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In this issue:

Mike Etheridge (above) resigned from BMR in June to take up consulting work combined with a post at the Australian National University.

Mike Etheridge on 'Recent and Future Trends in Geoscience Mapping'

Following is the text of a paper delivered by Dr M.A Etheridge to the Second Annual Sir Edgeworth David Memorial Symposium which was held at the Geology Department, Sydney University, on 14 June 1989. The theme of the symposium was, 'Geological mapping of Australia, from David to 1:50 000'.

The recent Woods Review of BMR emphasised the importance of geoscience maps as the basic means of portraying information about the Earth. Maps are fundamental to mineral and petroleum exploration, resource assessment, and land-use management, as well as to a wide range of research.

Geological mapping was the basis of most geoscientific activity until about 30 years ago. Since that time, principally due to an explosion in technology, geoscience has been increasingly dominated by laboratory and theoretical studies. In research in particular, field work and its principal output, the geological map, have become the poor cousins to tables of geochemical data spanning most of the known elements and their isotopes (no matter how trivial their abundance), a bewildering array of often simplistic experimental attempts to duplicate extraordinarily complex natural systems and processes, and theoretical studies of the earth and its processes that absorb the power of supercomputers to produce models that abound with simplifying assumptions and qualifiers. Geoscientists have been seduced by technology, and have to some extent fallen into the trap of pursuing more and more knowledge about less and less.

Before I am branded a philistine (or worse, given my own research record, a hypocrite) by my research colleagues, I must emphasise that these studies have led to a significantly more sophisticated understanding of earth processes. Geoscience has emerged with a more analytical approach to the science from an era dominated by empiricism and inductive thinking. There is a problem, however, when our apparent understanding of a process outstrips the quality of the documentation of the phenomenon that it produces, and when a complex phenomenon is 'explained' on the basis of a very limited, albeit highly sophisticated, data set.

The tide is on the turn. The reasons for this are complex, but the impetus has come from the range of applied geoscientists who simply want to know more about a particular piece of the Earth's surface and immediate subsurface, rather than about the intricate details of earth processes. The emphasis is on data and information, and the geological map is seen to be the prime geoscientific information base. The ultimate challenge facing the new generation of geoscience mappers is to ensure that a real increase in *knowledge* accompanies this new information base.

The Woods Review of BMR, with its emphasis on increased national effort in geoscience mapping, is by no means a lone voice in this regard. In the past five years, the United States (COGEOMAP) and Canada (Mineral Development Agreements) have addressed the same rising demand for sophisticated information about that part of the earth within human reach, by implementing (and funding!) enhanced geoscience mapping programs. Even the home of geological mapping, Great Britain, with its superb (even though mostly decades old) coverage at scales around 1:50 000, has undergone recent soul-searching about the adequacy of its geosience information base.

During his seven years at BMR, Mike made an outstanding contribution to the development and prosecution of BMR's programs. As a specialist in structural geology and metamorphism, including the role of fluids, he played a major part in the integration of studies on the Early to Middle Proterozoic of Australia, building upon the earlier BMR programs, especially in northern Australia. More recently, he initiated BMR's mapping/structure project in the Archaean of the Yilgarn Province in cooperation with the Geological Survey of Western Australia.

He has also been a leader in the application of the concepts of extension tectonics to a wide range of geological settings, most notably the structural evolution of the Bass Strait basins. He conceived and organised three very successful meetings to promulgate the results of work in these research areas — *Extension Tectonics, Early to Middle Proterozoic*, and *Gold Research*.

This direct contribution to BMR's program was achieved in addition to his duties as acting Chief of the Division of Petrology & Geochemistry for nearly three years, when he was closely involved in the Woods Review process and the beginnings of the consequent reorganisation of BMR's program. He helped drive the current transition to the use of modern information systems to improve the integration of disparate geoscientific data sets, and also the better integration of seismic reflection studies with geological work. These are important steps in meeting the need for a new generation of 'three-dimensional maps' and databases using the latest technology and concepts as required under the National Geoscience Mapping Accord.

BMR wishes Mike well and looks forward to a continuing close association with him in his new activities.

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To some extent, geoscience is simply coming to terms with what is increasingly widely recognised as the latest in a series of anthropological evolutionary stages — **the information age**. The Earth, especially that part of it within a few kilometres of the surface, is extraordinarily complex. Simply describing its characteristics and relating them to one another and the processes that formed them is almost as much a problem in information management as it is one in geoscience. The explosion in the sophistication and usability of data and information management systems has brought home to geoscientists the inadequacy of the available databases and information bases on even those most fundamental of earth properties — the spatial relations among rock bodies and their interfaces with the hydrosphere and atmosphere. The most basic (or potentially the most sophisticated, as we will see) of these information systems is the geoscience map.

We have now got to the core of the topic of this paper: **what are the most important recent and future trends in geoscience mapping**? I will deal with them under four main headings:
— Whither boots and hammer in geoscience mapping?
— Mapping is multidisciplinary research.
— The impact of the information revolution.
— Is there an appropriate scale for modern mapping?

Whither boots and hammer?

One of the outcomes of the technological revolution in geoscience is an impressive array of techniques for imaging the earth through, usually remote, measurement of selected physical properties. The earliest of these, aerial photography, revolutionised geoscience mapping in the post-war period. More recent developments, particularly multispectral satellite imagery and airborne geophysics, promise to have a dramatic impact in the near future. Some even say that revision of our First Edition map series can be accomplished largely by application of these technologies, and that only limited additional field checking is required. Are we on the threshold of **remote mapping**? Is the field geologist an anachronism?

I think not. Geoscience maps are (or should be) much more than records of the surface distribution of earth materials and structures. They are not just geological road maps. They should provide a **4-dimensional understanding** of the spatial and temporal relationships among the rock bodies. The remote mapping techniques principally provide only 2-dimensional information at the earth's surface, although the potential-field techniques give some information in depth, and seismic reflection data present vertical 2D images. Genuine understanding of the rock relationships adds a predictive capacity to maps, and requires often intensive field investigation to develop that understanding. The mineral exploration industry may say that they only need to know what is at or very close to the surface, but I suggest that future exploration must be built increasingly on such an understanding.

Despite the claims of the advocates of Landsat imagery, it is airborne geophysics that will have the most dramatic impact among the remote techniques, at least for the next decade. This is especially so in the large parts of Australia where the bedrock geology is so poorly exposed. At both the regional and relatively detailed scales, the impact of the spectacular airborne magnetics images is already being felt. Airborne radiometric images have been the poor cousins of the more 'rock-like' magnetics, but I predict that they will also have a major bearing on geoscience mapping, particularly of the regolith and environmental parameters.

In sedimentary basins where the bulk of the sequence is unexposed, multichannel reflection seismic data have revolutionised mapping, especially in the last five to ten years as data quality has markedly improved. However, significant uncertainties still exist in translating these 2D images into 4D understanding. The advent of the so called 3D seismic surveys has improved mapping confidence at the prospect scale, especially when supported by the chronological and rock material data derived from wells. Again, modern, processed, airborne magnetic images can help to add the third spatial dimension to the sections.

The new generation of geophysical products are so user-friendly, even to the traditionally innumerate geologist, that they can be directly applied to mapping by the geologist. Perhaps the appropriate question is 'Is the geophysical interpreter an endangered species as a result of the success of his acquisition and processing colleagues?!'

Mapping is multidisciplinary research

The traditional geological mapper has had to be all things to all persons, or at least to all rocks! He/she has potentially had to be a stratigrapher, a sedimentologist, a structural geologist, an igneous and metamorphic petrologist, and a palaeontologist, as well as something of a bushperson with side skills in geomorphology and botany. The remorseless intrusion of technology into geoscience has increased the range of required skills to include satellite imagery, geophysics, geochemistry, and isotope geochronology. Mapping is certainly a specialist skill, but the essence of that skill is the ability to integrate a wide range of geoinformation into the 4D picture of the Earth referred to above. In that respect, it is both specialist and multidisciplinary.

The modern mapper cannot reasonably be expected to cope with the range and sophistication of geoinformation necessary to achieve real advances in that 4D understanding. Modern mapping is a team game, and requires the application of the appropriate mix of skills for the particular region being mapped. The mapper must be enough of a generalist, a manager, and a scientific planner to assemble and organise the appropriate team. The most important scientific skill for mapping, is to be able to reconstruct geology in four dimensions.

Most of the geological map coverage of the continent, especially at 1:250 000, was strongly influenced by stratigraphic principles, with an emphasis on the surface distribution of stratigraphic units. Three (two spatial & one temporal) of the four dimensions were generally satisfactorily depicted. The deficiency in this coverage is therefore in its inability to project below the surface, rather than in its surface geology. Only a small minority of the 1:100 000 to 1:250 000 published maps contain cross-sections that can be balanced or palinspastically reconstructed. Many of the maps do not even contain sufficient information for a reasonable cross-section to be constructed by the user. The next generation of geological maps should therefore concentrate on the vertical dimension, while providing all possible improvement in the surface and temporal data. Dare I say that structural geology is the key sub-discipline for the next generation of geoscience maps, in order that a real increase in useful knowledge derives from the opportunities provided by the new technology.

The information revolution

I have used the term geoscience mapping advisedly, to reflect its broad multidisciplinary character. One of the recent trends has been the explosion of thematic maps that depict a particular feature of the earth, such as geophysical, geochemical, hydrological, mineral-deposit, regolith, tectonic, and palaeogeographic maps. These thematic maps range from fairly raw digital images of a directly measured property such as the Earth's magnetic field, to highly interpretive products that project us back in time and unravel untold complexity to present an ancient palaeogeography. The traditional geological map, in its most sophisticated form, attempts to incorporate many of these themes into a single 'image', and thereby comes up against its principal design limitation — the amount of information that can be usefully displayed on a single sheet of paper. The alternative is to prepare a set of separate thematic maps that can be physically overlaid — or is it?

I suggest that the most important set of (very) recent and future advances in geoscience mapping has and will come from application of electronic information systems, enabling genuine integration of the disparate data sets and data types in an environment that is manageable, cost-effective, and informative:

— **Computer-aided map production (CAM)** has been with us for some time, and is adding both efficiency and flexibility to that part of the mapping process that has often frustrated geoscientists — the final production of a coloured map. Most, conventionally published, full-colour geological maps are guaranteed 20-year lifetimes simply by the publishing and printing costs associated with revision. However, CAM, combined with the latest in digital colour printer/scanners, allows for both instant upgrading of the information and for production of the very latest map on demand.
— **Image processing techniques** have also been applied to a range of geoscientific data sets for some years. Variously processed images of airborne magnetics and radiometrics, gravity data, multispectral radiation, elevation, and even surface geochemistry are becoming increasingly widely used in geoscience mapping.
— **Relational database management systems (RDBMS)** with their SQL and similar search-and-find facilities have revolutionised the handling and analysis of large and complex databases. Their potential in geoscience mapping is in enabling many and complex spatial and attribute datasets to be readily interelated, in map and a range of other formats. Many of us had less than satisfactory experiences with the early attempts to 'computerise' field data recording and drill logging, largely resulting from frustration at the highly restrictive codification of data demanded by the primitive database structures available. Now it is possible to incorporate large amounts of textual, digital, and even graphical data into any 'box' in the database, and then for a user to extract very specific information and relationships from it with relative ease. The electronic field notebook is very much a reality, and the modern geological map is potentially a window into an extensive, thoroughly integrated data, information, and knowledge package.
— The real power of information systems technology in geoscience mapping is in the combination of CAM, image processing, and RDMS into such an integrated input-analysis-output system. Such a system

should begin with pre-field planning and carry through to the provision of a wide range of continuously updated products that can be specified by the customer. It should also allow high-level analysis of widely disparate information in real time and thereby materially increase the level of understanding. The basis of this ideal is already available in commercial **Geographic Information Systems (GIS)**. GISs were developed initially for the handling of land-use information, and have not been widely applied to the geosciences. Consequently, the commercially available GISs are not yet quite appropriately configured for our purposes. However, geoscience demand is building, and the existing deficiencies should soon be overcome.

Is there an appropriate scale for modern mapping?

The question of scale may seem to be a trivial one, with the obvious answer being, 'whatever scale is appropriate to the requirement'. However, there is an implication in the title of this seminar that future mapping will be at larger scales, presumably to provide more detailed information. I raise this issue to make the point that there is a fundamental distinction between the scale (i.e. level of detail) at which the information is *acquired*, the scale at which it is *presented*, and the scale at which it is *used*.

Industry wants 1:250 000 scale maps. Why? Because that is an appropriate scale for looking at regions or provinces for prospect generation. That is, they want the information presented at 1:250 000, but what level of detail is required in the information and knowledge base behind the map to answer the questions that they might raise? (that is, what determines the scale at which the information is acquired?).

One of the benefits of GIS technology is that it is essentially scale-independent. All information is location-coded, and can be presented in map form at a wide range of scales. However, the utility of a presentation at a particular scale depends on the spatial density of the data/information. I believe that future geoscience mapping should err on the side of too much detail for the apparent requirements. Such a policy would lead to an improved level of understanding simply as a result of the increased scientific effort. The customer can still dial up a map product at 1:250 000, but he/she would also have access to a superior level of understanding and information detail in the database on which to base decisions about prospectivity and exploration strategy.

Potentially the most far-reaching recommendation of the Woods Review of BMR was for the establishment of a *National Geoscience Mapping Accord*. The principle of the Accord has been accepted by BMR and the State/NT geoscience agencies, and the Accord is now being put in place. Under the Accord, the States/NT and the Commonwealth will agree to a priority mapping program, with input into priorities of map type, scale, and location by industry, government, and the geoscience research community. BMR and the State/NT agencies will devote the maximum resources possible to the Accord program. There is also provision under the Accord to provide geophysical data in direct support of the mapping, and to develop compatible GIS-based systems for the storage, analysis, and presentation of maps and related information.

In conclusion, I would like to present my vision of the geoscience mapper of the future. He/she will still spend significant time in the field collecting new data and information, although supported in pre-field planning and analysis by much improved images of the surface (and/or cross-sectional) geology. Because of this support, field efficiency will be improved. Once in the field, the geologist must be supported by helicopter, will locate him/herself with a portable GPS or similar position finding system, record data and information in an electronic note book, and, at the end of each day, update the GIS on a PC in base or fly camp. Location and map construction will be aided by digital images of airphoto mosaics and/or satellite data, which are also stored in the GIS. The PC will be linked by satellite to headquarters, where the field information is automatically overlaid on a digital topographic base, and the map(s) is(are) constructed. Output of the latest product is achieved on demand via a colour raster plotter.

The only problem with this as a vision of the future is that, apart from incomplete satellite location coverage, it is already here.

Irian Jaya full-colour geoscientific maps released

BMR, and the Indonesian Geological Research & Development Centre (GRDC), proudly announce the release of the first seven out of fourteen 1:250 000 full-colour combined geological/Bouguer anomaly maps covering western Irian Jaya (Fig. 1) — each to be accompanied by explanatory notes — scheduled for issue in 1989 and 1990.

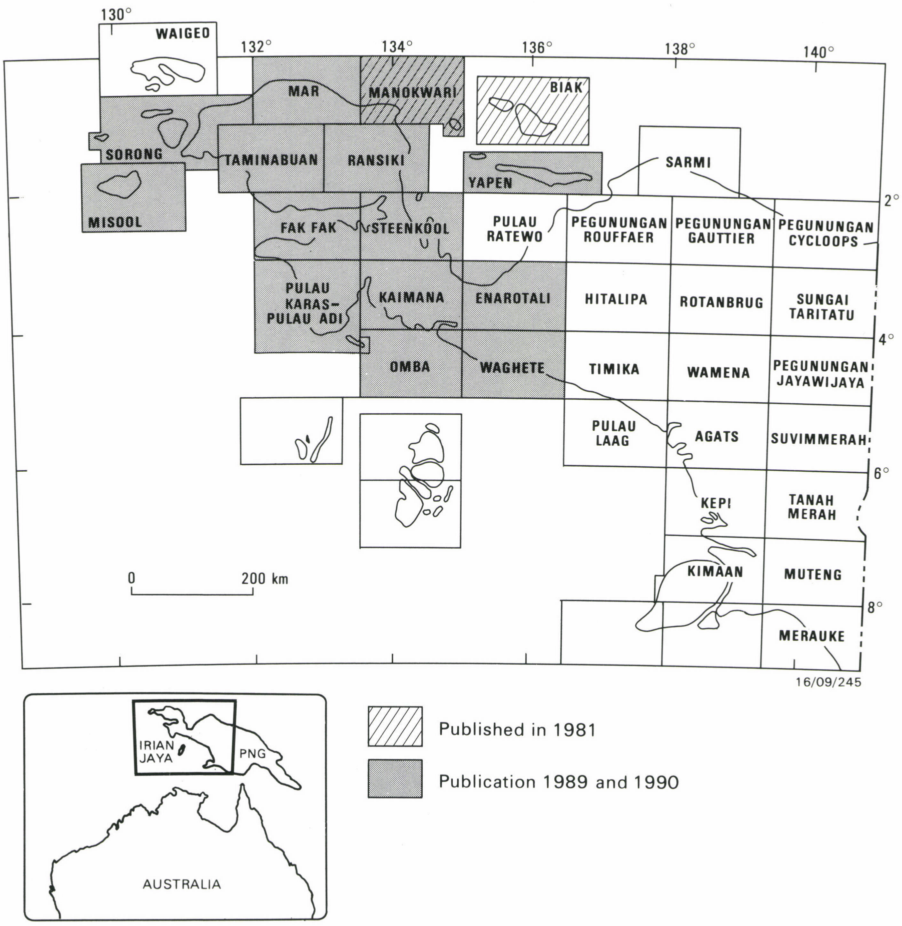
This invaluable series of earth-science databases for Indonesia's easternmost province is a product of the Indonesia–Australia Geological Mapping Project (IAGMP; formerly the Irian Jaya Geological Mapping Project, IJGMP), comprising collaborating geoscientists from BMR and GRDC, and funded by the Australian International Development Assistance Bureau AIDAB) and the Indonesian Department of Mines & Energy.

Data collection and preliminary map compilation

IJGMP fieldwork for systematic regional geological and gravity mapping and an integrated stream-sediment geochemical survey started at the western end of mainland Irian Jaya in 1978. After four consecutive field seasons, field mapping was abruptly terminated by a security incident at the start of the 1982 field season as operations progressed east of longitude 136° 30'E — the limit of data acquisition during the field season of the previous year. The resultant data — integrated with data which Dutch geoscientists had accumulated between 1935 and 1960 while investigating the petroleum prospects of large parts of Irian Jaya (synthesised by Visser & Hermes, 1962: *Koninklijk Nederlands Geologisch Mijnbouwkundig Genootschap, Verhandelingen, Geologische Serie*, 20) — formed the basis of a series of 1:250 000 two-colour preliminary-edition geological maps, each compiled soon after the completion of field mapping in a Sheet area.

Since the release of the preliminary-edition maps, the geological data have been reassessed in an integrated interpretation of the

Fig. 1. Western Irian Jaya: publication status of 1:250 000 full-colour combined geological/ Bouguer anomaly maps and Explanatory Notes, prepared by IAGMP.



geological development of western Irian Jaya. Fresh ideas have stimulated discussion that has led to the evolution of a more refined appreciation of the geology, which is depicted on the new 1:250 000 full-colour maps.

Cartographic input

In addition to the coverage of mainland Indonesia as far east as longitude 136° 30'E (Fig. 1), the mapping extended to the offshore islands of the Misool Archipelago, Biak, and Yapen. A 1:250 000 full-colour geological map of BIAK was prepared entirely by GRDC cartographers and draftsmen for printing in Indonesia, and released — with explanatory notes — in 1981. The two maps of the other islands have recently followed the same course. The topographic bases of 12 other maps are being scribed by GRDC and locally engaged IAGMP contract draftsmen working under the supervision of an Australian-recruited contract cartographer, who is also providing on-the-job training to GRDC counterparts. Additional work on these 12 maps is being done in Canberra by cartographers of the BMR Cartography Section, who are fair- drawing the geological information, providing a colour-design service, and co-ordinating and overseeing the contract printing by Mercury-Walch in Tasmania; these activities are being integrated with a training program for selected visiting GRDC cartographers.

The first 1989–90 full-colour map. . .

The first map to roll off the printing press — MAR — was delivered to BMR in April. This map straddles some of the most complex geology in Irian Jaya. It shows 24 Palaeozoic to Quaternary rock units referred to five *geological provinces*. Silurian to Devonian turbiditic rocks of the *Kemum Block*, extending latitudinally across the Sheet area, form a basement that is metamorphosed with an increasingly higher grade to the east, and overlain sporadically by outliers of late Palaeozoic and Triassic siliciclastic rocks and more extensive Tertiary carbonates and sandstone. To the north, the Kemum Block abuts the *Sorong Fault System*, a major crustal discontinuity comprising a belt — 1 to 10 km wide — of roughly east–west striking en-echelon and anastomosing faults (including strike-slip faults and thrusts) that bound a melange — emplaced between the Late Miocene and Recent — of diverse rock types that are mappable as coherent rock units only locally at 1:250 000 scale. The northern boundary fault of the Sorong Fault System in the east forms the planar boundary of a fault-bounded planoconvex complex of Triassic granitoids — the *Netoni Fragment* — locally overlain by Late Cretaceous quartz arenite. Juxtaposed to the north against the Netoni Fragment and Sorong Fault System, the *Tamrau Block* comprises locally metamorphosed Jurassic to Cretaceous siliciclastic sedimentary rocks and overlying Miocene carbonates, andesitic volcanics, and comagmatic intrusives and Pliocene to Quaternary coarse siliciclastic rocks — all considerably disrupted by slightly arcuate, mainly easterly trending faults. In the north, these faults are quite distinct from an irregular series of curved to straight, locally anastomosing faults that form the southern boundary of the northernmost geological province — the *Tosem Block*, composed entirely of Late Eocene to Middle Miocene andesitic to basaltic volcanics and comagmatic intrusives overlapping the coast.

. . . and Explanatory Note

Like other maps in the series, the MAR full-colour map is supported by an Explanatory Note in which an English-language text is preceded by a full Indonesian translation; both versions are accompanied by figures annotated and captioned in the appropriate language. The Explanatory Notes are printed — some by commercial printers in Australia, and others by GRDC on their Heidelberg offset printing press — from HP Laserjet-printed camera-ready copy prepared by IAGMP secretarial staff on an IBM-compatible personal computer using Wordstar 4 word-processing and Ventura II desktop publishing programs.

The format of the MAR Explanatory Note is typical of all in the series. It comprises a brief introduction, followed by sections devoted to physiography, stratigraphy (including a comprehensive table listing age, thickness, distribution, reference, lithology, sedimentary structures, relations, correlations, fossil content, depositional environment, and derivation of each of the 24 map units), geophysics, structure and tectonics, mineral resources, cited references, and appendixes (listing fossils identified by palaeontologists; K–Ar ages of rocks; and summarised stream-sediment geochemical data).

The Explanatory Note is an integral part of the publication package for each geological map. It elucidates those elements of the geology shown in symbolised form on the map and elaborates on other elements that the scale of the map precludes the cartographer from depicting. It also provides the reader with an interpretation that puts into perspective the various aspects of the geology which the compiler has identified in the peripheral elements of the map sheet — such as diagrams showing the geological provinces and the correlation of and relationships between map units. The MAR Explanatory Note, for example, tells the reader that all five geological provinces identified on the map are believed to be allochthonous terranes, and that the Tosem Block has oceanic/volcanic-arc affinities, while the other four provinces — bordering the northern margin of the Australian continent — have continental affinities.

Other maps and Explanatory Notes

In addition to the MAR package, six other maps have been released and two more are in press, and their Explanatory Notes are either in press or being finalised for press. The status of the maps in the series is as follows:

Published: MAR, MANOKWARI (2nd Edition), TAMINABUAN, WAGHETE.
In press (September 1989): OMBA, ENAROTALI, RANSIKI, MISOOL, YAPEN.
Scheduled for press before end of December 1989: SORONG, FAK FAK, PULAU KARAS–PULAU ADI, STEENKOOL, KAIMANA.

Purchase

The map and Explanatory Note for each 1:250 000 Sheet area are available as a package priced at $A9.60 (incl. tax, and cost of remittance by surface mail) from the BMR Bookshop, or Rp. 6000 (US$3.50, plus freight charge) from the Geological Research & Development Centre (Sales & Distribution), Jalan Diponegoro 57, Bandung, Indonesia. The map is available either folded or unfolded; orders should specify which.

For further information, contact Messrs David Trail or Peter Pieters in Bandung at Jalan Cilaki 49 (phone and fax 022–436693), or Messrs Geoff Bladon or John Casey at BMR.

Dr Stan Ozimic

Dr Stanley Ozimic, 1937–1989.

It was with great sadness that we learned of Stanley Ozimic's untimely death on 29 May 1989, after a long struggle with cancer. He was 51.

Stan was born in Slovenia and, after coming to Australia, joined BMR as a Laboratory Assistant in 1962. Starting without any recognised qualifications, he obtained his Leaving and Matriculation certificates at night classes and then began part-time university studies, and was awarded a B.Sc. degree in Geology from the ANU in 1973. Meanwhile, at BMR, he progressed through the ranks of Technical Assistant and Technical Officer to Senior Technical Officer and Reservoir Geologist (Science 2).

In 1978, Stan was awarded an M.Sc. degree from the University of Wollongong, and he obtained his Ph.D. from the same university in 1981. His thesis concerned the potential for underground storage of natural gas, in which he became one of Australia's foremost experts. In 1981, he won a Churchill Fellowship to study in the USA and Europe, and in 1984 he won a special scholarship funded by the Australian and French Governments to undertake further studies at the Ecole Nationale Supérieure des Mines de Paris. Stan convened the First Australian Symposium on Underground Gas Storage held in Canberra in 1986.

In recent years Stan headed the Petroleum Branch's Reservoir Geology Section. He authored or co-authored more than 80 papers during his career, and he had been hoping to present two invited papers at international conferences in Europe this year. The work undertaken in recent years by the Petroleum Branch in compiling strategic information on all identified petroleum resources in Australia's sedimentary basins, and their successive publication in the new *Australian Petroleum Accumulations Reports* series, stands as a tribute to Stan, who was the originator and driving force behind the work.

Stan was a gentle, likeable person who attracted great loyalty from staff who worked with him. His capacity for hard work was legendary. His election as staff representative to the BMR Advisory Council testifies to the respect with which he was regarded throughout BMR.

We extend our deepest sympathy to Stan's wife Barbara, sons Christopher (20) and Anthony (13), father-in-law Michael Konecki, and Stan's mother and brothers in Slovenia.

Recognising sinters in epithermal gold deposits

Surficial deposits of siliceous sinter are a common feature of present-day hot springs in areas of active volcanism, but they are rarely recognised in older, eroded volcanic terranes because of their low preservation potential, and their limited vertical and lateral dimensions. Sinters are important to exploration for epithermal gold deposits as they provide tangible evidence of the level of exposure of an ancient geothermal system, and indicate the potential for a significant mineralising system at depth.

Ancient sinters have been widely reported during recent intensive exploration for epithermal gold deposits in the Devonian–Carboniferous Drummond Basin in northeast Queensland. Possible sinter has been noted at Wirralie (Fig. 2; see Fellows & Hammond, 1988: *in* proceedings of Bicentennial Gold 88 Conference, Melbourne. *Geological Society of Australia, Abstracts*, **23**, 265–267), and sinters have been reported from prospects such as Verbena (see Cunneen & Sillitoe, 1989: *Economic Geology*, **84**, 135–142), Yandan, Bimurra, and Conway: many other prospects throughout the Drummond Basin are thought to contain them. (For a summary of the results of new geological mapping in the northeastern Drummond Basin, see *BMR Research Newsletter* **10**, of April 1989).

Although the recognition of sinters in a prospect area is clearly important, the characteristic features of modern sinters may be absent or are simply not preserved in ancient sinters. In the absence of diagnostic features, a chalcedonic and finely laminated rock may be incorrectly interpreted as a sinter, leading to false assumptions about the potential of an epithermal prospect and perhaps also to a misdirected exploration program.

Ancient sinters preserving many of the classical features of modern hot-spring sinters have recently been described at the Conway (Wobegong area) and Durah Creek prospects (White & others, 1989: *Geology*, **17**, 718–722). These sinters are conformable with subaerial, hydrothermally altered volcanic rocks, and are spatially related to rocks which predominate in modern hot-spring areas (e.g. air-fall tuffs, and fluvial and lake deposits in which hydrothermal eruption breccias are common). Preserved textures, characteristic of many modern sinters, include columnar structures perpendicular to laminated, depositional surfaces; striated surfaces apparently caused by silica deposition on filamentous algae; and fossilised plant material.

Oxygen isotopes

Recent research at BMR suggests that oxygen isotopes may provide an additional tool for characterising ancient sinters. Clayton & Steiner 1975: *Geochimica et Cosmochimica Acta*, **39**, 1179–1186) reported large ^{18}O enrichments ($\delta^{18}O_{SMOW}$ = +22.2 and 23.6 per mil) in siliceous sinter deposited at the surface at 55–60°C from water discharged from steam wells at Wairakei, in New Zealand. They noted that hydrothermal quartz deposited at depth at 250°C in the same system had a $\delta^{18}O$ value of only +3.9 per mil. At the nearby Broadlands system, Blattner (1975: *American Journal of Science*, **275**, 785–800) observed that the $\delta^{18}O$ value of vein quartz was generally in the range +3.9 to +12.3 per mil, and decreased with both depth and increasing temperature. Such marked ^{18}O enrichment for sinters relative to higher-temperature vein quartz can be explained by the rapid increase in the oxygen isotope fractionation factor for the quartz–water pair with decreasing temperature, particularly below 100°C (Friedman & O'Neil, 1977: *USGS Professional Paper* **440-KK**). Once deposited from solution, quartz is known to resist further isotopic exchange. Provided there is no significant exchange when the amorphous silica sinter recrystallises to cryptocrystalline quartz, the original ^{18}O-enriched signature should be preserved. Preliminary data for the Wobegong sinter and related, high-temperature vein quartz confirm these trends. The sinter averages +11.5±0.9 per mil, whereas the vein quartz ranges from +3.6 to +9.0 (mean 6.7±1.8) per mil. The sinter values are consistent with deposition from a fluid at 90–100°C having a $\delta^{18}O$ value of around –9 to –8 per mil, a value indicative of a meteoric water source and consistent with values suggested at the nearby Pajingo deposit (Etminan & others, 1988: *in* Proceedings of Bicentennial Gold 88 Conference, Melbourne. *Geological Society of Australia, Abstracts*, **23**, 434–435). The magnitude of ^{18}O enrichment in a given sinter will be variable and difficult to gauge, since the temperature at which the sinter was deposited and the isotopic composition of the fluid involved will strongly influence the fractionation.

Nevertheless, the results indicate that a suspected sinter should be significantly ^{18}O-enriched relative to higher-temperature vein quartz elsewhere in the system. Thus, if the 'sinter' is not enriched, it should be regarded with suspicion. Ideally, the oxygen isotope signature should be used in conjunction with other criteria, but, where field and textural relationships are either lacking or equivocal, isotopic data may be invaluable.

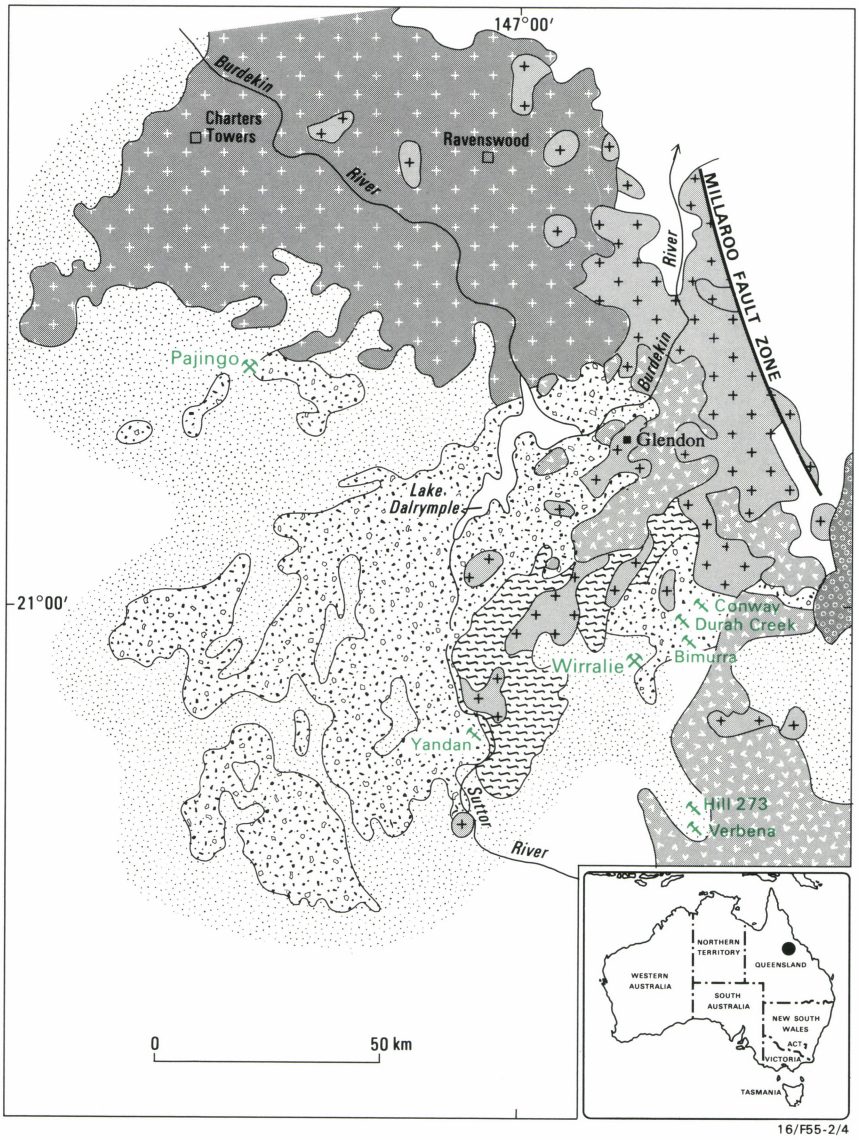


Fig. 2. Epithermal gold mines and prospects in the northeastern Drummond Basin, Qld.

This work is the subject of joint research involving BMR and BHP-Utah Minerals International and is being extended to other known and suspected sinters in areas held by that company. It forms part of an integrated BMR regional and prospect-scale study in the northern Drummond Basin.

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

Plotting spatial data held in an RDBMS

A software package — MAPDAT — has been developed in BMR's Geoscience Computing & Database Branch for plotting spatial data held in a relational database onto any map within the Australian region at any projection and scale. The software plots sample locations with information either beside each point or in a list at the side of the map.

Symbols with size proportional to a specified entity, town locations, survey paths, gridlines, survey areas, coastlines, and other linear geographical features can also be plotted. A system for defining geological structures within the database is included, so that any geological structure can be stored in the database and plotted.

MAPDAT does not compete with geographical information systems but fills a niche at a lower level of complexity. Thus, setting up the data and using the program are very straightforward, and the database operations are visible to the user.

MAPDAT allows geoscientists to store their field data in a standard relational database management system (such as *Oracle* or *Ingres*) and produce highly readable maps containing selected information. Besides producing standard-sized maps that can overlay published maps, photoscale maps can be produced to overlay airphotos.

The program is 'user-friendly'. It presents the user with screen menus, and most variables have default values. Mapping parameter defaults are set according to Australian mapping standard scales and projections, so that the user can produce standard maps without having to be a mapping expert. Also, the defaults can be changed easily. When selecting coastlines, the appropriate resolution is chosen according to the map scale being used. In the 'data-plotting menu' the user pieces together an SQL statement to retrieve the points to be plotted, and then can perform several selections of data and change the symbol type, size, and/or colour between selections to differentiate between data from different selections.

MAPDAT will be demonstrated at the forthcoming BMR Research Symposium, in Canberra (7–9 November). The PRO-FORTRAN code of MAPDAT is well-structured and highly maintainable and is currently being prepared as a saleable product.

For further information contact Mr David Collins at BMR (Geoscience Computing & Database Branch).

Present-day formation waters provide clues to origins of Canning Basin Zn–Pb deposits

The geochemistry of present-day, hypersaline, deep formation waters in the Canning Basin, WA is similar to that of brines from the Mississippi Salt Dome Basin, USA, which are known to be either metal or sulphide-rich. The Canning brines are bitterns which could have been expelled from clays during burial compaction, and mixed either with relatively low-salinity meteoric waters formed by solution of evaporites or with fresh meteoric waters. Palaeofluids trapped as inclusions in ore and contemporaneous gangue minerals in Zn–Pb deposits are 'hot' Ca-rich brines containing mature, oil-like hydrocarbons. Fluids in post-ore calcite veins are 'cooler' and less saline, and are either anomalously high in K and Mg or similar in composition to mixtures of low-salinity waters with the present-day Canning basinal brines. These changes in temperature, salinity, and chemical composition could reflect the expulsion of fluid from increasingly shallow depths within the basin and the mixing of these fluids with differing proportions of low-salinity, near-surface waters at the site of sulphide precipitation.

The Canning Basin, in northwest Western Australia, is a large Phanerozoic intracratonic basin with an onshore area of over 400 000 km^2 (Fig. 3). The northern part of the basin is dominated by the Fitzroy Trough, a major fault-bounded graben containing over 10 km of sediments deposited during several cycles of marine transgression and regression between the Early Ordovician and the Late Cretaceous. Southern areas consist mainly of the Kidson and Willara sub-basins, in which the sedimentary sequence is thinner (up to 5 km) and contains extensive deposits of marine evaporites. Minor petroleum and several Zn–Pb sulphide deposits have been found in Devonian carbonate reef complexes on the northern edge of the Fitzroy Trough, and in early Palaeozoic marine sediments on the northern margin of the Willara Sub-basin. These discoveries are considered as indicative of the basin's high prospectivity for base metals and hydrocarbons.

Both petroleum and Zn–Pb sulphides occur in the same structural units and basinal fluids associated with Zn–Pb mineralisation contain abundant hydrocarbons (Etminan & Hoffmann, 1989: *Geology*, **17**, 19–22). The nature and extent of any cogenetic relationship between oil and base metals has important implications for exploration strategies and is currently a subject of hydrological, geochemical, and petrographic studies in BMR. The results of these studies are being used initially to produce a model describing the origins, chemical evolution, and migration of basinal fluids and their role in the precipitation of Zn–Pb sulphides and the accumulation of petroleum.

The development of this model has involved three stages. Firstly, comparison of the present-day Canning formation waters with those of metal or sulphide-rich fluids from other sedimentary basins; secondly, comparison of the Canning palaeofluids in fluid inclusions with those from other Mississippi Valley-type deposits: and, thirdly, comparison of the poresent-day Canning fluids with the Canning palaeofluids.

Bitterns as ore-forming fluids

The present-day Canning basinal fluids are mainly mixtures of three types of formation water: (1) bitterns formed by evaporation of sea water to various degrees beyond halite saturation, (2) saline meteoric waters formed by dissolution of halite and gypsum/anhydrite evaporites, and (3) low-salinity meteoric waters whose composition is strongly influenced by water–rock interactions. Mixtures of these waters have salinities ranging from typically <5000 mg/L up to 250 000 mg/L locally.

Bitterns are the major component of the more saline waters. The original marine chemical composition was changed to that of an Na–Ca–Cl water when dolomitisation of aquifer marine carbonates added Ca and Sr, and removed Mg and SO_4. Reactions with terrigenous components of the sediments have added small amounts of radiogenic Sr (typical $^{87}Sr/^{86}Sr$ ratios of about 0.712 to 0.713), and resulted in equilibrium between the fluids and Li and Mg-containing phases. Mass balance considerations indicate that the dolomitisation phase was preceded by a decrease in the SO_4 content of the brine, possibly as a result of bacterial sulphate reduction.

The low-salinity meteoric waters are chemically diverse. The evaporite-dominated saline meteoric waters, however, are mainly of the Na–Ca–Cl–SO_4 type and have an unexpectedly restricted range of salinities (average value about 40 0000 g/L) in view of evidence of widespread dissolution of marine evaporites within the basin. Geochemical evidence (Fig. 4) indicates that mixing occurs mainly between the saline meteoric waters and the bitterns or between the saline meteoric waters and the low-salinity meteoric waters; mixing of the bitterns with the low-salinity waters is comparatively rare.

The presence of bitterns in the Canning is particularly significant because geochemically similar fluids occur in the Mississippi Salt Dome Basin and are either metal or sulphide-rich, depending on the organic content of the host sediments. Notably, in the Canning the bitterns have been found at the peripheries of at least two of the three major structural subdivisions (Fitzroy Trough, Willara Sub-basin, and Kidson Sub-basin). The range of formation waters and their mixing products within the Canning is much more limited than that of fluids in the Gulf Coast basins in the USA, which suggests that there are strong hydrologic controls on the production and distribution of the Canning basinal fluids. One indicator of the nature of these hydrologic controls is the salinity distribution of the formation waters within the basin.

Fossil salinity profiles

Salinity data from well logs indicate that regional hydraulic gradients directed northwest across the basin have allowed meteoric waters in present-day groundwater systems to displace the deep saline waters to a limited degree. In areas of relatively high groundwater flow, salinities are either generally low but increase gradually with depth, or change erratically because the groundwaters have selectively affected the more permeable sediments.

In some areas the salinity profile consists of several stacked sub-profiles, some of which correspond to separate marine transgression–regression cycles (Fig. 5). In each profile the salinity fluctuates, but there is an overall increase with depth, which suggests that they either could be 'fossil' profiles representing

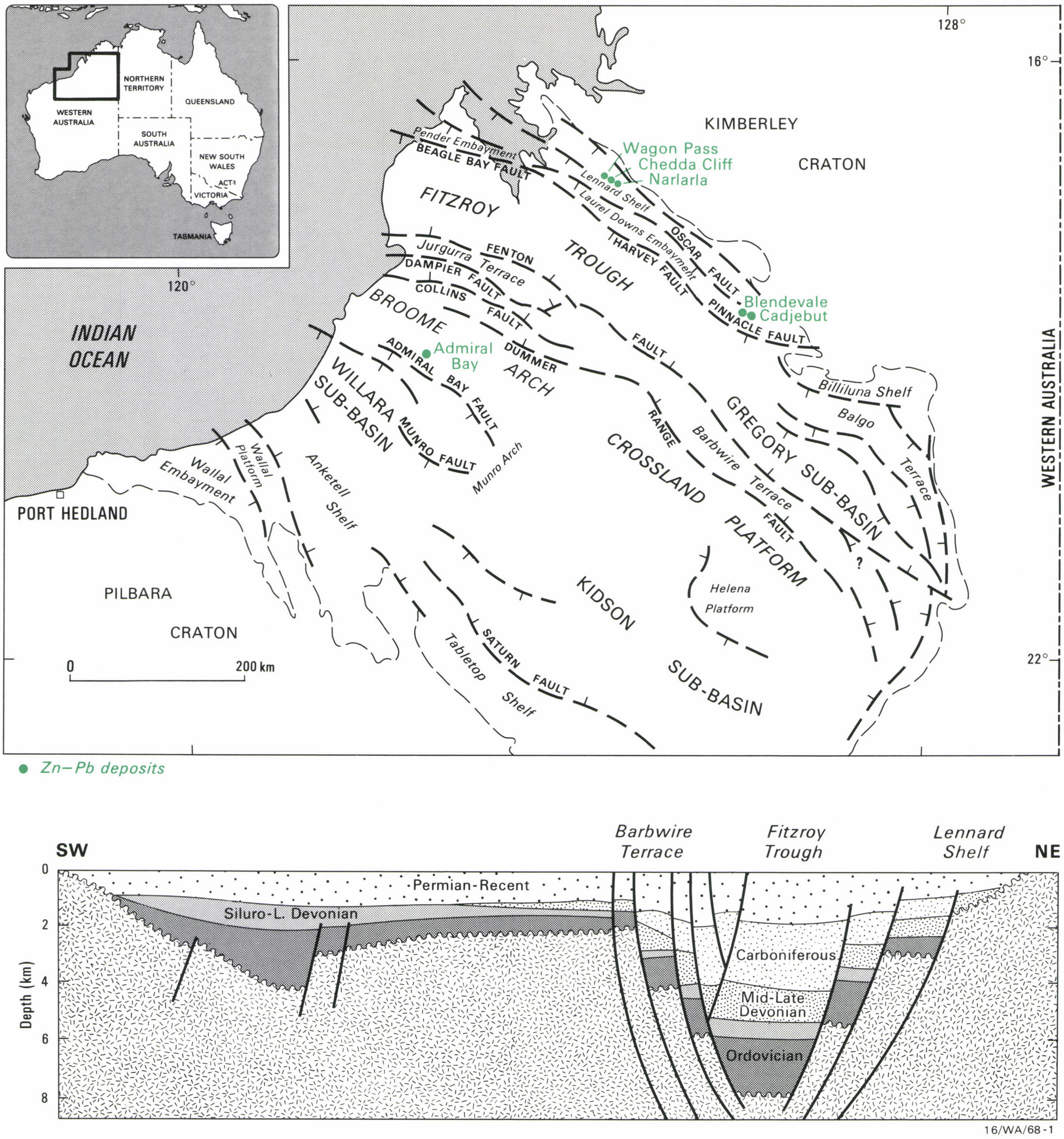


Fig. 3. Location of Zn–Pb prospects and deposits, and main structural units of the Canning Basin with schematic cross-section (adapted from Purcell, P.G. *in* Purcell, P.G. (Editor) — The Canning Basin, WA. *Proceedings of GSA–PESA Symposium, Perth, 1984*). Recent BMR seismic results have confirmed that the Fitzroy Trough is more asymmetric than shown here (see *BMR Research Newsletter* 8, 12).

conditions in the original depositional cycle, or could have formed during burial, as saline waters were squeezed from clays into adjacent sandstones. These profiles could be the physical basis of the geochemical mixing systems, with the bitterns or the saline meteoric waters at the base of the profile. In some areas of the basin, these mixing systems appear able to survive burial to considerable depths. If they became geopressured, and fluids were expelled from progressively higher up the profile, then successive pulses of fluid would become less saline and would increasingly have the geochemical characteristics of a mixed water.

Identification of areas of highly saline waters has been severely limited because salinities can be calculated from well log data only for sandy sediments. Significantly, one measurement indicates that, in the central Canning Basin, terrigenous sands directly overlying granitic basement contain brines with a salinity of about 250 000 mg/L. Conversely, areas of much younger sands (Grant Formation) that directly overlie marine evaporites do not contain highly saline waters despite evidence that deposition of the terrigenous sediments coincided with a major phase of evaporite dissolution during the Permo–Carboniferous. Possibly, sediment permeabilities are high in these areas, which, combined with the regional hydraulic gradients, facilitates the removal of saline waters as they are formed.

'Hot', Ca-rich brines in fluid inclusions

Fluid inclusions representing three phases of the mineralising process (the main phase, the transition phase, and the post-ore phase)

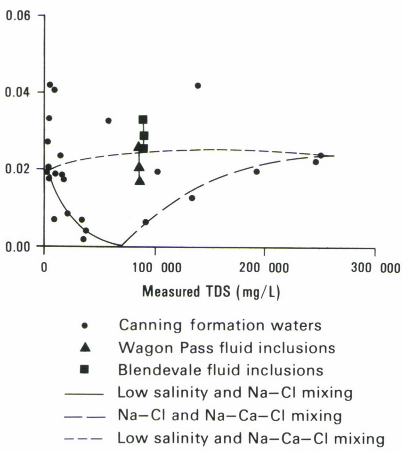


Fig. 4. Geochemical relationships between various types of present-day formation waters and palaeofluids trapped in fluid inclusions in the Canning Basin. Changes in the mK/mNa ratios of the waters with changes in TDS illustrate that most of the present-day waters plot near curves that represent mixing of saline meteoric waters of low mK/mNa ratios with either low-salinity meteoric water or bitterns with considerably higher ratios. In contrast, the palaeofluids in calcites formed during the transition and post-ore phases of mineralisation at Blendevale and Wagon Pass appear to contain significant proportions of low-salinity, possibly near-surface, waters.

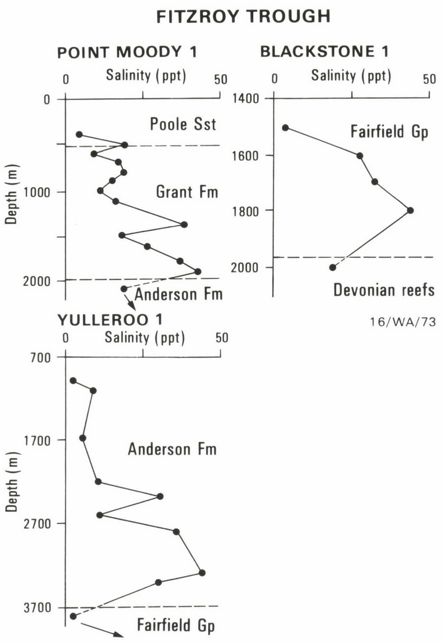


Fig. 5. Changes in salinity with depth as calculated from borehole data for relatively thick sedimentary units within the Fitzroy Trough. Salinities fluctuate but there is an overall increase with depth. The general impression is that of stacking of salinity profiles due to successive marine transgression–regression cycles.

in five Zn–Pb deposits (Cadjebut, Blendevale, Wagon Pass, and Narlarla on the Lennard Shelf, and the deep-seated Admiral Bay deposit on the Broome Arch), have been examined using microthermometry and leachate analysis. Sphalerite, calcite, and barite from the main phase of mineralisation were deposited from brines that were moderately hot (75–110°C), Ca-rich (first melting temperatures –40 to –50°C, and confirmed by laser mass spectrometry), and very saline (>23% equivalent NaCl). During the transition and post-ore phases calcites were precipitated under conditions of progressively decreasing temperature (down to 55–70°C), lower Ca content, and lower salinity (down to 6–11% equivalent NaCl).

Leachate analyses of fluids from the transition and post-ore phases indicate that some of the waters are mixtures of three components that are chemically similar in some respects to those in the present-day formation waters. Other waters have unusually high K and Mg contents. Unlike the present-day waters, the fluid inclusions contain low-salinity waters (Fig. 4), but the other components could be bitterns and saline meteoric waters like those that occur today. The proportion of bittern in the mixture appears to differ between deposits, and there are indications that lower proportions of bittern correspond to lower temperatures and salinities of the fluids. Comparison of the Blendevale and Wagon Pass data indicates a lower proportion of bittern waters at Wagon Pass, which is consistent with microthermometry data showing marginally lower temperatures and salinities. The microthermometry data indicate that the fluids involved in the main ore-forming phase could have included a hot, highly saline bittern.

A hydrological regime consistent with the above geochemical trends involves the interaction of two main processes: (1) mobilisation of progressively cooler and less saline pulses of fluid from increasingly high levels within a buried marine–meteoric mixing system in the basin; and (2) mixing, at the site of sulphide precipitation, of the expelled fluids with low-salinity near-surface groundwaters.

Implications for ore genesis

The Canning Basin formation waters have some of the hydrological and geochemical characteristics incorporated in well-established models of the genesis of Mississippi Valley-style ore deposits. In particular, the sequential expulsion of pulses of fluid from deeply buried sediments and mixing of these basinal fluids with near-surface waters is consistent with the Jackson–Beales model (1967: *Bulletin of Canadian Petroleum Geology*, **15**, 383–433), in which separate sources of metals and sulphide mix at the sites of metal sulphide precipitation, and models in which both the metals and sulphide are transported in the basinal fluids, either together or in separate pulses of fluid.

The Canning data have provided some insight into the origins of the basinal fluids and into the mechanisim that can lead to a sequence of fluid pulses which gradually become cooler, less saline, and simultaneously deposit a paragenetic sequence of minerals. If the involvement of bitterns in the formation of the base-metal-containing fluids proves to be critical, then the identification of these Ca-rich fluids in exploration wells may indicate that potentially ore-forming fluids have been present in that part of the basin.

For further information contact Dr Hashem Etminan or Dr James Ferguson at BMR (Division of Petrology & Geochemistry) or Dr Freidoun Ghassemi at the Centre for Resource & Environmental Studies, ANU.

Geoscience Mapping Towards the 21st Century

1989 BMR Research Symposium, 7–9 November, Canberra

This year's symposium will be an examination of the mechanisms, issues, and technologies involved in providing appropriate Australian geoscience maps and databases for exploration and resource management and for a range of land-use issues during the next decade and into the twenty-first century. Participants will have the opportunity to review and comment on recent developments in the direction of Government geoscience mapping, research, and technologies.

The symposium will include presentation of recent BMR and State geological survey products in mapping and databases.

A workshop preceding the symposium proper, on new-technology maps including Geographic Information Systems (GIS), and an associated trade fair during the symposium will provide opportunities to demonstrate the range of available technologies and their products.

Important components of the Symposium will be **poster sessions**, and **demonstrations of databases and software** (see below).

This year the BMR Research Symposium will be held at the new **NATIONAL CONVENTION CENTRE in Constitution Avenue, Reid (Civic)**.

Registration fees are: Symposium only, $325; Workshop only, $120; Symposium & Workshop, $380. Fees for the Symposium cover the cost of Abstracts of all papers, final program, list of participants, the icebreaker function, the dinner, lunches, and morning and afternoon teas. Fees for the Workshop cover the cost of papers, lunch, and morning and afternoon teas.

Australian Convention & Travel Services (ACTS) is the secretariat for the Symposium & Workshop. Registration enquiries should be directed to: **BMR Research Symposium, ACTS, tel. (062) 496440, fax (062) 573256**.

Program

DAY 1: TUESDAY 7 NOVEMBER: WORKSHOP
A one-day workshop on geoscience applications of Geographic Information Systems (GIS) technology, to be organised by the National Resource Information Centre (NRIC).

GIS technology is being used increasingly in mineral and petroleum exploration and geoscience research. The workshop will provide an opportunity for geoscientists in these areas to update themselves on current technology and applications.

The workshop will be led by **David Johnson, Ian Musto (NRIC), and David Stewart (USGS)** and will comprise presentations and demonstrations by NRIC staff and overseas and Australian specialists. The workshop will cover:

- current GIS technology
- principles of GIS in geoscience information handling
- the North American experience
- Australian case studies
- future trends

Evening icebreaker function 6 p.m. Symposium participants are encouraged to arrive on this evening so as to be in attendance for a 9.00 a.m. start on the following day.

DAY 2: WEDNESDAY 8 NOVEMBER: SYMPOSIUM

9.00 — Official opening by the Minister for Resources, *Senator Peter Cook*.

9.15 — KEYNOTE SESSION: GEOSCIENCE MAPPING IN THE NINETIES
General plenary session of forward-looking, scientific papers likely to have wide appeal to symposium participants from both the minerals and petroleum sides of the program.
- New directions for Australian geoscience maps and databases — an introduction: *Dr Peter Cook, BMR*
- Mineral exploration industry's needs — the challenge: *Mr Neil Herriman, CRA Exploration*
- Petroleum exploration industry's needs — the challenge: *Dr John Armstrong, SANTOS*
- Complementary interests — the environment and alternative land-use issues: groundwater, geological hazards, National Parks, agricultural land, etc: *Prof. Henry Nix, CRES*
- Remote sensing: current capabilities and limitations: *Mr Colin Simpson, BMR*
- Three-dimensional GIS: a new technology for integrated geoscience mapping: *Dr David Stewart, USGS*

12.30 — LUNCH

2.00 — SEDIMENTARY BASINS SESSION: MAPPING FOR PETROLEUM & WATER RESOURCES (oral presentations)
- Subsurface basin mapping with sequence stratigraphy: keynote speaker *Dr Colin Summerhayes, Institute of Oceanographic Sciences, UK*
- Mapping of the Australian continental margin: the U.N. Convention on the Law of the Sea and its resource implications: *Mr Phillip Symonds & Mr Barry Willcox, BMR*
- High resolution side-scan imagery and swath bathymetry: *Dr Donald Hussong, Seafloor Surveys International*
- Geochemical mapping of the seafloor and water column in the Bass Strait region: *Dr David Heggie & Dr Geoff O'Brien, BMR*

- — Concepts of paleogeographic maps and their applications in resource exploration: *Dr Marita Bradshaw & others, BMR*
- — Tectonic and structural evolution of the Amadeus Basin — map folio and overview of a major basin project: *Dr John Lindsay, BMR*
- — Subsurface maps and a geochemical approach to hydrocarbon prospect evaluation in the Clarence–Moreton Basin: *Dr Phil O'Brien & others, BMR*
- — Murray Basin hydrogeology: *Mr Ray Evans & others, BMR*

DAY 3: THURSDAY 9 NOVEMBER: SYMPOSIUM

8.30 — MINERAL PROVINCE SESSION: MAPPING FOR MINERAL RESOURCES & LAND MANAGEMENT (oral presentations)

- — Map integration and geophysical imaging: *Mr Frank Arnott, Stockdale*
- — Integrated geophysical/geological mapping and interpretation: case histories from the Charters Towers region and elsewhere: *Dr Steve Webster, AUSTIREX, & Dr Doone Wyborn, BMR*
- — Image processing for geoscience: *Dr Kerry O'Sullivan, CRA*
- — Future remote-sensing directions and their geoscience potential: *Dr John Huntington, CSIRO*
- — Geoscience mapping as a prelude to mineral resource assessment of the Kakadu Conservation Zone — a new approach to data presentation: *Dr Lesley Wyborn & others, BMR*
- — Geological maps of Indonesia: BMR mapping for geoscience aid: *Mr David Trail & others, Indonesia–Australia Geological Mapping Project*
- — Geoscience mapping in north Queensland: preliminary results and future direction: *speaker representing GSQ & BMR*
- — Geoscience mapping in the Eastern Goldfields of WA: *speaker from GSWA, Dr Peter Williams, & Mr Alan Whitaker, BMR*
- — Regolith terrain maps: *Ms Roslyn Chan, BMR*
- — The National Resource information Centre (NRIC) — its role in geoscience mapping and database development: *Dr David Johnson, NRIC/BMR.*

12.30 — LUNCH

2.00 — GENERAL SESSION & FORUM: TOWARDS A NATIONAL MAPPING STRATEGY

- — A National Geologic Mapping Strategy — the USA experience: *Dr Mitchell Reynolds, USGS*
- — Future directions for BMR geoscience mapping: the National Geoscience Mapping Accord: *Professor Roye Rutland, BMR*
- — The National Geoscience Mapping Accord — State perspectives: *speaker representing the Chief Government Geologists' Conference*
- — Panel discussion and open forum

4.00

Close (transport to airport provided)

POSTER SESSIONS, AND DATABASE AND SOFTWARE DEMONSTRATIONS

(BMR presenters unless stated)

Posters and Trade exhibits will be displayed in the Exhibition Hall during the full two days of the Symposium. Poster authors will be alongside their posters for a brief presentation and to answer questions at the times indicated on the program. Posters of particular interest to the minerals industry will be featured on Wednesday afternoon, and those of particular interest to the petroleum industry on Thursday morning. Database demonstrations will proceed on demand.

MINERAL PROVINCE POSTERS

- — Developments in CAD/CAM and database applications in the groundwater field: *Mr Steve Holliday & Mr Richard Cooper*
- — Australian groundwater maps: *Mr Ray Evans & others*
- — Current and future computer-aided drafting in BMR — Intergraph: *Mr John Hillier & Mr Steve Holliday*
- — Australian Geomagnetic Reference Field — models and charts: *Dr Charles Barton, Dr Prame Chopra, & Dr Phil McFadden*
- — Mapping earthquake risk: *Dr Marion Leiba*
- — Airborne geophysical mapping of Australia: *Mr Ian Hone, Mr Ken Horsfall, Mr Brian Minty, & Mr Vadim Anfiloff*
- — Regional geophysical interpretation of Australia by BMR: *Dr Peter Wellman & Mr Alan Whitaker*
- — Environmental mapping of coastal zones: *Dr Antonio Belperio (SADME) & Dr Robert Burne*
- — New international Precambrian time scale for geological mapping: *Mr Ken Plumb*
- — National and international maps: BMR's contribution: *Mr David Palfreyman*
- — Invited GSWA poster
- — Invited GSNT poster
- — Invited SADME poster
- — Invited GSV poster
- — Invited GSNSW poster
- — Invited GSQ poster
- — Invited GST poster
- — Computerised land information: a new foundation for Geoscience maps: *AUSLIG*
- — Geological mapping of the Mount Isa region: *Dr David Blake & Dr Alastair Stewart*
- — Permian coals and basins of eastern Australia: *Dr Larry Harrington*

SEDIMENTARY BASIN POSTERS

- — South Perth Basin regional basin study: *Mr John Marshall & others*
- — Palaeogeography of the Exmouth Plateau and its implications for the North West Shelf: *Dr Neville Exon & others*
- — Computer-assisted palaeogeographic reconstructions: *Mr Malcolm Ross*
- — LANDMARK mapping of the northeast Australian ODP drilling sites: *Dr David Feary & others*
- — Offshore Resource Map Series — first systematic maps of the Australian continental margin: *Dr Hugh Davies & others*
- — Northern Perth Basin — maps and prospects: *Mr Aidan Moore & others*
- — Cretaceous seismic facies of the central Exmouth Plateau: *Dr Ron Boyd*
- — SeaMARC mapping of the Manus and Woodlark basins, Papua New Guinea: *Dr Keith Crook*
- — Heatflow studies of the Australian margin: *Mr Mike Swift*
- — Magnetic maps of the Southern Ocean: *Mr Peter Hill*
- — Chronology of the Australian Phanerozoic, or towards an Australian time scale — new biochronological charts for geological mapping: *Dr Elizabeth Truswell & others*
- — Cambrian sequence analysis from outcrops, well logs, and seismic, Amadeus Basin — new data on basin history related to petroleum: *Dr John Kennard*
- — Cambrian sequence analysis from outcrops and seismic, Georgina Basin — oil and phosphate implications: *Dr Peter Southgate & Dr John Shergold*
- — Tectonics and structure of the Canning Basin — new deep seismic and its initial interpretation: *Dr Barry Drummond & others*
- — Australia's southern margin — petroleum potential and relationship to margin formation: *Mr Barry Willcox & others*
- — Mapping of the Australian continental margin: the U.N. Convention on the Law of the Sea and its resource implications: *Mr Phillip Symonds & Mr Barry Willcox*
- — Eromanga–Brisbane geoscience transect: a guide to crustal development across Phanerozoic Australia in southern Queensland: *Dr Doug Finlayson & others*

DEMONSTRATIONS

- — MINDEP — BMR's bold database: *Mr Brian Elliott*
- — PETCHEM — BMR's rock-geochemistry database: *Dr Rod Ryburn & Dr Lesley Wyborn*
- — GDA — Geochemical data analysis software: *Dr John Sheraton & Dr Doone Wyborn*
- — MDA — Mineral data analysis software: *Dr Lynton Jaques*
- — STRUCTURE — BMR's structural geology database: *Dr Peter Williams & others*
- — MAPDAT — A user-friendly geographic plotting system for Oracle databases: *Mr David Collins*
- — PEDIN — An *Oracle* database of petroleum exploration and development well data referenced to geophysical survey data: *Ms Sandy Radke*
- — AGRF — Australian Geomagnetic Reference Field: *Dr Phil McFadden*

The airship and the earth scientist

Airships Pacific Pty Ltd, of Sydney (a division of the Australian-controlled Airship Industries of Belfast), approached BMR in 1988 to offer the use of an airship for geoscientific tests. BMR scientists considered that the airship's capabilities could be tested for EM, gravity, radiometric, inverse radar, and magnetic surveys, and for slow and detailed airborne observation ('eye-balling') of geological features; the airship could be tested over land for small-scale and large-scale surveys, and also at sea in two different environments, one over the inner and outer continental shelf, and the other over regions far out to sea, such as the Lord Howe Rise. Staff from Monash University and the Australian National University were invited to participate in the tests.

The airship available, an AD 600 model, was one of the earliest made, and one of the smallest. The envelope is 60 m long, 15 m wide, and provides a total lift of about 6 tonnes and a payload of 800 kg, decreasing with altitude and decreasing also on hotter days. The craft has a cruising speed of around 35 knots, and can hover indefinitely. The gondola is spacious (large enough for 15 seated passengers) with plenty of room for geophysical instruments, scientists, and work-tables. Large windows provide excellent visibility and can be removed easily for photography and for deployment of instruments, which can also be lowered through the floor. An electricity supply is available on board. The navigation and altimetry devices on board are not sufficient for detailed geophysics, but GPS and radar altimetry can be fitted.

The first test flight in mid-February 1989 was also a routine transfer of the aircraft from Sydney to Melbourne, and was used to test 'eye-balling' and to make measurements with an accelerometer. For 'eye-balling', the airship proved to be a perfect platform. It could fly at any altitude between 50 and 600 m, could hover instantly, and could drift backwards or sideways. The observers had plenty of time to compare and discuss their observations and to mark them on maps, and they were freed from the slight nausea and disorientation sometimes felt during the banking and tight turning of fixed-wing aircraft and helicopters. Time was spent examining the surface effects of recent earthquakes near Picton south of Sydney and Gunning north of Canberra.

A BMR accelerometer was used by Dr Bob Musgrave (Geology Department, ANU) as a preliminary to testing a gravity meter when one becomes available. Gravity meters, suitably mounted, are used in ships, and the accelerometer was used to test how the 'porpoising' of the airship compares with that of a marine research ship in 'normal' operating conditions.

The test flight from Sydney was made over varied terrain, including 15 km over water along Burrinjuck Reservoir, on a hot summer day. The day in fact was almost a 'worst possible scenario' with temperatures of 37°C, numerous severe thermals and thunderheads, and two weather fronts. The accelerometer measurements showed that over hot dry land the porpoising was no greater than that of a ship in normal service, and over water was negligible. The pilots commented that over the sea the airship is also very stable because the winds are laminar. Even over land the airship was easily held nearly stationary for 40 minutes above a road intersection near Wangaratta, while facing a wind of 40 knots. Stability is better in winter and at night when thermals are absent. A detailed report on this testing by accelerometer has been prepared by Dr Musgrave.

A suitably-mounted gravimeter has been located in a University in the United States and an attempt is being made by ANU staff to obtain it for testing over land and over the continental shelf later in 1989. A cryogenic gravity gradiometer that is being developed in the University of Western Australia could be improved and might be available for testing late in 1989, onshore and offshore.

It was apparent from the beginning of the tests that the airship could provide an ideal platform for EM surveys, especially time-domain (TDEM). In May 1989 Dr Jim Cull of Monash University made an airship-borne test of SIROTEM over a known major conductive body associated with greenstones in northern Victoria. He regards the results as a great success and further tests are to be made over other known orebodies. Dr Cull has given an account of this work in a paper submitted for publication.

Cost will be crucial in the use of airships for regional surveys and exploration. An airship costs more to run per hour than other types of aircraft, but it has the capacity to do surveys of several types in the one flight. These preliminary scientific tests have been successful, and BMR will test a gravity meter and a gradiometer if they become available.

For further information contact Dr Larry Harrington or Dr Barry Drummond at BMR (Division of Petrology & Geochemistry).

Abolition of the Resource Assessment Division and the transfer of functions

The Woods Review of BMR recommended that the Resource Assessment Division (RAD) be abolished and that BMR's industry-related studies, including minerals statistical functions and support for regulatory-type activities, be subject to 'a rearrangement of functional responsibilities and establishment of appropriate linkages' within the Department as a whole.

Following the Government's acceptance of these recommendations, the RAD has been abolished and various functions have been rearranged within the Department (DPIE), as follows:

Transfer of BMR functions to ABARE

BMR's minerals statistical functions and some commodity specialist functions have been transferred to the Australian Bureau of Agricultural & Resource Economics (ABARE).

BMR retains responsibility for the potential-resources function (which includes regional geology, mineral provinces, deposit characteristics and models, and resource probability), **and studies relating to the discovery of resources** (e.g. new discoveries, exploration activity and priorities, and rate of discovery of resources).

ABARE has responsibility for macroeconomic studies (which includes work on economic outlook, industry structure, industry competitiveness, price formation, and investment in the mineral industry) **and for microeconomic studies** (such as supply/demand balance and forecasts, commodity uses and substitution, mineral processing and value added, and industry costs).

Both BMR and ABARE will be involved in studies relating to identified resources. BMR has responsibility for work on ore control and genesis, and on geological characteristics and recoverable resources of known deposits. Both bureaus may be involved in work on mining and processing methods, minimum economic deposits size and production capability from known deposits, and on future availability of resources. The contribution that each bureau makes to joint studies will depend on the nature of the study.

Following agreement on functions, 11 positions were transferred from BMR to ABARE, and in early June several members of the Mineral Commodities Branch moved to ABARE — four members of the Statistics Group and two commodity specialists. Also the Australian Bureau of Statistics officer outposted to BMR returned to ABS. The remaining six commodity specialists transferred to the Mineral Projects Evaluation Branch as the **Identified Resources Section**, and the Branch, which remained under the charge of Mr G. Battey, was renamed the **Minerals Resource Assessment Branch**. The Mineral Commodities Branch, along with the Resources Assessment Division of which it had been part, ceased to exist.

The Identified Resources Section will be the focus in BMR for work on identified mineral resources. It will assess and monitor Australia's known mineral resources, and will contribute to regional studies and mineral-potential studies for land use decisions. It is giving a high priority to putting data into the mineral deposits database, MINDEP, to facilitate its work.

The transfer of the mineral statistics function to ABARE means that BMR will no longer prepare and issue statistical publications and the *Australian Mineral Industry Annual Review*. The transfer also marked the end of over 40 years of work in this field by BMR. One of the first tasks of BMR's first Mineral Economist, Dr J.A. Dunn, in 1948, was to try to bring some uniformity to the statistics compiled and published by the several State mines departments. To co-ordinate the mineral statistics work of BMR with its own, ABS's predecessor, the Commonwealth Bureau of Census & Statistics, outposted one of its staff to BMR. This, their first outposting to another Commonwealth department, continued for nearly 40 years.

BMR is grateful for the co-operation it has received from ABS, State, and Territory mines departments, and industry in providing statistical data over the last 40 years. It could not have compiled and published comprehensive statistics on mineral commodities without this help.

The contact in ABARE for enquiries about mineral statistics is Mr Ian Haine, Economic Statistics Section. Telephone (062) 469 630.

Secondment of BMR staff to Petroleum Division of DPIE

Two professional officers (a petroleum geoscientist and a petroleum engineer) are being seconded from BMR to DPIE's Petroleum Division on a rotational basis for periods of twelve months in order to provide on-the-spot scientific and technical advice to the policy areas of the Department, and to provide more effective liaison with BMR. As a consequence, two BMR officers are currently working within Petroleum Division. The secondment arrangements are subject to review by BMR and Petroleum Division after six months.

World graphite resources report

BMR staff have compiled Australian data for a report on world natural graphite resources published recently by the United States Geological Survey (USGS Circular 930-H). The report, *International Strategic Minerals Inventory Summary Report — Graphite*, was prepared as a cooperative effort by BMR and counterpart agencies in Canada, Federal Republic of Germany, South Africa, the United Kingdom, and the United States.

Graphite occurs in metamorphic environments, in either 'crystalline' ('flake', or 'lump') or 'amorphous' form. It has properties, such as chemical inertness, low thermal expansion, and lubricity, that make it almost irreplaceable in certain applications. It is used in refractories, foundries, brake linings, lubricants, steelmaking crucibles, batteries, pencils, and other carbon products.

The report estimates that the world's identified economic resources of crystalline graphite are equivalent to 9.7 Mt of concentrate; in addition to this, in-situ economic resources of amorphous graphite total 11.5 Mt. Less than 2% of the crystalline ore and less than 1% of the amorphous ore is in Western industrialised countries. World mine output of both forms in 1986 was over 600 000 t, two-thirds of which was produced by centrally-planned-economy countries.

Australia's known resources of graphite are relatively very small (13 000 t economic, 63 000 t subeconomic); total output has amounted to only 6000 t, and the last production (61 t) was in 1963 from Collinsville, Qld. Imports of graphite in 1987 amounted to 3850 t, valued at $4.7 million.

The summary report on graphite is the eighth of an International Strategic Minerals Inventory (ISMI) project to compile non-confidential data on major deposits of strategic minerals, as a reliable basis for resource analysis and policy formulation. Earlier reports have covered manganese, chromium, phosphate, nickel, platinum-group metals, cobalt, and titanium. Copies of the graphite report can be obtained from BMR's Mineral Assessment Branch (Mr Ian McLeod, telephone (062) 499553).

New study completed on Bonaparte Basin petroleum accumulations

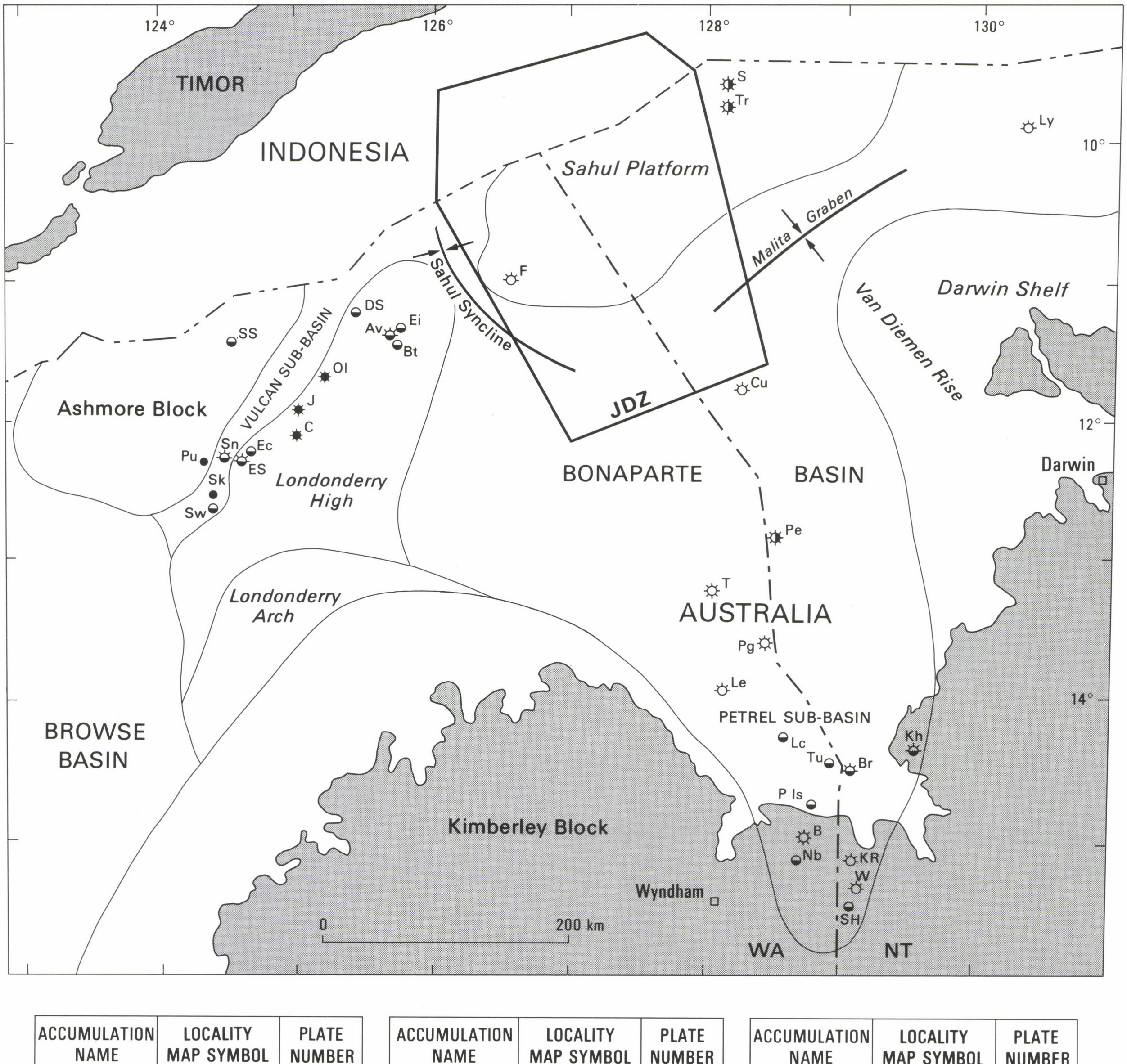
The 33 known petroleum accumulations in the Bonaparte Basin (WA & NT), currently Australia's most active area for petroleum exploration, are the focus of a study recently completed by the Reservoir Geology and Regional Assessment groups of BMR's Petroleum Branch. The study is summarised in *Australian Petroleum Accumulations Report 5* which was published in August and is available from BMR Publications Sales, price $39.95.

The report summarises all available data on the character, occurrence, location, and specific features of all significant petroleum accumulations in the basin, comprising two economic, nine subeconomic, and 22 unecomonic accumulations identified by petroleum exploration drilling up until 30 June 1988 (Fig. 6).

The most commercially significant petroleum resources are the Jabiru and Challis oil fields which were discovered in 1983 and 1984 by drilling on the western flank of the Londonderry High. Jabiru was developed in 1986 by means of an innovative floating production facility — a converted tanker (*Jabiru Venture*), moored at the wellhead. The Challis field is currently the subject of a development appraisal study which proposes to use a major floating facility based on a purpose-designed barge.

The data available on these and all other petroleum accumulations in the Bonaparte Basin are outlined in the report in the context of the basin's geological setting, structural elements, and the type of petroleum traps, as well as the reservoir and source rock sequences (Fig. 7).

Fig. 6. Locations of petroleum accumulations in the Bonaparte Basin together with major structural elements and relevant report plate numbers which show details of each accumulation. JDZ: Joint Development Zone, as proposed between Australia and Indonesia, September 1988.



ACCUMULATION NAME	LOCALITY MAP SYMBOL	PLATE NUMBER
Avocet	Av	2
Barita	Bt	4
Barnett	Br	3
Bonaparte	B	2
Challis	C	1
Curlew	Cu	4
Dillon Shoals	DS	4
East Swan	ES	3
Eclipse	Ec	4
Eider	Ei	2
Flamingo	F	2

ACCUMULATION NAME	LOCALITY MAP SYMBOL	PLATE NUMBER
Jabiru	J	1
Keep River	KR	2
Kulshill	Kh	2
Lacrosse	Lc	3
Lesueur	Le	3
Lynedoch	Ly	4
Ningbing	Nb	4
Oliver	Ol	4
Pelican Island	P Is	3
Penguin	Pg	2
Petrel	Pe	1

ACCUMULATION NAME	LOCALITY MAP SYMBOL	PLATE NUMBER
Puffin	Pu	1
Sahul Shoals	SS	4
Skua	Sk	1
Spirit Hill	SH	4
Sunrise	S	1
Swan	Sn	3
Swift	Sw	4
Tern	T	1
Troubadour	Tr	1
Turtle	Tu	3
Weaber	W	4

● *Oil* ☼ *Gas* ✸ *Oil/Gas* ◒ *Oil show* ☼ *Gas show* ◒ *Oil/Gas show* ✸ *Gas/Condensate*

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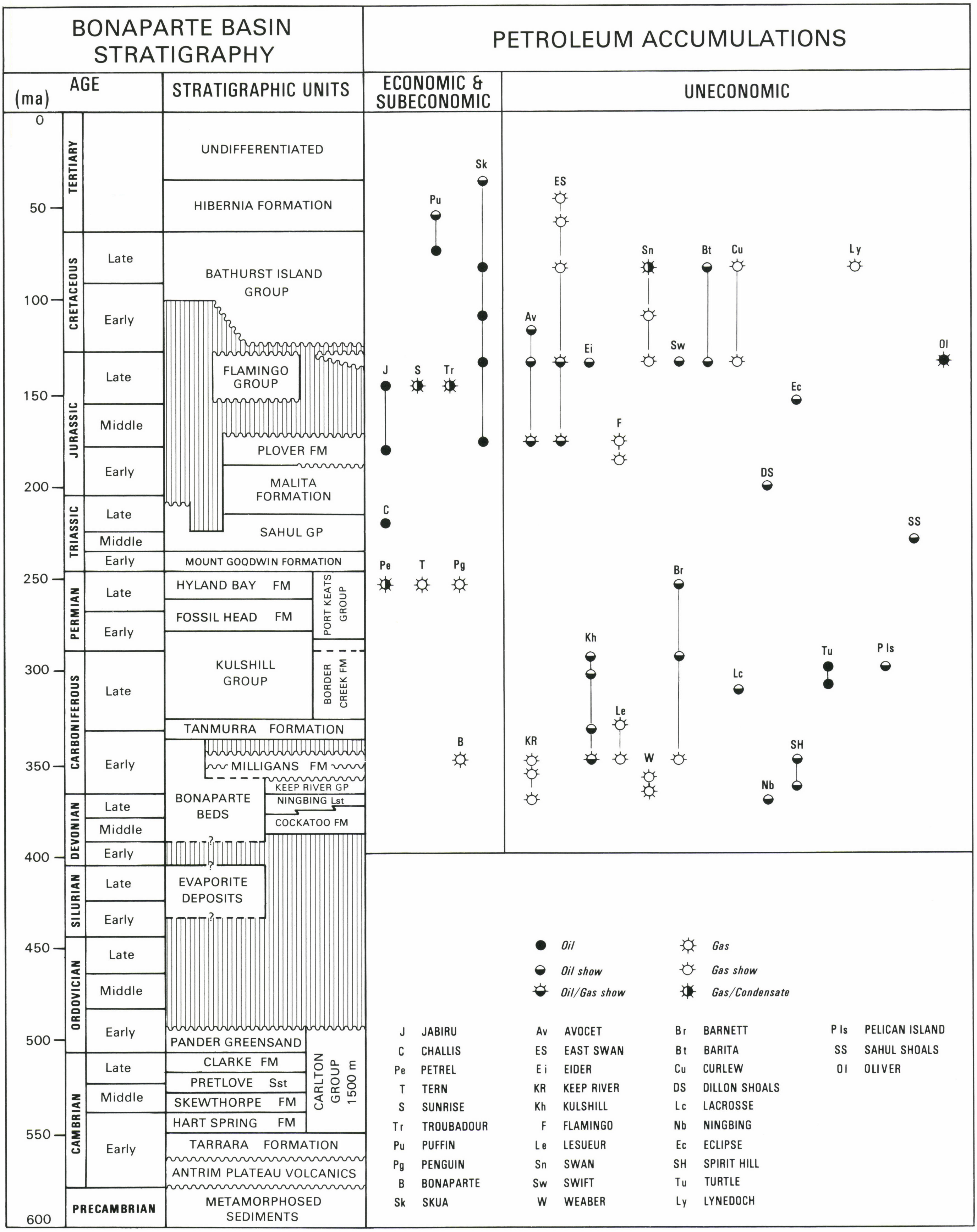


12/55-6

Fig. 7. Stratigraphic framework of the Bonaparte Basin sequence and petroleum accumulations.

The report is a major product of the work undertaken in recent years by the Petroleum Branch in compiling strategic information on all identified petroleum resources in Australia's sedimentary basins, and, together with the other reports in this series, stands as a tribute to the late Dr Stan Ozimic, the originator of the series, who died last June. The report is essentially a framework study, which BMR is uniquely able to undertake via its access to all technical information from offshore exploration and previous petroleum subsidy operations.

The Bonaparte Basin study was compiled with the cooperation of petroleum exploration operators, Northern Territory and Western Australian Departments of Mines, and BMR data sources, including the BMR Petroleum Exploration Database Index (PEDIN).

Previous reports in the series have covered the Amadeus, Bass, Gippsland, and Adavale basins.

For further information, contact Dr Ian Lavering at BMR (Reservoir Geology Section, Petroleum Branch).

Regional seismic profiling provides new information on tectonic evolution and possible petroleum plays in the Amadeus Basin, central Australia

Regional reflection seismic profiling in central Australia in 1985 has imaged deep structures and crustal-scale faulting in basement rocks below and adjacent to the Amadeus Basin, and has provided new information on the deformation of the sedimentary cover in areas where industry seismic coverage is sparse. The seismic section across the Missionary Plain in the northern part of the Amadeus Basin shows a gently northerly-dipping autochthonous sedimentary section which is about 8.5 km and 10.0 km thick respectively at the Gardiner Thrust and MacDonnell Homocline (the regional monoclinal flexure at the northern margin of the Amadeus Basin) (Fig. 8). The seismic profile across the platform area of the Amadeus Basin south of the Gardiner Thrust, where the exploration industry has recorded little seismic reflection data, suggests that the surface exposures there are allochthonous, and indicates repetition of the Late Proterozoic to Early Cambrian sedimentary sequence. The northerly-directed thrusting was 'thin-skinned', with Proterozoic salt deposits localising the detachment zone, and occurred during the Alice Springs Orogeny (400–300 Ma). In the Tempe Downs area there could be hidden petroleum plays in the Middle Cambrian sandstones that are facies equivalents of the Arumbera Sandstone, which is a known gas reservoir in the Dingo gas field to the east of the seismic profile.

The Amadeus Basin is a large intracratonic basin, approximately 800 km by 300 km. Sedimentation commenced in the Late Proterozoic, shortly after 900 Ma, and ended in the Late Devonian or Early Carboniferous as a result of the compressive Alice Springs Orogeny. The basin has been deformed by at least two separate compressive orogenies, but the Alice Springs Orogeny is the most important for generating possible petroleum traps. The basin contains two commercial petroleum fields: the Mereenie oil & gas field, and the Palm Valley gas field. The Dingo gas field east of Palm Valley has not been commercially developed.

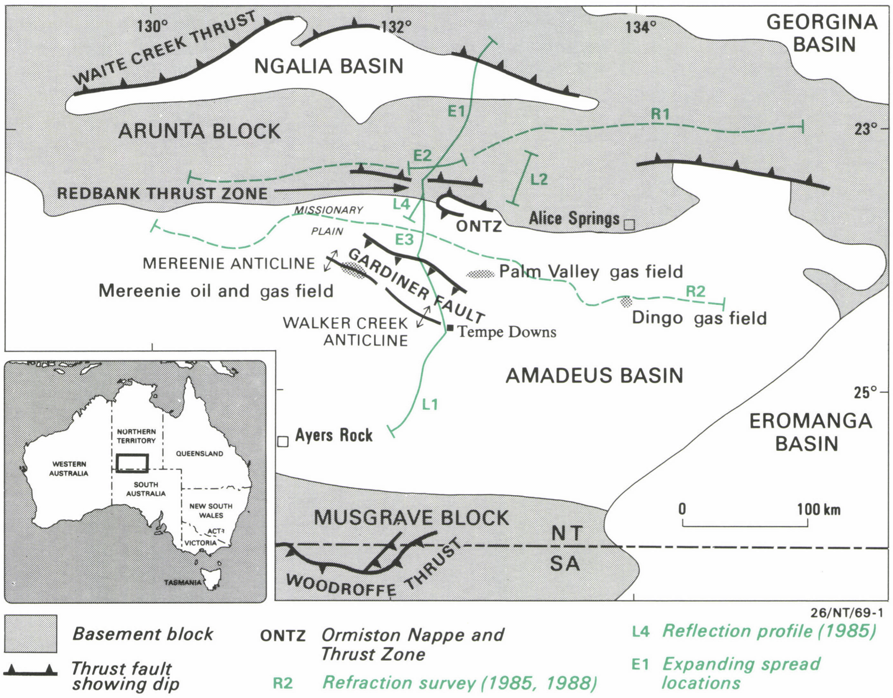
Missionary Plain seismic data

North of the Gardiner Thrust, beneath the Missionary Plain, no evidence of major thrusting has been observed in industry seismic data (Schroder & Gorter, 1984: *APEA Journal*, **24**, 19–41; Lindsay & Korsch, in prep.: in *BMR Bulletin* **236**) or in the present regional seismic profile (Shaw & others, in prep.: in *BMR Bulletin* **236**). Although this part of the regional seismic profile is important in understanding the structure of the underlying basement, it provides few new results on the structure of the sedimentary succession of the northern Amadeus Basin; most new information comes from the region south of the Gardiner Thrust. However, as part of the BMR seismic profiling, an expanding reflection spread was recorded in the southern part of the Missionary Plain (E3, Fig. 8) (maximum shot-receiver offsets of 25 km) that has enabled seismic velocity variations throughout the sedimentary succession to be measured with much greater accuracy than is normally possible from industry seismic data; these results assist refined stratigraphic interpretations by allowing more accurate estimates of formation thicknesses (Wright & others, in prep.: in *BMR Bulletin* **236**).

Seismic section from Gardiner Thrust to Tempe Downs

The BMR regional seismic data clearly show the Gardiner Thrust dipping to the south (Fig. 9). Southwards, the Bitter Springs Formation can be traced to the flat of the thrust at about 2.3 s (about 6 km). However, 12 km to the north, both the industry seismic data from the Missionary Plain (Lindsay & Korsch, in

Fig. 8. Setting of the Amadeus Basin, NT, showing location of the 1985 BMR deep seismic reflection lines ('E1', etc.), long-range seismic refraction profiles (1985 and 1988), oil and gas fields, and important structural features. 'L1' denotes the main regional north-south profile.



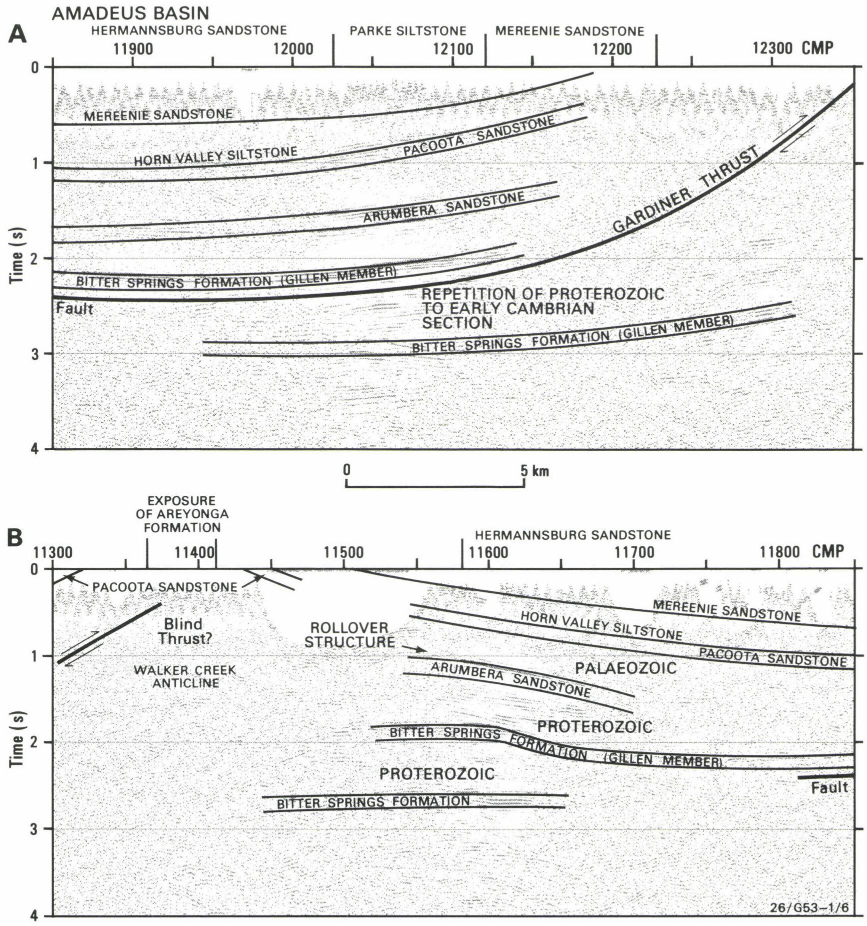


Fig. 9. Unmigrated seismic sections (looking west) south of the Gardiner Range, Amadeus Basin. A: northern section just south of the Gardiner Range, showing the Gardiner Thrust dipping to the south and repetition of the succession. B: section near Tempe Downs, showing the Walker Creek Anticline and the complicated (backthrust?) structure 6–7 km to the north.

press: *Basin Research*), and the BMR regional seismic line, map the Bitter Springs Formation at about 3 s (about 7.8 km depth). This formation projects onto the seismic line south of the Gardiner Range beneath the Bitter Springs Formation sitting on the flat. There is therefore a repetition of about 1.8 km of the Proterozoic to Early Cambrian succession between the salt horizon in the Bitter Springs Formation and the stratigraphically higher salt horizon in the Cambrian Chandler Formation (Shaw & others, in prep.: in *BMR Bulletin* **236**). Although this type of structure is of interest to petroleum explorationists, in this particular area the source rocks are probably overmature.

In the Tempe Downs area, the BMR seismic line (Fig. 8) crosses the eastern end of the Walker Creek Anticline (the eastern extension of the Mereenie Anticline). Here the Late Proterozoic–Palaeozoic succession, including the Ordovician source and reservoir rocks at the Mereenie field, has been eroded, leaving the Areyonga Formation, which is immediately above the Bitter Springs Formation, exposed at the surface (Fig. 9). The repetition of the Proterozoic and Early Cambrian part of the basin succession implies that the Arumbera Sandstone is present beneath the Proterozoic rocks exposed in the core of the Walker Creek Anticline.

There is a complicated structure some 6–7 km north of where the seismic line crosses the Walker Creek Anticline (Fig. 8). Surface mapping has located exposures entirely of Devonian Hermannsburg Sandstone and thus has not detected this structure. In the subsurface there is a small rollover structure below the Pacoota Sandstone (the reservoir at Mereenie) that extends to the Arumbera Sandstone facies equivalents at about 1 s (2.5 km depth). Because this is the only seismic line that crosses the structure, it is uncertain whether there is closure to the northwest and southeast. Interpretation of this structure is difficult because its southern side merges with steep dips in the Walker Creek Anticline.

The BMR regional seismic line has thus identified a structure near Tempe Downs that may be of interest to the petroleum industry.

Southern end of the BMR regional seismic line

The southern part of the BMR seismic line suggests complex faulting and folding of the basin succession, since there are only short sections where structures are clearly imaged. Furthermore, several tight anticlines mapped on the surface indicate the presence of structures that are not easy to map by the seismic reflection method. Strong reflections from within the basement have been imaged in this part of the basin (Goleby & others, 1988: *Australian Journal of Earth Sciences*, **35**, 275–294; Wright & others, in prep.: in *BMR Bulletin* **236**), showing that abundant seismic energy propagates through the sedimentary succession. The diffuse seismic images indicate features related to a north-directed overthrust system with several blind to emergent thrusts that branch off a main subhorizontal thrust. A low-angle planar feature, interpreted as a thrust, is imaged within basement to depths of at least 18 km (Wright & others, in prep.: in *BMR Bulletin* **236**), but its relationship to the 'thin-skinned' deformation associated with the Alice Springs Orogeny is unclear.

Tectonic implications

The Gardiner Thrust is interpreted as having a ramp-and-flat geometry, which differs from some earlier interpretations. The seismic sections show that strata exposed south of the Gardiner Thrust are allochthonous, having been transported at least 35 km to the north. South of the thrust, the Alice Springs Orogeny appears to have affected the sedimentary sequence throughout the southern Amadeus Basin. This implies that the role of the Petermann Ranges Orogeny (600 Ma) in the structural development of the southern part of the basin may have to be re-evaluated.

For further information contact Dr Cedric Wright, Dr Russell Shaw, or Dr Bruce Goleby (Division of Petrology & Geochemistry), or Dr Russell Korsch (Division of Continental Geology), at BMR.

National Geoscience Mapping Accord

This article is based on a BMR discussion paper prepared in May 1989. It does not take into account developments resulting from subsequent discussions.

One of the principal recommendations of the 1988 Woods Review of BMR was that as a matter of priority BMR and the State/NT Geological Surveys, through the Chief Government Geologists' Conference, and in consultation with industry and the academic community, should develop a national geoscience mapping strategy (National Geoscience Mapping Accord). BMR has undertaken a comprehensive review of its program in order to increase its mapping activities, and is entering into the consultations with a strong commitment to fulfilling the spirit of this recommendation.

BMR will contribute by

- participating directly in systematic mapping programs in collaboration with the States/NT;
- providing specialist expertise/facilities in direct support of priority mapping programs; and
- directing its geophysical mapping activities (both airborne and seismic) more closely to the geological mapping priorities.

BMR is committed to a number of major programs outside the NGMA, e.g. continental margins, resource assessment, nuclear monitoring, and geophysical observatories. However, it will, within the limitations of its overall budget, increase the proportion of resources available to mapping programs, especially in the minerals and land-use area. It will also increase the emphasis, in its wide range of regional programs, on the production of systematic geoscience maps and associated databases, while maintaining its commitment as recommended in the Woods Review to an integrated, multidisciplinary approach to regional geoscientific research.

Priorities for BMR's input into NGMA must take account of BMR's national role and its responsibilities to the Federal Government. They will be of mutual interest to the Federal and State governments: that is, they will be national priorities.

Major influences on priorities include

- the assessed value in filling gaps in the national geoscientific knowledge base relevant to petroleum, mineral, or water resources;
- the particular need for Commonwealth–State cooperation in provinces or basins that cross State borders;
- the need for the specialist expertise and capabilities that BMR can provide; and
- the need to balance resources between minerals, water, and petroleum programs and between different kinds of geological environment.

Priorities for BMR participation in the Mapping Accord have been discussed in relation to program elements relating to Onshore Fossil Fuels, Hydrogeology, Mineral Provinces, Regolith & Related Resources, Onshore Seismic, and Geophysical Maps & Data Sets.

As a basis of discussion, the following priorities were suggested by BMR in May 1989.

Onshore fossil fuels

The proposed strategy is to undertake a program in conjunction with the States/NT consisting of **detailed basin studies and continent-wide and regional studies**, with a view to developing an improved understanding of all of Australia's onshore sedimentary basins and their resources by the year 2000.

Effort will be balanced among different basin types, viz. Cratonic Basins, Eastern Australian Basins, and Coastal Margin Basins. **Current priority is given to the Canning Basin**, and a project is being developed on **the Gunnedah, Surat and South Bowen Basins** in New South Wales and Queensland.

Expected products include

- regional maps and cross-sections illustrating subsurface structure, thicknesses, isopachs, facies patterns, source rocks, and maturation;
- well databases incorporating revised stratigraphy, biostratigraphy, source-rock analyses and environmental interpretations; and
- revised scientific concepts relating to prospectiveness.

Priorities for continent-wide studies include **paleogeographic maps of the Australian continent** and accompanying cross-sections, sea-level curves, and subsidence analyses.

Hydrogeology

As a result of the high level of concern about the effects of salinisation, priority is accorded to multidisciplinary studies of the key parts of **major groundwater systems, especially the Murray–Darling Basin**.

A six-year mapping program to 1994 for the **Murray and Darling River Basins** resulting from extensive discussions with South Australia, Victoria, and New South Wales will lead to the production of **twenty-seven 1:250 000 and six 1:1 000 000 hydrogeological maps**.

The next immediate priority is seen to be a program to produce hydrogeological maps of the Great Artesian Basin using Intergraph technology. A map of the hydrogeology of the Great Artesian Basin at 1:250 000 would be prepared initially. **Maps (10) at 1:1 000 000 covering the complete Great Artesian Basin would be prepared within the next six years.** This would clearly need to be a cooperative program involving the three relevant States and the NT.

Mineral provinces

BMR resources will be balanced between programs in different regional geological environments, viz. West Australian Craton, North Australian Craton, South Australian Craton, East Australian Fold Belt. Suggested priorities are:

- *North Australian Craton*: cooperate with the West Australian and Northern Territory Geological Surveys in major syntheses through contribution to **1:100 000 and 1:250 000 geological mapping programs, especially in the Halls Creek, Arnhem, McArthur, and/or western Arunta domains** and through **major geophysical programs** aimed at poorly exposed and thinly covered areas.
- *West Australian Craton*: continue to contribute with the Geological Survey of

Western Australia to **1:100 000 geological mapping and a regional synthesis of the Eastern Goldfields province**, supported by seismic reflection studies.
- *South Australian Craton*: develop a program of **1:100 000 and/or 1:250 000 mapping of the Musgrave Block** with the Geological Survey of Western Australia, South Australia Department of Mines & Energy, and the Northern Territory Geological Survey, aimed at a modern synthesis of the geology.
- *East Australian Fold Belt*
- Continue to contribute with the Geological Survey of Queensland to **1:100 000 and 1:250 000 mapping in NE Queensland**.
- Carry out integrated studies of existing or proposed **World Heritage/National Park areas (e.g. Coen Inlier)**.
- Collaborate in State programs, both by field mapping and by provision of specialist support (e.g. geochronology, geophysics, geochemistry.

Regolith

BMR regards **1:1 000 000 Regolith Terrain Mapping (RTM) of the continent** as being its highest priority in regolith research. This national RTM program requires approximately 80–100 geoscientist years. The strategy for BMR would be to increase the resources available to RTM so that continental coverage could be completed in 20 years. Priorities would be developed through the Mapping Accord. Work currently planned is in the Yilgarn Block.

Onshore seismic

The integration of seismic studies with regional geological mapping is seen as a high priority. Current priorities for integration with the mapping programs summarised above are
- profiles across the Bowen and Gunnedah Basins;
- profiles in key basement provinces of the Eastern Australian Fold Belt in NSW, Victoria, and SA; and
- profiles in the Proterozoic of NT and SA and in the Eastern Goldfields of WA.

Geophysical maps and data sets

There is a national need for an integrated database of digital magnetic, radiometric, and gravity information that is Australia-wide and readily available to government and industry. The strategic plan to improve these databases over the next 20 years is as follows
- **complete the first-pass aeromagnetic coverage of the Australian landmass** and make the data available by the end of 1992;
- **refly the seventy 1:250 000 sheet areas of substandard data** in a seven-year program to provide high-quality digital magnetic and radiometric coverage;
- **carry out detailed airborne surveys (magnetic and radiometric) in key areas**, to support BMR–State projects;
- **carry out aeromagnetic surveys over the continental shelf** to encourage petroleum search and obtain reconnaissance information over the offshore areas; and
- incorporate within the **national gravity database**, data that are already available, **and complete more detailed systematic coverage** of selected 1:250 000 sheet areas in support of key BMR–State projects.

The products from this work program will be digital data tapes for map sheet areas and separate surveys, and 1:1 000 000 and 1:250 000 maps. It is also planned to produce a magnetic map of Australia at either 1:5 000 000 or 1:2 500 000, and 1:100 000 maps for special surveys.

BMR is able to make three kinds of contribution to a national mapping accord, viz.
(1) **BMR can strengthen the joint mapping programs through existing experienced mapping staff and possibly through recruitment of additional staff.**
(2) **BMR's *existing* specialist expertise in such areas as geochronology, geochemistry and structural geology can be deployed, as recommended in the Queensland submission and taken up in the Woods Review, in direct support of priority geological mapping programs.**
(3) **Major geophysical surveys. The existing programs of airborne geophysical mapping and onshore seismic can be redesigned to support, and integrate with, priority geological mapping programs, as agreed with the States.**

The strategy under the mapping accord recognises that the requirements of the minerals and petroleum industries are rather different. Both require 'large integrated databases of which updated geological maps would form an important component' (Woods Review). **However, the emphasis in the minerals industry is on updated 1:100 000 and 1:250 000 maps of key regions. On the other hand, in the petroleum industry the priority is for a reassessment of the structural and sedimentary framework**, using all available public and industry data and using modern approaches to basin analysis and fossil fuel occurrence. This will normally entail the production of uniform styles of maps, datasets, and synthesis on a basin scale (usually 1:1 000 000 or 1:500 000).

Determination of priorities

BMR priorities under the Mapping Accord will be of mutual interest to the Commonwealth and State Governments, that is, they will be *national priorities*.

Several criteria can be used in determining these priorities, viz.
(1) The assessed value in filling gaps in the national geoscientific knowledge base
- either in relation to basic understanding of geological relationships relevant to petroleum, mineral or water resources
- or in relation to specific commodities of particular importance

(2) The particular need for Commonwealth–State cooperation in provinces or basins that cross State boundaries
(3) The particular need for the specialist expertise and capabilities which BMR can provide
- such as the need for seismic profiling or geochronology
- or the need to apply and test new concepts, such as those of extension tectonics.

In applying these criteria it must also be recognised that all States have some claim on the national facilities and expertise in BMR; and that the need for a particular BMR capability may also dictate the allocation of other resources to ensure an integrated multidisciplinary approach. Thus for example a particular need for airborne magnetic or radiometric surveys may dictate the allocation of geological resources to the same program.

BMR also needs to balance its available resources between minerals and petroleum related programs.

Although the Review was not explicit, it seems clear that the main impetus for those recommendations was from the submissions of the minerals industry and **BMR is therefore giving first priority to the development of its minerals-related program**. However, the recommendations have broader implications and, following recommendations from the Government Geologists' Conference, each State has prepared a statement of its geoscientific mapping requirements for the next 20 years.

In general, cooperative programs between the States and BMR under the mapping accord can be seen as the main element in developing an up-to-date, comprehensive, integrated geoscientific knowledge base for Australia.

BMR currently carries out programs in five main areas, viz. **petroleum, minerals, groundwater, geophysical observatories, and database coordination.**

All of these programs have significant aspects of geoscientific mapping and associated databases. Here, however, discussion is confined to BMR's contribution to the mapping accord in relation to the first three programs.

BMR's marine geoscience programs are not included within the NGMA. However, they provide the main strategic knowledge base for offshore areas in the same way as mapping programs provide the equivalent knowledge base onshore. BMR's offshore programs need to be coordinated with its onshore programs and also with State programs, especially in relation to coastal-margin basins.

General strategy

The papers prepared by State geological surveys, in assessing their needs for the next 20 years, make a major contribution to the assessment of future national needs and priorities.

It is not appropriate for the Commonwealth through BMR to contribute to all of these State requirements. It is necessary to identify those high-priority programs, of mutual interest to the Commonwealth and the States, which are most in need of BMR–State collaboration so that the available resources can be most effectively used.

In Minerals programs there is also a need for BMR to maintain a national overview and thus to balance resources between studies of the major basement provinces. In addition, particular importance is attached to regolith studies in relation both to the importance of the regolith as a source of mineral deposits and as a barrier to the discovery of concealed deposits.

In Petroleum programs there is a corresponding need to balance programs on a regional basis between Cratonic Basins, Eastern Australian Basins, and Coastal-Margin Basins.

BMR also recognises the need to complement its contributions to particular basin or mineral province studies with continent-wide studies. Many of these studies also lead to map products which can be seen as contributions to the mapping accord. The *Palaeogeographic Atlas* project is a particularly important example.

Finally, BMR has a responsibility for review and synthesis of the accumulating knowledge base. For the mineral and petroleum industries the knowledge base is mainly valuable for area selection and for the development of exploration strategies. In addition however there is a need for government to synthesise the information in order to assess resource potential, and this should be seen as a further general objective of the Mapping Accord. BMR should also play a coordinating role (via the National Resource Information Centre) in establishing a national GIS-based format for all geoscience map products.

Recent publications, maps, and data releases

Over the period 1 March–31 August 1989 BMR released the following publications and data:

Publications

Bulletins

228 Lower Carboniferous Ostracoda (Beyrichicopida and Kirkbyocopa) from the Bonaparte Basin, northwestern Australia
230 Hydrogeology and groundwater resources of the Lake Amadeus and Ayers Rock region, Northern Territory

Reports

286 Rig Seismic Research Cruises 10 & 11: geology of the central Great Australian Bight region
287 Groundwater contamination incidents in Australia: an initial survey
288 Maastrichtian and younger sediments from the Great Australian Bight
289 First-order regional magnetic survey of Southwest Pacific islands, May–July 1985
291 Magnetic modelling of two and three-dimensional bodies
293 Union list of Australian geological excursion guide books

Resource Reports

5. Geology and economics of platinum-group metals in Australia

Australian Petroleum Accumulations Reports
5. Bonaparte Basin (NT & WA)

Australian Mineral Industry Quarterly, **41, Nos. 1 & 2**

BMR Yearbook, **BMR 88**

BMR Research Newsletter, **10**

Continental Margins Program Folios
2–Offshore Otway Basin
3–North Perth Basin

The Petroleum Newsletter, **101**

Petroleum Exploration & Development Titles Map & Key, **January 1989**

Geoscience maps
1:250 000, geological: **Mar**, Irian Jaya
1:100 000, geological: **Edith River region**, NT
1:75 000, geological: **South Alligator Valley Mineral Field**, NT
1:1 000 000 Landsat mosaic: **Murray Basin**, NSW, Vic., SA

Records released on open file
1987/54 Notes to accompany a 1:5 000 000 Silurian structural history map, 1987
1988/38 Definition of the Continental Margin using UN Convention on the Law of the Sea (Article 76), using its applications to Australia
1988/48 Structure, stratigraphy, evolution and regional framework of the Townsville Trough and Marion Plateau region, Research Cruise Proposal
1988/53 (Fossil Fuels 1) — Maturation levels of some Proterozoic organic matter in northern Australia: implications for oil exploration
1989/2 (Fossil Fuels 2) — Sedimentology and facies distribution within the Horn Valley Siltstone, Amadeus Basin: a reconnaissance study
1989/5 Sedimentological analyses from deepsea cores taken off southwest Victoria, and western and southern Tasmania
1989/6 Seismicity and earthquake studies in the Australian Plate and its margins
1989/8 Calibration of the BMR airborne gamma-ray spectrometer's upward-looking detectors, February 1989
1989/9 National Minerals & Energy Outlook Conference 15–16 March 1989, Canberra, Papers
1989/10 Petroleum exploration and development in Australia — activity and results, 1988
1989/12 Preliminary Postcruise Report: BMR Cruise 78, *Rig Seismic* geophysical and geological research cruise off western and southeastern Tasmania
1989/13 The Geology of Western Tasmania and its Continental Margin — particular reference to petroleum potential. Field Excursion Handout 1989 APEA Conference, Hobart
1989/15 Northeast Gippsland Basin and southern New South Wales Margin, BMR Marine Survey 68. Explanatory notes to accompany release of non-seismic data
1989/17 IOC Workshop Report: Benthic microbes and reefs, Townsville, Australia, August 1988
1989/19 PETCHEM Data Set: Australia and Antarctica — Documentation
1989/20 RV *Rig Seismic* Research Cruise 12, NSW—Phosphorites: explanatory notes to accompany release of non-seismic data
1989/22 Guidebook — Arunta Block, central Australia, IGCP Project 235 — Metamorphism and Geodynamics Field Conference on Granulite Facies Metamorphism June 25–July 1, 1989
1989/25 Mawson Geophysical Observatory Annual Report, 1988
1989/26 Rig Seismic Survey 79, Otway Basin geochemical survey, southeast Australia: explanatory notes to accompany release of non-seismic data
1989/27 BMR Marine Survey 77, Tasman Sea: explanatory notes to accompany release of non-seismic data

Release of data
Airborne geophysical maps
1:250 000 — 86 maps, showing either magnetic properties, magnetic contours or profiles, radiometric contours or profiles, or flight-line systems (all States)
Digital data
Digital-point-located airborne magnetic or radiometric data from forty-seven 1:250 000 Sheet areas
Marine geophysical data
South Perth Basin (BMR Marine Surveys 80, 81), Strahan Sub-basin, offshore west Tasmania (78, part), SE Bass Basin (Boobyalla Sub-basin) (82, part).

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 1: Publications other than maps; Part II: Maps)*, which is available free of charge from: **BMR Publication Sales, GPO Box 378, Canberra, ACT 2601 (phone 062—499 519)**. 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 (open 9.00–4.30, Mon.–Fri.). Further information on the availability of preliminary data may be obtained from the Information Section, phone 062–499620 or 499623.** 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 many 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 *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 so far in the *Resource Reports* series: uranium resources of Australia; coal in Antarctica; gold databases for WA, Qld, and NSW; and the geology and economics of platinum-group metals in Australia. *Australian Petroleum Accumulations Reports* so far cover the Amadeus, Bass, Adavale, Gippsland, and Bonaparte Basins.

The results of BMR's offshore surveys using RV *Rig Seismic* are being progressively released in a new *Continental Margins Program Folio* series, so far covering the Bass, Otway, and North Perth Basins.

The large-format looseleaf *BMR Earth Science Atlas of Australia* by now contains 17 maps of Australia, mainly at 1:10 000 000 scale, on various earth-science themes. In similar large format, the first volume (Cambrian) of a major new publication series, the *Palaeogeographic Atlas of Australia*, is now available.

Preliminary results, results of limited interest, and some other manuscripts are published in the *Record* series. Records are produced in limited numbers; 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 publishes geological, 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 *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.

Copy Service

Photoscale geological compilation sheets and other recent survey results are released as dyelines and transparencies through the BMR Copy Service. Some other documents, including Records, are also released through the Copy Service. Lists of 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.

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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 the staff of BMR's Cartographic Services Unit.

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 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 Executive 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.

News briefs

National Geoscience Mapping Accord

In response to a major recommendation of the Woods Review of BMR, ('that as a matter of priority, BMR and the State/NT Geological Surveys, through the Chief Government Geologists' Conference, and in consultation with industry and the academic community, develop a national geoscience mapping strategy (National Geoscience Mapping Accord)'), BMR has undertaken a comprehensive review of its program with advice from the BMR Advisory Council, in order to increase its mapping activities, and is entering into the proposed consultations with a strong commitment to fulfilling the spirit of this recommendation.

A program of State seminars has been arranged to gather community views on priorities for the Accord. The first of these took place on 19 May in Perth.

A discussion paper on priorities has been produced by BMR (see p.14) and each State.

1989 BMR Research Symposium to focus on mapping

This year's national BMR Symposium (see p.8) will draw together speakers from BMR, State geological surveys, the mining and petroleum industries and other organisations concerned with the production of geoscience maps. Subjects will cover conventional geological mapping, remote-sensing techniques, geophysical maps, databases and image processing, and production of maps of the continental margin and onshore sedimentary basin, including hydrogeology.

The symposium, to be held from 7–9 November in the new National Convention Centre, Canberra, will consist of a one-day workshop on Geographic Information Systems and related database/image-processing (organised by the new National Resources Information Centre), followed by two days of paper presentations, poster and discussion sessions, and a trade display.

Exmouth Plateau Triassic reefs — new petroleum prospects

The recent Ocean Drilling Program of scientific coring on the Exmouth Plateau, adjacent to the Northwest Shelf, was based on BMR marine research and discovered an ancient (Triassic) coral reef. Such reefs were not previously known from Australia, but this discovery suggests that they may be widespread on the Northwest Shelf. Ancient buried reefs are commonly petroleum traps, and a recent BMR assessment suggests that there is a 50% chance of there being 60 million barrels (10 GL) of undiscovered oil with a current value of $1.6 billion in Triassic reefs on the Northwest Shelf.

BMR's Marine Division is planning further research cruises to follow up this discovery of a major new potential oil play. The first cruise, scheduled for the first half of 1990, will try to better define the character and distribution of the buried reefs in the area where they were first discovered. The second, scheduled for later in 1990, will seek evidence of similar-aged reefs in the highly prospective Bonaparte Basin.

Rig Seismic refit

Major reconstruction of the rear deck area of RV *Rig Seismic* began in May after five year's service with BMR. Barnes & Fleck were the contractors and the work was carried out at the FORGACS yard, Newcastle (NSW). Work progressed steadily despite difficulties experienced when the ship's plans were found to vary from the actual vessel construction!

The refit was completed in early September and sea trials began in late September, following remobilisation of the seismic and geological back-deck equipment. New sleeve gun arrays and 240-channel seismic streamer will be fitted about March 1990.

Support data to accompany Petroleum Release No. 2 for 1989

Release of offshore permits in the Perth Basin was announced on 14 August. To assist evaluation of petroleum potential, BMR's Division of Marine Geosciences & Petroleum Geology produced a comprehensive package that included 2420 km of regional seismic reflection data from the South Perth Basin, a report on the prospectiveness of the South Perth Basin, and a folio review of the North Perth Basin. In addition, 2449 km of seismic data shot by BMR in 1986 and released in August 1988 has now undergone migration processing to assist interpretation.

The multichannel seismic reflection data from the South Perth Basin cover the more prospective shelf and upper slope areas. The report on the South Perth Basin's prospectiveness includes updated interpretations of previous open-file data from the 13 offshore wells and 6000 km of company seismic data. In addition, outcrop samples, dredged from the walls of the large submarine canyon off Perth, have been analysed to produce a new insight into the biostratigraphy and organic geochemistry of the deeper part of the basin. These results, in conjunction with 300 km of high-resolution (watergun) seismic reflection profiles, allow interpretation of the structure and maturation trends in this previously unknown part of the basin.

The North Perth Basin Folio is a comprehensive analysis of the stratigraphy, structure, and hydrocarbon potential of this part of the basin, largely based on seismic data collected in 1986. A new model for basin development, based on a predominantly strike-slip tectonic setting, reveals the potential for previously untested plays.

As part of a special permit-release offer, BMR is releasing the South Perth Basin Seismic (Part 1), the South Perth Basin Petroleum Evaluation Report, and the North Perth Basin Folio as a combined package at the special reduced prices of A$35 000 (including stack profiles and location map) and A$45 000 (including stack and migration profiles and location map). This offer will apply until 31 December 1989. A brochure is available from: BMR Copy Service (062) 451374, Fax (062) 472728.

South Alligator Valley Conservation Zone

Data obtained from the airborne geophysical survey of the Conservation Zone (CZ) in September 1988 have undergone preliminary analysis. The results, together with those from field and geochemical studies, confirm that areas of high mineral potential exist throughout the presently defined CZ.

Extensions of structures known to control the distribution of mineral occurrences, and not evident from ground mapping, are revealed by the geophysical data.

The distribution of an alteration style associated with all the known mineralisation of the CZ is shown by the data to be more widespread than previously thought, as the altered rocks have a distinct geophysical signature clearly visible in the new data. All the altered zones represent prime targets for exploration for gold, platinum, palladium, and some other commodities.

Further analysis of the geophysical data and integration with other data sets will be facilitated by the new Image Processing Centre in BMR.

Return of field parties

Field parties returned to Canberra in September from mapping in the South Alligator Conservation Zone, NT, and in the Mount Isa Inlier, Qld. Work in the South Alligator area concentrated on determining the extent of rock alteration known to be related to mineralisation in the region, and its relationship with geological structures. This information will form part of a data package being developed for the 5-year Resource Assessment Program of the CZ planned by Government. The Mount Isa work has completed major mapping, which has been in operation since 1983, to be reported as a Bulletin and folio of about 16 detailed maps.

Image processing centre nears completion

The new BMR Image Processing Centre is currently being established and equipped. It consists of International Imaging Systems and Intergraph workstations and Sun 4/280 computers to support the digital image processing network. Additional workstations will operate via landline to NRIC in John Curtin House. When completed, the Image Processing Centre will be the most advanced of its type in Australia with the capability to handle the requirements of all BMR Divisions wishing to digitise, display, manipulate, and output data as imagery or to merge it with other data as image-map products.

Joint BMR–CSIRO regolith appointment

BMR and CSIRO have agreed to an equally shared joint appointment of Dr Max Churchward, a landscape and weathering specialist with several years' work experience with CSIRO in the Yilgarn Block, WA. Dr Churchward's expertise in this complex weathered terrain will be a valuable addition to BMR's Regolith Program. The joint appointment will also provide an important interface between BMR and CSIRO research in that region of WA.

Geographic information systems

The Division of Petrology & Geochemistry has invested in a PC-based Geographic Information System (GIS) to investigate new ways of handling and presenting geological, geophysical, and topographic information. The system, SPANS, will initially be used to analyse data collected from the Eastern Goldfields and Kakadu projects.

Training courses in the use of GIS are being given. In parallel with expansion of GIS, digital database development is continuing, with the ultimate aim of integrating map and digital information to form the basis of a modern geoscientific data package available in both hard-copy and digital form. This will require a considerable effort in the future to integrate attribute data on the BMR mainframe computer, vector data on the Intergraph facility, image-processed data, and the GIS facility.

Development of BMR programs in environmental geology

The earth sciences have a major role to play in increasing understanding of the processes of environmental (including climatic) change. The data acquired by earth scientists hold the archival records of past changes and provide a perspective against which present human-induced changes can be evaluated. They also provide an understanding of the processes operating at or below the Earth's surface.

BMR is investigating the feasibility of developing co-ordinated programs in environmental geology. A number of projects already being undertaken in BMR encompass environmental issues that are currently of concern. An informal workshop held in BMR on 13 June, focused on these. The projects identified fall into two categories: (1) those concerned with processes currently operating in the geosphere, and (2) projects involved with determining the past record of environmental change; these latter provide the evidence for naturally occurring change and the database to test predictions of future change. Projects in the first category include those in groundwater, where emphasis is on the Murray–Darling Basin, and projects directed toward understanding the regolith, or weathered surface. Current projects in the second category include those of BMR's Continental Margins Program, which provide a record of biological, climatic, and temperature changes.

A BMR committee will co-ordinate the projects and their possible expansion. Main priorities include the geological basis of soil degradation, the provision of high-resolution records of naturally occurring change, an investigation of climatic and sea-level changes in the Australian coastal zone, and the potential impact of climate change on groundwater resources. After consultation with a range of State, Federal, and international organisations, it is hoped that programs can be developed within these areas.

Hydrogeology of the Great Artesian Basin

BMR continues to update and refine the hydrogeological database of the Great Artesian Basin with assistance from State authorities. The basin-wide computer simulation model is being improved for use in the prediction and monitoring of hydraulic effects following management interventions such as reduction of wastage. This work is part of a joint program with Queensland, New South Wales, South Australia, and the Northern Territory. The aims are to define problems and propose remedial measures in the Basin as a basis for the better management of artesian groundwater resources. Proposed measures include the rehabilitation of uncontrolled bores, the establishment of a rational monitoring network, and research into corrosion, discharge, and recharge.

Murray–Darling Basin groundwater

Production of the first map of the new Murray Basin Hydrogeological Map Series at 1:250 000 scale is nearly complete. Planned for a November release, the full-colour Pooncarie Sheet is being produced on an Intergraph CAD/CAM workstation and is the first of seven such maps due for release this financial year. The maps will form part of a spatial database linked to a groundwater attribute database and will form the basis of a comprehensive Geographic Information System for the hydrogeology of the Basin.

The map series is being produced in response to the Commonwealth and State Government Murray–Darling Basin Initiative for the Murray–Darling Basin Ministerial Council, as a cooperative project by BMR and State water authorities of New South Wales, Victoria, and South Australia.

In-house airborne geophysical mapping cost-effective

A detailed analysis conducted by the private consultancy firm of Price Waterhouse has shown that it is cheaper for BMR to conduct its own airborne surveys and process the data than to have this work done under contract. Accordingly, Price Waterhouse recommended that BMR continue to use its own aircraft and facilities to acquire and process airborne geophysical data. Price Waterhouse also recommended upgrading the airborne magnetometer and compensation system and investigating the purchasing or renting of a radionavigation system.

Airborne geophysics, gravity maps and data — in demand!

In 1988–89, the Regional Geophysical Surveys group, which includes airborne mapping and database, gravity, and interpretation, generated cost-recovery revenues through sales of data and maps of $371 000. This is equivalent to 35% of operational funds expended by the group.

Canning Basin seismic survey

BMR's seismic crew completed a six month field survey in the northern Canning Basin in October 1988. During the field work, 625 km of deep seismic reflection data was recorded. Processing of the data is continuing, and already some exciting new results are apparent.

For the first time, the base of the Fitzroy Trough has been imaged. Previous estimates of sediment thickness in the trough were based on depth to magnetic basement, but the seismic data show a base-to-the-sediments at 6.5 s two-way-travel time, or about 12 km. The data also confirm that the Fitzroy Trough is indeed asymmetric. This had been predicted from a recent review of company seismic data, but having the confirmation is both rewarding for those who made the prediction and important for building conceptual tectonic models of the basin. In addition to the promise of increasing the prospectiveness of the basin using new conceptual models, data should also have an immediate and direct impact on prospectiveness. For example, they show some previously unmapped structures in the middle of the Fitzroy Trough that give the promise of new play concepts.

The data also have something for those interested in studying crustal structure and tectonics. A major reflector cuts the crust, starting at the surface near the northern margin of the Fitzroy Trough, and dipping southward through crust and into the upper mantle, cutting the crust/mantle boundary near the axis of the Trough. The precise nature of this feature and its age are uncertain, although it probably played an important role in the formation of the proto-Canning Basin by acting as a focus for the first episode of extension.

Continental Margins Program equipment upgrade

A $2 million science grant from the Federal Government is being used to upgrade both acquisition and processing equipment in accordance with recommendations made in the Woods Review. New seismic acquisition and high-speed processing equipment will be purchased over a two-year period. This will enable the collection and presentation of industry standard data from both unexplored and conventionally explored parts of the continental margin.

Sponsors meeting for BMR–APIRA Project

Industry sponsors for the joint BMR–APIRA Phanerozoic History of Australia Project were in Canberra for a two-day project meeting at BMR on 8–9 August. Representatives from the 14 sponsoring companies, including several from overseas, attended the meeting.

The meetings are held each six months to review the project's recent scientific findings, receive comment from industry specialists, and discuss future work plans. At the August meeting, some of the items discussed included expanded palaeogeographic maps of the northern Australian Plate, incorporating data from the earlier Palaeogeographic Maps Project with new information from PNG and Irian Jaya, together with regional cross-sections and the marine inundation curve for the continent over the past 600 million years, showing how relative sea level has varied through time. The maps, charts, and reports produced by the project are used by industry sponsors to aid in the search for petroleum. These products then become BMR Records and are available for general release after 12 months.

Current sponsors are: AGL Petroleum, Amoco Production Company, Arco Oil & Gas Co., BHP Petroleum, Bridge Oil Ltd, Chevron Exploration Corp., Comalco Aluminium Ltd, Conoco, Delhi Petroleum, Esso Australia Ltd, Mobil New Exploration Ventures Company, Pacific Oil & Gas Pty Ltd, The Shell Company of Australia Ltd, and Texaco Oil Development Co.

CCOP/SOPAC Annual Session Canberra, 1989

The CCOP/SOPAC Regional Workshop, 'Geology, Geophysics, & Mineral Resources of the SW Pacific,' was held at ANU from 25 to 29 September, and was followed by the Eighteenth Annual Session of CCOP/SOPAC from 2 to 13 October, hosted by BMR and funded by AIDAB.

BMR scientists formed the Australian Steering Committee for the Session, led by Dr Neville Exon, Vice-Chairman of CCOP/SOPAC.

The Technical Advisory Group for the Session include scientists from CCOP/SOPAC itself, the member countries, and supporting countries and organisations. This year the group devoted three days to problems of major concern to the island countries in their coastal zones:

— coastal erosion
— harbour developments
— finding offshore sand and gravel deposits
— harvesting of precious corals
— environmental pollution
— baseline studies related to the above.

New monograph on volcanism in eastern Australia and New Zealand

The major monograph, *Intraplate Volcanism in Eastern Australia and New Zealand*, is due to be published this month (October) by Cambridge University Press in association with the Australian Academy of Science. The volume represents a major interdisciplinary assessment of Cainozoic volcanism, continental lithosphere, and tectonic evolution involving 59 authors mainly from BMR, State geological surveys, and universities in Australia and New Zealand (Editor: R.W. Johnson (BMR); Associate Editors: J. Knutson (BMR) & S.R. Taylor (ANU)).

Mineral deposits data

Comprehensive data for the 60 main gold deposits in New South Wales from BMR's mineral deposits (MINDEP) database will be released in October 1989. The data cover the location and regional setting of the deposits, their characteristics, geology, resources, production, development history (including references to mines), host rock and orebody characteristics, genetic models and controls, ownership, and bibliographic references. The data will be available as a microfiche ($24.95), or paper printout ($75), or as diskette or tape in ASCII ($150) or Oracle ($200) formats. Similar data are also available for 80 deposits in Western Australia and 36 deposits in Queensland. For further information contact Brian Elliott (062 499502).

Woods Review of BMR

To implement recommendations of the Woods Review of BMR, the BMR Planning Subcommittee and the BMR Review Task Force have been appointed by the Minister for Resources, Senator Peter Cook. The issues that have been dealt with so far include:

—Mineral statistics functions have been transferred from BMR to the Australian Bureau of Agricultural & Resource Economics (ABARE).
—Price Waterhouse were engaged to assess the cost-effectiveness of contracting out BMR drilling services and acquisition of land-seismic and airborne geophysical data. Their report recommends, on a cost basis, that:
  — the land-seismic reflection data acquisition and drilling services be contracted out to private enterprise;
  — the recording capacity for refraction seismic acquisition services be retained in-house but private contractors be used for the drilling associated with this work; and
  — BMR should retain its in-house capacity for airborne geophysical data acquisition, including retention of its aircraft.

A small team of consultants from Coopers & Lybrand has been engaged to assist with development of BMR's Strategic Plan. This is involving all staff and will result in an agreed corporate plan that will document a strategy and timetable for the continuing implementation of BMR's new charter provided by the Government in June this year.

Ocean drilling proposals

The full scientific impact of Australian membership of the Ocean Drilling Program (ODP) is now being realised. Proposals for drilling in the Australian region after 1992 are now being prepared by Australian marine scientists, with a particular eye on the problems of the Australian continental margin and the global climate. Three priority areas have been defined:

(1) The northern margin — two distinct but related proposals have been developed and sent to ODP:
  — Neogene–Quaternary collision tectonism and foreland basin development across the northern Australian margin;
  — Cainozoic global climatic evolution: the record across the northern Australian margin.
(2) The eastern margin — a mature proposal has been submitted for drilling on the Marion Plateau, aimed at defining the absolute change of sea level in the Middle Miocene.
(3) Preliminary proposals have been submitted for the Southern Ocean, with three themes:
  — seafloor spreading mechanisms between Australia and Antarctica;
  — magmatic evolution in relation to seafloor spreading;
  — climate evolution and sea level in the Southern Ocean.

The first Australian ODP Workshop was held in Canberra from 23–24 September, and was successful, with lively discussion. New proposals for the eastern and southeastern margins are expected to arise from the Workshop.

Antarctic Environmental Geoscience Program proposal

BMR's Division of Marine Geosciences & Petroleum Geology is developing an offshore Antarctic research program proposal, using RV *Rig Seismic*. The three main objectives are:

— Environmental baseline studies of an International Heritage Park aimed at estimating the advance of human-induced pollution and aiding sound management.
— Studies in a unique wilderness laboratory. The Antarctic provides a unique laboratory for studying past events in earth history, e.g. the mechanisms, rates, and timing of glaciations and their effect on sea-level changes. Such studies are relevant to understanding Australian geological history. Less than 100 million years ago Antarctica and Australia were one continent.
— Studies of global climatic change. Sedimentological studies offshore in conjunction with glacio-stratigraphic studies onshore will define the natural variability of climate and sea-level change and provide a better basis for predicting the onset of the next glacially induced sea-level fall, against which predicted greenhouse effects must be judged.

Co-operative research agreement with TEG

The content and context of a three-year co-operative geochemical research agreement with Transglobal Exploration & Geoscience (TEG), a California-based geochemical–oceanographic consulting corporation, have been agreed to in principle by TEG and BMR's Marine Division. The agreement is to study the occurrences and nature of hydrocarbon gas seeps from the seafloor of the Australian continental margin and to relate these parameters to petroleum accumulations at depth. The document is undergoing final consideration prior to ratification. Once signed, Marine Division will take delivery of the equipment for installation in *Rig Seismic*. The equipment detects hydrocarbons in sea water using a towed 'fish' and sensitive onboard analytical instrumentation. The methodology has not been widely used on the Australian continental margin. BMR will investigate its application as part of the Continental Margins Program.

Earthquakes

Every Australian short-period, long-period, and broadband seismograph, with the exception of BMR's modified and newly installed Wood-Anderson torsion seismograph, was saturated by seismic waves generated by the great earthquake of 23 May on the Macquarie Ridge.

At Ms 8.2 (USGS magnitude), this is the biggest earthquake known to have occurred on the Macquarie Ridge, at least since instrumental recording commenced in Australia in 1901 and it was the world's largest since the 1977 Sumba (Indonesia) quake. BMR seismologists have estimated the return period of an earthquake of this size at about 100 years.

The ANARE base at Macquarie Island, which houses BMR's now unmanned seismograph station MCQ, is only 210 km south of the computed epicentre and the intensity at the ANARE base on the island was about VII on the Modified Mercalli scale.

The Wood-Anderson torsion seismograph, modified by BMR engineers, performed perfectly, and its unique record of the earthquake will prove useful to the world seismological community.

A small tsunami was generated by the earthquake, with an amplitude of 0.3 m at Rocky Bay in southern Tasmania, at a period of 15 minutes. The wave-train travelled at a speed of about 500 kph and continued to be recorded for up to seven hours.

Ayers Rock and the Olgas were shaken by a magnitude 5.7 earthquake on 28 May. The epicentre was at the northern edge of the Musgrave Block, 50 km northwest of Ayers Rock. Minor damage was reported at Yulara, where walls were cracked in some buildings.

Central Australia has experienced an upsurge in seismicity in the last few years. In 1986, an earthquake in the Musgrave Ranges (M 5.8) produced a surface rupture about 13 km long, and the Tennant Creek earthquake (M 6.3–6.8) of January 1988 was associated with over 30 km of surface faulting. The Tennant Creek earthquake damaged ($500 000) the gas pipeline from Palm Valley to Darwin.

A few small earthquakes (M 4.5) have occurred in the northern part of the Musgrave Block in recent years, but no foreshocks had been detected for the 28 May event. The closest seismograph is at Alice Springs, about 350 km from the epicentre.