus, after allowing for the relatively small amount of CO_2 dissolved in pore waters, there is still a large excess of CO_2 available to facilitate the migration of crude oil. Indeed, in source rocks with TOC values of only 5%, the CO_2 generated *in situ* can still dissolve and transport over 110 ppm of hydrocarbons.

Laboratory comparison of a Bowen Basin crude oil with a source-rock extract from the same location showed that the crude oil is enriched in biphenyl, methylbiphenyls, dimethylbiphenyls, and fluorene. This enrichment can be replicated in the laboratory by extracting crude oil with supercritical CO_2. As the temperature and density conditions for the extraction are similar to those in the reservoir, the enrichment of biphenyls and fluorene in the crude oil, relative to the sediment, is attributed to a migration effect caused by selective solvation and extraction of these compounds from the source rock by supercritical CO_2. Similar examples of crude oils showing fractionation effects consistent with migration in supercritical fluid CO_2 are known from the Gippsland, Carnarvon, and Cooper–Eromanga basins.

For further information contact Dr Mike Strachan, Professor Bob Alexander, or Associate Professor Bob Kagi of the Petroleum Geochemistry Group, Curtin University of Technology, Perth.

Comparison of Amadeus Basin with Sichuan Basin, southwest China

A project, 'Comparative Studies of Petroleum-bearing Basins in China and Australia', is one of several selected for cooperative research between BMR and the Chinese Ministry of Geology & Mineral Resources under a current Memorandum of Understanding. Within the project a number of sub-projects have been identified, including Gases in Coal-bearing Palaeozoic Basins, Comparative Studies of Palaeozoic Basins, Comparative Studies of Mesozoic and Cenozoic Basins, and The Cambro-Ordovician Boundary.

In April 1988 an Australian delegation comprising Dr Russell Korsch of BMR and Mr John Gorter of John D. Gorter Pty Ltd, Epping, NSW, representing industry, visited the Sichuan Basin in southwest China to compare that basin's structural style, stratigraphy, and hydrocarbon potential with that of the Amadeus Basin in central Australia. The delegation participated in a field trip through the Sichuan Basin, including a visit to the giant Weiyuan gas field, and then travelled through the Yangtze Gorges nearby to examine the regional stratigraphy and structural geology. The delegation visited several Chinese geological institutes and held discussions on the geology, in particular the petroleum potential, of the Sichuan Basin. At each institute lectures were delivered on the geology and petroleum potential of the Amadeus Basin.

In June 1988 a Chinese delegation (Dr Sun Zhaocai and Mr Mai Huazhao from Central Laboratories of Petroleum Geology, Ministry of Geology & Mineral Resources, Wuxi, Jiangsu Province) visited Australia on a reciprocal visit, examining the stratigraphy and structure of the Amadeus Basin and visiting the Palm Valley gas field. They also visited BMR, and in Sydney visited several companies and CSIRO.

The Sichuan Basin (Fig. 12) evolved in four main stages, the first being from the Sinian (about 850 Ma) to the Silurian with the formation of the extensive Yangtze Platform dominated by shallow-water carbonates. At the end of the Silurian, the centre of the basin was extensively uplifted (Caledonian movement) with exposure of rocks as old as Early Cambrian. During the second stage (Devonian to Carboniferous) sediments were deposited only around the rim of the present basin. During the third stage, from the Permian to the Middle Triassic, an extensive cover of dominantly shallow-marine sediments was deposited, the basin being essentially a very stable cratonic area. The fourth stage (Late Triassic to present) commenced with the closure of the Tethys sea (Indo-Sinian movement) and led to the present configuration of the basin, with the development of continental foreland sub-basins. Initially an overthrust margin was formed in the southeast near the then main depocentre. In the Jurassic, owing to early Himalayan events, the locus of main overthrusting moved to the Longmenshan on the northwest margin of the basin, and the depocentre also shifted to near this margin. The last stage is dominated by fluvial to lacustrine facies.

The Sichuan Basin is thus very similar to the Amadeus Basin. Both basins have a major overthrust margin with a thick sedimentary succession in a depocentre adjacent to this margin. Further basinward, both basins have a central broad, flat, synclinal area, followed by a series of smaller (though still of regional scale) anticlines and synclines.

The Sichuan Basin is a major producer of petroleum. Interestingly, its exploration history began as long ago as 221 BC when boreholes over 300 m deep were drilled into evaporites, using bamboo rods hardened in salt water; natural gas from the holes was used to extract salt from the brine. Exploitation continued sporadically but modern exploration commenced only in 1949. The basin is an important fossil fuel base for China because of the discovery of over 60 gas fields and 10 large oil fields, and it is considered to be highly prospective, particularly for additional large reserves of natural gas.

The preparation of a joint paper by the two delegations, comparing the structural evolution, stratigraphy, and petroleum potential of the two basins, is in progress.

For further information, contact Dr Russell Korsch at BMR (Division of Continental Geology) or Mr John Gorter at John D. Gorter Pty Ltd, Petroleum Consultants, PO Box 572, Epping NSW 2121.

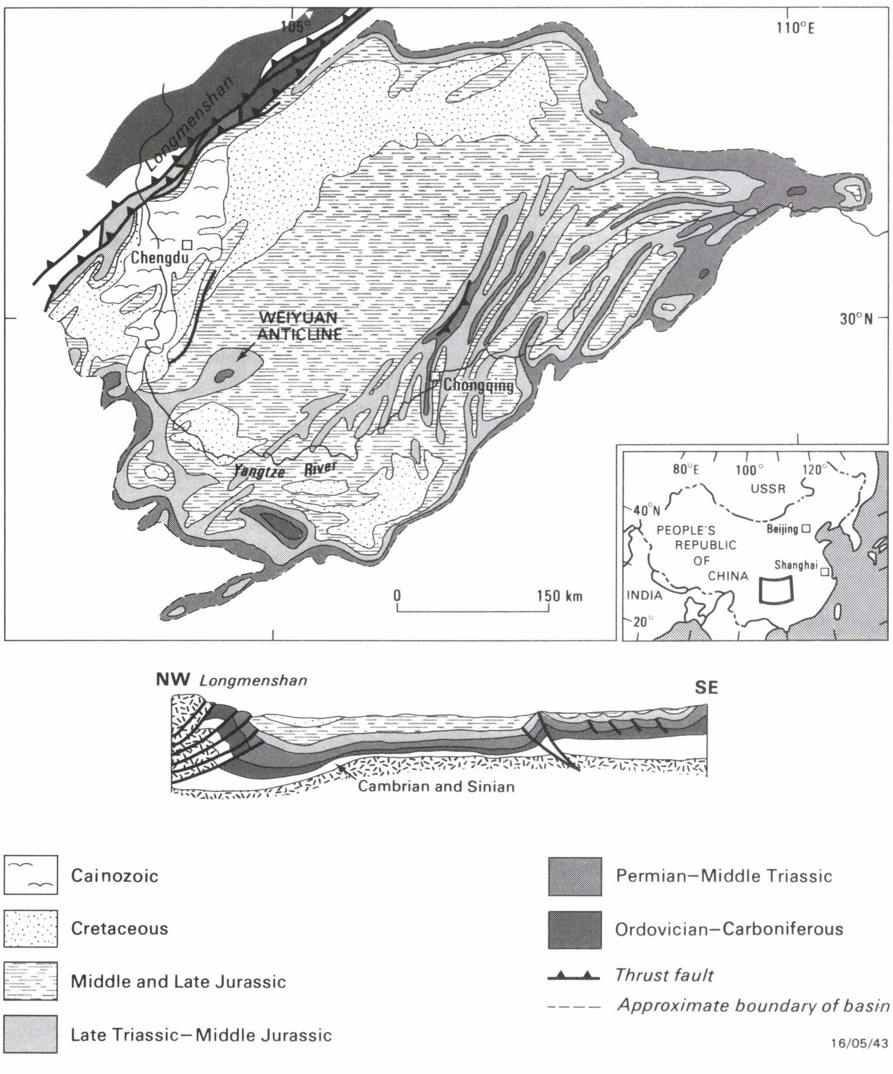


Fig. 12. Simplified geological map of the Sichuan Basin, southwest China, and schematic NW–SE cross-section.

Non-volcanic sources of diamond: subducted eclogites and peridotite massifs?

Deep-seated volcanic rocks — kimberlites and more recently lamproites (*BMR Research Newsletter, 1,* 10; Jaques, Lewis, & Smith, 1986: *Geological Survey of Western Australia, Bulletin* 132) — are generally considered to be the means by which diamonds are carried from the mantle to the Earth's surface. Recent isotopic dating of diamond indicates that most diamonds are xenocrysts in their volcanic host (*BMR Research Newsletter, 6,* 15–16) and the presence of diamond rather than graphite at the Earth's surface is due to its metastable preservation by rapid eruption (0.1–10 metres per second) from deep in the mantle.

In contrast to this generally held view there are reports of diamonds in alpine-type peridotite from the USSR (Shilo & others, 1978: *Doklady Akademii Nauk SSR,* **241,** 933–936) and Tibet (Yan & Sun, 1982: *Bulletin of the Institute of Geology, Chinese Academy of Geological Sciences,* **5,** 64) and in metamorphic rocks (Dergachev, 1986: *Doklady Akademii Nauk SSSR,* **291,** 189–190). Other non-kimberlite occurrences of diamond have been described by Kaminski (1984: Diamondiferous Non-Kimberlitic Rocks, *Nedra, Moscow,* in Russian). Despite the absence of pyrope garnet and other indicators of high-pressure origin, obducted ophiolites have recently been suggested as the source of certain anomalous occurrences of diamond (Nixon & Bergman 1987: *Indiaqua,* **47,** 21–27). More compelling evidence for a non-volcanic origin of certain diamonds has recently come from two sources.

Graphitised diamonds in the Beni Bousera peridotite massif

Octahedral aggregates of graphite up to 12 mm in length inferred to be pseudomorphs after diamonds have been found in pyroxenite, garnet pyroxenite, and garnetite layers in the Beni Bousera peridotite massif in northern Morocco (Slodkevitch, 1982: *Zapiski Vsesoyznogo Mineralogicheskogo Obshchestva*, 13–33, in Russian). The Beni Bousera massif, which forms part of the Palaeozoic Betico–Rifeo orogenic belt, consists mostly of isoclinally folded spinel peridotite with minor pyroxene-rich layers, and was tectonically emplaced from mantle depths of up to 90 km (Kornprobst & Vielzeuf, 1984: *Developments in Petrology*, **11B**, 347–359). Recent studies (Pearson & others, 1987: *Terra Cognita*, **7**, 618; Pearson, 1988: *Indiaqua*, **50**, 35–39) indicate that not only do the graphite pseudomorphs have forms and surface features comparable with those of diamond but they also contain mineral inclusions similar to eclogitic-suite inclusions in diamond. The pyroxenites are believed to be subducted oceanic lithosphere based on the REE content and Sr, Nd, and Pb isotopic compositions of the clinopyroxenes (Pearson & others, 1987: *Terra Cognita*, **7**, 618). The graphite pseudomorphs have strongly ^{13}C-depleted carbon isotopic compositions (-19.1 to -22.9 per mil), similar to those of eclogitic-paragenesis diamonds, many of which are now believed to have formed from crustal carbon (*BMR Research Newsletter*, **6**, 15–16).

Diamond in high-pressure metamorphic rocks in the Ural Mountains

The second source of evidence for transport of diamond in non-volcanic rocks comes from the discovery by Soviet scientists of accessory diamonds included in garnets and zircons from Caledonian (475 Ma) garnet–biotite gneiss and schist, garnet pyroxenite, and pyroxene–carbonate rock from eclogite-facies rocks in the Kokchetav massif in northern Kazakhstan. This discovery was reported at a recent scientific meeting in Novosibirsk (see below) by N.V. Sobolev and co-workers (Sobolev & Shatskii, 1987: *Geologiya i Geofizika*, **28**, 69–72). The diamonds, which have an average size of 12.5 ± 5.8 micrometres and cubo-octahedral or cubic forms, are intergrown with mica, rutile, and zircon, and are commonly associated with graphite. They are believed to have formed in crustal rocks deep in the mantle (at least 120 km) at temperatures of 800–1000°C.

International Symposium, 'Composition and Processes of Deep-seated Zones of the Continental Lithosphere'

This symposium was held in Novosibirsk, USSR, from 30 May–2 June to commemorate the 80th anniversary of Soviet Academician V.S. Sobolev (1908–1982). Sponsored by the International Lithosphere Program, it was attended by some 120 delegates including 22 from overseas. Prof. D.H. Green (University of Tasmania) and Dr A.L. Jaques (BMR) attended as invited speakers.

In a particularly interesting paper W. Schreyer reviewed studies of the pyrope + coesite-bearing white schists from the Dora Maira massif in the Italian Alps and presented convincing evidence for the transport of crustal rocks to great depths within the Earth (Schreyer, 1988: *Episodes*, **11**, 97–104). The Dora Maira rocks, which crop out over an area of about 10 km^2, were subducted to depths of ~100km under a low geothermal gradient and then returned rapidly to the Earth's surface. Schreyer suggested that return transport of deeply subducted continental crust with preservation of such high-pressure minerals is unlikely except under a low geothermal gradient such as in the early phases of collision orogeny.

A major question in diamond research is the relationship between kimberlite/lamproite magmatism and processes associated with diamond growth in the sub-continental lithosphere (*BMR Research Newsletter*, **6**, 15–16). Several papers presented evidence for a close association between geochemical enrichment (metasomatism) of the deep sub-cratonic lithosphere and alkaline ultrabasic magmatism: this association now seems well established. Large-ion-lithophile-element (LILE)-enriched titanates occluded in diamond (from Yakutia) and K-bearing pyroxene in diamondiferous peridotite (from Argyle) provide mineralogical evidence for geochemical enrichment of the sub-continental lithosphere extending into the diamond stability field. This amplifies the concept of craton roots extending into the diamond field (150–200 km) first proposed by Boyd & Gurney (1986: *Science*, **232**, 472–476) from studies of xenoliths in kimberlite from southern Africa, where the commercial diamondiferous kimberlites are restricted to the Archaean Kaapvaal craton. The lithosphere beneath all cratonic regions appears to have had a complex geochemical history involving early geochemical depletion and later enrichment. The presence of ancient enriched isotopic signatures and mantle-derived metasomatic minerals such as Cr-rich LILE titanates in volcanic rocks indicates development of old, thermally isolated lithosphere potentially favourable for diamond formation. Mantle depletion events may correlate with major periods of Precambrian mafic–ultramafic magmatism (such as Archaean komatiite magmatism in southern Africa), but metasomatism appears to be a pervasive feature of all cratons and the geochemical enrichment is difficult to relate to specific crustal events. However, there is increasing evidence for recycled ancient crustal material in the diamond-forming environment and the source regions of lamproites and micaceous kimberlites.

Alkali basalts have been proposed to host the diamonds in southeastern Australia (Sutherland & others, 1985: *Mineralogical Magazine*, **49**, 748–751) and elsewhere. This controversy has been fuelled by the recent discovery of small diamonds (0.5–2 mm) in Early Cretaceous basanite diatremes at the western margin of the Syrian–Lebanese rift in western Syria. Two joint Soviet–Syrian papers presented at the symposium concluded from studies of the xenoliths (eclogite and garnet granulite) and megacrysts (Al-augite, Mg-poor ilmenite, kaersutite, Cr-poor pyrope) that, in common with basanitic rocks elsewhere, the deepest material sampled by the diatremes appears to have formed at depths no greater than 80 km. From this and the broken and abraded nature of the stones they suggested that the diamonds had another, as yet unknown, primary source.

Implications for diamond exploration

The discoveries of diamond, or, in the case of the Beni Bousera massif, of graphite pseudomorphs after diamond, in high-grade metamorphic rocks and peridotites indicate that diamonds can form and, in certain favourable circumstances, be tectonically transported to the Earth's surface in metamorphosed crustal rocks and mantle peridotites. Such rocks must now be considered as possible sources in the course of diamond exploration, and some anomalous alluvial diamonds (e.g. Urals, Copeton ?) might have been derived from such sources. A crustal source would explain the unusually heavy delta ^{13}C values (-3.3 to $+2.4$ per mil) and the peculiar calc-silicate inclusion assemblage of the Copeton diamonds (Sobolev, 1985: *University of Western Australia, Geology Department & Extension Service, Publication* **8**, 213–219). With the exception of the Beni Bousera occurrence where the graphite pseudomorphs are abundant, the very low diamond grade of such occurrences suggests that most are unlikely to constitute primary deposits of economic significance. Nevertheless, recognition that not all diamonds are necessarily derived from kimberlite/lamproite pipes could prevent fruitless exploration for primary volcanic sources of alluvial diamonds shed from non-volcanic sources.

For further information contact Dr Lynton Jaques at BMR (Division of Petrology & Geochemistry).

Use of aeromagnetic flight-line profiles: mapping lithological trends in high-grade gneiss

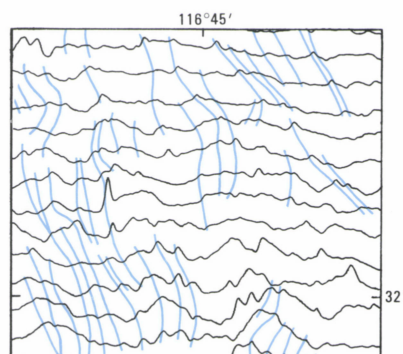
Recently there has been emphasis on the large amount of geological information that can be interpreted from pixel images of aeromagnetic data. However, many interpreters may not realise that stacked magnetic profiles contain information that cannot be displayed on pixel images. A complete interpretation of aeromagnetic data should consist of combined interpretation of the three presentations: pixel images, contours, and stacked profiles.

A case in point is the high-grade gneiss terrane in the Pinjarra 1:250 000 Sheet area, WA. The pixel map shows many linear and curvilinear features, some at low angles to the flight path. These are interpreted in BMR as cross-cutting faults and dykes. No lithological banding can be inferred. However, the stacked profiles (Fig. 13) show numerous short-wavelength anomalies, many of which can be correlated between adjacent profiles on the basis of their amplitude, characteristic shape, and position relative to large anomalies. They are interpreted as lithological banding, each anomaly being due to a variation in aggregate magnetics along the flight line, not to a single magnetic band. It is difficult to prove this because individual bands generally cannot be mapped geologically, but the magnetic trends approximate (s.d. = 27°) the mapped foliation trends for the PINJARRA Sheet as a whole.

In the Pinjarra Sheet area the data are recorded at 60 m intervals along flight lines 1.5 km apart. The smallest anomalies that can be correlated from line to line have a wavelength of 500 m. In the pixel presentation, data obtained from flight lines are represented on a 400 m grid (a finer grid cannot be used because of the increasing difficulty of interpolating between flight lines). It is obviously impossible to determine the existence and shape of a 500 m wavelength anomaly when sampling at 400 m, which is why these anomalies are not apparent on the pixel map.

For further information contact Mr Alan Whitaker or Dr Peter Wellman at BMR (Division of Geophysics).

Fig. 13. Stacked aeromagnetic total-force profiles for part of the PINJARRA sheet, showing correlation of short-wavelength anomalies.



Ocean drilling on the southern Kerguelen Plateau

Legs 119 and 120 of the Ocean Drilling Program (ODP), from December 1987 to April 1988, were directed at the Kerguelen Plateau and the Antarctic continental margin. The objectives were to study palaeogeography and palaeo-oceanography, and to resolve the origin and evolution of the Plateau. Seven sites were occupied on that part of the Kerguelen Plateau which is under Australian jurisdiction, for a total of 1681 m of core.

Drill sites (Fig. 14) were selected on the basis of seismic reflection data collected by BMR scientists in 1985 (RV *Rig Seismic*) and by the French research and supply vessel *Marion Dufresne* in early 1986 (*BMR Research Newsletter* 5, 12–13).

The program was mounted from the drill ship *JOIDES Resolution* and was manned by scientists from the 18 ODP member nations and Australia. BMR supported the participation of Dr C. Jenkins of the University of Sydney on Leg 119, and Dr M. Coffin of BMR on Leg 120. Full results will appear in the *Proceedings of the Ocean Drilling Program: Initial Results and Proceedings of the Ocean Drilling Program — Scientific Results.*

Three of the seven sites (748, 750, 751) were located in the major sedimentary basin (Raggatt Basin) outlined by BMR in 1985; of the others, one was sited to the north of the basin (747), one to the west (749), and two to the south (744 and 738). Sites 748 and 750 were designed to test the lower sedimentary section and basement, and thus were on the margins of the basin where the section is thinnest.

The two holes directed at basement (748, 750), as well as three of the others, bottomed in mid and Late Cretaceous basalt (ages from overlying sediment). The basalt is of ocean-island character and some flows have been subaerially weathered, with development of soils and plants (now charcoal). The overlying marine sediments indicate relatively rapid subsidence of the northeastern margin of the plateau through the Late Cretaceous, while the central spine (748) remained at relatively shallow depths.

Pelagic sedimentation was continuous from the late Maastrichtian to the Middle Eocene and, after a break, from Middle Eocene to Pliocene. Plio–Pleistocene cover is thin and discontinuous.

The high organic carbon content of some of the older sediments enhances the petroleum potential of the Raggatt Basin. However, the basin, because of its remote location and relatively great water depths (1000–2000 m), is unlikely to attract exploration interest in the short term.

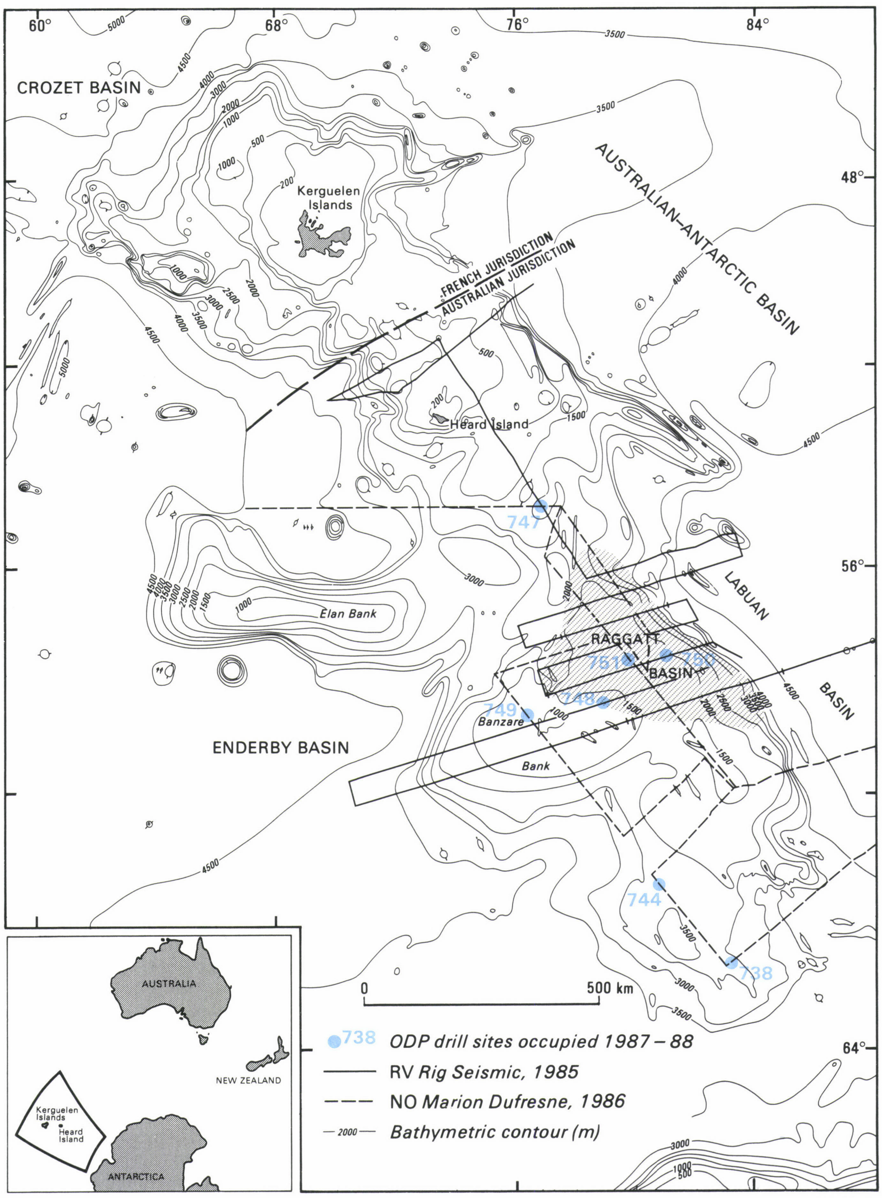
The suggested evolution of the southern Kerguelen Plateau is as follows:

1. Basalts were erupted prior to the Cenomanian, subaerially or in shallow water.
2. During the Cenomanian, Turonian, and probably Santonian, open-marine conditions evolved in the eastern part of the Raggatt Basin (Site 750) and the eastern margin of the plateau subsided slowly to about 50 m below sea level. To the west (Site 748) the plateau remained subaerial or at very shallow depth.
3. During the Campanian and late Maastrichtian, the eastern margin subsided rapidly to about 2000 m below sea level, and the western part of the plateau subsided slowly, remaining at about 50–200 m below sea level. At roughly the Campanian–Maastrichtian boundary major normal faulting affected the eastern margin (Site 750). To the west, along the 77 Graben (Site 748), major faulting occurred in the late Maastrichtian.
4. From the late Maastrichtian to the Middle Eocene, sedimentation (mainly nannofossil chalk and ooze with some chert) was essentially continuous over the entire plateau. However, a hiatus of at least 2 Ma occurred during Middle Eocene time at Sites 748 and 750, and at Site 747 a hiatus of 15 Ma is accompanied by subsidence of about 500 m (30 m/Ma).
5. From Middle Eocene to Pliocene time, sediment was continuously deposited over the entire southern plateau.
6. The paucity of Plio–Pleistocene sediment over most of the southern Kerguelen Plateau is probably related to the high-energy Antarctic Circumpolar Current.

As part of BMR's continuing Continental Margins Program the RV *Rig Seismic* is scheduled to return to the southern Kerguelen Plateau in early 1989 to better resolve the resource potential of the area under Australian jurisdiction, to acquire geophysical and sampling data complementary to ODP results, to carry out geothermal studies related to hydrocarbon generation and migration, and to investigate the plateau's deep crustal structure.

For further information on Ocean Drilling Program studies of the Kerguelen Plateau, contact Dr Mike Coffin; for information on the planned 1989 Kerguelen Plateau research cruise, contact Dr Mike Coffin and Dr Hugh Davies, both at BMR (Division of Marine Geosciences & Petroleum Geology).

Fig. 14. Kerguelen Plateau region, showing the southern Kerguelen Plateau ODP sites and the location of the 1985 RV *Rig Seismic* (heavy black line) and 1986 NO *Marion Dufresne* (broken line) multichannel seismic reflection data.



New waterguns improve seismic resolution aboard *Rig Seismic*

New 0.245 L (15 cubic inch) and 1.31 L (80 cubic inch) waterguns were recently commissioned on BMR's RV *Rig Seismic*, for use in the offshore programs being conducted by the Division of Marine Geosciences & Petroleum Geology. These new seismic sources will complement the large, high-capacity airgun arrays used for lower-resolution, deep-penetration studies (see *BMR Research Newsletter 7*, 7).

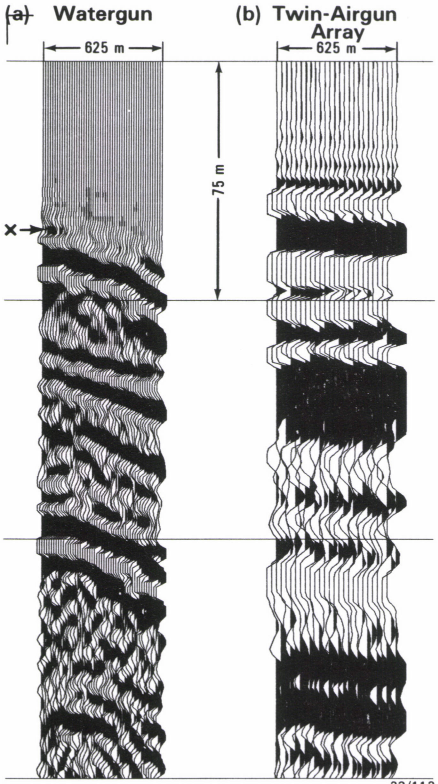


Fig. 15. Portions of stacked seismic sections from 950–1270 m water depths off northeast Australia, showing the high resolution achieved using the new 80 cubic inch watergun (A) compared with the twin-airgun-array seismic source (B). The small precursor pulse (x) visible immediately above the water bottom on the watergun section denotes the ejection of water from the gun ports, before the main implosive acoustic impulse. (Data collected during the October and December 1987 *Rig Seismic* cruises.)

The watergun energy source was acquired because of BMR's requirements for high-resolution regional surveys and detailed surveys of prospective sampling sites. The major advantages of this type of source include: easy deployment; good quality, on-board monitor sections; wide frequency band width (up to 300 Hz); low maintenance; and good acoustic penetration in shallow and intermediate water depths (<3500 m).

High-resolution seismic records are a crucial element in the integration of seismic and sampling (core or dredge) data to determine the processes which formed the continental shelf and slope, and an understanding of these processes is a fundamental requirement for the development of petroleum migration and entrapment models.

The Seismic Supply International waterguns (*S15* and *S80* models) purchased for this program are activated by electrical solenoid release of compressed air, which expels water from either a 15 or 80 cubic inch capacity chamber. A cavity is formed when all the water has been expelled, and the collapse of this cavity produces the implosive acoustic signal. Although compressed air is the driving force, no air is released into the surrounding water and therefore no bubble pulse oscillation is produced. The wide frequency response and rapid cycling time between shots (1 and 4 seconds for the 15 and 80 cubic inch guns respectively) provide the high-resolution seismic record required. In the case of the 80 cubic inch source, shot spacing of only 12.5 m can be obtained at normal ship speed during seismic operations (5 knots), compared to 50 m shot spacing for the large airgun arrays.

These new units were first deployed from the *Rig Seismic* during the October 1987 cruise off northeastern Australia. They produced excellent data for a detailed regional survey of the Marion Plateau to determine basement depth and structure, and provided exciting new insights into the character and timing of multiple phases of carbonate platform development. They also proved to be both effective and reliable during high-resolution surveys of prospective Ocean Drilling Program drill sites in the Queensland Trough and on the margins of the Marion and Queensland Plateaux (see *BMR Research Newsletter* **4,** 8–9).

For further information, contact Dr David Feary or Mr Philip Symonds at BMR (Division of Marine Geosciences & Petroleum Geology)

BMR's Murray Basin Groundwater Project: a Commonwealth–State joint venture

During the past one hundred years the Murray Basin has become one of the most important agricultural regions in Australia. It also contains areas of great natural beauty and historical significance. Unfortunately, clearing of natural vegetation, and irrigation, have been accompanied by rising groundwater-levels and discharge of saline waters to the land surface. In order to develop strategies to combat this problem, an understanding of the controlling processes is essential. In particular, it is fundamental that the relationships between aquifer geometry, recharge, groundwater flow, and distribution of surface discharge features be fully understood.

Against this background, BMR, in co-operation with the State geological and water agencies, initiated a groundwater project to examine the Murray Basin unencumbered by State boundaries. BMR's role has been to establish a basin-wide geological and hydrogeological framework, and to provide basin-wide perspectives on the groundwater systems and processes that result in surface salinisation. These basic frameworks are now established and the processes well understood. The project is now entering a new phase in which emphasis has shifted to the development of predictive models to support the management of the water resources. This will facilitate the development of a co-ordinated strategy aimed at minimising the salinity problem.

With the creation of the Murray–Darling Ministerial Council in 1985, the original groundwater project steering committee was formalised as the Groundwater Working Group, reporting to the Council through the Murray–Darling Basin Commission. The scope of the project was also expanded to include reconnaissance investigations of the Darling River drainage basin, to reflect the Council's Murray–Darling perspective.

The Groundwater Working Group will provide technical advice to the Murray–Darling Basin Commission on groundwater matters and will facilitate the basinwide study of all aspects of groundwater in the Basin.

The Working Group is currently developing a detailed work program aimed at providing technical information to natural resource managers.

Some products from the Group have already been made available:

Murray Basin 88 Conference

A major conference, organised by the Working Group, titled 'Murray Basin 88 — Geology, Groundwater and Salinity Management' was held in Canberra during May 1988. The conference was aimed at identifying the nature and extent of groundwater-related problems in the Murray Basin, communicating this information to non-groundwater people, and canvassing issues in Murray Basin resource management. A 200 page volume of Extended Abstracts was published in BMR's *Division of Continental Geology Groundwater Series (No. 12: BMR Record* **1988/7**).

Salinity Map of the Murray Basin

A shallow groundwater and salinity map of the Murray Basin, at 1:1 000 000 scale, was released at the Murray Basin 88 conference. This map was compiled by BMR from contributions by the various State agencies using BMR's Intergraph CAD/CAM system. The map was produced in 12 months from conception to release.

Hydrogeological mapping project

At the request of the Ministerial Council the Working Group has started a project of hydrogeological mapping for the Murray Basin that will ultimately provide an integrated high-quality groundwater database. The project will make use of all available groundwater expertise in the basin by involving all relevant agencies. Additional funding has been made available for BMR's contribution to a 6-year program of mapping that will collate and enhance existing computerised databases to generate twenty-seven 1:250 000 scale hydrogeological maps in the Murray Basin. In addition, a series of 1:1 000 000 reconnaissance scale maps of the Darling River drainage basin are planned. Each of the participating organisations are obtaining compatible CAD/CAM systems to facilitate exchange and maintenance of databases.

A set of hydrogeological maps, at 1:250 000 scale, will be generated which will: show the influence of groundwater on land salinisation and surface water salinity; delineate usable groundwater resources; highlight the present and potential salinity hazard; enhance community awareness and understanding of groundwater system; and be used to focus management and research tasks for salinity control.

The 1:1 000 000 scale shallow groundwater and salinity map of the Murray Basin can be obtained from BMR Publication Sales in Canberra, and Australian Government Publishing Service (AGPS) Bookshops in all capital cities, price $29.95 (including postage).

For further information, contact Dr Malcolm Walter, Mr Ray Evans, Mr Campbell Brown, Mr Jim Kellett, or Mr Gerry Jacobson at BMR (Division of Continental Geology).

New National Resource Information Centre 'NRIC'

Sound policy decisions on natural resource management require a comprehensive and reliable information base. A further step towards achieving this was taken in May 1988 when the Federal Minister for Primary Industries & Energy, Mr John Kerin, announced the establishment of a National Resource Information Centre (NRIC) within his Department (DPIE).

NRIC will draw upon, expand, and complement the existing data, facilities, and expertise of the Bureau of Rural Resources (BRR) and BMR. The resource data held will be augmented substantially by information supplied by other Commonwealth agencies, by State agencies, and by other organisations.

NRIC will help in the more rapid resolution of land use conflicts arising from contrasting developmental and environmental goals. It will also provide ready access to information in national land use issues that cross State boundaries, including regional planning studies in, eg., soil salinity and acidification, kangaroo management, or major river catchment investigations.

The primary goals of the Centre are to maximise the availability of information on Australia's natural resources, minimise the time and cost of information retrieval, and respond to requests for information both to satisfy strategic needs and to support particular projects.

An inventory of sources

NRIC will not hold large amounts of primary data. In essence it will be a computer-based inventory of *sources* of information — primarily, what data is available, who is responsible for the data, where it is located, and how it may be accessed. Control of access remains with those who have the responsibility for the content and maintenance of any constituent database. In this respect the structure of NRIC is similar to the hub concept that is used in some States and provides for communication between agencies and helps in the integration of data.

Geographic information system

Because much of the information will be geographically related, a geographic information system (GIS) will normally be used to interrogate the inventory. It is envisaged that organisations contributing to the inventory will have access to the GIS and associated inventory.

Facilities will allow the transfer of information between remote databases, including, where necessary, appropriate translation protocols and provision for invoicing costs involved.

Gateways

Access to NRIC from external users will be through dial-up telephone communication or through one of the NRIC gateways. A gateway may reside in a State Hub system and could contain a copy of the NRIC inventory. It would also contain procedures for handling protocol conversions and will enable high-speed communication between NRIC and the user.

Once the required data sets have been accessed, GIS techniques will enable users to combine, compare, and present information of quite different types, eg biological, geological, and economic. Such techniques will permit alternative policy options to be rapidly evaluated.

NRIC management

NRIC's operations are under the management of an Executive Committee that includes the Directors of BMR and BRR and reports to the Secretary DPIE. An Advisory Council comprising representatives from Commonwealth and State Government organisations will also be established.

A Project Team is being formed to address the wide range of tasks involved in the early development of NRIC including definition of user needs, evaluation of requirements for hardware and software, and the establishment of cooperative links between the Commonwealth and the States.

It is envisaged that by mid 1989 the Centre will be in a position to access remote databases where data exchange agreements have been established.

Certainly the complexity of the systems and the quantity of information involved will mean that NRIC's capabilities will evolve over a period of some years.

The creation of NRIC is a sign of a growing awareness of the need for a more rational approach to the sustainable use of natural resources in Australia. The rapid evolution of land-use philosophies now taking place means that NRIC will have an exciting and rewarding future.

For further information please contact one of the NRIC coordinators: Dr David Johnson (BMR), tel. (062) 49 9540, or Dr John Mott (BRR), tel. (062) 71 6353.

Recent symposium, 'Deep Seismic Probing of Continents and their Margins'

Understanding the basic geological processes that have formed the continental crust is an important goal for more effective exploration, because it is these processes that have controlled the distribution, both in time and space, of the Earth's mineral and hydrocarbon resources. Seismic probing is undoubtedly the best technique for extending the two-dimensional surface geological information into the third dimension of depth, thereby enabling the integration of geophysical and geological information to test ideas on tectonic processes.

At the recent international symposium, 'Deep Seismic Probing of Continents and their Margins', organised by BMR and the Australian National University, geoscientists from all major deep seismic research groups compared and contrasted results of their investigations. This conference, held in Canberra in July 1988, was the third in the series. The first was held at Cornell University (home of COCORP) in 1984, and the second at Cambridge University (home of BIRPS) in 1986.

The Canberra meeting highlighted the significance of Australian research in the field. In his opening address Professor Roye Rutland reviewed the BMR's early pioneering work and BMR geoscientists presented papers on the Exmouth Plateau, Otway Basin, and Lord Howe Rise offshore areas, and the central Australian and southern Queensland onshore areas.

A subject of particular interest and debate during the conference was the nature and origin of the lower crustal reflectors. Although not ubiquitous in the continental crust, these high-amplitude reflectors are common to many areas, and contrast with the relatively non-reflective upper crust. It is the structure of these lower crustal reflectors which reveals most about deep crustal processes.

One of the most interesting and detailed deep seismic projects to date has been the mapping of the Outer Isles and Flannan faults by the BIRPS group. The upper crustal Outer Isles Fault does not connect with the Flannan Fault (a sub-Moho feature that can be seen to a depth of around 100 km): the two appear to be offset horizontally at the lower crustal reflective zone. Reactivation of these major deep faults has formed the overlying graben basins. The recent MOBIL survey (a cooperative venture with industry) aimed to investigate the way in which these crustal-scale processes relate to the formation of the North Sea Basin.

In a keynote address, Prof. Larry Brown from the COCORP group (Professor Brown also collaborated with BMR scientists in Canberra for four weeks after the conference), outlined the frontier areas of deep seismic research in which future developments are expected to produce significant results, including:

— Three dimensional imaging of features within the continental crust to better determine their structure.

— Longer seismic traverses allowing integration of the regional geology into the modelling of crustal processes.

— Comparisons of deep crustal structure within the youngest and oldest terranes to investigate the similarity of geological processes through time.

— The development of supercomputers for faster processing and interactive manipulation of the seismic data.

Seismic programs in many countries are now exploring in detail the depth dimension of the continental crust from which we derive our mineral and petroleum resources. These programs will result in an improved understanding of crustal evolution and of the processes that have influenced the Earth's resources.

An example of deep geology interpreted from basement reflectors has been BMR's work in the Roma Shelf petroleum province in the Surat Basin in southeast Queensland. Under the 2 km thick, flat-lying sedimentary sequence at the surface is a 9 km thick non-reflective (deformed) deep-water turbidite sequence, strong reflectors at 12 km depth possibly from intrusive rocks, intersecting dipping reflectors at 24–33 km indicating a geosuture (geological province boundary), and a well-defined crust/mantle boundary at 36–39 km. The geosuture is associated with the boundary between the Nebine Ridge and the younger Bowen Basin and may penetrate the non-reflective upper mantle.

For further information, contact Dr Jim Leven at BMR (Divison of Petrology & Geochemistry)

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This number of the *BMR Research Newsletter* was edited by A.G.L. Paine and word-processed by P. Nambiar; the figures were drawn by staff of the BMR Cartography Section.

The purpose of the *BMR Research Newsletter* is to provide the exploration industry with early information on the progress of BMR research and on the availability of new data relevant to exploration and to resource assessment; to provide commentaries on relevant research developments worldwide; and to encourage close liaison between the exploration industry and BMR. Readers' comments and suggestions — addressed to the Director — are welcome. Requests to be placed on the mailing list should be addressed to: Information Section, Bureau of Mineral Resources, GPO Box 378, Canberra, ACT 2601.

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News briefs

Copy Service: new arrangements

On 1 February 1988 BMR took over the operation of the Copy Service from AGPS.

The new **BMR Copy Service,** which is now part of BMR's Publications Section, is located on the 4th floor of NRMA House, 92 Northbourne Ave, Braddon, ACT. Address: Copy Service, BMR, GPO Box 378, Canberra ACT 2601; tel. (062) 451374, telex AA 62109, fax (062) 472728.

Boost to Australia's mineral reserves

In March, BMR announced a 24% increase in Australia's economic demonstrated resources of gold (as at the end of 1987), to almost 1300 t. This is three times the total at the end of 1983.

Economic demonstrated resources of black coal (recoverable) also increased sharply, by 48%, largely because of a reassessment of NSW resources by authorities in that State.

Demonstrated resources of ilmenite and rutile increased by 33%.

Murray Basin salinity: key issues

'Murray Basin 88', a conference organised by BMR in May and aimed at identifying the nature and extent of groundwater-related problems and finding solutions to the salinity problems of the Murray Basin, identified several major issues: (1) the problems of disposing of saline water, (2) the need to look more closely at the joint use of surface water and groundwater, and (3) the absolute necessity of understanding the groundwater picture before embarking on major revegetation programs in the Basin.

Discussions revealed that the salinity problem was more widespread than even the 170 delegates (Commonwealth and State experts responsible for water management in the region) had realised.

A report subsequently prepared for the Murray–Darling Basin Commission recommends specific investigations and management initiatives. Future cooperative research will allow more accurate predictions of salinity trends and lead to long-term, basin-wide management strategies. BMR also will undertake an expanded program of hydrogeological mapping of the region (see article on page 15).

Rig Seismic charter extended

The Minister for Resources, Senator Peter Cook, announced in May that the charter of RV *Rig Seismic* would be extended for a further 10 years, enabling Australia to continue a major BMR research program investigating the petroleum and mineral potential of the continent's vast offshore area.

The program, costing $10 million/year, has operated since 1985.

Major achievements to date include identifying new areas of petroleum potential in the offshore Otway Basin and Great Australian Bight, and the discovery of new sedimentary basins on the Queensland Plateau.

Areas being studied in 1988–89 include the Perth Basin, Gippsland Basin, and part of the North West Shelf.

Major release of offshore resource data

The release was announced in June of 15 000 line-km of seismic and related geophysical data recorded by RV *Rig Seismic* from a number of BMR research projects in the Great Australian Bight, Exmouth Plateau, Townsville Trough, Queensland Plateau, and Kerguelen Plateau.

The information is available as maps and seismic sections and in digital form on magnetic tape.

Details and price lists may be obtained by contacting Mr Craig Penney, Marketing Manager, Division of Marine Geosciences & Petroleum Geology, BMR, tel. (062) 499278.

BMR iron ore study commissioned

On 4 July, Senator Cook commissioned a new program of applied research at BMR into prospects for further beneficiating Australian iron ore for export, by reducing the phosphorus content.

Phosphorus is the main impurity in Pilbara iron ore.

The work will be done in cooperation with the industry, as a supplement to the industry's own work.

Kakadu airborne survey

Senator Cook also announced in July that BMR would conduct an airborne geophysical survey of the Kakadu Conservation Zone, NT, which covers an area of some 2300 km^2 of highly prospective, mineralised land. The purpose is to obtain data for research and for the assessment of the Zone's resources.

The information will be used in establishing a comprehensive database for use in resource assessment and in park and wildlife planning.

Record gold output predicted for 1988

In August, BMR forecast Australia's gold output in 1988 to be the highest ever, at about 142 t, easily surpassing the previous record of 119 t set in 1903.

Gold exports in 1987 were valued at $1693 million.

The present boom in gold production started in 1981 when 18.3 t was produced.

Oil potential of North Perth Basin reassessed

The Minister announced in August the public release of the initial results (seismic data) of a major offshore regional study of the North Perth Basin, carried out by BMR in 1986 to gain a better understanding of the geological framework of the basin and to reassess its petroleum potential.

Initial results are encouraging: a new pattern of basin development has been identified that suggests there is untested petroleum potential beneath the shelf and slope.

Satellite links outback seismic centre

In August, BMR and AUSSAT announced the establishment of an important satellite link from the Warramunga Seismic Array near Tennant Creek, NT, to BMR's Australian Seismological Centre in Canberra.

The new link allows BMR to analyse seismic events in Australia and the surrounding region at almost the same time as they occur, and, when supplemented with data from the Alice Springs Seismic Array, is expected to greatly aid in the detection of nuclear explosions.

BMR, which operates a network of remote seismic stations throughout the continent, is hoping to extend its satellite network to other remote locations.

BMR reviewed

On 8 August the Minister for Resources announced he had commissioned an independent, comprehensive review of BMR.

The review is being undertaken by Mr Alan Woods, who recently retired as Secretary of the Department of Defence and was formerly Secretary of the departments of National Development and Resources & Energy.

BMR is the Government's main agency for geoscientific information on minerals, petroleum, and groundwater exploration and assessment.

Among its other functions are seismic monitoring for earthquake risk prediction and for detecting undergound nuclear explosions.

It has almost 600 staff, the majority of whom are professional scientists and technicians, and an annual budget of around $40 million.

The review is covering all aspects of BMR's role, its programs, organisation and staffing, and is including an examination of the effectiveness of BMR's relations with industry, the States, and other bodies in the private and public sector.

Special attention is being paid to ways of associating BMR more closely with industry needs and priorities, and to the potential for cost recovery.

Australia's oil reserves increased

On 6 September, details of BMR's latest six-monthly review of Australia's petroleum reserves and resources were announced.

Commercial oil reserves have been increased by 75 million barrels (6%) to 1333 million barrels; this compares with annual consumption of about 220 million barrels and annual production of 175 million barrels.

The increase was the solution of an equation comprising (1) production over the period, (2) adjustments of existing estimates of reserves for some fields, and (3) new discoveries.

The estimates are as at 31 December 1987, and therefore exclude significant recent discoveries or reserve increases in the Timor Sea or elsewhere during 1988.